RESIDUE UTILIZATION
MANAGEMENT OF AGRICULTURAL & AGRO-INDUSTRIAL RESIDUES

Seminar Papers & Documents

Volume 1

The General Assembly of the United Nations at its 27th session late in 1972 adopted Resolution 2997 (XXVII) declaring itself "Convinced of the need for prompt and effective implementation by Governments and the international community of measures designed to safeguard and enhance the environment for the benefit of present and future generations of man".

The Resolution stated further that the Assembly was "Aware of the urgent need for a permanent institutional arrangement within the United Nations system for the protection and improvement of the human environment", and proceeded to create:

1. A Governing Council for the Environment Programme composed of 58 member countries elected by the General Assembly.

2. A small secretariat to serve as a focal point for environmental action and coordination within the United Nations system to be headed by an Executive Director elected by the General Assembly on the nomination of the Secretary General.

3. An Environment Fund to provide additional financing for environmental programmes.

4. An Environment Coordination Board under the chairmanship of the Executive Director.

Industry Sector Seminars

RESIDUE UTILIZATION
MANAGEMENT OF AGRICULTURAL & AGRO-INDUSTRIAL RESIDUES

Rome, January 18-21, 1977

Papers & Documents

Volume 1

United Nations Environment
Programme

Food & Agriculture Organization
of the United Nations

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FOREWORD

From the first session of the UNEP Governing Council, held in June 1973, the importance of environmental issues associated with industrial development was recognized and a programme of activities on environmental problems of specific industries was initiated by the Executive Director.

One of the industries chosen for evaluation by the Governing Council was the agro-industrial sector. In view of the expertise already available through FAO and the desire to make maximum use of existing U.N. activities, the evaluations in relation to the agro-industrial sector were undertaken jointly with FAO. The first of these evaluations was on the subject of residue utilization in agriculture and agro-industries, and a seminar on this subject was held in Rome in January 1977.

This report gives the Proceedings of the Seminar, which includes the background papers prepared for the Seminar, as well as all the documents presented.

The views expressed in this report do not necessarily represent the decisions or the stated policy of the United Nations Environment Programme or those of the Food and Agricultural Organization of the United Nations, nor does mention of trade names or commercial processes constitute endorsement.

Introduction

The Seminar was held in Rome from 18 to 21 January 1977 under the sponsorship of the United Nations Environment Programme and the Food and Agriculture Organization of the United Nations. The Seminar was organized jointly by both organizations as part of their responsibilities and concern for the protection of the environment and the need of increasing food supplies.

World food and feed production barely keep pace with population growth and reserve stocks have declined. The traditional method of increasing food supplies is to put more land into production and to increase the output per acre through the increased use of fertilizers, energy and improved genetic strains. It is equally important to obtain the maximum benefit from the existing agricultural products, especially from that portion which generally is considered a waste and can result in air and water pollution.

In the context of this Seminar, wastes from agriculture and agro-industries are the excesses and residues from the growing and processing of raw agricultural products, such as fruits, vegetables, meat, poultry, fish, milk, cereals, roots and tubers, and trees. These wastes are residues of production that have not been effectively utilized.

With the development of intensive production and processing methods for animals, crops, fish and forestry, the problems of agricultural and agro-industrial waste management have drawn increasing attention. These problems are two-fold: under-utilization of available resources and environmental hazards. Considerable experience has already been obtained in certain aspects of residue utilization and pollution control. However there remains an urgent need to use and develop environmentally sound technologies, adapted to and compatible with the economic, social and political situation. The ultimate goal is the better use of residues and by-products resulting in a maximum utilization of the raw material and serving the dual purpose of resource conservation and environmental protection. Thus, agro-waste management becomes responsible resource management.

The major objectives of the Seminar were to:

1. provide a survey of the main problems as well as the occurrence of wastes and residues associated with agriculture, fisheries, forestry and agro-industries;

2. review the available experience and technology for solving these problems;

3. discuss economic, social and political situations that are compatible with and conducive to environmentally sound residue utilization;

4. identify existing gaps and possible action programmes to fill such gaps;

5. assess the relative importance and priorities of such action programmes, taking into account the particular interests and requirements of developing countries;

6. outline a framework for international co-operation.

Agricultural and agro-industrial residues are the end-products of production that have not been used, recycled, or salvaged. Their economic value is less than the cost for collection and transformation for use. They therefore are perceived to have a negative value and are discharged as wastes. However, the increased environmental concerns and constraints result in an increased cost for treatment and management of these wastes prior to discharge. The collection, transformation and utilization of the residues may be less than traditional treatment and disposal techniques. Both the environmental constraints and the need for better resource management are causing residues to have a more positive value and residue utilization to receive more favourable consideration.

The intent of the Seminar was to increase awareness of the opportunities for improved residue utilization, to encourage governments and industry to initiate practical action programmes and to enhance continuing co-operation on this subject.

Both UNEP and FAO have major responsibilities related to the objectives and intent of the Seminar. Both are deeply concerned with the utilization of environmentally sound and appropriate technologies to increase food production, to reduce waste, to manage natural resources constructively, and to maintain the health and well-being of the people. At the conclusion of the Seminar, the participants expressed appreciation for the catalytic and co-ordinating role of both UNEP and FAO in developing and arranging the Seminar. The participants also looked forward to the implementation of the recommendations as soon as possible by UNEP, FAO, other interested Organizations, and Governments.

The Seminar was organized to provide for the interaction of the participants and the development of feasible action programmes. The Seminar was attended by a total of 218 participants representing 41 countries, 45 industrial organizations and 11 international organizations. A complete list of participants is presented in Appendix A. The participants were invited experts from Governments, Governmental and Non-Governmental Organizations, and Industry.

The Seminar was divided into four plenary sessions, one day devoted to separate working sessions on specific commodities, and a final day of discussions and finalizing the conclusions. The detailed agenda is presented in Appendix B.

In the plenary sessions, Session I dealt with the problems and possibilities of residue utilization from a broad perspective. Session IIa was devoted to the constraints experienced in residue management and utilization, and the incentives that may be needed to overcome these constraints. Session IIb illustrated existing situations using two major parts of the world (Asia and Africa) as examples. Information exchange was the subject of Session IIc. Included was a report on existing facilities and suggestions for improved communication between people working in identical fields. Session III reviewed existing and possible end-use oriented technologies. Experts from FAO and throughout the world prepared and presented the papers in each session.

During Session IV the participants were able to introduce subjects and topics that they felt were relevant to the Seminar objectives. In each session, ample time was provided for discussion and submission of information by the participants.

The working groups analyzed the residue utilization opportunities of specific commodities and included the possibilities of the end-use technologies discussed in the plenary sessions. The commodity areas and their residues that were discussed included:

- sugar by-products
- cellulosic residues
- oils and oilseeds by-products
- cereal by-products
- fruit and vegetable by-products
- animal by-products and wastes
- residues of starchy roots/tubers
- residues of the beverages industries
- fish wastes
- single cell protein

The list of papers that were presented is given in Appendix C. Also included is a list of the other material and reports that were distributed or available to the participants. During the Seminar there was an exhibition of books and documents related to residue utilization organized by the FAO Library for the attention and inspection of the participants. Also on display were the draft Directory of Institutions (2nd edition) involved in agricultural waste management and residue utilization and the draft Compendium of Residues Technologies (1st edition). A Bibliography of books and articles on residue utilization as from 1970 also was distributed.

2. Strategies

Each country and industry should establish definite, feasible residue utilization strategies and priorities for residue utilization that reflect realistic social, economic and technical goals. The strategy must be compatible with environmentally sound decisions that reflect existing physical, human and other resources. Desirable residue utilization approaches will depend upon the use of the indigenous capacity to generate and operate economically viable appropriate technologies. Such strategies and priorities should take full account of the interrelated policy questions of land-use, energy and transportation as well as the various socio-economic, ecologioal, and environmental considerations. This will call for co-ordination among responsible authorities in countries and may require the establishment of suitable mechanisms for this purpose.

Greater effort should be made by both industry and governments to reduce the quantities of agro-industry wastes that are generated. In doing so, the efficiency of food production can increase and a greater quantity of food supplies will result. In each country and industrial operation, a major programme should be initiated to identify, control and reduce the major losses in food materials, i.e., generation of residues, which occur in food processing between harvest and consumption.

In developing strategies for implementing residue management policies, authorities should ensure that appropriate controls and regulations are based on sound scientific data, that they are enforceable, and take into consideration socio-economic conditions. Care also should be taken not to create non-tariff trade barriers through unjustified import restrictions.

3. Information Exchange

There should be an interchange of information between adjacent or similar regions especially on local use technologies and incentives. Governments, international organizations and non-governmental organizations should assist in the development or utilization of existing centres to encourage such interchanges since much information and experience on possible utilization approaches exist in local areas and regions.

4. Incentives

Greater incentives should be provided to reduce the generation of agricultural and agro-industrial wastes. Incentives such as stricter pollution control regulations, waste discharge taxation, subsidies to enhance utilization, and other possible incentives should be evaluated in specific social and economic conditions. Included in the evaluation of feasible residue utilization approaches should be an analysis of possible legal constraints. Guidelines for appropriate legal approaches, such as model laws, should be developed.

5. Education

Ways to educate the public, and inform industry and government concerning the need for low residue, environmentally sound agricultural production and processing methods should be explored. Educational approaches to increase the use of such methods and to achieve the acceptance of residue utilization products need to be applied more broadly. The success of utilization approaches depends upon the acceptance of an approach and the resultant product.

6. Implementation

a. Existing Institutes of similarly oriented ecological zones should co-operate for the purpose of the joint organization of training courses, pre-investment feasibility studies, research and demonstration projects, incentive and market possibilities, evaluation of social, legal and economic impacts, and an information exchange system, based on the

At the opening ceremony, the Deputy Director-General of FAO, Mr. Roy I. Jackson, welcomed all participants on behalf of the Director-General, Dr. Edouard Saouma. Mr Jackson noted that "War on Waste" has long been one of the concerns of FAO, especially with the conservation of productive resources. The hope was expressed that the Seminar would not only examine the available technology for the utilization of residues, but also the fundamental problem of why present technologies are under-utilized. The need and expectation of proposals leading to measures for concrete action was stressed, as was the hope that there would be fuller utilization of national institutions and the training of local personnel in the transfer and use of appropriate technologies.

The Executive Director of UNEP, Dr. Mostafa K. Tolba, also welcomed the participants and stressed satisfaction with the help and co-operation provided by FAO in developing the Seminar. This Seminar is but one of 30 ongoing joint projects that focus on the environmental impact of man's activities in the field of food production and agricultural development. Dr. Tolba highlighted the important and urgent task of securing vastly increased food production without destroying the ecological base required to sustain it. The need to have recommendations for action programmes which will help to attain the common goal of "development without destruction" was also stressed by Dr. Tolba. The draft Compendium of Residues Technologies, which was discussed during the Seminar, was identified as the type of information that could serve all interested in this topic.

Agenda of the Seminar

Tuesday, 18 January

08.30 - 10.00	Registration of Participants
10.00 - 10.30	INAUGURATION OF THE SEMINAR
	- Address by Dr. Edouard Saouma, Director-General of FAO - Address by Dr. Mostafa K. Tolba, Executive Director of UNEP
	SESSION I OVERVIEW OF PROBLEMS AND POSSIBILITIES
10.30 - 11.15	Utilization of residues from agriculture and agro-industry (Loehr, Cornell University, Ithaca, USA)
	SESSION II CONSTRAINTS AND INCENTIVES IN RESIDUE UTILIZATION
	SESSION IIa Institutional Aspects
11.30 - 13.00	Socio-Economic Aspects (Szczepanik, FAO) Health Aspects (Strauch, WHO) Legal Aspects (Guttieres, International Juridical Organization)
	SESSION IIb Regional Surveys
14.30 - 16.30	Report on the Asia Survey (Bharat Bhushan, Regional Research Laboratory, Hyderabad, India) Report on the Africa Survey (Stanton, University of Malaysia, Kuala Lumpur)
16.45 - 18.00	Information exchange (Barreveld, FAO)

Wednesday, 19 January

	SESSION III TECHNOLOGIES
	SESSION IIIa
09.00 - 11.00	Energy from Organic Wastes (Stout, Michigan State University, USA) Food from Wastes and Nutritional Considerations (Kapsiotis, FAO) Microbial Conversion of Wastes (1) (Stanton, University of Malaysia) (2) (DaSilva, UNESCO)
	SESSION IIIb
11.15 - 13.00	Fertilizer from Organic Residues (Hauck, FAO) Animal Feed from Residues (Chenost, FAO) Construction Materials, paper and paperboard from agricultural residues (Lintu, FAO)

SESSION IV PERCEIVED NEEDS AND OPPORTUNITIES INCLUDING TRAINING, RESEARCH AND DEVELOPMENT

14.30 - 18.00	Reports and suggestions from participants (see Appendix C(b))

Thursday, 20 January

09.00 - 16.00	Working Group Sessions

Subject areas:

- Sugar by-products
- Cereal by-products
- Starchy by-products
- Cellulosic residues
- Fruit and vegetables by-products
- Beverage residues
- Oils by-products
- Animal by-products
- Fish
- Single cell protein

Friday, 21 January

14.00	Presentation of the Report Adoption of findings, conclusions and recommendations
18.00	Closing of the Seminar

Introductory Statement by Dr. Edouard Saouma

"War on Waste" has long been one of the leit-motivs of this Organization. This is a slogan, and while slogans may be attractive, by themselves they are not of much help in solving problems. Words must be matched to action. We hope that this Seminar will point to courses of action.

For many years "War on Waste" has been synonymous in FAO with the conservation of productive resources - our soils, our forests, grasslands and fish-stocks - and with the protection of crops, livestock and harvests against pests and diseases. These problems remain with us and renewed efforts are needed to resolve them.

However, this Seminar provides an opportunity to direct attention to another crucial aspect of wastage in food production. Agriculture and agro-industries leave behind large amounts of residues and wastes which could be utilized to serve man as food, feed, fuel, fertilizers and fibre resources. The fact is, however, the present trends in the intensification of agriculture and the development of agro-industry leave the impression that the amount of residue and waste is growing faster than the production of food and other agricultural commodities.

It is our hope that this Seminar will not only examine the technology already available for the utilization of residues but will also address itself to the more fundamental problem of why present technologies are under-utilized. Specifically, what changes should be made in the context of the development of a new international economic order to arrest this wastage so as to enhance the welfare and self-reliance of developing countries?

I presume it is known to many of you that one of my first decisions after election as Director-General was to make a substantial reduction in the number of meetings and the volume of documentation in this Organization in favour of more concrete activities in the field. This Seminar, however, was retained on our schedule and you have before you a considerable amount of documentation. There are several reasons for this. Let me mention but three.

This is the first time that FAO has attempted to address itself to the management of waste in agriculture in a comprehensive manner. We are making an effort to bring together the expertise and experience available not only in the industrialized world but also in developing countries by undertaking surveys, in Africa and Asia, of the problem of wastage and of existing technologies which could help to resolve them. Second, in addition to management. all of the relevant aspects of the problem are being studied - socio-economic, legal and, with the cooperation of WHO, the health aspects. Finally the efforts which have gone into the preparatory work over more than a year testify to the importance which UNEP and FAO attach to this meeting.

I will be frank by saying that I will not be satisfied if this Seminar produces only a set of recommendations. I am confident that Mr. Tolba and all of you will share this view.

I hope this meeting will reflect the change in attitude which is so necessary if we are to succeed in our efforts to increase food and agricultural production. Such a change in attitude is needed not only by United Nations Agencies but also all who are involved in development activities including industry which has the technological know-how to assist in the formulation of new models of development. We are entering a new era when our finite world will have to solve its problems, not by consuming even more resources but by re-applying the old principle of good husbandry. This is particularly true in agriculture where wastes must be re-cycled and multiple use be made of all parts of crops and animals produced.

Above all - and I repeat this deliberately for emphasis - I would ask this Seminar for proposals leading to measures for concrete action. It is my hope that special attention will be given to improving village level re-cycling as traditionally practised in many of the developing countries. The fuller utilization of national institutions and the training of local personnel in the transfer and utilization of appropriate technologies, are other areas which should be emphasized. Action in these areas could lead to greater investment in projects which stimulate agricultural development, strengthen processing industries, and provide higher levels of employment.

I am gratified that so many recognized specialists have accepted the invitation to participate in this Seminar. I wish to thank you all for coming and I wish you every success in your deliberations.

Introductory Statement by Dr. Mostafa K. Tolba

May I begin by expressing deep gratitude, personally and on behalf of the United Nations Environment Programme, to my friend and colleague Dr. Edouard Saouma, the Director-General of the Food and Agriculture Organization, and to his associates for their cooperation in making this meeting possible. In fact, I must stress our deep satisfaction in UNEP with the help and cooperation that characterizes all our relationships with our sister Organization, FAO.

Collaboration between UNEP and FAO is best illustrated by the fact that there are no less than 30 on going joint projects. While these include subjects as diverse as monitoring food contamination, monitoring and combatting soil degradation and the conservation of aquatic mammals, they all highlight the importance that UNEP attaches to the environmental impact of man's activities in the field of food production and agricultural development.

Viewed from the environmental perspective, the principal issue in the agricultural sector is the need to secure vastly increased food production without destroying the ecological base required to sustain it. The urgency and magnitude of the task of more than doubling world food production by the end of the century, while ensuring the availability of supplies for the generations to come, cannot be underestimated. But simply increasing the production of food is not enough. We must overcome the problem of inequitable distribution of available food, and the tragic situation that an ever increasing number of people lack adequate food, an essential and basic human need. It is heartening that the international community considers the satisfaction of the basic human needs to be an urgent and fundamental task. We must find means of providing for those who lack the essentials - food, shelter, clothing, education, health, and productive work. And it is imperative that these basic needs of every human being should be satisfied on a long-term sustained basis without destruction of the resource base upon which the achievement of such lofty goals rests and without transgression of the outer limits of the carrying capacity of the biosphere.

Rich and poor countries must find paths of development which are more rational and less arrogant in their demand on resources. This is especially true in the agricultural sector. Rational management of arable agricultural land is becoming increasingly critical. Each year more and more fertile land is being lost because of erosion, salinization, urbanization and industrial development. Meanwhile, the poverty stricken, in their desperate endeavours to survive from one day to the next, are forced increasingly to resort to ever more marginal lands to produce their minimum daily requirements, a practice which often proves to be ecologically disastrous.

Agricultural practices in the developed world have become increasingly energy-intensive. As the prices of energy escalate, approaching the point of diminishing returns, we should re-examine and perhaps re-orient some of our present agricultural production practices. The "green revolution" type of agriculture that has been exported to some parts of the developing world can no longer be considered a model. It is energy-intensive. The new strains of wheat, corn, rice, etc., need more fertilizers, pesticides and irrigation waters to provide maximum yields. The Green Revolution also puts genetic diversity at risk and produces crops highly vulnerable to pests, and even minor changes in environmental conditions. We must find alternatives, and there is certainly a case here for in-depth studies of the possible uses of native crops and underexploited plants which may not need such expensive inputs to produce high yields.

Practically all major agricultural practices can be environmentally damaging, and thus, in the long term, self defeating. But this need not be so. Let me give you some brief examples.

Environmentally unsound irrigation practices lead to a host of hazards including health problems caused by water-borne diseases. Deterioration of fertility and loss of agricultural land in irrigated areas as a result of increased salinity, alkalinity and water logging is a common problem in many parts of the world. Irrigation schemes are essential to increased agricultural production but without the application of sound ecological and environmental principles right from the planning stages, the short term benefits are often offset by long-term degradation.

Fertilizers are indispensable for increasing food production but increasing reliance on chemical fertilizers has caused several concerns. Chief among these are the the contribution of phosphate and nitrogen fertilizers to eutrophication, and the possible risks to the ozone layer, with ensuing health and other hazards, as a result of increased use of nitrogen fertilizers. Available fertilizers should therefore be used with maximum efficiency and biological sources of fertilizer, especially microbiological nitrogen fixation and compost, should be developed and expanded.

An essential to increased food production is the control of pests which cause significant losses to crops worldwide. But pest control through increased use of pesticides has resulted, through natural selection, in the appearance and proliferation of new strains of pests which generally turn out to be more destructive and certainly less susceptible to chemical control. Existing methods of applying chemical pesticides have extremely low efficiency rates and create unnecessary ecological hazards. The highest pesticide concentration levels occur in the higher animals and man, because of selective concentration as they pass through successive levels of food chains. We need new concepts of integrated pest management, an ecological approach to pest control, involving optimal combinations of biological and chemical control techniques.

Food losses and wastes can be appallingly high even in the most developed countries despite the sophisticated crop handling and storage techniques available. Prevention of these losses is another prerequisite to improvement of the world food situation. More appropriate technologies must be developed and employed in manufacturing, processing, storage and transportation systems. Processing residues must be considered as a resource for which uses should be sought, not a waste to be discarded, thereby contaminating the natural environment.

It is our job in UNEP, to cooperate with other UN organs, who have vast experience and information, in the adoption of environmentally sound approaches to development as a programme of action for implementation by the UN system and others. A key element of our programme is the interrelatedness of environment and development. We are concerned that the development process, in rich and poor countries alike, should be able to continue without reducing the productive capacity of the environment or using resources wastefully. Within this broad context, as you are perhaps aware, UNEP is holding a series of seminars on the environmental problems of specific industries. The main purpose of these seminars is to assess the environmental problems and solutions relevant to the various industrial sectors.

You will be interested to know that at an important consultative meeting of government and other experts, convened by UNEP last month, to discuss the objectives of the programme in relation to the environmental problems of specific industries, residues utilization and environmental impacts of agricultural and agro-industry development were considered by the participants to require priority attention from UNEP. This joint

UNEP/FAO Seminar covers, of course, but one aspect of the complex issue of food and the environment. Equally important aspects are post harvest losses, use of fertilizers and pesticides and crop intensification within environmental constraints. All these issues require joint and systematic UNEP/FAO attention in close co-operation with governments, industry and concerned international governmental and non-governmental organizations.

We hope that your meeting will help to attain the common goal of "development without destruction". We need to ensure that the activities of agriculture and agro-industry do not discharge harmful residues and wastes into the atmosphere, the rivers and oceans and the land we all live on. We must not continue to regard the natural environment, man's common endowment, as a bottomless receptacle of man's wastes. We need to incorporate such "curative" measures as proper pollution abatement and waste treatment systems and at the same time we should aim at low-waste technology systems and at systems under which wastes could be recycled or reused as raw materials for other needs. Such endeavours would serve the dual purpose of resource conservation and environmental protection - a theme of this meeting.

Turning finally to the specifics of this meeting, I note, with great interest and high hopes, the topics you will consider.

I feel no need, Ladies and Gentlemen, to elaborate on the various issues of residue applications, since you are all experts and much more versed in the field than myself and since reports and background papers giving ample material for your consideration are already in your hands.

Two points however are worth particular mention. The first relates to the first draft for a Compendium of Residues Technologies which is presented to you for consideration in one of the sessions of this meeting. I believe that such a compendium could serve as an important source of information for those involved in residue technology activities.

The second point is that this meeting has been structured so that one whole day is scheduled for working groups. I sincerely hope that this arrangement will enable those of you who have common areas of interest to get together to discuss in depth, exchange views and experience and reach - in your collective wisdom - the expected guiding principles and recommendations for action.

Ladies and Gentlemen, you have a very full schedule in front of you and I shall not use more of your valuable time. I wish to conclude by suggesting to you what might emerge at the conclusion of this meeting. We look forward to:

1. a better understanding of the opportunities for residue utilization;
2. the identification of appropriate technologies for utilization of agricultural residues and wastes;
3. the initiation of greater impetus towards the development, adoption and implementation of low waste technologies in all agricultural and food production systems;
4. the enhancement of the knowledge base of residue utilization through the establishment of a continuously updated Compendium of Residue Technologies which would ensure acquisition, analysis and dissemination of relevant information;
5. the identification of gaps that appear to require highest priority consideration and study in agricultural and agro-industrial residue utilization; and
6. a comprehensive plan of action for implementation by all those concerned: governments, industry and intergovernmental and non-governmental organizations.

I know I am asking a lot, but, and I am sure that my dear colleague Dr. Saouma would agree, the presence of such a distinguished gathering of experts in this hall encourages us to expect free and frank discussions, and a sharing of knowledge and experience, which will permit the meeting to conclude with concrete action-oriented recommendations. That will help both of us to participate meaningfully in the international endeavour to meet a most basic human need: food.

Thank you Ladies and Gentlemen and I wish you every success in the formidable task ahead of you.

Summary of Presentations and Discussions

SESSION I presented an overview of the problems and opportunities in the area of utilization of residues from agriculture and agro-industry. This session was opened by Dr. Raymond C. Loehr, Director, Environmental Studies Programme, Cornell University, Ithaca, New York, who emphasized the following points:

Residue utilization should be considered with optimism because of the large quantities of wastes that are produced, the obvious need to make better use of existing resources, and the successes that have occurred. However, this optimism must be tempered by caution since the result must be a usable product at an economical cost while not causing greater environmental or social problems.

Residues should be considered as resources and not as wastes. Incentives will be needed to have such a change in philosophy. Existing incentives include the finite limit of the world resources, the increasing costs of raw materials, and the need to maintain a satisfactory quality of the environment. However, other incentives are needed which may result in institutional changes in the relations between governments and industry.

Keys to successful residue utilization include: a) a beneficial use, b) an adequate market, c) use of appropriate technology, and d) an enterprise that is socially and economically feasible although not necessarily profit-making. Many enterprises may be satisfactory if the overall cost of waste management were less than other alternatives, or if they increased employment possibilities, or if local or regional food supplies were increased.

Residue utilization considerations should include more than the technological aspects. Critical evaluation also is required of the economic, social and legal aspects as well as the development of environmentally sound approaches.

For the most part, available information on the characteristics of agricultural residues lacks specificity on the important factors of distribution, seasonality, condition, changes in characteristics that take place with time, and the detailed characteristics. Greater detailed information is necessary at the local, regional and national levels to assist with residues utilization decisions.

An important aspect in residue utilization is to minimize the residues that are generated, thus making better use of raw materials and obtaining greater efficiency of production. Such reductions directly increase the quantity of usable food supplies. In each industry and in each country, a major programme should be initiated to identify, control and reduce the losses in food materials which occur between harvest and consumption.

Residue utilization methods rarely solve an entire waste problem, since the material produced or removed may be only a small component of the original residue. Thus environmentally sound approaches will continue to be needed for the remaining residues and wastes.

The selection of appropriate residue utilization approaches requires careful study. The following factors deserve close evaluation: possible markets, health aspects, the level of economic and technological development in the local area, available physical and human resources, social changes that may be needed to implement the approaches, research and development institutes which may be needed to explore potential approaches, industry and government policies, national interests, and possible legislation as well as other incentives.

There is no one best approach that can be used in all residue utilization situations. In each situation, the possible alternatives need careful evaluation with the most appropriate approach chosen to provide the desired environmental, economic and social objectives.

The questions to be focused on are:

- Is there adequate information upon which to make residue utilization decisions and if not how can it be obtained and disseminated?
- What are the factors currently constraining broader residue utilization and what possibilities exist to reduce the constraints?
- What are the promising technologies, end-uses and markets for agricultural and agro-industry residue utilization?
- What priorities and action programmes should be established?
- What incentives or education is necessary to increase the use of environmentally sound and socially feasible residue utilization approaches?

SESSION II focused on the constraints and incentives in residue utilization. Session IIa emphasized the institutional aspects.

(A) Dr. E.F. Szczepanik, Senior Economist, Policy Studies Group, Policy Analysis Division, FAO, discussed the socio-economic aspects. He emphasized the need to establish national research and development centres on residue utilization and recycling, the necessity for research on appropriate technologies, the need for research on the social costs of residue utilization, the need for social changes in attitudes, economic and social organization, and intersectoral planning, and the need for information and adult education programmes to create the required awareness.

During the discussion the participants raised the following points:

It was suggested that it might be advisable for governments to aim that animal feeding be restricted to agriculture and agro-industrial residues, thus reserving grains for human consumption.

It would be useful for governments to establish a mechanism to monitor and encourage developments in the recycling of residues.

The "appropriate" technologies should include those aimed at "reducing poverty", in addition to those aimed at specific products or markets.

The definition of the optimum size of recycling units was found impossible in general terms without specific reference to the nature of residues, quantity, type and location of the end-use of the finished product, the infrastructure and personnel available. In developing countries, transport was perhaps the most important consideration and it was suggested that recycling units be installed at the site of the industry producing residues where feasible.

The cost of recycling the residues is increasing and, although the costs are possibly lower than the costs of treating urban effluents, the profits of recycling rarely cover the processing expenses.

The necessity of co-ordinating the manifold aspects of residue utilization and management at the international level was stressed. This matter should receive close evaluation in considering residue utilization approaches. Such co-ordination could be done through national centres on residue utilization, regional centres, and/or international organizations such as FAO and UNEP.

The expression "waste", having the connotation of uselessness, should be replaced by a positive term such as "residues".

(B) A discussion on the health aspects of agricultural residue utilization was presented by Dr. Dieter Strauch, Institute of Animal Medicine and Animal Hygiene, University of Hohenheim, Stuttgart. The presentation emphasized the need to minimize the transfer of human and animal pathogens when utilizing agricultural and agro-industry residues, the types of infectious diseases that can be transmitted, technologies that can be used for control, problems with the use of antibiotics in animal feeds and their resultant concentrations in manures, and common hygienic problems such as soil and water contamination that result from excess application of manures to the land.

The discussion following the presentation covered the following issues:

It was not always desirable that straw surplus be applied to the soil since it took a long time to degrade in certain soils and the residue could hamper tillage operations. Excess amounts of straw applied to the land might produce phytotoxic effects. With extensive crop production, the resultant crop residues could be more than should be applied to the soil.

Adequate testing of agricultural residues at the earliest possible stage should be a part of all utilization approaches. This testing should include testing for faecal pathogens and other possible health hazards. In doing so, decisions on suitable technologies or modifications in the technology could be made in the light of the test results.

Chlorine disinfection continued in wide use although there was concern regarding potentially toxic substances formed during the chlorination of heavily contaminated waste streams. Ozone and other disinfecting agents were under investigation. Effective disinfection works best on effluents containing low BOD and suspended solids concentrations. Thus removal of the BOD and solids prior to chlorination is desirable.

In deciding upon suitable residue utilization approaches, consideration should be given to the possible transfer of metabolites, such as antibiotics, metals and similar material, when residues are used for animal feeds. Possible environmental problems need to be identified and evaluated.

A balance must result between complete removal of health hazards and complete avoidance of environmental problems. In many cases, these desirable aims are in direct conflict. It was also stressed that legislation prohibiting the use of certain materials in feeds or requiring specific health and safety measures should be based upon fact and supportable data.

(C) Information on the legal aspects of agricultural and agro-industrial waste management was presented by Avv. Mario Guttieres of the International Juridical Organization, Rome. This presentation stressed the need for further information on appropriate legislative and administrative instruments for waste utilization and control, especially in view of the requirements of developing countries. In most developed countries, legislative measures had been taken to promote rational management of residues in various sectors, but only few countries had enacted organic environmental legislation facilitating an integrated approach. A summary of the recommendations formulated by the IJO working group, both as regards improvements in national legislation and as regards international harmonization of standards was presented. These recommendations included the following:

(a) Each government should:

- Integrate the different rules, regulations, and laws relating to residue utilization into comprehensive legislation to avoid duplication among agencies, departments, and ministries.
- Reduce any administrative fragmentation relating to residue utilization to unify as much as possible the various functions and responsibilities and to better co-ordinate environmental legal policies.
- Help ensure local implementation of residue utilization programmes by public authorities and private organizations, possibly through a specialized administrative office.
- Promote legislation to encourage research and development of residue utilization technologies.
- Help ensure that common enviornmental and sanitary standards are applied to products resulting from residue utilization for both internal consumption and export.
- Develop training programmes that include specialized courses in environmental law and economics for the training of waste management and residue utilization experts.

(b) At the international level, action should be taken to:

- Promote a comparative study of the most advanced national legislation relating to agro-waste management, to serve as background information for legal and institutional reforms in other countries.
- Co-ordinate advisory services on appropriate waste management and residue utilization legislation that can assist developing countries.

In the discussion, the following comments and suggestions were made:

Because of the priority of technical and economic requirements over purely legal considerations and because of the difficulty to reconcile conflicting legislative objectives, legislation, in order to be effective, should be (a) based on good scientific evidence, (b) enforceable in practice, and (c) fair to all parties concerned.

National sanitary controls imposed by importing countries must not be used as a pretext for non-tariff trade barriers against products from developing countries. With regard to the need for uniform safety standards for commodities in international trade, reference was made to indirect methods of international standardization which had proved to be effective even without being formally binding, such as the guidelines for novel protein sources.

Legal measures should facilitate systematic collection and international exchange of statistical data relating to residues utilization.

Attention was drawn to the importance of legal liability incurred by the producers of residues which are not recycled or treated in accordance with environmental standards, and to the need for a common legal and fiscal regime for agricultural and other wastes.

In response to a comment, a clarification, supported by the Chairman, was made, that any harmonized strategies at an international level must take due account of national sovereignty and that the competent central authority mentioned in the recommendations, referred to co-ordination at the national level rather than at the international level.

Session IIb contained presentations on regional surveys in Asia and Africa as well as an information exchange.

(A) The paper by Dr. Bharat Bhushan, Deputy Director, Regional Research Laboratory, Hyderabad, India, assessed the availability and utilization of agricultural and agro-industry wastes in India, Indonesia, Malaysia, Philippines, Singapore and Thailand. Potential possibilities for exploitation of these residues were also suggested. The main findings of the survey were:

- Rice is the major crop of the region and it generates an estimated amount of residues as follows: 270 to 300 million tons of straw, 20 to 23 million tons of husk and 3 to 3.5 million tons of rice bran.
- Uncontrolled denudation of forests for lumber and fuel causing land erosion and floods.
- Production of commodities obtained mainly by primary processing (e.g. palm oil, rubber, coconut, sugar, etc.) and inadequate development of secondary and tertiary processing industries.
- The predominance of fishing and fish culture but, with the exception of Singapore, insufficient attention to livestock farming.
- High post-harvest losses especially due to inadequate and poor storage facilities.
- The capital-intensive and labour-saving technologies now being introduced in the region are in most cases not compatible with the social and economic needs.

In the discussion, the following comments and suggestions were made:

- In Malaysia, special attention should be paid to the utilization of agricultural waste and preparation for animal feed. At present nearly 2 million gallons of palm oil sludge goes to waste annually. However, this residue could be absorbed on tapioca chips to render it useful for animal feed.
- In the Philippines, there is an urgency for the utilization of coir pith waste (dust) resulting from the manufacturing of coir products.
- With regard to cassava, simple methods are now available to enable the roots to be stored for several weeks.

(B) At the request of the Chairman, Dr. M. Fleischman made a brief report of the Project of the American Institute of Chemical Engineers for the League for International Food Education (L.I.F.E.) sponsored by the U.S. Agency for International Development.

- In the Philippines, from the standpoint of environmental impact as well as potential residue utilization, distillery slops from manufacture of alcohol from molasses, reject bananas and coconut waste water from dessicated coconut factories are important considerations. In Thailand, sugar wastes, tapioca starch wastewaters and pineapple canning wastes are significant. In Indonesia, the emphasis is primarily on food production and employment and not as yet on environmental matters. Another factor limiting waste utilization is the largely rural based and widely dispersed food industry. Potential possibilities for residue utilization are wastes from palm oil, trash fish and wastewater resulting from coconut dessication. In Malaysia, palm oil wastes are of major environmental concern and hence are a major source of residue. Much work is being done on treatment and utilization of this waste for animal feed.

- Attention was also drawn to the pilot plant in the Philippines, for manufacture of dextrine and single cell protein from coconut wastewater.

(C) Prof. W.R. Stanton, Faculty of Sciences, University of Malaya, Kuala Lumpur, Malaysia, reported on the survey made in Egypt, Sudan, Kenya, Tanzania, Nigeria, Ghana and Algeria. The main conclusions are that with the exception of residues from starch and sugar production, the opportunities for residue utilization in the region surveyed are comparatively limited in the immediate future. The report also noted that throughout the countries surveyed, particularly those south of the Sahara, there was a shortage of food in general, as distinct from a protein shortage. Radical changes in agricultural pattern would need to be implemented to meet this need for food directly, by improved supply of primary products rather than by indirect supply of protein via animals. Grain legumes were noted to be the group of crops which can best provide an effective total utilization of the biomass grown.

Comments and suggestions made in the discussion are:

- In Nigeria, research is being carried out on the fermentation of over-ripe fruits such as bananas, plantains, and pineapples to produce alcohol. In addition, work is being carried out on the use of palm kernel shells to produce carbon. However, the existence of large deposits of crude petroleum in the country may not make this venture commercially and economically attractive.

- In Ghana, agro-based industrial by-products are being investigated for use as animal feed, either as substitutes for expensive feeds or as supplement, especially where fodder is scarce or inadequate. Among the items being studied are wheat-bran, rice-bran, corn-cob, spent malt, copra cake, groundnut cake, and peelings from cassava, pineapples and plantains.

- In Egypt a new process for extracting pectin has been patented. Mango seeds are now used to produce starch, oil and animal feed products. Bricks, stronger and lighter than the conventional variety, are now manufactured from rice hulls.

- In the Sudan, large acreages are now under cultivation for sorghum, wheat and cotton. However, about 30% of the grains are lost during the post harvest period.

- The question of what is the stimulant for residue utilization was raised. The contention that technical issues are not of primary importance, but plant managers, farmers etc. must be motivated to utilize wastes, was also made.

- There is a great need for small-scale driers, especially using solar energy, for the drying of agricultural products. This comment also applied to other developing regions.

(D) At the request of the chairman, Mr. S. Barnett made an additional report of the Project of the American Institute of Chemical Engineers for the League of International Food Education, sponsored by the U.S. Agency for International Development.

- A conclusion of the study is that there is a great need for small-scale driers, expecially using solar energy, for the drying of agricultural and food processing residues.

- In Ghana, cocoa processing residues are a major waste. In the Ivory Coast, oil palm sludge is a major residue. While pineapple canning residues were wasted in Ivory Coast and Ghana, they were used as cattle feed in Kenya. Although some countries waste molasses, Kenya is starting to produce animal feed from molasses.

(E) The topic on information exchange was introduced by Mr. W.H. Barreveld, Agricultural Industries Officer with FAO. Initiatives by FAO on information exchange with regard to agricultural residues began in 1973, when the first international directory of institutions involved in residue utilization was published. This will be followed by the publication of a compendium of selected applied technologies and a bibliography on selected topics. FAO intends to regularly update these three publications. The second edition of the directory and the compendium were on display at the Seminar and additional information or corrections from the seminar participants were requested.

Mr. L. de Rosen, Director, Industry Programme, UNEP, also described the concept and work of UNEP's Information Referral System (IRS).

For the discussion, representatives from the following countries provided additional information.

- Egypt - The Academy of Scientific Research and Technology, Cairo has information on residue utilization, pertaining specially to Egypt and would be willing to assist FAO/UNEP.

- France - The Centre de Documentation Internationale des Industries Utilisatrices de Produits Agricoles (CDIUPA) computerizes about 1000 publications and can provide references and abstracts on articles appearing in these publications.

- The French Ministry of Industry is conducting a census on existing residue disposing and utilizing processes which have some economic viability.

- Attention was drawn to the monthly publication, Resource Utilization and Conservation, published by Elsevier Press.

- India - A copy of the draft status report "Utilization and Recycling of Wastes", prepared by the National Committee of Sciences and Technology was provided.

- USA - Mention was made of the work being done by EPA in relation to IRS as well as with the EPA bibliographic and documentation system and also of the facilities available at the EEC Documentation Laboratory on Computers located at ISPRA Italy.

- The delegate from Sweden mentioned the catalytic and co-ordinating role of UNEP. Other international organizations, especially within the UN family, for example, UNIDO, WHO, ILO are also involved in work that relates to and has an impact on the environment. These organizations must be cognizant of the environmental aspects of relevant problems and their respective activities.

- Because methods of waste disposal may differ due to meteorological, topographical and other conditions, a classification of abatement techniques, for dissemination and exchange of experiences, was suggested.

- In response to a comment that often developing countries have a need, not only for abstracts but the complete article, mention was made that FAO's Library and Documentation Systems Division can provide copies of documents available at FAO. If the material is not available then addresses of other possible sources would be provided.

- The possibility of regional documentation centre(s) pertaining to residue utilization was raised.

- The UNIDO International Centre for Industrial Studies and the Industrial Information Bank that provide information on technologies, policies, engineering and other aspects of industries were also described. UNIDO has considerable information available, part of which deals with the utilization of industrial by-products and the safe disposal of wastes.

- The need for improving and updating information on residue utilization and the effective dissemination of this information was reiterated.

SESSION III - Technology which may be considered for the utilization of residues was the subject of this third session and covered the fields of energy, food and animal feeds, fertilizers, construction materials and paper from wastes as well as the microbial conversion of wastes.

(A) Energy from Organic Waste was discussed in a report presented by Professor B.A. Stout, Agricultural Engineering Department, Michigan State University. The report reviewed the techniques available for converting organic residues to more directly usable solid, liquid or gaseous forms of energy as well as the feasibility of various conversion processes. It also discussed the economics of production and suggests some incentives to industry and individuals for applying these processes.

Note was taken that although enormous quantities of biomass (1×10^{11} t/a) are available for the use of man, there are a number of competing uses, such as food, clothing, construction, fertilizers, etc., besides energy. The cost of collection of residues can be a formidable obstacle to their use as sources of energy. Furthermore, quantity of energy required to use organic wastes as a source of energy should be taken into account in each application. In general the growing of crops specifically for use as fuels is not considered cost effective.

Note also was taken of a number of recommendations to governments, industry and international organizations:

(a) To governments:

- Initiate surveys and studies to determine the quantity of organic residues available for direct use as fuel or for conversion to more convenient solid, liquid or gaseous fuels.

- Identify and assess appropriate technologies for converting organic residues to more convenient solid, liquid and gaseous fuels and for useful work.

- Suggest research and demonstration projects to more clearly define optimal use of organic residue as fuel, fertilizer, feed or for other uses.

- Provide incentive programmes to encourage individuals and industry to take the necessary risk and make investments to develop and apply innovative technology to utilize organic residues as appropriate for fuel, fertilizer, feed or other uses. Mount a publicity campaign to advertise these new incentives and highlight successful adoptions.

(b) To industry:

- Each industry and each company is urged to analyze its own operations to assess the potential for economic utilization of its organic by-products and residues. Industry should communicate to the government the nature of bottlenecks and restraints which prevent more effective utilization of organic resudues and seek improvements in incentives and reduction of disincentives for adoption of new and innovative residue utilization practices.

(c) To international organizations:

- In collaboration with Governments, develop and encourage adoption of standard terminology and methodology for reporting data on quantities of organic residues available for use as fuel, fertilizer, feed, etc.
- Develop and disseminate technical and economic parameters governing optimum use of organic residues for fuel, fertilizer, feed or other uses.
- Tabulate and disseminate examples of successful use of organic residues as energy sources and publish guidelines for transferring successful technology elsewhere.

(B) Food from Waste and Nutritional Considerations was discussed by Dr. George D. Kapsiotis, Senior Officer, Food Policy and Nutrition Division, FAO. The report dealt with production of foods from residues in the light of the two major world problems of food shortages and pollution. The types of food products considered are those which are recovered as nutrients and those which may be transformed through bioengineering processes. Nutritional impliocations of various available technologies and present practices are considered and guidelines already in use were stressed. In this context note was taken of the work of the Protein-Calorie Advisory Group of the UN System (PAG).

Consideration is given to the safety and wholesomeness of various foods from residues and the methods of testing and examination required are discussed. Nutritional values of foods are also discussed. The important questions of acceptability and tolerance by the consumer are dealt with as well as the need to adapt food regulations before commercial investment is made.

Discussion focused on aspects of the production of single cell protein (SCP). The reluctance of the consumer to accept new food, particularly derived from SCP, was observed, particularly under conditions of large traditional food surpluses. The present case of the skim milk surplus within the European Community was mentioned. It was pointed out, however, that the situation varied in different parts of the world. Whilst the demand for SCP would not be competitive in the Western European market, it was reported that the U.S.S.R. and Venezuela are considering large investments in SCP production to supplement animal feed. Capital investment in SCP production facilities in Europe had been made, but production awaited a decision as to safety of the product for specific uses.

In developed countries, SCP production is apt to be promoted to reduce pollution because governments are imposing legislation to reduce industrial pollution and in some cases SCP production may offset wastewater treatment costs. In developing countries there is a shortage of protein and the use of residues to produce SCP is to produce protein and not primarily to reduce pollution.

Whilst some delegates considered that the nutritional as well as the toxicological aspects of SCP had been solved for the most important types which have been developed for growth on n-paraffins and certain odd carbon fatty acids, others stated that the economic feasibility as well as the nutritional and toxicological considerations needed further examination. This raised the question of the use of SCP for direct human consumption as well as for animal feed. The value of exchange of experience amongst countries was noted. In this context the proposed compendium would make a useful contribution.

Concerning the cost of SCP harvesting it was reported that whilst there were high costs and harvesting problems with chlorella algae, there were no problems in harvesting biomass from fermentation processes.

Finally, there was a discussion on yields of protein from various conversion processes. It was reported that experimental evidence shows that ingested protein is converted as follows:

by dairy cows to milk : 30 to 33%
by poultry (broilers & layers): appr. 20%
by pigs : appr. 15%
by ruminants (beef cattle) : appr. 5%
sheep : appr. 8%

Although the meat ruminants appear inefficient with regard to protein conversion, these animals (cattle, sheep, goats and buffaloes) feed on rough grazing and on hill or mountain pasture which is not likely to be cropped in any other way, hence they are more competitive in terms of protein conversion than the data suggest.

It was noted that SCP is used mainly for feeding pigs and poultry and supplements the use of grain feedstocks which could be better used for direct human consumption.

It was noted that there are different types of problems if the residues are fed to animals which are used for human food or if residues are processed directly as human food. If the first approach is used, there can be fewer problems since the animal acts as an efficient biological filter provided that care is taken to eliminate non-metabolizable contaminants such as heavy metals or substrate residues and pathogenic organisms which may be non-harmful to the animals but harmful to man. If the second approach is considered, there are more formidable problems and great care must be taken before the processed residues are used for human consumption, such as feeding residue generated SCP directly to man.

(C) Microbial Conversion of Wastes was the subject of a report by Professor W.R. Stanton, Faculty of Sciences, University of Malaya, Kuala Lumpur. A presentation on the same subject was also made by Dr. Da Silva of UNESCO.

Professor Stanton's report provided a systematic summary of the microbiological processes available for various residues, particularly cellulosic and starch wastes, sugar and mixed effluents, animal by-products and toxic wastes. Certain practical aspects were considered. Emphasis was placed on the need for more information from industry on the latest processes and it was observed that more information is available on the larger scale processes than the smaller scale processes. Comment was made on the need for more attention to be paid to microbial degradation of raw wood ligno-cellulose. It was observed that residues vary in quantity, condition and distribution and must be treated as found. In this context attention should be paid to dilution and contamination of the substrate. Finally, it was emphasized that, whilst most microbiological research has been carried out in the temperate climate countries, many developing countries have high ambient temperatures and high and regular solar input. The "environment" of the microbial processes is paramount. Attention was drawn to the green algae, yeasts and lactobacilli.

Dr. Da Silva drew attention to the assistance UNESCO is giving in establishing a data bank of culture collections in Brisbane and the training courses on microbiology organized by the UNEP/UNESCO/ICRO Panel on Microbiology.

There was considerable discussion on process optimization and the hazards of microbial toxins. It was considered that where SCP production has been developed under strictly controlled conditions, the danger of secondary metabolite production, e.g. aflatoxin, is minimized. However, it was pointed out that, in practice, many substrates differ in their contents due to seasonal and other changes and it would not be possible to guarantee the same behaviour of the micro-organisms during the whole process of growing on such substrates.

The optimization and consequent design of equipment and its control system, by use of mathematical models to meet the requirements of chemically defined, but variable, wastes in activated sludge processes was discussed. It was reported that mathematical models for multi- and sequential organism processes are not well advanced, and the models available treat the mixture of organisms as a non-variable factor. This simplification is, however, useful in practical designs.

There was also discussion on the availability of nitrogen and phosphorous as feedstock for microbial processes. It was reported, for example, that 100g of protein requires 19g of ammonia, 34g of urea, or 75g of ammonium sulphate. As SCP contains approximately 50% crude protein, very large quantities of fixed nitrogen are involved. It was noted, however, that the 50% fixed nitrogen recovery in fermentation processes contrasts with 1% for agricultural processes. The need to optimize the process of feedstock production by agriculture with optimal post-harvest technology was emphasized. Similar considerations hold for phosphorous.

The representative of UNIDO reported on a pilot plant (10 tons/day) in Mexico to produce flour from algae. It was stated that methods have been developed for harvesting, de-colourization, purification and extraction of pigments from this material. Information on this plant was offered by UNIDO. A commercially viable plant for the production of Chlorella exists in Southeast Asia where there is a market for the product. This product is not considered solely as a source of SCP.

(D) The paper on "Waste and Organic Materials as Fertilizers", prepared by the Soil Resources Development and Conservation Service, Land and Water Development Division, FAO, was presented by Mr. W. Hauck of the Division. The increasing interest in developing and developed countries in an intensified use of organic materials as fertilizers as a consequence of the price increases and shortage of fertilizers during the recent energy crisis was described. The expected benefits from organic fertilizers include a supply of plant nutrients and the improvement of physical properties of the soils.

Organic fertilizers should not replace mineral fertilizers. The experience gained in various parts of the world has shown that the optimal combination of organic and mineral fertilizers is the most efficient way of increasing and maintaining soil productivity and conservation on a long term basis.

A number of constraints are limiting the wider use of organic materials as fertilizers such as: lack of knowledge of methodologies in processing and utilization, economic considerations under certain conditions, and tradition and use of organic materials for other purposes such as fuel and fodder. More intensive utilization of rural wastes is essentially a problem of information and training and international assistance should concentrate on transfer of useful practices, training of staff and supply of teaching material.

In the field of urban and industrial wastes, action is required on the development of more rational processing plants, on the organization of the compost distribution and utilization, and on special problems in relation to the control of toxic and hazardous waste components.

FAO is co-operating in the field of waste and organic materials as fertilizers with UNEP, UNIDO and bilateral organizations on this topic. Organic wastes as fertilizers will be a priority area in FAO's activities in the years to come.

The comments following the presentation emphasized the following:

- All forms of organic material can be considered as potential fertilizers, including green manures, peats as well as urban and industrial wastes.
- There is a need for simple methods for preparing residues, such as composting, for use as fertilizers and soil conditioners. With proper preparation, such residues can help restore the quality of soils and its organic matter.
- The emphasis should be on methods that have a positive benefit, such as utilization, rather than on those of disposal or dumping. The emphasis is equally valid for both developed and developing countries.
- Multi-disciplinary efforts are needed to achieve proper utilization of residues as fertilizers. The talents of engineers, agronomists and soil scientists are needed. Criteria are needed to use the residues as fertilizers. The criteria should recognize the differences in the characteristics of the residues, the type of soils, the crops to be grown and geographical differences of climate, temperature and humidity.
- When residues are applied to the soil as a conditioner or fertilizer, they should be applied at an appropriate rate to avoid contamination of run-off and soil water and to avoid odour problems. The residues should be applied at optimal rates to make best use of the material and to avoid environmental problems. Considerable research is needed to identify the optimal rates for specific conditions and on the utilization of certain types of wastes requiring specialized treatment and control of toxic and hazardous waste components.
- Priorities will be needed on specific situations, to identify the proper use of residues for fuel, fodder or organic fertilizers since such uses could compete with each other in a number of countries.

(E) Utilization of Waste Products in Animal Feeding was reported on by **Mr. M.** Chenost of the Animal Production and Health Division of FAO, who summarized the Consultation held at FAO in November 1976 on New Sources of Feed for Animals. This consultation had as its objective examination of the use of (a) low quality coarse forage, (b) agro-industrial by-products, (c) by-products from the wood and cellulose industry, and (d) of the recycling of animal residues and municipal wastes. The following conclusions of the Consultation were reported: (i) by-products represent an enormous under-exploited potential; (ii) techniques exist for incorporating by-product residues in animal feed but their use is sometimes restricted by economical and technical considerations.

The problem of the pharmaceutical product content, particularly of poultry manure, and the possible hazards to animals fed on processed manure was discussed. It was reported that these products may not be affected by any processes applied to treat manure used as a supplement in animal feed. This situation may call for government regulation.

In relation to sugar cane processing it was observed that not all the bagasse is available for animal feed, since in practice it is used for fuel in the processing operations. It was observed that while bagasse is a suitable substrate for SCP production and subsequent use in animal feed, pre-treatment is necessary and this step could result in costs for protein being as much as 50% greater than alternative protein sources such as soya bean.

Successful experience in using onion peelings in animal feed was reported by the representative of Egypt whereas garlic peelings appeared to have an adverse effect on animal performance.

It was observed that use of agricultural residues for animal feed may sometimes require sophisticated treatment and a certain density of animals in the production units, thus possibly leading to additional pollution. Consequently care has to be taken in choosing priorities for use of these residues. It was also noted in this context that certain agro-industrial residues may have a negative value and it was recommended that further research is needed in finding improved or other uses.

The opinion opposing the use of large quantities of cereals for animal feed was noted. Less intense animal production patterns may be required for more effective use of agricultural residuals in feed.

(F) Mr. L. Lintu, Forestry Officer, of the Forest Industries and Trade Division of FAO summarized the paper on construction materials, paper and paperboard from agricultural residues. Two groups of end-products were discussed - pulp for paper industries and non-wood panel board. Regional statistics on the quantities of residue used for each end-product were reviewed. Five requirements of a satisfactory supply of raw materials were enumerated:

- The supply must be large to permit economies of scale;
- It must be even throughout the year;
- The supply must be guaranteed for the lifetime of the mill equipment;
- The quality of the raw material must be homogeneous and constant;
- The cost must be competitive;

The potential supply of agricultural residues far exceeds actual utilization because:

- Agricultural residues are often widely dispersed and therefore costly to collect and transport;
- The denisty is low and in some cases unwanted materials are included;
- The harvesting period for annual crops is limited to a few months;
- Local weather conditions may adversely affect the supply of residues;
- Some residues have an excessively high silica content;
- Residue availability may be reduced by changes in agricultural policy.

The use of agricultural residues in panel products and paper industries is restricted mainly by economic factors while most of the technical limitations can be overcome.

No questions or corrections were submitted by the Delegates.

SESSION IV - The following contributions from participants were presented at the Wednesday afternoon session:

- Dr. James Parr, Chief, Biological Waste Management and Soil Nitrogen Laboratory, United States Department of Agriculture, Washington, D.C., talked about the recent conference on the crop residue management systems, held at Houston, Texas. He focused on the need to change systems in view of the move to the introduction of reduced or zero tillage. Some areas of the United States of America have more than enough crop residue to prevent soil erosion while other areas are less fortunate. The Conference discussed the related problems and suggested the need for further research to determine the amount of crop residues needed for erosion control, the amount which could be removed for fuel, cattle feed, etc., to determine the factors affecting decomposition when residues are left on or just below the surface in minimum tillage systems. It was also felt that plant breeders should develop varieties which will respond well under a trash tillage environment rather than clean tillage; similarly there is a need to breed higher nitrogen content residues, which would reduce the carbon/nitrogen ratio and the energy required to decompose the residue.

- Dr. Barnett of L.I.F.E. introduced some findings of the survey recently undertaken in some Latin American countries - Guatemala, Colombia, Ecuador, Peru and Brazi Reference was made to the high rate of waste bananas which amounts to 10-30% of the exported crop. A second product is pineapple waste, which only on one occasion was seen to be used as an animal feed. Rice hulls are burnt or piled up. No use is made of them. A process using Aspergillus fumigatus is applied in Colombia, using cassava as a substrate. The fermented broth is pressed in common jute bags and further sundried and used as pig feed.

  A major waste in Brazil is stillage from alcohol produced for fuel from sugar residues The quantity of this waste is expected to increase.

  Bagasse is mainly used as fuel. Mention was made of a sugar operation where the filtermud was used to feed a 900 head pig operation. In Peru citrus pulp is a prominent residue. Constraint for use is its high moisture content and development of solar driers is recommended. In the discussion the question was raised whether the strain of micro organism used could not create a health hazard. The speaker indicated that no problems had been experienced.

- Mr. André Bonin of SODETEG, France, presented a paper on electrodialysis. One of the appropriate technologies which can be used to convert effluent liquids from agro-industries is the system of electrodialysis. The system developed by SRTI gives a high rate of mineral salt removal, a low membrane surface area, a one or two-stage operation, a compact technology with low overall dimensions which consumes little electrical power. The system has been used with success in the French Dairy Industry to produce both acid and sweet wheys and has other agro-industrial application.

- The National Swedish Environment Protection Board (Ulla-Britte Fallenius) introduced a paper on "Handling of Wastes in Food Industry": About 90% of the residual products in this industry is utilized for various purposes, frequently for animal feed. Utilization may yield an economic gain, however waste handling costs often exceed the value of the recovered products. Specific examples of concern and of successful utilization were discussed.

- Non-fossil Carbon Sources (J.C. Shorrock, Battelle, Switzerland). The meeting was informed of the Battelle Institute's programme of research on non-fossil carbon sources and in particular the programme to demonstrate the technical and economic feasibility of using agricultural by-products as raw materials for the chemical and agro-food industries. Particular mention was made of the project currently in the pilot plant stage to develop the acid hydrolysis of straw, bagasse and other cellulosic residues to C_5 and C_6 sugars which can then be fermented to SCP or ethanol.

- An Approach to Waste Utilization in Rural India -(J.J. Patel, Bombay) The approach deals with the production of biogas, or gobargas, from the fermentation of cattle manure and other wastes. Data on the quantity of the wastes was provided. Most of the electricity in rural areas comes from such systems. This approach also conserves the nutrient value of the wastes and helps avoid the use of other scarce resources. About 30,000 plants are now working in India.

- Bio-Gas (Gobar Gas) and Manure from the Waste of Farm Animals -(H.R. Srinivasan, Gobar Gas Scheme, Bombay). The paper is based on work done in India during the past four decades. The effect is to supply the rural population with efficient non-commercial fuel, reducing use of commercial fuels. The resultant manure from the gas plants is superior to available farm yard manure. Farmers using gas plant manure obtain 25 to 33% more yield from their fields. The gas is also used for domestic purposes as well as for the energy needs of other operations such as poultry production and laundries. International assistance is needed to expand and enhance the use of this scheme. .../

- Pig and Poultry Wastes in Hong Kong (P.C.G. Isaac, J.D. & D.M. Watson, U.K.) The seminar was informed of the problems of disposal of pig and poultry wastes in Hong Kong, presently the main source of organic pollution. Landspreading can do little to mitigate the problem in Hong Kong. The only answer is artificial drying to produce fertilizer or animal feed supplement. Pilot plants for continuous drying of poultry manure and a batch dryer for pig manure have been installed. The costs of the continuous process are presently rather high and require skilled supervision. Assuming further modifications to the dryers it may be possible to considerably reduce costs. The products from these processes have a wide application, especially as animal feed supplement. In answer to a question mention was made of the after burner which reduces any noxious odours.

- A paper on the problem of the utilization of organic waste on Italian livestock farms was introduced by Mr. Domenico Siniscalchi of the Ministry of Agriculture. Some 100 million tons of animal waste are generated yearly, 20% of which are produced in intensive animal production units. Most of these latter wastes do not re-enter the productive cycle and are estimated to represent a loss of one hundred million dollars. The most severe problems are encountered by the disposal of waste waters from pig farms. Specific problems are existing in the Po plain where the concentration of intensive production units is very high. Lagooning is practised most frequently in Italy. After separation of the solid parts the liquid is used for irrigation. Also dry removal of animal manure is increasingly applied in modern production units.

- Animal Feedstuffs from Waste and Surplus Fish (D. James, Fishery Industry Division, FAO, Rome). Fish meal production utilizes about 27% of the fish that are caught. Other processes include fish silage and fish powder. Fish ensilage could be on a village or industrial level for small fish catches. There is need for experimental work in the mechanism for acid production and on feeding trials with livestock, particularly in the tropics. Possible constraints relate to taints in meat and eggs, the corrosive nature of silages, and the need for starter cultures of microorganisms.

- Leaf Protein (A. Salgado de Oliveira, Talleres Ovidio Martinez S.A., Spain) The Seminar learnt with interest of experimental work carried out in Spain to utilize the grasses which grow luxuriantly in the humid tropics during the wet season. In the past this grass has simply been burnt at the end of the dry season. The process described produces a number of products including grass meal, edible oil, leaf protein and fermentation products. The introduction of an oxygenator improves the efficiency of the process.

- Recovery and Utilization of Residues from Brewing and Other Fermentation Processes (R.M. Gray, A.P.V.) Five processes to recover protein-bearing materials from brewery wastes were discussed: waste brewers yeast, brewers grain processing, spent molasses wastes, distillers dark grains, and distillers dried solubles. Installations have proved that in favourable circumstances, such operations can be economically attractive. Certain problems remain unsolved such as the use of large quantities of energy used in evaporators and driers and life of membranes in mechanical separation methods.

- A paper on Protein Recovery from Abattoir and Poultry Processing Wastewaters was introduced by Alwatech, U.K. The Alprecin Process for protein recovery from meat and fish industry wastewaters is in fullscale operation in several countries. The process is based upon protein recovery with lignosulphuric acid at pH3, followed by dissolved air flotation; the flotated material is concentrated together with blood and dried with other products in a rendering plant. The safety of the recovered product in animal feed has been established, and the efficiency of the system for effluent treatment has been demonstrated at about 80% BOD removal.

The economics of the process are usually good for units above a minimum size - for example, plants with a throughput of more than 300 cattle or 20,000 chickens per day.

- The subject of utilization of wastes from agriculture and agro-industry in Central America was introduced by Mrs. Schneider de Cabrera. The utilization of coffee processing wastes is a major problem in Central America. Coffee is processed by wet processing and there is coffee waste water, 40% by weight of pulp and 20% mucilage. Fungi grown on coffee waste water produces an animal feed supplement. A pilot plant has been established in El Salvador. The high caffeine and polyphenolic content of pulp has limited its use in animal feed. A system of fermentation has been developed which reduces the content of these limiting substances so it is now hoped to start feeding trials. Work is being reactivated on methane production from pulp. The possibility of pressing the pulp so as to use the dry pulp as fuel and the liquid phase as a fermentation substrate. The mucilage layer, having a high carbohydrate, mainly pectin, can be used as a substrate for fungal growth and also for the production of commercial pectin.

- A paper on Considerations Concerning the Upgrading of Cellulosic Wastes and Carbohydrate Residues from Agriculture and Agro-industries was presented by Dr. J.L. Baret of Battelle Research Centre in Geneva. Various processes are considered in the paper as well as technological alternatives, their applicability and their costs. The paper indicates that although use of cellulosic wastes remains limited, there are efficient, economically feasible, industrial processes for upgrading these wastes for further use. More research is required on the hydrolysis of cellulosic materials to produce sugars. Research was reported to develop a non-waste technology in order to minimize the problems of biological sludge disposal, with simultaneous recovery of valuable materials as SCP.

The following papers were distributed to participants but not orally presented to the Seminar:

- Products based on sulphite spent liquor (Ministry of Agriculture and Forestry, Finland)
- Processes for SCP recovery from agricultural wastes (Tate & Lyle, Ltd., U.K.)

- Stillage treatment in sugar and molasses distilleries
  Recovery of fat and solids from filleting waste waters
  Centriflow fish liver oil process (Alfa Laval, Sweden)

- Waste bioconversion : environmental management for economic progress in developing countries (UNESCO/UNEP)

Summary of Working Groups

Working groups were established in broad commodity areas to draw upon the experiences of the participants, to identify gaps in existing knowledge, and to identify needs and action programmes to help fill such gaps. The following material summarizes the discussion and suggestions of the various working groups. The recommendations of the working groups have been incorporated in Section II. The participants in each working group are identified in Appendix F.

1. Fruit and Vegetables

The following commodities were reviewed: tomatoes, peas, artichokes, string beans, potatoes, carrots, citrus fruit, grapes, olives, apricots, peaches, mangoes, guava, quince, onions, garlic, dates, cocoa, bananas, pineapples, apples, cherries and figs. Processing of these commodities produces the following residues: seeds, peels, cores, stones, husks, leaves, rejected whole fruit and juice.

These residues occur in all geographical regions and in various seasons, depending on commodity, but usually in short periods, thus creating problems of supply. The residues occur mainly during canning or bottling but also when fruit and vegetables are picked from the trees or collected on the ground.

The residues under review could be reduced by alterations in the main process or parent material, particularly by improving juice extracting equipment and by genetic improvement to reduce peel content in citrus fruit and to increase the usable portions of fruit and vegetables.

The most promising end-uses of residues include direct animal and fish feeding either in wet or dry form, fuel, compost and construction materials.

The most promising technologies include composting, fermentation, drying, land filling.

The main constraints in effective use of the residues consist of health and sanitary regulations with regard to animal feed, irregular and thin geographical spread of supply, lack of export markets and unfamiliarity with appropriate technology.

It was agreed that assistance should be provided to developing countries in the processing of fruit and vegetable residues. The following commodities, among others, were recognized as particularly important: citrus fruit, bananas, grapes, cocoa, coffee and olives. Priority should also be given to energy-reducing techniques, research programmes, demonstration units, and training programmes.

2. Beverages

The main residues from beverage industries were identified as: spent molasses liquor, spent brewery and distillery cereals, coffee grounds and spent green tea, and residues of fruit and vegetable juices, including wines, cashew and apple.

Molasses, the by-product of beet and cane sugar, is used throughout the world for the production of industrial and beverage alcohol, citric acid and a number of other biochemical and pharmaceutical products. The problem associated with molasses fermentation is the disposal of residues (distillery slop, stillage, vinasse). Some technology for further processing, such as evaporation, anaerobic fermentation, yeast and protein separation, and desalination is available.

The residues have a relatively high mineral content and high BOD which makes further utilization difficult. No satisfactory economical and commercial use of the end product has been found.? To the knowledge of the Group, there is very little current research work in this particular field anywhere in the world.

With the expansion of sugar production and concentration of industry, the problem related to spent molasses liquor has become more acute. The problem for developing countries appeared to be one of usability of spent molasses liquor whereas for developed countries the question was primarily associated with the prevention of serious pollution.

Well developed technology exists for the treatment of residues from cereal based beverage processes to render them suitable for blending with other materials to form excellent feed materials. Present technology tends to be energy intensive. In some countries such technology was not commonly applied. This was attributed to comparatively low profitability, the absence of feed manufacturing industries in areas unfavourable to animal husbandry; and a lack of recognition of the potential by possible users.

The utilization of coffee grounds and spent green tea does not present serious problems. Research into further utilization of these end products is well underway. With an increasing production of instant coffee in developing countries, new pathways of residue utilization might have to be pursued.

Fruit juices are, for the major part, produced in tropical or semi-tropical countries. Residue utilization in the form of oil production, manure and fuel did not seem to present problems. Residues of several fruit juices are being utilized in the manufacture of natural colours.

3. Cellulose Residues

All plants contain cellulosic materials and cellulosic residues are therefore widely available. Plants can become a residue in four different stages: when being left unused such as the tropical grasses, after harvesting the main crop such as straw in cereal production, after processing the plant in industrial or semi-industrial operations, such as bagasse in the sugar industry, and after consumption of the product.

Most of the cellulosic residues are available seasonally although there are some residues which become available continuously, e.g. urban solid waste. Ecological zones have an effect on the type of the residue. Development of new plant varieties affects the quantity and quality of residue. In some instances use of cellulosic residues can be improved through plant breeding. Quantification of the availability of cellulosic residues for any particular use always should take into account the competing uses. An inventory by countries of the quantities and qualities of cellulosic residues available for use in each country should be made.

Reduction of residues may be possible through genetic selection and during the processing stage of residue utilization, such as the example of the differences in the residues generated by the wet or dry methods for coconut husk processing.

A great number of technologies for residue conversion to more useful products is available but their application completely depends on the economical feasibility. For instance under present economical conditions, wheat straw, of which 8 million tons are produced in Denmark, can be successfully converted to feedstuff for cattle by mixing with other agricultural wastes. Of the other methods for processing cellulosic residues, silage, composting, chemical hydrolysis and anaerobic fermentation appear to have economic possibilities.

The proper end-use of cellulosic residues is mostly for feedstuff so far as industrial conversion of residues is concerned. The use of sea-plants may be new materials for feedstuff because they are not limited. Further research is requested on this subject. Other possible uses of cellulosic residues are as medicines, chemicals, energy sources.

The economics of collecting and processing the cellulosic residues are the most severe constraint to their use. Identification of appropriate technologies, encouragement to their use, and additional basic research on the physical, chemical and biochemical properties of materials that is relevant to the residue utilization, could help to increase the use. Exchange of information on technical and economic parameters governing the optimum use of residues as means for furthering their use is needed.

4. Fish

The fishery industries have a unique residue pattern which does not conform with that of other agro-industries. The most pressing problem is the loss or wastage of high quality animal protein which results from ineffective utilization of what is harvested. The solution to this problem, which is particularly apparent in tropical developing countries, lies in a long and slow development effort to make more and better fish available for direct human consumption. At the same time catches not suitable for, or surplus to, human requirements should be processed to high quality animal feedstuffs.

The major residues and losses in the fishery industries are in three broad areas:

a) in many fishing operations, particularly trawling, considerable quantities of low value or undesirable species are taken incidentally to the target species. Where the difference in value is great, such as in the shrimp trawling industry, the low value species are frequently discarded immediately after the catch. It has been conservatively estimated that 5 million tons of by-catch is discarded annually by shrimp trawlers. This represents a net loss as the fish is dead when returned to the sea.

b) The second major area where high losses occur is where fish is allowed to spoil or lose nutritional value as a result of bad handling or processing, before reaching the consumer. Significant losses of dried fish also result from infestation by insects and rodents, representing a net loss of protein. It is difficult to quantify these losses, but an overall figure of 30% would not be unreasonable.

c) Potential pollutants from fish processing operations which are discharged into water bodies or the atmosphere lead to environmental hazards as well as protein loss. These can range from the discharge of large volumes of effluent with high BOD to disposal of processing offal in unsanitary circumstances. There is no data to quantify these losses.

By its nature, fishing is seasonal and losses are particularly likely to occur at peak fishing seasons. Most of the by-catch discarded by shrimp trawlers is in developing tropical countries. These countries also account for a high proportion of spoilage and infestation losses during processing and distribution. Additionally, economics force the population to consume some spoiled or infested fish. The only alternative is direct feeding to domestic animals (ducks and pigs) or farmed fish. In developing countries, potential pollution from fish processing is not considered a significant problem except where high volume operations, such as fish meal production, are established.

In developed countries, the by-catch is generally better utilized and spoiled fish, while lost to human consumption, is usually processed for animal feeding purposes. Recently because of stricter environmental legislation, pollution from fish processing plants has become a significant problem.

Considerable reduction of losses could be achieved in all areas of the world. However, this demands willingness to change traditional practices and the transfer of appropriate technology.

The priority area for attention is the increased use of marine resources as human food. Introduction of new technology, leading to reduced losses, will contribute to this aim.

The resources which are available but which for one reason or another are surplus to present requirements should be converted to effective animal feedstuffs. The possibility of extracting valuable industrial or pharmaceutical products from fish wastes should not be overlooked.

In all areas of fish production for human food or animal feed, low cost products generally demand low cost technology. A number of low cost technologies are being developed to fulfil these needs. As examples there is a need for improved drying methods for fish where attempts are being made to introduce better solar driers and to use the waste heat from stationary diesel engines more effectively. Improved smoke-drying ovens for fish have been developed and are being introduced.

The proper use of ice, and where appropriate the use of boxes, can play an important role in reducing spoilage. At present ice is expensive, but the development of wind-driven ice plants should significantly reduce the cost.

Low-cost products can also be made by machinery which has been developed for separating fish meat from skin and bone. This method is particularly applicable to utilization of mixed species from the by-catch. As a raw material this separated fish can be used for sophisticated, blended and extruded products for developed countries. There are also opportunities for producing very low-cost products for low income consumers by mixing with salt or blending with cereal and frying.

Apart from the well advanced fish meal technology which is available, the most promising avenue for animal feed production would appear to be the ensilage of waste and surplus fish. Although a considerable amount of work is underway, a greater development effort is needed. The major requirement is for intensive feeding trials under tropical conditions to establish the economics and safety.

Developments in the technologies of FPC Type B production for human feeding and fish hydrolysates as milk replacers should not be overlooked. However, these technologies are likely to be considerably more complex and capital intensive than those mentioned above. In addition they are unlikely to be applicable at a village level.

A great deal of effort has been put into control of pollution from large plants and processes, and an array of relatively expensive technology has resulted. It is clear that waste recovery will only be undertaken where there is certainty of profit from the sale of recovered materials or where the polluter must pay for the costs of waste treatment.

Economics is the principal barrier to reduction of losses. As an example, the by-catch situation could be improved by selective trawling and separation of the catch. It is still difficult to persuade captains and crews to handle fish of low market value. Economic studies, including the use of collector vessels, have shown marginal profitability and legislation may eventually be necessary to ensure greater food production.

To date the lack of motivation and interest has hindered more effective utilization. In addition it is difficult to change entrenched social customs and established food habits.

Geographically the priority area for attention is the entire belt of tropical developing countries where it is vitally necessary to develop efficient utilization practices. These will result in better nutrition whether fish is made available directly as human food or is cycled through domestic animals. In the developing world the technology introduced should be simple, cheap and foolproof without sacrificing hygienic standards.

There are severe economic and nutritional problems caused by loss and wastage of world fish resources. As there is every indication that exploitation is approaching the maximum in many areas, the only room for further increase of production will be by more effective utilization. There is an urgent need for development of technology in this area.

5. Animals

The topic is extremely broad. A distinction should be made between the utilization of by-products and residues of animal industries (meat, milk, leather and utilization of carcass offals) and the utilization of animal manures.

Meat processing whether at the village or industrial level, produces a number of by-products including hides and skins, intestines and paunch content; wool, hair and feathers; hoof, horn, bone and blood and meat trimmings. Depending on the size of operation, these by-products can be processed into a single product for fertilizer, or into a large array of products, such as through tanning, wet or dry rendering, fat and oil extraction and other processes. While the technologies for these processes are widely available, in many countries there are legal requirements which have to be considered. These legal measures have been introduced to protect the environment and to protect human and animal health in the case of recycling into the food chain.

Some problems which require further research include the effective utilization of paunch content where it appears that after drying it becomes an acceptable animal feed supplement. This process has not been widely accepted because of the economics of water removal. The disposal of spent chrome tanning liquors is a recurrent problem for the tanning industry. There is also the problem of animal disease dispersion in effluents and in particular, dispersal of anthrax spores from tanneries which are importing their hides.

In most of the developing world there is no major problem in the disposal of milk by-products since there is a ready market for fresh milk. In the developed countries there are major problems with regard to the disposal of whey. The disposal problems of sweet whey are due to marketing problems whereas the disposal problems of acid whey are due to technical problems. Flash drying as well as reverse osmosis and electrodialysis are possible technical solutions for acid whey conversion.

The disposal of animal manure only becomes a problem where livestock numbers exceed available land for land spreading operations. Purification techniques may give good results provided that treatment processes are used which are adapted to this type of effluent. Well designed aerated lagooning for example allows a purification rate of at least 95% of the BOD5. While standards for a livestock/land ratio should be established, the standard will vary from place to place depending on such factors as climate, animal diet, species, and soil types. The aim of animal manure disposal technology should be to concentrate the solid phase and to use it as fertilizer. Changing population patterns in rural areas are becoming constraints to the expansion of animal production near human habitation as the tolerance to odours is reduced. Experience with anaerobic fermentation to produce methane from manures does exist. Global co-operation in, and financing of research for, efficient methane utilization is needed.

The Group noted with interest the Dutch experience of a "Manure Bank" where about 400,000 tons per annum are transported over considerable distances for subsequent land application. This calls for specialized tanker transport in order to avoid spillage and spreading of disease.

Little direct experience on the use of animal waste for animal feed is available at the present time. However, the human health aspects of this problem were discussed at a WHO Conference held in October 1975 at Bratislava. The seminar was organized by the Czechoslovak Research and Development Centre for Environmental Pollution Control - UNDP/WHO programme, under the sponsorship of the Federal Ministry of Agriculture and Food and the Federal Ministry of Technical and Investment Development and in co-operation with World Health Organization Regional Office for Europe. Proceedings will be available in May 1977 from Applied Science Publishers.

The production of animal feed from ensiling mixtures of animal and crop residues was discussed. In considering the refeeding of animal waste, attention has to be paid to the danger of disease transmission, and build-up of toxicity due to chemical compounds used as feed additives or in therapy.

In several countries the legal regulations on waste discharges are based on effluent technology and sanitation aspects. Other countries have proposed more stringent measures based on a "receiving water" quality standard. It is difficult to get environmental biologists to agree on such standards.

6. Cereals

The cereals and their residues were discussed in their order of importance, i.e.: rice, wheat, corn, sorghum and millet, grain legumes, barley and oats.

The production of rice is approximately 344 million tonnes, which can potentially provide over 60 million tonnes of husk, 12 million tonnes of bran and 1.9 million tonnes of oil. At field level, this generates close to 100 million tonnes of straw. Most of these residues are not optimally utilized and in many cases, up to 50% are wasted. As such, they are not only a loss but create disposal and environmental problems. Improvement of technologies for processing and optimal utilization of these residues could help to produce food for human consumption, animal feed, activated carbon, sodium silicate, silica molecular sieves, furfural, cement and other construction material. Rice straw if collected carefully, can be utilized in animal feed, manufacture of strawboard, and also as substrate for mushroom cultivation.

The production of wheat is nearly 355 million tonnes. It is the largest food crop in the world. Although it occupies a secondary position in the diet of most of the developing countries, efforts should be made to introduce technologies which will ensure utilization of high extraction flour. This could increase food availability from milled products by 20-25% and reduce corresponding residues. Where a sufficient amount of wheat germ can be collected for processing, it should be possible to manufacture germ oil and tocopherols from it with the extracted material used in the manufacture of protein rich foods. Bran could be used in composite animal feeds.

The production of corn is 322 million tonnes, that of sorghum 55 million tonnes and that of millet 46 million tonnes. These are important crops for dry land cultivation and deserve special attention in many developing countries. Their processing technologies should be upgraded to utilize them better for human consumption and also in the manufacture of composite flours. The residue from milling operations could be used in animal feed.

The production of grain legumes is nearly 47 million tonnes. Although these are not cereals, they are the largest source of protein in many developing countries. Their improved storage and milling operations can increase the supply of edible material by 5 to 10% and also improve nutritional quality.

These crops are important for many countries, especially in the manufacture of composite animal feed. Barley has a very large use in the fermentation industry. Special attention should be paid to the use of spent grain from the brewing industry not only for utilization in animal feed but also to upgrade it for human food.

In producing cereal crops, the quantity of straw that is produced is equal to or greater than the quantity of edible grain. Its utilization is therefore of great importance. A considerable amount of work has been done on the use of rice and wheat straw. New technologies have been developed for their efficient utilization in composite animal feed. Similar attention is required for straw from sorghum, millet, grain legumes and corn cobs.

The main constraints recognized to cereal by-product utilization were: availability of information, transfer of appropriate technologies, research and development infrastructure, training to build competence, practical demonstration of low residue processes, absence of integrated policies, allocation of adequate resources, collection of residues, management, marketing and distribution.

7. Starchy Roots and Tubers

Concentration was placed on residues from cassava, and potatoes since no industrial processing of other roots is known. Yam, sago palm and sweet potatoes were therefore not considered. Bananas were included in the discussion since this commodity was not covered by other working groups and was of interest to some participants.

The major residues that result are water slurries and solutions and solid residues. Crop residues such as stems and leaves from cassava also result. These residues occur at various stages of processing such as peeling when potatoes are used for French fries or mashed potato production, or when cassava is used for starch production. Slurry and liquid residues occur during washing, blanching, and trimming. Cassava residues are produced practically all the year round in starch plants in developing countries as are banana leftovers and offgrades. Potato residue production differs among regions varying from three to six months.

Residues could be reduced by better process operation controls during peeling and trimming and by water recycling improvements, particularly in cassava starch production.

The most promising end-uses are recovery of starch for cattle feeds, proteins and sugar recovery from potato residues, biogas production and SCP, provided a useable concentration from the recovery is obtainable.

The constraints which have to be overcome are: (a) the transport costs due to the scattering of residues and diluted effluents in small quantity, (b) capital costs and (c) lack of awareness of available technologies. A way to overcome this situation is to develop technologies capable of being used at local levels and at low level production plants such as those with 2 to 5 tons of cassava per day processing capacities. Another possibility is farm level production of SCP from agricultural starch (cassava or bananas) to feed directly to cattle or poultry and pigs and thus short cut marketing costs which would make such SCP uncompetitive to other protein products.

Major priority areas are:

(a) Where large industrial starch plants already exist in developed or developing countries;
(b) Where small quantities of residues are available with many plants located in the same area;
(c) Where the end use can be made valuable due to partial or total processing of the residues or due to pollution control regulations. Answers can be only made on a case by case basis and require detailed feasibility studies.

8. Oils and Oilseeds

The following commodities were reviewed: groundnuts, cottonseed, soyabean, coconut, sesame seed, sunflower seed, saffron flower, rapeseed, mustard seed, rice bran, palm oil, castor bean, tung seed, olive seed, kapok seed, linseed and rubber seed. The processing of these commodities produces the following residues: shell, husk, lint, coir, fibre, sludge, presscake and water.

These residues occur in all geographical regions. However, they prevail in tropical zones and are seasonal, depending on the commodity. The residues occur mainly during the pre-processing stage but also at the stage of refining and final processing. Some of these residues are unavoidable, whereas others could be limited. Except for groundnut, cottonseed, palm oil and olive seed, the occurrence of oils and oilseed residues may be reduced by alteration in the process or of parent material.

The most promising end uses of these residues include direct animal feeding, fertilizer use, and for composting. The shells of some of the oil seeds also could be used as raw material for the production of activated carbon. In the particular case of the palm oil industry they may be an important source of energy, possibly capable of making a processing plant self-sufficient in energy.

The most promising technologies include animal feeding, protein recovery, composting, production of lignin, pentosans, cellulose (furfural, zylitol), fertilizers for fast depleting arid lands, activated carbon, and production of various fibre-based materials. With palm oil processing, the importance of sludge may be minimized through better design of the manufacturing process.

The main constraint in the effective use of residues is the difficulty of collection and transport to a central processing place, particularly in developing countries. Until such time as organized animal husbandry is combined with animal breeding, it may not be possible to make optimal use of some of the residues. Lack of an export market and of appropriate utilization technologies were also felt to be responsible for ineffective use of these residues.

Prior to determining the end use of a residue, efforts should be made to quantify the socio-economical impact of the operation. Residue utilization in the case of oil seeds is a two-fold problem; one being an effective use of all products derived from the process, and the second being related to the protection of the environment. These two aspects are interrelated.

Specific action programmes should depend on individual country or regional needs. However, high priority should be given to research on developing adequate technologies so that oil seeds could be defatted as completely as possible. The amount of residues might be reduced if a complete dehulling of the oil seeds could be achieved.

The problems related to soap stocks and volatiles from de-odourization also were reviewed. It was felt that soap stocks should not be considered as residues and in fact they are not where appropriate facilities exist for fatty acid separation. However, such facilities are not available everywhere and wherever the oil extraction industry is not equipped to treat soap stocks, these could be considered as residues. Volatiles from the de-odourization, although they might constitute a problem in some countries, are not considered to be a major residue problem.

With regard to spent bleaching clays the Group could not envisage any possibility of recuperation. It was, however, suggested to bleach the clays in order to recover most of the oil.

Spent liquor from animal rendering occurs after centrifugation and becomes a residue which might be reduced by concentration or the use of less water during the process. As a single product it might be considered as the largest oil source as compared with individual vegetable oil seeds. There do not seem to be any constraints in its effective use. Such uses could be in the pharmaceutical industries where it serves as a substrate for microbially produced bio-chemicals.

9. Sugar By-Products

Sugar cane is an important crop for conversion of solar energy. In the future sugar cane product may be directed towards that of an energy crop, where not only crystalline sugar will be extracted. In practice, sugar cane by-product utilization must be considered on a country by country basis.

The supply of bagasse for other uses or as a residue, is dependent on energy costs and the use of bagasse as a fuel. The quality of bagasse in terms of digestible carbohydrate (non-extracted juice) affects its value as an animal food. Bagasse paper is not highly valued and, therefore, is not competitive on the world market. The technology for further processing of bagasse is well developed; though continued research to produce structural materials is required. Bagasse is one of the best substrates for cultivation of mushrooms and the fermentation residue can be used as an animal feed.

Total processing of sugar cane can be economically advantageous, if carefully managed, since production of other products besides crystalline sugar may provide more flexible options.

Account should be taken of the cost of pollution abatement. New developments in decortication (deriding sugar cane) may improve the utility of bagasse and so affect its economic value. Incorporation of bagasse into soil is not economical.

In general bagasse is used as a fuel in sugar cane except where alternative fuels, e.g., natural gas, are cheap. There is usually a surplus of bagasse, however, and this may be used for producing paper, board, or chemicals. These by-products, however, may not be produced competitively compared with alternatives, unless protected by tariffs.

The present use of molasses is limited by cost and availability of transport. Attention is called to the OECD report on the world-wide utilization of molasses. Cuba has a full-scale process for use of molasses in feeding animals. The rapid development of fermentation technology will have an impact on the economics of utilization of both molasses and cane juice. Currently, molasses is the preferred substrate for bakers' yeast production and the present trend is the use of full-strength molasses as feedstock.

The pollution potential, e.g. BOD of vinasse depends on the original substrate (sugar cane juice, molasses, wine, etc.). Vinasse contains biodegradable carbohydrates not available to yeast in relation to small-scale tropical distilleries, and continued research is needed on anaerobic, aerobic denitrification and algae recovery for fodder feed. Vinasse may generate a heavy metal (non-fermentation toxic) load.

Although the cost of fermentation alcohol is generally higher than chemically (C_2H_4) derived alcohol, it should be noted that the overall economy of a country might be served by a controlled ethanol market. Brazil is a case in point.

Citric acid may be produced from sugar by-products, but with the current world capacity for citric acid production, further development of capacity, except for local internal markets, should be approached with caution.

The present potential of molasses for the production of microbial polysaccharide is recognized as being low. Glucose and sucrose are preferred feedstocks from a technical point of view.

Full scale integrated chemical and fermentation plants using molasses as a feedstock or substrate are in operation in certain countries where the politico-economic situation is appropriate.

Water pollution problems arise not only from vinasse, but also from both cane and beet industries through the incorporation of carbohydrates from various stages in process water. The level of pollution is higher for the beet sugar industry than for the cane sugar industry. Abatement of these problems is required at a plant engineering level.

Bagasse is one of the best cellulosic sources available for the production of pentosans, for which there is an expanding market. A large range of other products is theoretically producable from sugar cane, but other sources, feedstocks and substrates are economically superior for these end products.

Filter press mud is usually dumped in rivers, a practice which should be avoided. It has been used (after cooling) in spreading on land, but this use should be treated with caution. The recovery of wax from the mud is considered uneconomic. The study of its use for soil conditioning and as a source of phosphate and potassium could be recommended.

The pollution problems arising from the sugar beet industry differ from those of the cane industry, due to the large quantities of water used in the beet sugar industry. The current practice of leaving the leaves in the field is economically preferable. Contamination by soil of the raw material is more severe for the beet than for the cane industry.

Beet pulp residues can be used as a feed, but it is necessary to press and dry the pulp prior to feed use since wet pulp presents a mycotoxic hazard in an aerobic condition and moreover is a source of bad odours. Extraction of specific amino acids using beet tops is not considered currently economic.

In the future the world supply of sugars and sweeteners might be furnished from starch and cellulose raw materials. Industries based on development in sucrose chemistry might have an overall benefit on carbohydrate producer countries. Thus these industries might lead to improved *per caput* incomes.

Over-enthusiasm for sugar cane production as a cash crop may act to withdraw land from food production.

10. Single Cell Protein

(a) General Position of SCP Production

In recent years tremendous progress has been made in research and development of single cell protein production on unconventional substrates like gasoil, paraffins and methanol. The construction of production plants with capacities up to 100,000 tons per annum is announced for the United Kingdom, Italy and the Soviet Union and in a number of cases already completed.

The development as mentioned forms a stimulus for intensification of the study of the potentials of SCP production based on organic residues of agricultural origin. The Working Group focused its attention on this field.

(b) Requirements of SCP Production Unit for Agro-residues

It was recognized that the logistic aspects concerning the substrates form a major problem. Seasonal variations in the supply of residues and the limited amounts available per production site lead to the conclusion that for most residues small scale production units of a relatively simple design are required. Capital and exploitation costs have to be low, technology involved should not be too complicated in order to make a project economically and technically feasible.

(c) Aims of the Production

The production of protein rich materials for *animal feed* was generally recognized as more realistic than the direct production of human food. Animals can usually eat and utilize the whole content from the fermentor.

From the U.S.A. as well as from Thailand the idea was launched that *pollution control* can be the primary object of SCP production, because the system uses residues that are otherwise discharged into the environment.

During fermentation the microbiological status of the residue may be improved, depending on temperature applied.

In the case of algae, the production of pigments was considered as a valuable item.

(d) Nature of Substrates and Organisms

A large number of potential substrates was mentioned.

In particular the substrates rich in cellulose that are available in large quantities, like straw (USA), corn cobs (Bulgaria) and cellulose from wood (Finland) reached the level of advanced research-projects or even the production stage. Not everybody is optimistic about the economic aspects.

Fruit by-products, distillery effluents and molasses were mentioned as substrates under investigation.

Fungi, yeasts and bacteria are most frequently used as an organism. Their genetic potential is of predominant significance for the success with which the substrate is attacked and for the amino acid composition of the protein produced.

Algae, usually mentioned together with the other categories seem to offer less bright prospects from the viewpoint of production technology.

(e) Nutritional and Toxicological Evaluation

The Protein Advisory Group of the UN System provided guideline 15 for testing novel sources of protein. Such a full scale testing is costly and time-consuming. To provide applicable data, the testing has to be carried out with a standardized product. For economic reasons elaborate testing is impossible for the small scale production units under discussion.

If the degree of novelty of substrate and of microorganism is limited, and comparatively small quantitative impacts are to be expected, then safety and nutritional aspects can probably be determined at an acceptable degree by small scale experiments.

These experiments have to be preferably carried out with the animal for which the product is destined, the target species, because they respond often specifically. By making use of young animals the amount of material required for testing can be limited.

About the nature and extent of testing required and about the evaluation of the data, an international body might give advice (FAO, PAG).

(f) Internationalization of Know-how

It was mentioned by a number of representatives that research results and technological know-how should be made available for developing countries via FAO.

It might be useful to select microorganisms and test their products under standardized conditions which are of relevance for the areas discussed. These microorganisms could then be made available for general use.

Recommendations

Based upon the material presented in the papers and the oral reports presented at the Seminar and the issues and concepts brought out in the discussions and working groups, as identified in Sections III and IV, the Seminar makes the following recommendations.

The Seminar participants recognized that in considering the utilization of agricultural and agro-industrial residues, it is essential that the environmental impact of these residues be properly evaluated as a basis for work in the field. Environmental protection implies more than the abatement of pollution. Some agricultural residues may be of considerable environmental value, for example, in the prevention of erosion, even though it is difficult to place an economic value on such use. On the other hand, investments in residue utilization for environmental improvement may increase costs of food and other agricultural products. However, such direct cost increase may be offset by the advantages gained by the public through the removal of the adverse effects of the residue or by the savings in costs to industry of complying with regulations imposed to correct the adverse impacts.

A. IMPROVING INSTITUTIONAL CAPABILITIES

1. National Centres

Each country or region should establish or have available a centre to co-ordinate and carry out, as appropriate, the research, development and other investigations necessary for the evaluation and success of possible residue utilization approaches. Where needed, assistance from international, intergovernmental and non-governmental organizations should be provided to increase the capabilities of such centres.

The action programmes for residue utilization approaches must be multidisciplinary and multifunctionary. Co-ordination of these programmes is necessary to achieve desired results. The disciplines that should be involved in the approaches include engineers, food scientists, microbiologists, agricultural scientists, economists, sociologists and lawyers.

2. Strategies

Each country and industry should establish definite, feasible residue utilization strategies and priorities for residue utilization that reflect realistic social, economic and technical goals. The strategy must be compatible with environmentally sound decisions that reflect existing physical, human and other resources. Desirable residue utilization approaches will depend upon the use of the indigenous capacity to generate and operate economically viable appropriate technologies. Such strategies and priorities should take full account of the interrelated policy questions of land-use, energy and transportation as well as the various socio-economic, ecological, and environmental considerations. This will call for co-ordination among responsible authorities in countries and may require the establishment of suitable mechanisms for this purpose.

Greater effort should be made by both industry and governments to reduce the quantities of agro-industry wastes that are generated. In doing so, the efficiency of food production can increase and a greater quantity of food supplies will result. In each country and industrial operation, a major programme should be initiated to identify, control and reduce the major losses in food materials, i.e., generation of residues, which occur in food processing between harvest and consumption.

In developing strategies for implementing residue management policies, authorities should ensure that appropriate controls and regulations are based on sound scientific data, that they are enforceable, and take into consideration socio-economic conditions. Care also should be taken not to create non-tariff trade barriers through unjustified import restrictions.

3. Information Exchange

There should be an interchange of information between adjacent or similar regions especially on local use technologies and incentives. Governments, international organizations and non-governmental organizations should assist in the development or utilization of existing centres to encourage such interchanges since much information and experience on possible utilization approaches exist in local areas and regions.

4. Incentives

Greater incentives should be provided to reduce the generation of agricultural and agro-industrial wastes. Incentives such as stricter pollution control regulations, waste discharge taxation, subsidies to enhance utilization, and other possible incentives should be evaluated in specific social and economic conditions. Included in the evaluation of feasible residue utilization approaches should be an analysis of possible legal constraints. Guidelines for appropriate legal approaches, such as model laws, should be developed.

5. Education

Ways to educate the public, and inform industry and government concerning the need for low residue, environmentally sound agricultural production and processing methods should be explored. Educational approaches to increase the use of such methods and to achieve the acceptance of residue utilization products need to be applied more broadly. The success of utilization approaches depends upon the acceptance of an approach and the resultant product.

6. Implementation

a. Existing Institutes of similarly oriented ecological zones should co-operate for the purpose of the joint organization of training courses, pre-investment feasibility studies, research and demonstration projects, incentive and market possibilities, evaluation of social, legal and economic impacts, and an information exchange system, based on the important residues of agriculture, forestry, fisheries and related industries occurring in a zone. It is suggested that International Agencies support appropriate networks of institutes which could increase the capability of national institutions to provide required services and technical assistance.

b. In a follow-up programme, UNEP should give consideration to providing a forum for exchange of experience amongst countries in establishing and implementing effective residue management strategies which improve the quality of the environment and use of resources. Consideration should also be given to establishing one or more regional demonstration projects, of particular interest to developing countries, illustrating the application of environmentally sound and appropriate residue utilization techniques.

c. Each government and industry, through its existing laboratories and organizations, should initiate surveys and studies to evaluate the nature, magnitude and characteristics of their agricultural and agro-industry residues and their impact on the environment. Authorities should assess the residue utilization potential in their countries, calculating the types, quantities and distribution of these residues. The characteristics of agricultural and agro-industrial residues are vital information for sound utilization approaches. Information on the characteristics should include parameters to measure their pollution potential, their nutritional and energy value, and potential health hazards. Where such information is not available, adequate testing of the residues should take place for such parameters prior to decisions on residue utilization.

d. To enhance the knowledge base of residue utilization possibilities and appropriate technologies, there should be a central information centre that would, over and above the information supplied by the IRS of UNEP, acquire, analyze and summarize information from diverse sources, and distribute it to potential users. Information from original sources is needed by those considering various utilization approaches. Existing research institutes, industries and organizations should be encouraged to supply information, reprints, articles, reports and similar material to the central information centre for acquisition by other interested parties.

e. FAO has taken an important step to provide information in agricultural waste management and residue utilization. FAO should update the material in the Directory of Institutions, the Compendium of Residues Technologies, and the Residue Utilization Bibliography at a minimum of every three years.

f. A comprehensive assessment of traditional local village level residues technologies should be made to identify possible application in other situations.

g. Pilot and demonstration projects should be established on small community recycling systems and on small-scale processing facilities aiming at total utilization of resources.

h. There should be experimentation with technology adapted to local situations and there should be greater support for such experimentation. Governments and non-governmental organizations, including industry, should develop a detailed action programme to establish development and field projects with the appropriate residues and technologies in their region or country.

i. When residues or products derived from residues are considered for use as human or animal food or as fertilizers, the presence of toxic substances and pathogenic agents should be monitored to avoid subsequent hazards to man, animal, crop or soil. Intensive and continued recycling of residues may result in a change in the character of primary materials and may result in unknown effects in primary products.

j. To initiate a change in understanding and recognition concerning the potential value of agricultural and agro-industrial residues, the discarded solids and liquids should, as often as possible, be referred to as "residues" rather than as "wastes".

B. MEASURES FOR IMPROVED RESOURCE MANAGEMENT IN SPECIFIC AREAS

Each of the working groups was requested to identify recommendations that would improve residue management in the commodity that the group discussed. These recommendations are presented in the following paragraphs. There were, however, a number of recommendations common to more than one working group. To avoid repetition, but more importantly to emphasize that certain recommendations were felt important by more than one group, these recommendations are presented first.

General

These recommendations were presented by more than one working group.

- Governments and agro-industries should attempt to make the greatest possible use of residues as a source of raw materials.

- Governments should establish regulations that would lead to a reduction of environmental pollution.

- Governments, International Organizations, and agro-industries should support research and demonstration projects that more clearly define the proper use of residues as fuel, fertilizer, feed and other uses.

- International Organizations, in collaboration with Governments, should develop and encourage adoption of standard terminology and methodology for reporting data on quantity and character of organic residues.

- Governments, International Organizations, and agro-industries should initiate surveys and studies to determine the quantity and characteristics of available agricultural and agro-industrial residues so that the optimum end use will be achieved and the best technology utilized.

- When planning agricultural and agro-industry development, governments and industry should provide careful thought to the technical and socio-economic oonsiderations of agricultural and agro-industrial residue generation and utilization.

- Appropriate residue collection and utilization technologies should be identified and utilized to obtain the greatest benefit from agricultural and agro-industrial residues by all concerned parties. Information on the successful utilization technologies, institutional approaches, and incentives should be broadly disseminated.

1. Fruit and Vegetable Residues and By-products

(a) Governments

- Should provide, where necessary, technical assistance, regulatory strategies, and economic and other incentives to stimulate the utilization of residues.

- Should undertake market research with reference to export outlets for end-products of residues.

- Should re-examine health and sanitary legislation with regard to animal feeds so that it does not unduly hamper the use of residues.

- Should pay greater attention to the development of energy-saving technologies.
- Should give special attention to the development of residue utilization technologies for small farmers and small-scale processes.

(b) International Organizations

- FAO and UNEP should ask member governments to provide information on the existing technologies for agricultural processing industries.

- FAO and UNEP should encourage studies of the utilization of agricultural and agro-industrial residues with the view to improving these activities.

- FAO should keep up to date the compendium on the residue utilization technologies and management.

- FAO should collect and disseminate bibliographical information on residue utilization and management.

- FAO and other UN Agencies involved should assist programmes for an effective transfer of appropriate technologies from developed to developing countries through regional and sub-regional centres or networks.

- In the work of international organizations primary attention should be given to implementation aspects rather than research.

- The Protein-Calorie Advisory Group (PAG) or its successor mechanism of the UN System should continue to review the appropriate aspects of residue utilization.

- Aid-giving agencies should consider the possibility of providing the necessary financial and technical assistance to developing countries through established government and other agencies as well as research institutions or ad hoc investigations on residue utilization and management.

(c) Agro-Industries

- Attention should be given to the potential use of residues as sources of direct energy, feedstuffs, fertilizers and other products. Full use should be made of bioconversion processes in various stages of processing. Full use also should be made of solar and other kinds of renewable energy.

- Industries should help as much as possible in research, education and training in the field of residue utilization and management.

- In order to diminish the risk in marketing the end-products of residues, industries could try the method of vertical integration by forming suitable consortia which might have catalytic effect on farmers, co-operatives, etc.

- As regards the priorities in industrial programmes, primary attention should be given to the maximization of yield from basic processes, followed by concentration on best utilization of one or two by-products, and in the last resort SCP production should be considered.

- The interest of producers of processing equipment must be attracted in stimulating better utilization of residues.

2. Beverage Industries Residues and By-products

- Private and governmental institutions should be strongly encouraged to set up pilot plant studies to develop low cost, economically viable technologies for the use of spent molasses liquor and satisfactory means of disposal.

- The production of animal feeds from residues of cereal based beverages should be encouraged where plants exist for the production of such beverages or where such plants are to be established.

This may be achieved by issue of information on feed material to users and to compound manufacturers where they exist, bearing in mind that utilization of residues from the brewery and distillery industries in new areas will ultimately depend on their marketability.

3. Cellulosic Residues

(a) Governments:

- Should support and conduct further research on the physical, chemical and biochemical properties of cellulosic materials and study applications related to residue utilization through subsequent processes.

- Should provide incentive programmes to encourage individuals and industry to take the necessary risk and make investments to develop and apply innovative technology to utilize organic residues as appropriate for fuel, fertilizer, feed or other uses and should mount a publicity campaign to advertise these new incentives and highlight successful adoptions.

- Should encourage industrial companies to seek opportunities for commercial exploitation of agricultural residues outside their normal sphere of operation.

(b) Industry:

- Each industry and each company is urged to analyse its own operations or production practices to assess the potential for economic utilization or reduction of its organic by-products and residues. Industry should communicate to the government the nature of bottlenecks and restraints which prevent more effective utilization of organic residues and establish or seek improvements in existing incentives and reduction of disincentives for adoption of new and innovative residue utilization practices.

(c) International Organizations:

- Should analyse technical and economic parameters governing optimum use of organic residues for fuel, fertilizer, feed or other uses and disseminate this information.

- Should collect and disseminate examples of economically viable and environmentally sound uses of organic residues as fuel, fertilizer, feed or other uses and publish guidelines for transferring successful technology elsewhere.

- Should inform Governments of countries where conversion of available organic residues would seem economically viable and of the possibility of developing industrial utilization of these residues.

- International Financing Agencies should consider possibilities of financing national projects on residue utilization through a soft financing arrangement, since the residue collection and utilization may not be highly profitable.

- The appropriate international organizations are urged to provide technical assistance in carrying out residue utilization projects initiated by the governments.

- Should undertake a strategic study of land use planning on starch and cellulose as raw materials for sugar production and energy and feedstock sources.

4. Fish Residues and By-products

Priority attention should be given to developments which will improve the living conditions of small-scale fishermen in tropical developing countries.

It is recommended that relevant international organizations should intensify the level of technical and financial assistance in post-harvest aspects of fish production, particularly in the following areas:

- There are latent prospects for establishing projects to utilize by-catch by developing products from minced fish in many countries including Mexico, Guyana, Thailand, Malaysia, Philippines, Indonesia, India, Sri Lanka. A variety of products and processes could be developed in these countries. It is recommended that promising projects be assisted by relevant international organizations to a point where commercial feasibility can be assessed. Transfer of the resulting information to other geographical areas should be encouraged.

- Suitable technology for better solar drying can be developed in Asia, Africa and Latin America. Specific projects where assistance could be provided are under way in Bangladesh, Sri Lanka, Senegal, Mexico and other countries. Parallel investigations should be carried out to augment solar energy with other reasonably priced energy sources. It is recommended that assistance be provided.

- As the major demand is and will continue to be for fresh fish, it is recommended that increased attention be paid to the development of less energy intensive ice production. Wind driven and absorption systems show promise and should be further investigated. Suitable locations would be Sri Lanka or India.

- Work on the production of animal feed by ensiling is proceeding at a low level in a number of centres. Both acid and microbiological methods suitable for small-scale production in the tropics are being developed. There is an urgent need for more animal feeding trials which could be carried out by increasing the level of assistance to the FAO Programme of Co-operative Research in Fish Technology in South-East Asia.

It is considered that assistance in developing these technologies could have a significant impact at the village level. As a result they would contribute to improving the living conditions of the rural poor in fishing/farming communities.

5. Animal By-products and Residues

In view of the fact that the animal by-products industry is constrained by failure to gain planning consents for new operations and existing operations are being closed due to the difficulties of controlling environmental problems, it is recommended that consideration be given to the following:

- Investigation of low energy (cold processing) as an alternative to present hot processing techniques in so far as the products of these processes must be free from pathogenic and toxic substances and that such methods may conserve protein quality;

- Research development, and increased application of techniques that will allow for the use of whey in human feeding;

- Upgrading of materials such as blood and certain other so-called non-edible offal by extracting protein for human use;

- Where centralized plants involve high transport costs and deterioration of raw material, investigation of chemical control of spoilage between site of production and site of processing, using non-toxic substances;

- Effective recovery of all by-products, by providing suitably sized integrated processing plants and mobile plants as an alternative to large centralized rendering plants;

- In view of strong social pressures against environmental nuisances including odour and water pollution from the animal waste industries and from land spreading activities, every effort should be made to encourage co-operation between technical and legal experts involved in this problem;

- Attention should be paid to maximize agro-industrial efficiency through technological and managerial in-plant improvements and thereby reduce the production of agro-industrial wastes;

- As a general rule animal manures should be returned to agricultural land following any necessary treatment, as long as the danger of soil, surface, and ground water pollution is prevented.

It is further recommended that:

- When livestock wastes are used on the land, the ratio of livestock numbers to the available land should not be excessive to insure the efficient use of the plant nutrients contained in the manure and so avoid environmental pollution;

- In tropical and sub-tropical countries where energy may be limited, attention should be given to the conversion by anaerobic fermentation of animal manure and night-soil into biogas. Financial assistance on a soft-loan basis might be required to initiate applied research and for training;

- In all technologies used to produce fertilizer, food or feed, and in manure transport measures must be taken to ensure that no disease is transmitted to humans or livestock;

- In view of the dangers of environmental pollution from agricultural and agro-industrial pursuits, attention must be given to site selection so as to minimize this pollution and nuisance;

- Attention should be given to the hazards arising under circumstances where infrequent, intensive slaughter of animals takes place;

- The recycling of animal wastes as a feed deserves more attention in research and in practice.

6. Cereal Residues and By-products

It is recommended that governments, international organizations and agro-industries:

- Identify and use available appropriate technologies that will reduce agricultural residues generated in processing of food grains and in their transfer and utilization;

- Transfer viable technologies for utilization of cereal residues such as rice husk, rice bran, wheat and corn germ and the necessary adaptation and modification of the technologies;

- Train personnel to build competence in technology transfer, research and development, plant operation and management;

- Give special attention to the utilization of cereal residues such as straw and cobs for the manufacture of animal feeds and other industrial products.

- Develop a policy, as appropriate, and an integrated programme of action for improvement of the food grain processing industry.

- Create centres at national and regional levels for demonstrating integrated operations of the cereal industry generating low residues and utilizing them efficiently.

7. Residues and By-products of Starchy Roots and Tubers

(a) Governments:

- Should not only establish pollution controls and rules but also study location and industrial units to avoid pollution concentration and wherever possible and economically feasible in a given context mix wastes from starch factories with municipal wastes to increase N and P contents of the mix for any biogas/ fertilizer production;

- Should make every effort to obtain from international organizations and others, engineering feasibility studies to determine which technologies are more applicable to their national situation for starch/glucose/sugar production, SCP and biogas production from starch concentrated residues of bananas, cassava and potatoes;

- Should establish pilot demonstration projects for (a) starch recovery from effluents both for large and small starch factories and glucose/fructose production, (b) uses of starch for biogas production which residues can be used again as fertilizers;

- Should implement wherever possible, measures for regenerating the agricultural soil with crop residues and used water;

(b) International Organizations:

- Should assist in the technical and financial establishment of the pilot demonstration projects listed above, especially at small-scale levels;

(c) Agro-Industries:

- Should carry out feasibility studies including the evaluation of starch residues using available technologies and make a special effort to produce economically useful products such as animal feeds, biogas, fertilizers, glucose/fructose syrup.

8. Oils and Oilseeds' By-products and Residues

As the optimal utilization of husk residue in the oilseed industry depends on many factors such as local situations, technological infrastructure and international market, the recommendations are:

(a) Governments:

- Should use husks linked with local requirements but in certain cases with international markets;

- Should reduce environmental pollution by appropriate use of oilseed residues;

- Should introduce technologies which are energy saving.

(b) Food Industries:

- Should make special efforts by all concerned with coconut processing activities to find markets for traditional coir goods and develop new marketable coir products;

- Should encourage palm oil factories to optimize the use of residues and energy, give attention to selection of varieties with low lipase activity in the maturing fruit, encourage modification of palm fruit processing to minimize entrainment of extraneous mineral matter during harvesting and processing, encourage dissemination of technical data on optimizing oil extraction to minimize the oil content in the residues and waste streams.

9. Sugar Residues and By-products

- Harvesting machinery for sugar should be designed to recover cane tops for animal feed;

- Countries should investigate the "local" use of molasses in the production of secondary products;

- Encourage investigation into greater recovery of sugar from molasses, including the study of the feasibility of the use of flocculants to improve recovery;

- Further testing should be undertaken on the animal feeding systems using high rates of molasses in the feed;

- Special training courses should be organized on water pollution control techniques for plant engineers in the cane and beet sugar industries;

- Cane growing countries are encouraged to investigate the feasibility of production of pentoses or furfural from bagasse.

10. Single Cell Protein

- Special emphasis should be given to research and development that will indicate the approaches for the generation and utilization of SCP that will be applicable at the farm or village level;

- To obtain rapid results in economic utilization and avoid the complicated technology and regulations necessary to produce palatable and acceptable products for direct human consumption, SCP produced from agricultural residues should be used for animal feeding;

- Attention should be paid to nutrients other than proteins which result from SCP production, such as oil, vitamins, etc.;

- SCP production from residues should be considered as a means of combatting environmental deterioration;

- Adequate feeding tests regarding safety and nutritional efficacy should be carried out with the target species at an early stage;

- Information regarding the technical, logistic and other aspects of SCP production should be made available to all interested individuals and organizations;

- The International Fund for Agricultural Development should consider the inclusion of SCP developments in its programme of work.

C. ADDITIONAL RECOMMENDATIONS

Specific recommendations that were made following the presented papers, but which were not included in the working groups' recommendations include those for research which should be initiated or intensified in the following specific subject areas:

- Recovery of proteins from green plants, especially in the tropic regions;
- Down-scaling of existing residue technologies for application in small-scale operations;
- A comparative study of national legislation, with a view to harmonizing applicable standards for international trade and transportation of products resulting from agricultural and agro-industry residue utilization;
- Assessment of the social benefits of residue utilization;
- Investigation of the possibilities of utilizing suitable agricultural and agro-industrial residues for fertilizing forest plantations when environmentally and socially acceptable.

An Overview
Utilization of Residues from Agriculture and Agro-Industries

by Raymond C. Loehr

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AN OVERVIEW -
UTILIZATION OF RESIDUES FROM AGRICULTURE AND AGRO-INDUSTRY

Dr. Raymond C. Loehr

1. INTRODUCTION

In the context of this report, wastes from agriculture and agro-industries are defined as the excesses and residues from the growing and processing of raw agricultural products, such as fruits, vegetables, meat, poultry, fish, milk, grain, and trees. These wastes are excesses of production that have not been effectively utilized.

Traditionally, wastes have been regarded as the inevitable by-products of industrial activity, and the usual aim of waste management has been minimum treatment and disposal. In only a few cases has residue utilization been practiced as a waste management policy. However, the dual concerns of adequate food and environmental pollution have emphasized the inadequacies of a minimum treatment and disposal approach and have resulted in an examination of alternatives. The idea of the "finite earth" is becoming accepted, and increasing attention is being paid to the development of policies and practices that will minimize the problems of pollution and the wasting of natural resources.

This overview discusses the possible utilization of residues from agriculture and agro-industry, rather than their treatment and disposal, and includes:

- the amounts and characteristics of such residues
- technology that can be considered to utilize these residues
- non-technical aspects that may be constraints or incentives to utilization
- examples of successful utilization

Residue utilization should be considered with optimism because of the large quantities of wastes that are produced and the obvious need to make better use of existing resources. However, this optimism must be tempered by caution since the result must be a usable product at an economical cost while not causing greater environmental or social problems. It makes no sense to take a waste or a residue that no one wants and turn it into a resource no one wants.

Residue utilization needs to be viewed realistically with a reasonable perspective of the constraints and opportunities. This overview attempts to provide such a perspective.

1.1 - General - Residues are those end products of production and consumption that have not been used, recycled, or salvaged. They are the non-product flows of materials and energy whose economic values are less than the cost of collection and transformation for use, and they are therefore discharged as wastes. The volume and composition of these residues could be reduced if there were technological means for converting them into some usable product and if the value of the subsequent product were to exceed the costs of conversion or if it were judged to be sound governmental policy to encourage recovery and reuse.

If residues can be utilized for human benefit, they are no longer wastes but become new resources to augment limited existing resources. Residue utilization can be considered to be the equivalent of resource utilization. This relationship should receive broader recognition. Most current waste management approaches are methods of concentration and relocation of the wastes, such as waste treatment and discharge to the environment. Recycling, reprocessing, and utilization of all or a portion of the wastes offers the possibility of returning such residues to beneficial use as opposed to the traditional methods of disposal and relocation. The keys to successful residue utilization are a beneficial use, an adequate market, suitable technology to process the residue under local conditions, and an overall enterprise that is socially and economically feasible although not necessarily profit making. Many such enterprises could be satisfactory if they caused the overall cost of waste management for the industry to be less than other alternatives. Others could be satisfactory if they increased employment possibilities or helped increase local or regional food supplies.

The traditional focus on treatment and disposal of wastes can prevent material and energy resources from being utilized. The one time use of materials is a result of economic, political, and technical policies developed during abundance of materials and energy. If greater use of residue utilization technologies is to occur, these policies should be rethought and reconsidered, technology must be developed and demonstrated, and information should be exchanged on as broad a scale as possible. Government, industry, and the general public must all participate in this effort.

In considering residue utilization possibilities, more than the technological aspects require evaluation. Critical evaluation also is required of the economic, legal, and social aspects of such utilization since these can be important constraints. The resultant environmental impact of residue utilization, i.e., other residues or wastes that result and their impact, also needs evaluation. The broad rather than the narrow picture must be viewed. Residue utilization cannot be considered in isolation from the other concerns of the industry and the country in which the utilization is being considered.

The success of residue utilization depends on cooperation of various parts of society such as:

- local authorities who must be assured that health and environmental criteria will be met and that utilization will not cause larger or different public concerns
- public and private groups that should support policies of residue utilization and resources recovery
- public or private enterprise that must acquire the residues at reasonable cost and be assured that they will be able to sell the recovered material after processing.

The fact that residues are the by-products of production and processing after the values in the products have been extracted suggests a rational approach to better utilization of the residues - a) to increase the value of the residues and/or the products from residue utilization to commercially marketable levels, or b) to make it profitable for producers to make better use of the original material, i.e., not to produce as large a quantity of residues or waste. Either of these approaches is likely to require institutional changes in the relations between governments and industry. Current approaches employ police powers to impose prohibitions or standards of acceptable levels of discharge. Alternatively, government can work with industry as an enticer rather than a prohibitor. It can create conditions in which it is in the interest of the residue generating industry or a suitable secondary industry to utilize the residues.

Efforts are needed to develop technology and institutional arrangements to better utilize the residues from agricultural production. The need is to consider residues as potential resources rather than as undesirable wastes. This will require not only better use of technology and incentives but also a change in philosophy and attitudes.

1.2 - Concerns - The concerns that have led to an increased focus on residue utilization are many. All fall under the broad topic of resource utilization. The finite limit of world resources, the increasing costs of raw materials, the need to maintain a satisfactory quality of the environment, and the need to meet world food requirements are providing motivation to make better use of the residues from agricultural production.

Food supplies and demands in recent years have made it clear that increasing the rate of food production is the highest priority of mankind to meet the expected population growth and the need to increase the quality of life. World food demand in the next fifteen years is expected to grow at a rate of 2.5 percent per year of which 2 percent represents the population increase and 0.5 percent represents increased purchasing power (1). There are major differences between countries. In the developed countries the growth rate of demand is projected at 1.6 percent per year, while in the developing countries, it is projected at 3.7 percent per year.

With increased affluence, people will spend more of their income on protein foods, in particular, proteins derived from animal origin. Promising areas for increasing and improving animal and human food include the efficient use of residues from agriculture and agro-industries.

During the same period in which it has become obvious that our resources are finite and that residues from agricultural production need to be better utilized, these residues have caused a variety of environmental problems. Methods of handling, treating, and disposing of agricultural and agro-industry wastes may adversely affect air, water, and soil quality and may be a nuisance to those who dwell nearby.

The trend toward industrialization continues in all countries for agriculture as well as for other industries. As production increases, both the size of facilities and the quantity of wastes will increase. The greater quantities of waste at a location increase the possibilities for resource utilization while at the same time increasing the pollution potential.

Examples of adverse environmental quality problems attributed to agricultural operations include: a) excessive nutrients from lands used for crop production or waste disposal that unbalance natural ecological systems and increase eutrophication; b) microorganisms in waste discharges that may impair the use of surface waters for potable or recreational use; c) impurities in groundwater from land disposal of wastes; d) contaminants that complicate water treatment; e) depletion of dissolved oxygen in surface waters causing fish kills and septic conditions; f) odors from concentrated waste storage and land disposal; g) air pollution that may be caused by burning of straw and crop residues; h) ammonia and other matter that is volatilized; and i) water pollution from surface runoff.

Thus, the better use of residues from agricultural production can help accomplish two important objectives: a) better utilization of existing resources to meet human and animal food needs, and b) reduction of potential environmental problems caused by such residues.

1.3 - Non-technical Aspects - The actual utilization of agricultural residues will be determined not only by technological possibilities but also by economic forces, regulations, regional customs, and institutional and political arrangements to enhance or constrain such utilization.

The selection and/or development of appropriate residue utilization technologies requires careful study. The following factors deserve close evaluation:

a) the level of economic and technological development in the area of potential utilization
b) available physical and human resources
c) social change that may be necessary to implement the technology or that may be caused by the use of the technology
d) existing practices and technologies capable of use
e) institutional arrangements to implement the technology and utilize the product of the technology
f) available research and development institutes to help modify and develop suitable technology, to raise the level of application of existing technologies, to assist with production of new products, and to identify the market potential of the resultant product, including export possibilities.

The successful application of residue utilization will require a systematic effort for the selection, modification, transfer and utilization of technologies for use in a specific location and with specific residues. The ability of local manpower to operate and service the various technological approaches requires careful evaluation. Specific educational programs may need to be instituted to assure qualified manpower.

Achieving better waste management and residue utilization will depend on the development of the indigenous capacity to generate and operate ecologically and economically viable technologies. The technology for residue utilization has to be applicable to and integrated with the actual needs of a country or region. The level of operations, availability of raw materials, market demands, and trained personnel vary from region to region. Adequate research and development must be employed and modification of possible technology must be explored to meet the specific needs of an area. Market surveys and studies of the rate of growth of demand for the products of the residue utilization also need to be undertaken.

Residue utilization approaches that do not include adequate consideration of the socio-economic conditions of the specific region or country are less likely to succeed.

Systems for residue management consist of a combination of: a) methods for reducing residual discharges, b) incentives to encourage the utilization of residues, including economic and regulatory incentives, and c) institutional arrangements to encourage and implement the incentives. Desirable implementation strategies are the combinations of methods, incentives and institutions which increase the utilization of the residues.

Current and past approaches to residue management may have been ineffective because the implementation strategies have not functioned over a problem-wide geographic area, have not integrated residue management into a unified program, have not included a sufficiently broad array of incentives, or have been otherwise unsuited to the problem. An important need exists to identify those combinations of incentives and institutional devices that would be most effective for enhanced residue management.

The principal methods by which institutions such as governments or governmental organizations can influence residue management are direct regulation, subsidization, economic incentives, or reliance on voluntary processes.

In the field of waste management, and thus indirectly for residue management, direct regulation is the most commonly employed method. It includes prohibitions, performance standards, permit and licensing systems backed by enforcement powers such as for pollution control, and resort to the courts to enforce or to challenge regulatory requirements.

Under the heading of subsidies and economic incentives would be included grants for construction of processing facilities, tax relief, and the granting or withholding of various benefits. The capacity to subsidize residue utilization is funded by the taxing, borrowing, and assessing powers of government. A "carrot and stick" combination of subsidy with regulation frequently can be observed.

Residue management also may rely to some extent on voluntary processes, such as the perception of mutual advantage embodied in contractual arrangements, profits from recycling, and voluntary cooperation in general such as pressure from citizens groups, boycotts, sensitivity to corporate image in the face of public opinion, or collective perception of costs and benefits to the community, region, or country.

Considerations of alternative residue management approaches must include the social costs and impacts. To focus only on technological aspects would ignore some of the most important components of such approaches, namely the economic, social and institutional components.

There can be various mixtures of direct regulation such as tax policies, effluent or user charges, administered markets for recovered materials, and government subsidies. Changes can be induced in raw material inputs for production processes, in process or recycling technologies, waste-generating sources, or in patterns of distribution to encourage better residual utilization.

There is a bewildering array of alternative approaches and implementing measures, each with its own advantages and drawbacks when considered singly or in combination with others. The alternatives need to be evaluated from various points of view--technical, environmental, economic, institutional and political--with particular stress on the means whereby the power of government can be exercised to secure the desired results.

The problems of agricultural waste management and residue utilization generally have been tackled in piecemeal, technical manner. They rarely have been looked at in the context of resource management or on a regional and institutional basis. One of the larger problems is to provide the organizational structure and authority to encourage residue management. Such management must be on a large enough scale to facilitate intelligent, cost-effective choices among alternative control strategies, including those for dealing with conversion of residues from one form to another and for the resultant secondary residue utilization, treatment, or disposal. The need for regionalization can be clear, as where liquid or solid residues from separate locations can be brought to a centralized facility for processing.

There are difficulties in providing the necessary organization and anthority for residue utilization. A major challenge is to obtain the necessary institutional arrangements, including inter-agency and intergovernmental arrangements, to implement the required residue management strategies. Regionalization may increase although the degree of it, the form it takes, and the level at which it occurs will vary. Regionalization _per se_ is certainly no guarantee that an institution will function responsively to the public it serves and with sensitivity to policies or issues lying beyond its ken. In many cases, strengthening and coordinating existing institutions may be a preferable tack to follow. Not every problem must be solved at once; there still will be room for piecemeal, incremental progress and not every problem needs to be solved by bringing new institutions into being; there are perhaps too many of them already.

The ultimate step of residue utilization is the application of suitable technology to the local situation and adoption of the technology as common practice. Demonstrations can be one of the most effective means of implementing a new practice or technology. Such demonstrations are necessary to obtain local, public, governmental and industry interest and cooperation and should be planned jointly by the industry, those developing the technology, and those using the results of the technology.

One of the needs related to residue utilization is for information systems which can be used to compare the advantages of a particular technology, the quantity and physical, chemical, and biological properties of the waste that is or will be generated, the potential markets and distribution for recovered materials, and the institutional arrangements necessary to utilize the technology. Environmental, energy, and social costs all are factors which must be incorporated into decisions on residue utilization. Systems which provide this type of information will be invaluable to those attempting intelligent decisions about residue utilization.

There is no one best approach to residue utilization. In each situation, the possible alternatives need to be carefully evaluated and the most appropriate single technology or combination of technologies chosen that will provide the desired environmental, economic, and social objectives.

2. RESIDUE GENERATION

Residues and wastes always have been associated with agriculture and agro-industries. However, they have become more noticeable because the natural cycles associated with agriculture have been altered and in some situations broken.

The basic needs of man include food, fiber, fuel, fertilizer, and shelter. Small farming operations can and do cycle available resources (Figure 1). The basic cycle is one of the land furnishing fuel, fiber, shelter, and food in the form of crops and animals to the consumer. Part of the residues resulting from harvesting and processing were used directly by the consumer, and the remainder were returned to the land for further utilization in additional crops. This approach had the benefit of proper utilization of the residues but resulted in a low level of agricultural productivity.

Inexpensive fossil fuel, inorganic fertilizers, and greater mechanization have been used to increase agricultural productivity and increase the food supply and standard of living in many countries. However, the consumer-land link becomes weakened and can be broken. Residues are no longer as well utilized and the residues from agriculture and agro-industry become more apparent.

Animal production offers an opportunity to examine the alteration of a natural cycle in agriculture and the resultant environmental effect. The basic cycle consists of the land providing feed for the animals whose waste is returned to the land to help produce more feed. The wastes also can be processed and beneficially utilized. With large scale animal production, fertilizer, pesticides, external energy and other inputs are necessary to obtain needed crop and animal production levels. As long as the resultant animal manures are utilized in the cycle as noted, the cycle essentially remains closed, external inputs are minimal, and environmental concerns related to the wastes are low. However, when there is a lag in the cycle or improper management of one of the components, environmental problems increase.

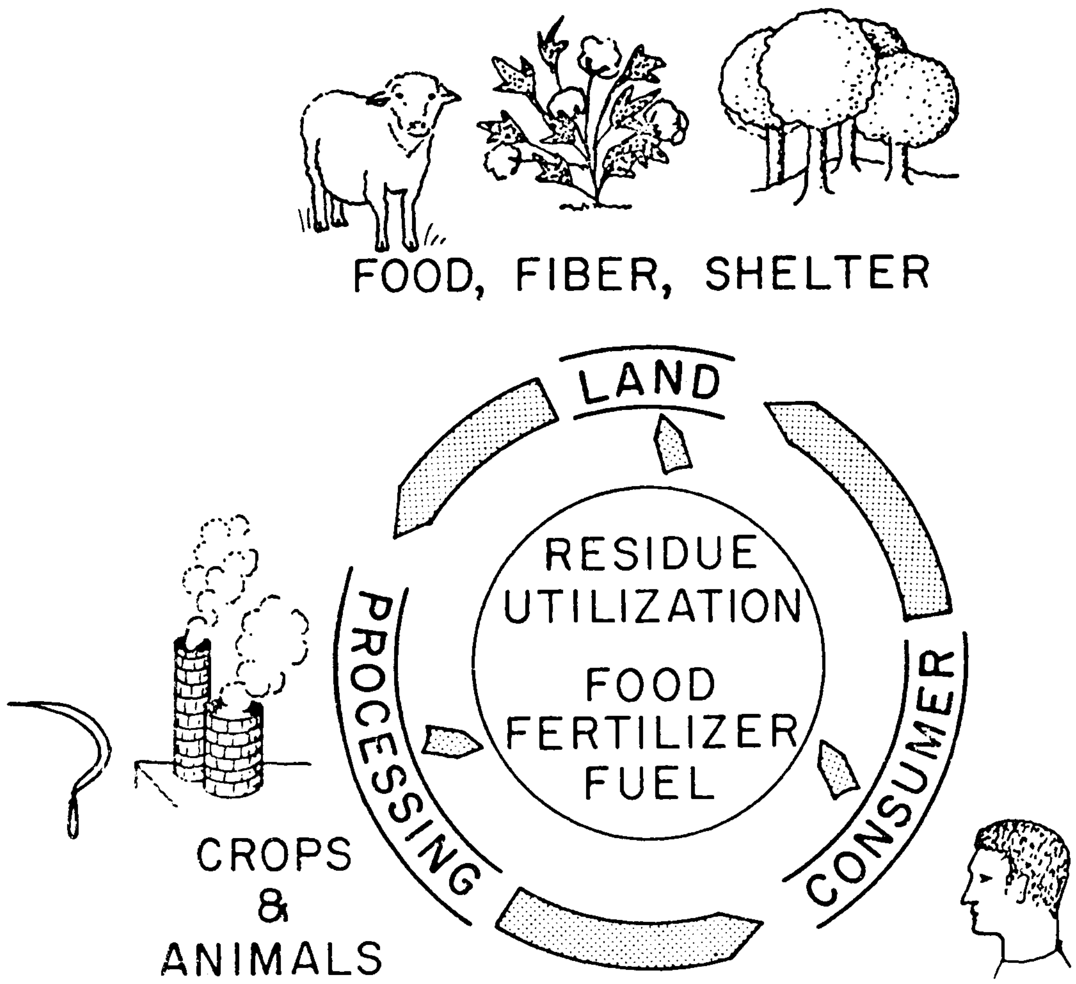


Figure 1. Schematic of the Ideal Cycle for Agricultural Production and Residue Utilization

When the wastes accumulate prior to land application, odors can result and precipitation can transport a portion of the wastes to streams. If the wastes are improperly applied to the land, nutrient losses and surface and groundwater pollution can result. The larger animal production units have increased animal protein production but can accumulate large quantities of waste, can weaken the waste-land link, can result in residues that require treatment and disposal, and can influence other natural cycles (Figure 2).

The further from the basic cycle the situation is permitted to go, the more unbalanced the situation becomes and the greater the costs of proper waste management. The basic cycle is easier to maintain with animal production than it is with food and fiber processing. Such processing is further removed from the site of original production, and a closed cycle is less possible. The food and fiber processing pattern is a sequence involving many natural cycles (Figure 3). Although closed cycles may not be possible throughout agriculture or agro-industries, the residues or by-products should be considered as resources to be utilized rather than merely wastes for disposal.

The generation of residues from agriculture and agro-industry is a function of many factors. The quantity and quality of the residues will depend upon the type of raw materials, the production processes, the product mix, the production rate, the product output specifications, the prices of inputs and product, the regulations affecting product quality and use, and any constraints imposed upon residuals discharge. The generated residues are materials and energy. The material residues may be liquid, gaseous, or solid or a combination of forms. The principal energy residues are heat and noise.

Residue generation is dynamic reflecting the requirements of laws, regulations, and prices of the inputs and outputs. As these factors change, the extent of residue recovery and utilization may increase or decrease. Knowledge of the factors that can or do affect the quantity and characteristics of the residues is important to decisions on the feasibility of residue utilization approaches.

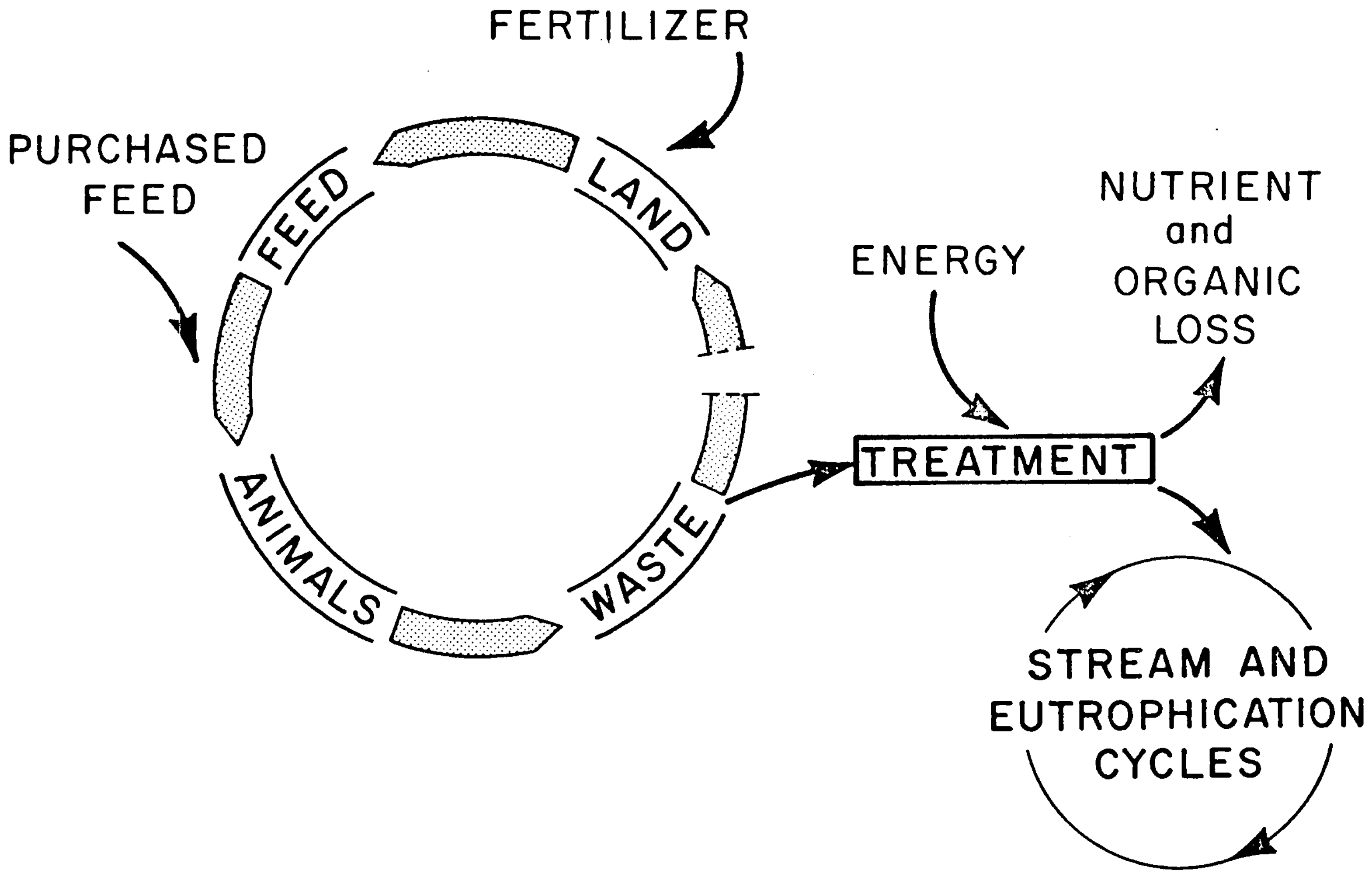


Figure 2. Schematic of the Large Scale Animal Production Requiring Waste Treatment

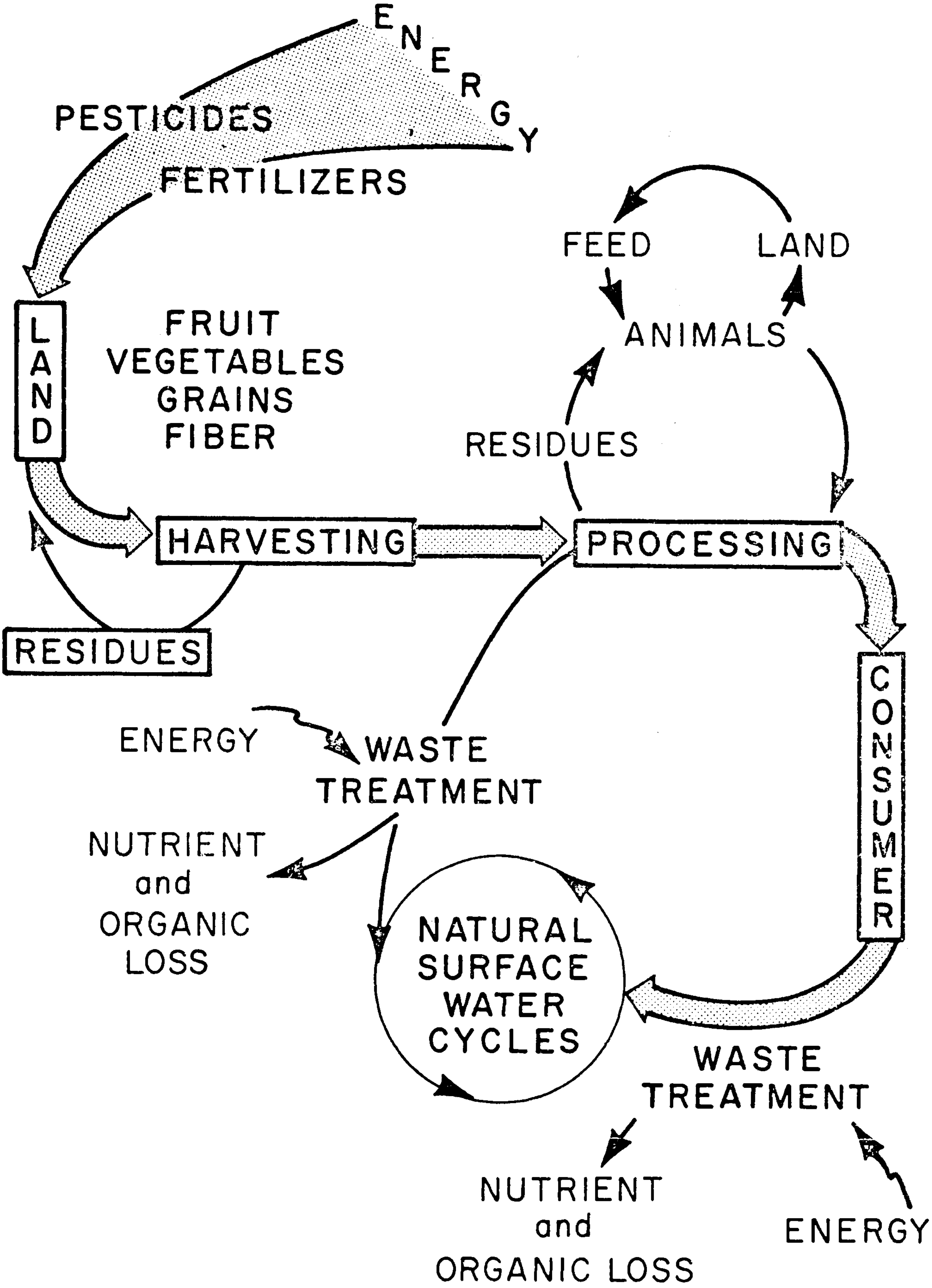


Figure 3. Schematic of Food Production Inputs, Residue Utilization, and Waste Management

3. RESIDUE CHARACTERISTICS

3.1 - General - The residues from agriculture and agro-industry are mainly organic and can be in a solid, slurry or liquid form. Significant amounts of these residues are generated each year. The feasibility of residue utilization for energy or feedstock production depends on the characteristics of the residue, the quantity that is realistically available, ties to existing or future utilization facilities, the continuity of supply, current uses, values of the residue as a useful by-product or raw material for other products, and the cost of residue collection. A few estimates of types of residue production have been made. For the most part, available information on the characteristics of agricultural residues lack specificity as to detail, distribution, seasonality, and condition.

The basis of many discussions on the possibility of agricultural residue utilization is that residues are apparently available in some, generally undefined quantity and that, in general, technology exists for converting them to usable products. The characteristics of agricultural residues must be known in greater detail.

An estimate of the quantity and quality of the waste material is important knowledge that is needed to assess whether it is feasible to consider utilization of a part or all of the wastes. Available waste characteristics rarely provide enough information on specific components that may be of interest. Rather, the characteristics are measured only in general terms, primarily to assess the pollutional characteristics, such as BOD, COD, TKN, suspended solids, and grease, rather than those that may be more appropriate for utilization. Until recently, the data rarely was in terms of characteristics per unit of production, such as kilograms of nitrogen per 1000 kilograms of product processed. Information on characteristics generally is available in concentration units, mg/l, which do not identify either the quantities of the waste material generated or the quantities available for utilization.

Knowledge of the residue characteristics permits consideration of use of waste liquids for the transport of raw products, of recovery of specific components, of irrigation possibilities, of by-product development, and of fertilizer value. Therefore, an important first step in residue utilization is to determine the quantity, quality, and source of the residues actually produced in the industry. A water and mass balance on the processes used will identify the sources and quantities of the residues that are generated. With this information known, the feasibility of residue recovery and utilization become better known. Examples of the type of mass balances that are helpful are noted in Figures 4, 5, and 6.

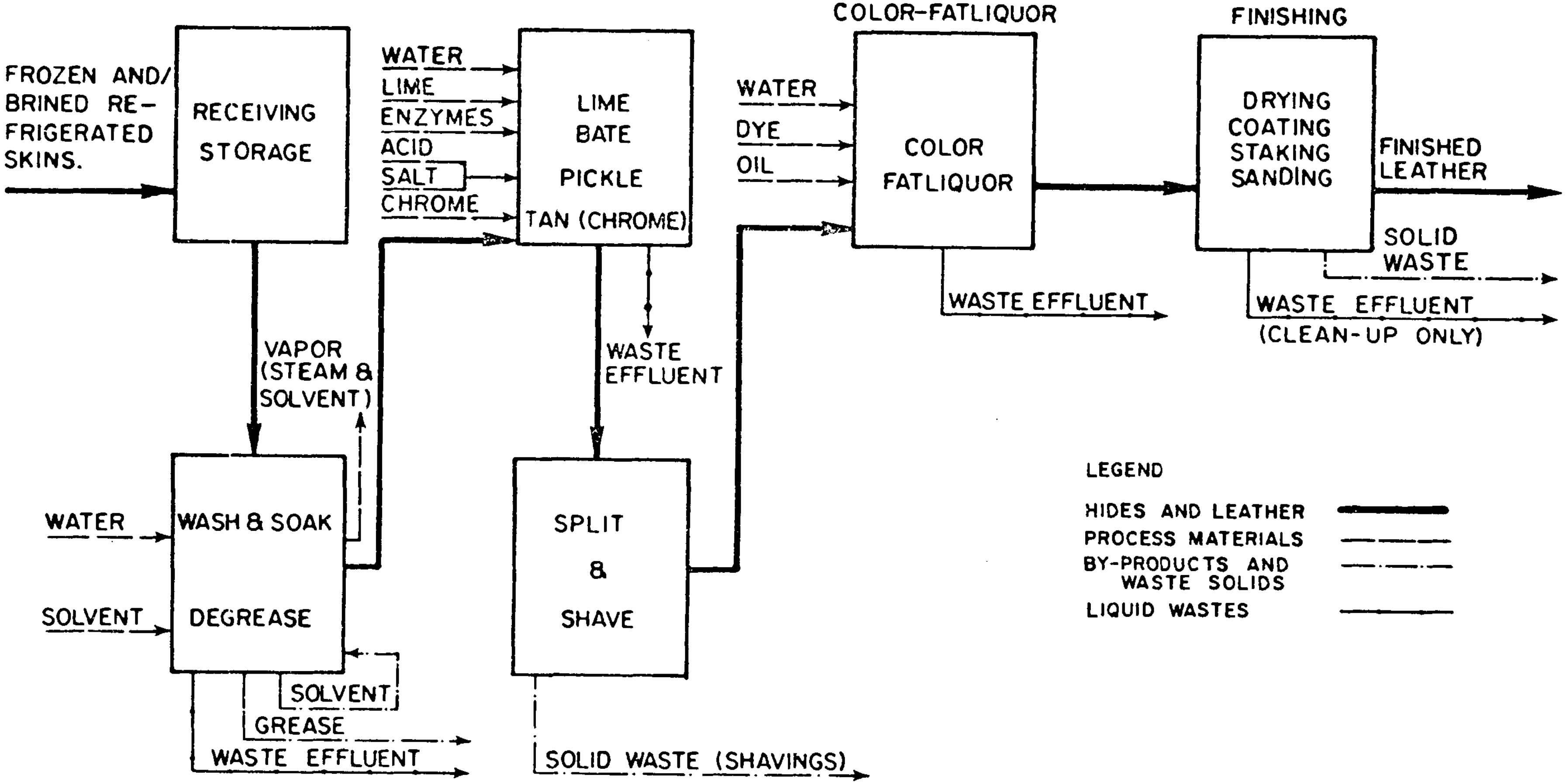
Figure 4 indicates a flow diagram for a typical pigskin tannery noting inputs and outputs from each process including processed leather, by-products and wastes. While such a diagram helps identify possibilities of waste separation and possible utilization, greater detail on the quantity and quality of the residue streams is needed. Figure 5 provides information on the flow, BOD and suspended solids content of wastes from frozen potato product processing (2) while Figure 6 indicates the wastewater and BOD production from condensed milk processing. Even greater detail may be needed about the characteristics of the residues that are generated from a particular process.

An accurate, comprehensive analysis of many residues is not available. Only by collecting such data can a useful evaluation of potential utilization be made. Much of the published analyses of some of the residues are old or incomplete and others are nonexistent. Considerable residue analysis may have to be done before any residue utilization possibilities can be evaluated

Many publications exist that identify the characteristics of various agricultural and agro-industrial wastes (3-8). This section will not duplicate the material of these publications. Rather the intent of this section is to identify the types of residues that can be available, data on characteristics that may not be generally available, information related to application of the available characteristics, and general illustrations of how the residues may be utilized.

Figure 4

FLOW DIAGRAM
TYPICAL PIGSKIN TANNERY



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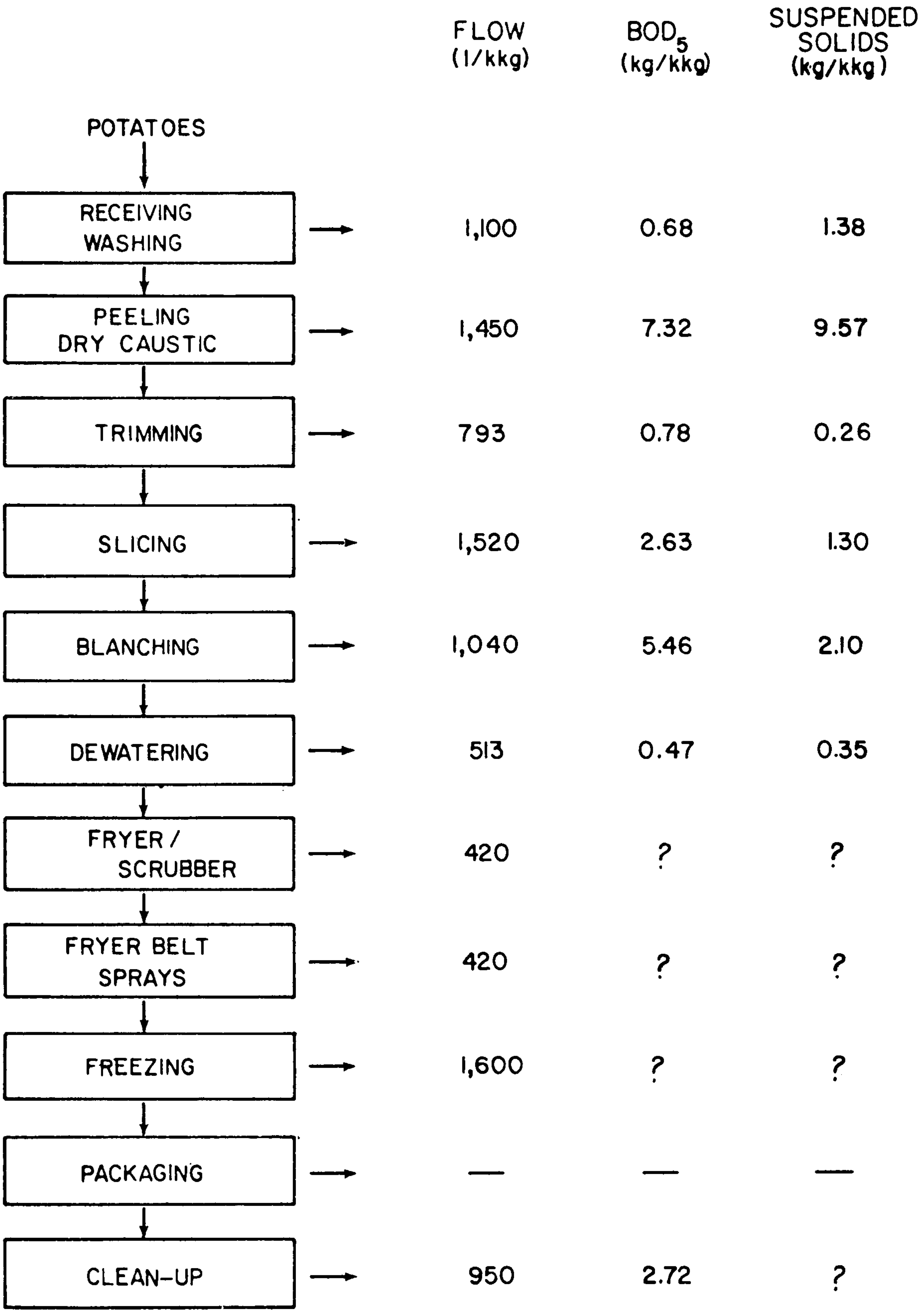

	FLOW (l/kkg)	BOD$_5$ (kg/kkg)	SUSPENDED SOLIDS (kg/kkg)
RECEIVING WASHING	1,100	0.68	1.38
PEELING DRY CAUSTIC	1,450	7.32	9.57
TRIMMING	793	0.78	0.26
SLICING	1,520	2.63	1.30
BLANCHING	1,040	5.46	2.10
DEWATERING	513	0.47	0.35
FRYER / SCRUBBER	420	?	?
FRYER BELT SPRAYS	420	?	?
FREEZING	1,600	?	?
PACKAGING	—	—	—
CLEAN-UP	950	2.72	?

WASTE AND PROCESS FLOW DIAGRAM
FROZEN POTATO PRODUCTS

Figure 5

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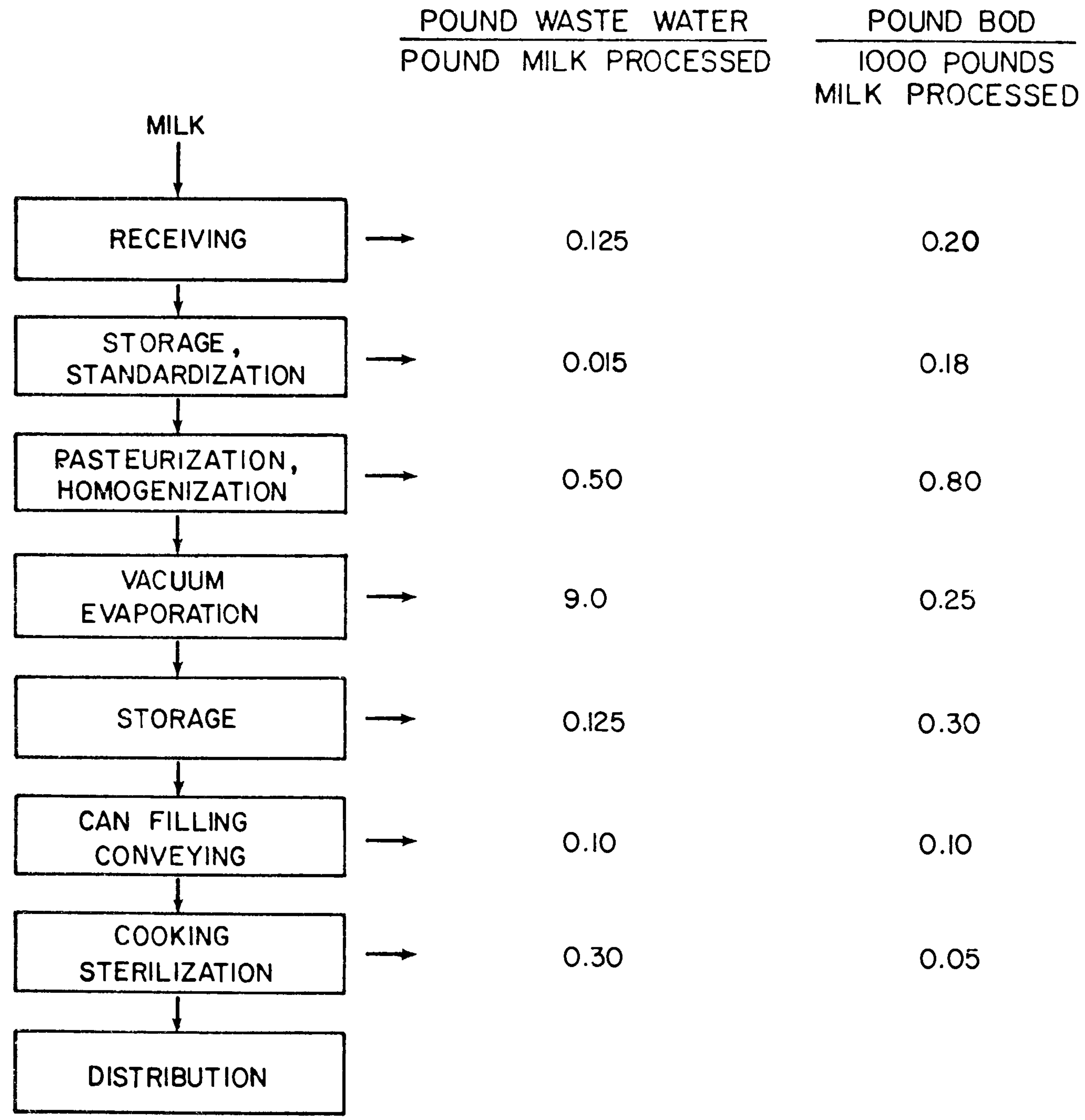

WASTE AND PROCESS FLOW DIAGRAM
CANNED CONDENSED MILK

Figure 6

3.2 - Meat and Poultry Processing - Meat processing plants conduct the slaughtering and processing of cattle, calves, hogs, sheep, and other animals for the preparation of meat products and by-products. Plants in this industry range from those that carry out only one operation, such as slaughtering, to comprehensive plants that not only slaughter animals but also accomplish various degrees of processing. A slaughterhouse is a plant that slaughters animals and has as its main product fresh meat in portions of the carcass, while a packinghouse is a plant that both slaughters and processes fresh meat to cured, smoked, canned and other prepared meat products.

The non-meat portion of an animal results in significant waste loads. Wherever possible, such material should be separated from the general waste stream at the source. The main wastes originate from killing, hide removal or dehairing, paunch handling, rendering, trimming, processing, and cleanup operations. The wastes contain blood, grease, inorganic and organic solids, and salts and chemicals added during processing operations.

Meat processing plants produce both edible and non-edible residues. The edible items include lard, intestines, glands and blood. The non-edible items include hides, hair, bones, horns, and hooves. Many of these residues can be utilized, and this industry is an example of the conversion of agricultural wastes into useful products. Typical by-products and their uses have been:

edible fats - tallow, grease
meat scraps and blood - animal feed
bone - bone meal for fertilizers
intestines - sausage casings, surgical thread
glands - pharmaceutical products

The benefits derived from such utilization include: a) improved sanitation at the slaughterhouse, b) establishment of secondary industries, c) better use of existing resources for animal and crop production and for human well-being.

Numerous opportunities exist for recovery of meat processing residues for by-product use. Detailed information on the characteristics and utilization of meat processing residues has been developed (3).

Recent data has permitted the residue production to be calculated on a per unit livestock basis. As in other industry categories, a wide variation exists in the waste characteristics from different plants. The average data from U.S. plants is reported in Table 1. Frequently, however, the data from different plants varied by a factor of 10 or more. As an example, in the simple slaughterhouse category, the BOD_5 data ranged from 1.5 to 14.3 kg/kkg LWK and the grease data varied from 0.24 to 7.0 kg/kkg LWK. In general, increased water use caused increased pollutional waste loads in the meat packing industry.

Poultry processing plants slaughter, dress or eviscerate, ice or freeze pack, and further process chickens, turkeys, ducks, geese, and other poultry. At these plants wastes originate from killing, scalding, defeathering, evisceration, washing, chilling, and cleanup operations. Residue quantity and quality depend on the manner in which the blood, feathers, and offal are handled, the type of processing equipment used, and the food and pollution control regulations that are enforced.

Residue production data has become available on a per bird processed basis. The average data from U.S. plants is reported in Table 2; however, the characteristics between plants varied considerably. For example, for the chicken processor category, the flow data ranged from 15.9 to 87.0 liters per bird - with an average of 34.4 liters per bird. In the same category, the BOD_5 ranged from 3.26 to 19.86 kg/kkg LWK and grease ranged from 0.12 to 14.03 kg/kkg LWK. The average values for these parameters were 9.89 and 6.91 kg/kkg LWK respectively. For both the chicken and turkey processing plants, the available data suggested that increased water use may result in higher raw waste loads as measured by BOD_5.

There are many opportunities to utilize the residues from meat and poultry processing. The recovery and scale of about 15,000 pounds of protein

TABLE 1

Raw Waste Characteristics[a/] for Slaughterhouses and Packinghouses[b/]

Type of Plant[c/]	Flow	BOD_5	Suspended Solids	Grease	Kjeldahl Nitrogen as N	Chlorides as Cl	Total Phosphorus as P
Simple Slaughterhouses	5330 (1330-14,640)	6.0 (1.5-14.3)	5.6 (0.6-12.9)	2.1 (0.2-7.0)	0.7 (0.2-1.4)	2.6 (0.01-5.4)	0.05 (0.14-0.86)
Complex Slaughterhouses	7380 (3630-12,500)	10.9 (5.4-18.8)	9.6 (2.8-20.5)	5.9 (0.7-16.8)	0.8 (0.1-2.1)	2.8 (0.8-7.9)	0.33 (0.05-1.2)
Low Processing Packinghouses	7840 (2020-17,000)	8.1 (2.3-18.4)	5.9 (0.6-13.9)	3.0 (0.8-7.7)	0.5 (0.04-1.3)	3.6 (0.5-4.9)	0.13 (0.03-0.43)
High Processing Packinghouses	12,510 (5440-20,260)	16.1 (6.2-30.5)	10.5 (1.7-22.5)	9.0 (2.8-27.0)	1.3 (0.6-2.7)	15.6 (0.8-36.7)	0.38 (0.2-0.63)

[a/] The raw waste loads are in terms of liters per 1000 kilograms of liveweight killed (LWK) for flow and kilograms per 1000 kilograms (kkg) LWK for all other parameters. Data in parentheses represent the range of values reported; the single number is the average value for that parameter and type of plant.

[b/] from: Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Red Meat Processing Segment of the Meat Product and Rendering Processing Point Source Category," EPA-440/1-74-012a, Washington, D.C., February 1974.

[c/] Simple Slaughterhouse - very limited by-product processing
Complex Slaughterhouse - does extensive by-product processing such as rendering, blood processing, hide or hair processing, or paunch and viscera handling
Low Processing Packinghouse - processes no more than the total animals killed at that plant
High Processing Packinghouse - processes both animals slaughtered at the site and carcasses from outside sources.

[illegible]

Summary of Waste Characteristics[a] for Chicken, Turkey, Fowl, and Duck Processing[b,c]

Parameter	Chicken		Turkey		Fowl		Duck	
	ave.	range	ave.	range	ave.	range	ave.	range
Flow	34.4	15.9-87.0	118	36.3-270	48.9	11.0-159	74.9	71.5-78.3
BOD_5	9.9	3.3-19.9	4.9	1.0-9.1	15.2	11.8-23.1	7.1	6.6-7.5
Suspended solids	6.9	0.13-22.1	3.2	0.6-10.9	10.1	6.1-14.9	4.4	3.5-5.2
Grease	4.2	0.12-14.0	0.9	0.3-1.8	2.3	0.7-3.3	1.9	0.7-3.1
COD	19.7	2.0-56.8	7.4	3.1-10.9	41.4	24.3-58.5	14.1	13.6-14.6
Total volatile solids	13.3	3.5-47.2	8.4	2.2-19.2	18.4	13.1-23.7	7.1	6.7-7.5
Total dissolved solids	11.7	3.5-45.8	13.5	1.5-38.5	24.9	9.1-40.6	8.3	4.0-12.6
Total Kjeldahl nitrogen as N	1.8	0.15-12.2	0.9	0.4-1.9	0.3	-	1.4	0.8-2.0
Ammonia as N	0.23	0.005-0.73	0.15	0.06-0.37	0.1	-	0.8	0.06-1.5
Nitrate as N	0.008	0-0.14	0.004	0.005-0.09	0.004	-	0.03	0.02-0.04
Nitrite as N	0.007	0-0.037	0.001	0.001-0.002	0.0005	-	0.01	0.001-0.02
Chlorides as Cl	1.97	0.006-9.16	2.5	0.04-5.4	4.0	-	1.4	0.8-2.1
Total phosphorus as P	0.40	0.05-2.46	0.1	0.03-0.18	0.3	-	0.08	0.07-0.10

[a] The raw waste characteristics are in terms of liters per bird processed for flow and in terms of kilograms per 1000 kilograms (kkg) per live weight killed (LWK) for the other parameters.

[b] Chicken processing includes processing of broilers and of chickens not classified as mature chickens or fowl; turkey processing includes processing of hen or tom turkeys of varying age and size; fowl processing includes processing mature chickens larger in size and older than broilers and geese, capons, and roosters.

[c] From: Environmental Protection Agency, "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Poultry Segment of the Meat Product and Rendering Process Point Source Category," EPA 440/1-75/031b, Group I, Phase II, Washington, D.C., April 1975.

solids per week is an example of one type of residue utilization that can occur in the food processing industry. A processor of specialty poultry products had discharged 25,000 gallons of cooking liquid each day to the local sewers. With the installation of a broth concentrator, a soluble, concentrated broth containing about 5-15% dissolved solids and almost all protein has resulted (9).

Secondary industries, such as rendering, leather production, and animal feed production have been developed to utilize meat and poultry processing residues.

3.3 - Rendering - Rendering is a process to convert animal by-products into fats, oils, and proteinaceous solids. Heat is used to melt the fats from the tissue, to coagulate cell proteins and to evaporate the raw material moisture. Rendering processes feathers, bones, fat tissue, meat scraps, inedible animal carcasses, and animal offal.

Both wet and dry rendering processes can be used. Edible rendering requires fresh material and is usually conducted by a wet or low temperature process which does not evaporate raw material moisture during cooking. The liquid separated from the edible product contains significant soluble organics and has a high pollution potential. Inedible rendering is accomplished by dry rendering in which the raw material is cooked without the addition of steam or water.

The wastes from rendering also can be considered for possible further utilization. Table 3 presents the characteristics of these wastes on a per unit of raw material processed basis. Considerable variations exist between plants and are due to different types of rendering and the general management at the plants.

3.4 - Leather Production - Leather is produced by the reaction of the collagen fibers in animal skins with tannin, chromium, alum or other

TABLE 3

Summary of Raw Waste Characteristics[a] for Rendering Industry[b]

Parameter	Average	Range
Flow	3260	470-20,000
BOD_5	2.15	0.1-5.8
SS	1.13	0.03-5.2
Grease	0.72	0-4.2
COD	8.04	1.6-37.0
Total Volatile Solids	3.34	0.04-13.1
Total Dissolved Solids	3.47	0.01-11.7
Total Kjeldahl Nitrogen as N	0.48	0.12-1.20
Ammonia as N	0.30	0.08-0.74
Nitrate as N	0.008	0-0.06
Nitrite as N	0.003	0-0.04
Chloride as Cl	0.80	0.08-2.56
Total Phosphorus as P	0.04	0.003-0.28

[a] The raw waste loads are in terms of liters per 1000 kilograms of raw material (RM) processed for flow and in terms of kilograms per thousand kilograms (kkg) RM for the other parameters. All raw waste data represents the effluent following any in-plant materials recovery such as catch basins, skimmers, etc.

[b] from: Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Renderer Segment of the Meat Products and Rendering Processing Point Source Category," EPA-440/1-74/031d, Group I, Phase II, Washington, D.C., January 1975.

tanning agents. The process of tanning developed as an art many centuries ago but has been modified by the application of scientific principles. There is a significant variation in processing techniques, even between two tanners producing the same finished product. It follows that the residues resulting from the production of leather also will vary.

In addition to the organic constituents resulting from the processing of the animal skins and the oils used to finish the leather, the residues will contain quantities of the chemicals used. Lime, sodium sulfide, sodium sulfhydrate, chromium sulfate, alum, vegetable compounds, mineral acids, and salts are employed in the various processes. The characteristics of the wastes from U.S. plants in this industry, expressed on a per unit of hide processed basis, are illustrated in Table 4.

3.5 - Seafood Processing - Fish represent a largely untapped source of large quantities of protein, particularly parts of fish or whole fish being underutilized or wasted. At the present time, more than two-thirds of the harvested seafood is not being utilized directly as human food.

The residues generated in seafood processing vary widely. Fish which are rendered whole to produce fish meal result in no solid waste. Crab processing results in up to 85% solid waste. Each fish processing operation will produce significant liquid flows from the cutting, washing, and processing of the product. These flows contain blood and small pieces of fish and skins, viscera, condensate from cooking operations, and cooling water from condensers.

In this industry the residues result from the inedible portions of the fish carcass material. Fish processing by-products generally are limited to fish meal and fish oil. Other possible by-products include fish glue, gelatin, vitamin concentrates, biochemical and pharmaceutical products, animal and plant food, and fish protein concentrate. Detailed information is available (5) for the processing and utilization of fish by-products.

TABLE 4

Summary of Waste Characteristics[a] Resulting from Leather Tanning

Category[b]	1		2		3		4		5		6	
Parameter[c]	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
Flow	0.05	0.007-0.156	0.06	0.001-0.19	0.05	0.007-0.106	0.02	0.003-0.033	0.06	0.006-0.20	0.03	0.014-0.056
BOD_5	95	4.8-270	69	22-140	67	7.4-130	37	6.7-67	67	10-140	110	32-160
COD	260	10.5-595	140	88-215	250	24-695	28	5.7-63	170	11-265	230	53-155
Total Solids	525	36-980	480	140-900	345	120-800	140	4.7-285	490	52-980	595	210-910
Suspended Solids	140	6.7-595	145	30-350	135	20-445	47	7.0-125	88	3.1-865	110	44-185
Total Chromium	4.3	0.1-19	4.9	0.3-12	0.2	0.1-0.6	2.6	0.4-4.8	1.2	0.1-2.1	4.4	3.8-5.9
Sulfides	8.5	0.1-46	0.8	0.1-2.8	1.2	0.1-4.2	2.1	-	4.5	-	3.7	2.0-6.3
Grease	19	0.1-70	43	0.7-105	33	0.1-160	7.9	2.2-19	24	0.6-4.6	6.6	1.0-19
Total Nitrogen as N	17	3.1-44	13	3.6-22	9.2	0.9-23	3.7	0.8-6.5	6.0	0.6-29	16	14-18

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[a] Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Leather Tanning and Finishing Point Source Category," EPA-440/1-74-016a, March 1974, Washington, D.C.

[b] 1 - chrome tanning, hair removal by chemical loosening and dissolving; 2 - chrome tanning, hair removed, saved and separated from the wastes; 3 - vegetable tanning, hair removed, saved, and separated from the wastes; 4 - previously tanned hides with hair previously removed; 5 - chrome tanning, hair previously remove or retained; 6 - chrome or no tanning, no leather finishing.

[c] flow - m^3/kg; BOD_5, suspended solids (SS), grease, total nitrogen as N(TN) - kg/kkg of hide processed.

Additional information on the wastes produced per unit of fish processed are available (Table 5). The various types of processing used will affect the quantity of residues that are generated. In the United States, Atlantic menhaden and Pacific anchovies are processed into fish meal, oil, and solubles. Table 5 notes the important role that waste recovery plays in reducing the pollution potential in the fish meal industry.

The processing of bottom fish and finfish involves the preparation of fillets or whole fish for the fresh or frozen market. The fish waste, usually heads, viscera, and carcasses are collected and rendered or recovered for animal food. Mechanized processing (Table 5) increases the waste production from this category.

Little of the fish which enter the processing plant need be regarded as waste. Stickwater (water which has been in close contact with the fish and contains considerable organics) and the non-edible portions can be collected and processed into other products such as fish meal or fish solubles. The waste solids can be ground, cooked and pressed to remove valuable liquids and oils before the resultant solids are dried. This fish meal can be bagged and marketed for different uses including fertilizer and animal feed additives. The liquids and oils from the processing of the cooked solids can be concentrated along with stickwater and ground viscera in a solubles plant. After concentration, the solubles can be marketed as animal feed and other uses.

3.6 - Fruit and Vegetable Processing - Each food processing plant has wastes of different quantity and quality. No two plants are the same and estimates of residues generated from each plant must be regarded as approximate. Few plants have adequate knowledge of the volumes, characteristics, and fluctuations of their wastes. At each processing plant, material and water balances on the inputs and outputs to the plant can provide reasonable estimates of the total waste flow and residue generation.

Much of the available information on food processing waste characteristics is not comprehensive. Average waste loads reported in the literature

TABLE 5

Summary of Waste Characteristics for Selected Seafood Processing[a]

Category	Parameter[b]				
	Flow	BOD_5	SS	Grease	TKN
Tuna Processing	22,280 (5,590-45,100)	14.6 (6.8-20)	10.8 (3.8-1.7)	5.7 (1.7-13)	1.38 (0.75-3.4)
Fish Meal					
with solubles recovery	35,000	2.96	0.92	0.56	-
without solubles recovery	1,900	62.2	34.8	22.8	-
Bottom Fish[c]					
conventional processing	5,240	3.32	1.42	0.35	-
mechanized processing	13,500	11.9	8.9	2.48	-
Sardine Canning	3,640	10.0	2.9	2.0	-
Herring Filleting	8,090	32.0	22.6	6.1	-

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[a] Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Catfish, Crab, Shrimp and Tuna Segment of the Canned and Preserved Seafood Processing Point Source Category," EPA-440/1-74-020a, June 1974, Washington, D.C.; and Environmental Protection Agency, "Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Fish Meal, Salmon, Bottom Fish, Sardine, Herring, Clam, Oyster, Scallop, and Abalone Segment of the Canned and Preserved Seafood Processing Point Source Category," EPA-440/1-74-041, January 1975, Washington, D.C.

[b] flow - liters/kkg; BOD_5, suspended solids (SS), grease, and total Kjeldahl nitrogen as N (TKN) - kg/kkg of fish processed. Data in parentheses represent the range of values reported; the single number is the average value for that parameter.

[c] such as halibut, whiting, and miscellaneous finfish.

should be regarded as guidelines rather than exact values that can be extrapolated to different plants.

The effluent from fruit and vegetable processing plants consists mainly of carbohydrates such as starches and sugars, pectins, vitamins, and other components of the product cell walls which have been leached during processing. Of the total organic matter, 70-85% can be present in the dissolved form. These dissolved solids are not removed by mechanical or physical separation methods, although they can be stabilized and/or removed by biological or chemical oxidation and adsorption.

Food processing wastes result from the washing, trimming, blanching, pasteurizing, juicing of raw materials, the cleaning of processing equipment, and the cooling of the finished product. The characteristics of food processing wastes are such that they generally are low in nitrogenous compounds, have a high oxygen demand, and undergo rapid decomposition. Some wastes, such as those from beet processing, are highly colored. Fresh wastes generally have a pH close to neutral. During storage the pH decreases. In addition to the organic content, fruit and vegetable processing wastes can contain other pollutants such as soil, lye, heat, and insecticides.

The pH values of some fruit and vegetable processing wastes result from the use of caustics such as lye in peeling. These caustic solutions can have a pH about 12-13 and are discharged intermittently as they lose their strength resulting in slug loads to the waste treatment facilities. Pickle and sauerkraut wastes are acidic and contain large chloride concentrations as well as organic matter.

Different food processing operations can affect the quantity and quality of the residues requiring treatment or being available for utilization. As an example, dry caustic peeling of fruits and vegetables results in less waste than that from the wet peeling process. The pounds of dry solids per ton of potatoes resulting from the wet caustic peeling system were about 3.75 times that for the dry caustic system. Similarly the pounds of BOD per ton of potatoes were about 4.5 times larger with the wet system. These systems are illustrative of the changes in the quantities of residues that can result from processing plant technology changes. Residue utilization evaluations should consider the effect processing operation changes may have on the availability and type of residues.

Information on the waste characteristics, expressed on the basis of the quantity of material processed or quantity of material produced, is presented in Tables 6 and 7. Table 6 presents the average characteristics for U.S. plants processing fruits, vegetables, and some specialty foods. Wastewater volumes and waste generation vary significantly between categories and between plants within categories.

Table 7 indicates the average characteristics of wastes from U.S. plants preparing specialty foods. These plants produce wastes that are highly organic. The wastes are often deficient in nutrients and contain significant oil and grease where substantial frying is done.

3.7 - Dairy Product Production - The largest wastes from dairy food plants are whey from cheese production followed by wash water and pasteurization water. The manufacture of cheese from either whole or skim milk produces cheese and a greenish yellow fluid known as whey. Whole milk is used to produce natural and processed cheeses such as cheddar and the resultant fluid is sweet whey with a pH in the range of 5 to 7.

Skim milk is used to produce cottage cheese and the by-product fluid is called acid whey with a pH in the 4 to 5 range. The lower pH is the result of the acid developed during or employed for coagulation. Each pound of cheese produced results in 5-10 pounds of fluid whey. About 70% of the nutrients in skim milk are part of the acid whey. The BOD of whey ranges from 32,000 to 60,000 mg/l depending on the specific cheese making process used. Whey contains about 5% lactose, 1% protein, 0.3% fat, and 0.6% ash.

The protein and lactose in whey could be used in many by-products if excess salts were removed. Investigations on the use of whey in food products

TABLE 6

Raw Waste Loads[a] for the Fruit, Vegetable, and Specialties Processing Industry[b]

Category	Flow gallons/ton	BOD lbs/ton	Total suspended solids lbs/ton
Fruit			
Apple Processing	690	4.1	0.6
Apple Products except juice	1,290	12.8	1.6
Apricots	5,660	30.9	8.5
Caneberries	1,400	5.7	1.2
Cherries			
sweet	1,860	19.3	1.2
sour	2,880	34.3	2.1
brined	4,780	43.5	2.9
Cranberries	2,950	19.9	2.8
Citrus all products	2,420	6.4	2.6
Dried Fruit	3,180	24.8	3.7
Grape Juice			
canning	1,730	21.4	2.5
pressing	370	3.8	0.8
Olives	9,160	87.4	15.0
Peaches			
canned	3,130	28.1	4.6
frozen	1,300	23.4	3.7
Pears	2,840	42.3	6.5
Pickles			
freshed packed	2,050	19.0	3.8
process packed	2,300	36.7	6.5
salting stations	250	15.9	0.8
Pineapples	3,130	20.6	5.5
Plums	1,190	8.2	0.7
Raisins	670	12.1	3.3
Strawberries	3,150	10.6	2.7
Tomatoes			
peeled	2,150	8.2	12.3
products	1,130	2.6	5.3

continued.

TABLE 6 continued.

Category	Flow gallons/ton	BOD lbs/ton	Total suspended solids lbs/ton
Vegetables			
Asparagus	16,520	4.2	6.9
Beets	1,210	39.4	7.9
Broccoli	10,950	19.6	11.2
Brussel Sprouts	8,720	6.9	21.6
Carrots	2,910	39.0	23.9
Cauliflower	21,470	10.5	5.1
Corn			
canned	1,070	28.8	13.4
frozen	3,190	40.4	11.2
Dehydrated onion and garlic	4,770	13.0	11.8
Dehydrated vegetables	5,300	15.8	11.3
Dry Beans	4,310	30.7	8.8
Lima Beans	6,510	27.8	20.7
Mushrooms	5,380	17.4	9.6
Onions - canned	5,520	45.1	18.7
Peas			
canned	4,720	44.2	10.8
frozen	3,480	36.6	9.8
Pimentos	6,910	54.5	5.8
Sauerkraut			
canning	840	7.0	1.2
cutting	103	2.5	0.4
Snap Beans			
canned	3,690	6.3	4.0
frozen	3,820	12.1	6.0
Spinach			
canned	9,040	16.4	13.0
frozen	7,020	9.6	4.0
Squash	1,340	33.6	4.6
Sweet potatoes	990	60.2	22.9

continued.

TABLE 6 concluded.

Category	Flow gallons/ton	BOD lbs/ton	Total suspended solids lbs/ton
White Potatoes	1,990	54.6	74.8
Potatoes			
frozen	2,710	45.8	38.8
dehydrated	2,100	22.1	14.7
Specialty Foods			
Baby Food	1,770	9.1	3.2
Chips			
corn	2,880	70.4	59.8
potato	5,630	74.0	84.4
tortilla	4,880	59.4	72.1
Jams and Jellies			
Mayonnaise and Dressings			
Soups			

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a/ The raw waste load is in terms of the quantity of wastewater parameter per ton of raw material processed for fruits and vegetables and per ton of final product for the speciality foods. The values noted are the average raw waste loads for the available data.in the categories noted. Except where noted, the raw waste loads are those generated from canning processing.

b/ from: Environmental Protection Agency, Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Fruits, Vegetables, and Specialties Segment of the Canned and Preserved Fruits and Vegetables Point Source Category," EPA 440/1-75/046, Group I, Phase II, Washington, D.C., October 1975.

Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Apple, Citrus, and Potato Processing Segment of the Canned and Preserved Fruits and Vegetable Point Source Category," EPA-440/1-74-027a, Washington, D.C., March 1974.

TABLE 7

Average Wastewater Characteristics in the Specialty Food Industry[a]

Category	Parameter[b]						
	Flow	COD	BOD	SS	Total P	TKN	Grease
Prepared Dinners	12,000	34	17	14	0.19	0.44	15
Frozen Bakery Products	11,000	52	23	14	0.08	0.30	11
Dressings, Sauces, and Spreads	2,800	13	7.5	3.5	0.03	0.04	5.7
Meat Specialities	10,000	19	9.9	6.1	0.10	0.57	4.0
Canned Soups and Baby Foods	22,000	20	12	7.6	0.18	0.47	2.4
Tomato-Cheese-Starch Combinations	29,000	17	7.2	6.0	0.28	0.23	4.7
Sauced Vegetables	85,000	45	25	21	0.33	1.1	-
Sweet Syrups, Jams and Jellies	2,400	8.7	5.1	1.0	0.05	0.04	0.6
Chinese and Mexican Foods	14,000	12	6.9	2.8	0.14	0.28	3.0
Breaded Frozen Products	48,000	53	26	26	0.35	2.6	-

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[a] Schmidt, C.J., Farquhar, J., and Clements, E.V., "Wastewater Characterization for the Specialty Food Industry," Environmental Protection Agency, Rept. of Grant R-801684, EPA 660/2-74-075, December 1974, Washington, D.C.

[b] flow - liters/kkg of product; COD, BOD, suspended solids (SS), total P, total Kjeldahl nitrogen (TKN) and grease - kg/kkg of product.

and on the use of electrodialysis and reverse osmosis to remove the salts have been successful. The high bulk and low value of whey make it impractical to transport long distances and handling is difficult and costly. Whey is a good medium for bacterial growth and fermentation and has been used for microbial and yeast protein production.

Data on the waste characteristics from U.S. plants processing milk and dairy products are presented in Tables 8, 9, and 10. A wide range exists in the characteristics from different plants and types of processing.

BOD_5/COD ratios of wastewaters from a variety of milk processing plants ranged from 0.40 to 0.97 with most of the ratios below 0.5. In addition to waste flow and BOD, other characteristics of these wastes can be of interest, such as suspended solids and inorganic constituents. Information on these constituents is less available than that on flow and BOD. BOD to solids relationship in dairy food plant wastewaters are noted in Table 10.

3.8 - Grain Processing - The milling of grains dates to the beginning of recorded history. The cereal grains include barley, corn, grain sorghum, millet, oats, rice, rye, and wheat. The grains are milled by either wet or dry processes, each producing different waste volumes and characteristics. General characteristics of wastes produced from U.S. grain milling plants are presented in Table 11.

The milling of rice differs from other cereal milling in that the product is whole grain rather than flour or meal. During the process of rice milling, the layer around the endosperm is removed. This layer is called rice bran. The bran constitutes between 6-10 per unit of the unpolished rice and contains about 15-20 percent oil. It also contains the vitamin B complex and amino acids such as cystine, lysine, histidine, tryptophane and arginine (6).

The oil in the rice bran can be extracted and utilized as edible oil after refining, for the manufacture of soap and for other industrial uses. The de-oiled rice bran can be utilized as an animal feed.

TABLE 8

Milk Plant Waste Water Coefficients[a]

Type of Product	Waste Volume (lb/lb milk processed)		BOD (lb/1000 lb milk processed)	
	Average	Range	Average	Range
Milk	3.25	0.1-5.4	4.2	0.2-7.8
Cheese	3.14	1.6-5.7	2.0	1.0-3.5
Ice Cream	2.8	0.8-5.6	5.7	1.9-20.4
Condensed Milk	2.1	1.0-3.3	7.6	0.2-13.3
Butter	0.8	-	0.85	-
Powdered Milk	3.7	1.5-5.9	2.2	0.02-4.6
Cottage Cheese	6.0	0.8-12.4	34.0	1.3-71.2[b]
Cottage Cheese and Milk	1.84	0.05-7.2	3.47	0.7-8.6[b]
Cottage Cheese, Ice Cream, and Milk	2.52	1.4-3.9	6.37	2.3-12.9
Mixed Products	2.34	0.8-4.6	3.09	0.9-6.9
Overall	2.43	0.1-12.4	5.85	0.2-71.2

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[a] From: Harper, W.J. and Blaisdell, J.L., "State of the Art of Dairy Food Plant Wastes and Waste Treatment," Proc. 2nd Nat. Symp. Food Process. Wastes, pp.509-545, Pacific Northwest Water Lab., Environmental Protection Agency, 1971.

[b] Whey included, whey excluded from all other operations manufacturing cottage cheese.

TABLE 9

Milk Plant Processing Waste Data from Five Plants (mg/l)[a]

	Range of Averages	Total Range of Data
BOD	940-4790	400-9440
COD	1240-7800	360-15,300
Ammonia	7-36	1-76
Organic Nitrogen	36-150	9-250
Alkalinity	81-505	0-1080
pH	4.8-6.8	4.2-9.5
Total Solids	2280-6490	1210-11,990
Suspended Solids	360-1040	270-1980
Volatile Suspended Solids	300-1000	200-1840

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[a] From: Lawton, G.W., Engelhart, L.E., Rohlich, G.A., and Porges, N., Effectiveness of Spray Irrigation as a Method for Disposal of Dairy Plant Wastes. Wisc. Engr. Exp. Sta., Res. Rept. 15, 1960.

TABLE 10

Milk Plant Waste Characteristics[a]
BOD-Solids Relationships[b]

Product	SS/BOD ratio	TS/BOD ratio
Cheese	0.35	1.6
Butter	0.28	1.65
Milk	0.32	1.7
Combined dairy products	0.35	1.6
Average	0.32	1.62

[a] Environmental Protection Agency "Dairy Food Plant Wastes and Waste Treatment Practices" Report by Department of Dairy Technology, Ohio State University, Columbus, Ohio, Grant 12060 EGU, March 1971, Washington, D.C.

[b] SS = suspended solids; TS = total solids

TABLE 11

Summary of Waste Characteristics from Grain Processing[a/][b/]

Parameter[c/]	Corn Wet Milling ave.	Corn Wet Milling range	Corn Dry Milling ave.	Corn Dry Milling range	Wheat Milling ave.	Wheat Milling range	Rice Milling ave.	Rice Milling range
Flow	18.3	3.1-41.7	-	0.5-0.9	-	-	-	-
BOD	7.4	2.1-12.5	1.14	0.5-2.2	0.11	-	1.8	-
COD	14.8	6.8-22.3	2.69	1.44-3.93	-	-	-	-
Suspended Solids	3.8	0.5-9.8	1.62	0.8-2.8	0.10	-	0.07	-

[a/] corn wet milling - such as to produce corn syrup or starch; corn dry milling - such as to produce meal and flour, water use limited to corn washing, tempering and cooling; wheat milling - data provided is for bulgur production, the normal milling of wheat into flour uses water only in tempering and cooling and no process wastewaters are discharged; rice milling - data provided is for parboiled rice, normal milling of rice to produce either brown or white rice utilizes no process waters and generates no wastewaters.

[b/] Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Grain Processing Segment of the Grain Mills Point Source Category," EPA 440/1-74-028a, March 1974, Washington, D.C.

[c/] flow - m^3/kkg; BOD_5 and suspended solids (SS) - kg/kkg of grain processed.

3.9 - Animal Waste - Animals convert non-edible plants to high quality protein foods and therefore their wastes represent the results of that conversion. The proper handling of animal wastes is an essential element of any livestock management system. Along with its pollution potential, animal waste represents an economic loss to cattlemen as unused feed. In the United States it takes about 7-8 pounds of feed to produce one pound of beef.

Large animal "feedlots" are becoming more common and continue to grow to meet consumer demand for animal protein. The amount of manure produced at such feedlots is large, often exceeding the capacity of the soil and plant cover in the immediate area to recycle it.

Large numbers of livestock are raised with the result that in the United States over 2 billion tons of manure are produced ear year. Part of the total livestock waste production remains in the pasture and rangeland, but large volumes accumulate in concentrated feeding operations (feedlots) and must be collected, transported, and disposed of in an economical and non-offensive manner.

The characteristics of livestock wastes are a function of the digestibility and the composition of the feed ration. The feces of livestock consist chiefly of undigested food, mostly cellulose or fiber, which has escaped bacterial action. A portion of the other nutrients also escape digestion. Undigested proteins are excreted in the feces and the excess nitrogen from the digested protein is excreted in the urine as uric acid for poultry and urea for animals. Potassium is absorbed during digestion but eventually almost all is excreted.

The average characteristics of manure produced by U.S. animals is indicated in Table 12. Characteristics of these and other animal wastes are presented in greater detail in other publications (7).

As with other wastes, there are variations in the characteristics of wastes from different animals and from different livestock feeding operations.

TABLE 12

Summary of Animal Waste Characteristics[a]

Parameter[b]	Dairy cow	Beef feeder	Swine feeder	Sheep feeder	Poultry		Horse
					layer	broiler	
Raw Manure (RM)[c]	82	60	65	40	53	71	45
Total Solids	10.4	6.9	6.0	10.0	13.4	17.1	9.4
Volatile Solids	8.6	5.9	4.8	8.5	9.4	12.0	7.5
BOD_5	1.7	1.6	2.0	0.9	3.5	--	--
COD	9.1	6.6	5.7	11.8	12.0	--	--
Nitrogen (Total, as N)	0.41	0.34	0.45	0.45	0.72	1.16	0.27
Phosphorus (as P)	0.073	0.11	0.15	0.066	0.28	0.26	0.046
Potassium (as K)	0.27	0.24	0.30	0.32	0.31	0.36	0.17

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[a] Miner, J.R. and Smith, R.S., editors, Livestock Waste Management with Pollution Control, North Central Regional Research Publication 222, MWPS-19, Midwest Plan Service, Iowa State University, Ames, Iowa, June 1975.

[b] Characteristics are in terms of weight of parameter per day per 1000 liveweight units (pounds or kilograms).

[c] Feces and urine with no bedding.

One must be cautious in assuming that results of waste management studies using wastes from one species of animal will be applicable to other animal species. One should be equally cautious about assuming that the wastes from animals in one country of the world are comparable to those in other countires, especially where there are different types of feed used, where different animal management systems exist, and where there are different climatic conditions.

The above data provide information on the characteristics on livestock for food production. Knowledge of the characteristics of wastes from other animals may be of interest such as those from pets, stables, veterinary facilities, animal farms, and pharmaceutical testing laboratories. Such data are meager but some that are available are presented in Table 13.

TABLE 13

Composition of Animal Wastes[a]

Animal	Weight/ head (lb)	Feed(dry)/ head/ day (lb)	Hydraulic load (gpd)[b]	5-day BOD (lb/day)[c]	Total solids (lb/day)	Susp. solids (lb/day)	N (% by wt.)		Phosphate (% by wt.)[b]		Potassium oxide (% by wt.)[b]		Carbohydrates (% by wt.)[b]	
							Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid
Horse	950-1400	30-45	20.0	6.50	15.0	12.5	0.50	1.2	0.30	Trace	0.30	1.60	27.1	1.9
Cattle	900-1250	25-40	20.0	6.50	15.0	12.5	0.30	0.9	0.21	0.03	0.18	0.93	16.7	1.3
Calf	450-600	15-20	15.0	3.50	10.0	8.0	0.32	0.95	0.20	0.01	0.15	0.80	15.9	0.9
Pig	100-300	8-12	5.0	0.70	1.7	1.1	0.6	0.3	0.50	0.15	0.12	0.50	15.5	0.3
Small pig	20-90	3-8	3.0	0.40	1.1	0.6	0.3	0.4	0.13	0.13	0.10	0.44	12.2	0.7
Rabbit	4.0-4.5	0.25-0.33	0.4	0.08	1.2	0.9	0.4	0.2	0.10	Trace	0.07	0.50	30.0	0.3
Rat	1.5-2.0 oz	0.04-0.05	0.2	0.04	0.08	0.02	0.2	0.3	0.05	Trace	-	0.10	16.0	0.2
Mouse	0.5-1.2 oz	0.01-0.015	0.1	0.01	0.02	0.01	0.4	0.3	0.05	-	--	0.10	15.0	0.2
Sheep	100-150	4.0-6.0	6.0	1.20	2.50	2.0	0.65	1.7	0.51	0.02	0.03	0.25	30.7	0.9
Monkey	4.0-5.0	0.25-0.40	2.5	0.10	0.20	0.10	0.9	1.2	0.30	0.02	0.05	0.30	17.0	0.1
Dog	50-70	0.25-0.40	1.0	0.08	0.30	0.18	0.75	1.1	0.30	Trace	0.02	0.58	17.0	0.1
Cat	4.0-4.5	0.17-0.37	0.2	0.06	0.15	0.07	0.70	1.2	0.20	Trace	0.02	0.50	17.5	0.1
Turkey	20-25	0.75-0.80	0.4	0.12	0.35	0.20	1.2	0.5	1.00			0.60	31.0	0.1
Chicken	2.0-4.0	0.25-0.30	0.2	0.07	0.12	0.05	1.4	0.5	0.90	-	--	0.50	30.0	0.1
Duck	3.5-5.0	0.25-0.30	0.4	0.10	0.15	0.07	1.5	0.8	0.89		-	0.40	12.0	0.1
Goose	7.5-9.5	0.50-0.75	1.0	0.20	0.35	0.10	1.8	0.8	1.20	--	--	0.70	14.0	0.1

[a] From: Howe, R.H.L., Research and Practice in Animal Wastes Treatment, Water Wastes Eng. 6, A14-A18, 1969.

[b] Including spilled water.

[c] Including spilled food.

Notes: All observed animals were kept in cages or stalls. COD for all wastes was 1.30 to 1.50 times higher than 5-day BOD. Data obtained on confined animals at a scientific laboratory.

4. RESIDUE UTILIZATION TECHNOLOGY

4.1 - General - Man uses only a part of the crops that are processed; the remainder is wasted but can be considered as an unused resource. Agricultural and agro-industry wastes are renewable resources in the sense that additional matter will be produced through photosynthesis and converted into human and animal food by the general ecological cycles. However, the fact that the processed crops are renewable should not detract from the fact that the wastes from such processing are resources to be utilized where possible.

The goal of environmental waste management, although difficult to achieve is low net "waste" production and where possible approaching "total utilization." The objective is to make productive use of everything harvested. Those familiar with agriculture recognize that the economic and efficient utilization of the crop or animal occurs when all parts of the raw product are utilized. In addition, such utilization also conserves natural resources. More efficient utilization could result from improved methods of recovering edible food products from the slaughter and processing of food animals and fish and from the better utilization of horticultural and cereal crops. Improved utilization of the about 1.2 billion pounds of seafood waste could provide significant quantities of high quality protein.

Approaches to agricultural residue utilization should focus not only on the utilization of the residues that are produced but also on reducing the quantity of residues that are generated. Such reductions directly increase the quantity of usable food supplies. In each plant and possibly in each country, a major program should be initiated to identify, control, and reduce the major losses in food materials which occur in food processing between harvest and consumption. Overall it has been estimated that losses could be reduced by 30-50 percent thus increasing the available food supply by 10-15 percent. This would have the effect of reducing waste while better utilizing available resources.

The concept low net "waste" production is not new and has been part of waste management decisions for all industry including agriculture. For reasons presented earlier, greater emphasis and interest is being focused on such approaches.

Residues from agricultural production have been utilized in many situations. Examples include: fruit and vegetable wastes utilized as animal feed, mushroom growing using horse manure as a medium, paper making from straw, chemicals extracted from organic residues, fish meal from seafood processing waste, and methane production from fermentation of organic residues. Several industries such as soap, leather, and animal feed manufacturing utilize meat packing wastes. Biochemicals such as hormones, vitamins, and enzymes also have been produced from packinghouse residues. Animal manure has been used as a soil conditioner, an animal feed supplement, for fertilizer, and to produce methane. Other examples can be provided and will be identified in subsequent sections of this report.

While these and other methods can be used for residue utilization, they rarely solve an entire waste problem since the material produced or removed may be only a small component of the original residue. There will be secondary residues requiring treatment or disposal. Such residues will be either portions of the original residue or residues generated in the utilization process. Thus residue utilization should not be considered as a panacea or substitute for waste management. The goal of "total utilization" has not been achieved with most utilization approaches.

Any residue utilization process will be subjected to the same pollution control measures and resource utilization concerns that have led to the need for better residue utilization. Provisions must be made for acceptable ecologic and economic disposal of residues and wastewaters from any residue utilization process.

In many areas, the basic technology for residue utilization is known and available. A combination of factors, depending on individual situations, contributes to a reduced technology utilization:

- non-competitive costs
- being accustomed to think in terms of disposal, not utilization
- lack of managerial and technical skills to utilize the technology at the site of residue production
- limitations on the end use of the produced product
- lack of capital resources for the purchase and operation of the technology, especially for small plants
- uncertainty about the marketability of the produced product
- inadequate supplies of the residue for the technology.

Knowledge that is needed for residue utilization decisions includes:

- composition of the residues such as carbohydrate, fat and oil, moisture, protein and general nutrient content as well as other characteristics that are pertinent to the utilization technology being considered
- availability - time, location, seasonality, and ability to store the wastes
- convertability - handling, separation, transportation, and physical processing of the residues and end products of the utilization technology
- use of the end product - markets, demand and rate of growth of demand, storability, seasonality of use
- socio-economic aspects - needs of areas, countries, and regions, overall goals, available skills, impact on the culture.

Information about the properties of agricultural residues is fundamental to the development of feasible residue utilization systems. Technology that may have been successful with certain residues may be less successful with other residues unless the technology is modified to accommodate the characteristics of the agricultural residues being considered. Agricultural and agro-industry residues vary in quantity and quality. Wastes from food processing generally are low strength, high volume liquid wastes; wastes from livestock operations tend to be high strength, low volume wastes; and wastes from crop and forest production tend to be drier, bulky, and dispersed solid wastes. Solid wastes also are generated in food processing and livestock operations.

Agricultural residues consist of food processing wastes, liquid and solid animal wastes, waste packaging materials, agricultural chemical losses, crop and field residues, greenhouse and nursery wastes, and dead livestock. These residues are organic and biodegradable. Utilization technology must either use the residues rapidly or the residues must be stored under conditions that do not cause spoilage or render the residues unsuitable for processing to the desired end product.

Information on the frequency and quantity of available residues is necessary to design facilities that can handle constant as well as intermittent residue supplies such as those due to the seasonal nature of fruit and vegetable processing. Identification of the residue sources within a processing plant also can be important since it provides information for in-plant separation of the residues. Separation of residues at the source is a major means of assisting residue utilization. Such separation generally permits less contaminated and more concentrated wastes and can enhance technical and economic utilization of the separated wastes.

An important issue is the availability of or proximity to central locations for processing of the residues and distribution and utilization of the end products. Many residues, such as crop residues and animal wastes, are not utilized because of difficulties of collecting and transporting the waste to a central location for processing.

An an example, in the United States, the total quantity of agricultural residues has been estimated at about 474 million dry tons annually - crop residues 322, manures 66, and forestry 116 million dry tons annually. The total amount currently collected has been estimated at 109 million dry tons annually with the following distribution - crops 7, manures 36, and forestry 75. Thus only a small percentage of existing crop residues is collected in contrast to manures and forestry residues. The majority of the crop residues (about 75%) and manures (about 68%) are returned directly to the soil. Only a small portion of these agricultural residues are sold - crop 4%, manures 17%, and forestry 33% (10).

The application of science, technology, and economics to residue utilization problems in a critical evaluative manner is a major factor in the development of solutions to such problems. To be fully realistic, all potential utilization of residues must be linked to local opportunities. Candid recognition of the economics involved in residue utilization is important. Solutions satisfactory for a given set of conditions may not be satisfactory under other conditions because of residue availability technological capability, and actual market potential. Numerous pertinent factors must be evaluated before the feasibility of any utilization concept can be established.

Often an entrepreneur does not pursue a utilization scheme because he is unaware of how to ascertain the feasibility of a concept. The basic elements of such an approach include:

- complete familiarization with the properties of the residue
- an inventory of locally available sources of supply, skills, and facilities
- thorough evaluation of existing literature to determine applicable technology
- evaluation of available market potential
- possibilities for change in the production process to generate a residue more suitable for utilization
- determination of regulations governing the transport, processing, and utilization of the residue and any resultant residue product
- overcoming traditional product use and regulatory barriers.

Technical solutions to the utilization of agricultural residues exist and others will be found. The application of these methods will depend upon existing social, legal, economic, and political conditions and upon success in the marketing and public relations areas.

Few really novel residue utilization technologies exist. A variety of technologies have been tried at various levels including laboratory, pilot plant, and possibly full scale with at least one waste product. When considering residue utilization technology possibilities, it is important to avoid reinventing the wheel. Available information should be critically analyzed to learn from and adapt the knowledge and experience that does exist.

A key to the development and application of suitable residue utilization technologies is the ability to modify the technologies to the local conditions and the characteristics of the specific residue. Large scale pilot plant and full scale studies illustrating the application of technologies to different wastes and situations are essential to demonstrate their technical and economic feasibility.

Information is becoming available for many technologies that permit a reasonable evaluation of their application to agricultural residues. On the basis of current information, many utilization processes have significant potential but will result in a low level of application until such time as social or economic constraints make their use more appropriate.

The degree to which agricultural residues are utilized will depend upon pressures to force a change from present practice and the competition of the products produced with those available from other sources. The pollution concerns, the food and energy situations, and the need for adequate resource utilization are causing a change from existing approaches.

There are many technologies that can be used with agricultural residues. The intent of this section is not to provide details of all of thesavailable processes. Rather the following material will attempt only to summarize some of the processes that appear applicable to a variety of agricultural and agro-industry residues. In addition, their real or potential application to these residues is indicated.

4.2 - Energy Generation

4.21 - General - Man will continue to utilize renewable resources, including agricultural residues, to help satisfy energy needs. Biomass including wood can be used directly as a fuel by combustion or may be fermented to produce methane with the subsequent residues applied to the land for crop production or as a soil conditioner. The particular approach depends in part upon the moisture content of the material. One advantage of such material as a fuel is the low sulfur content in comparison with most fossil fuels.

When used directly as a fuel, the residues should be as dry as possible. The BTU values of wood range from 8000 to 9000 BTU per pound on a dry weight basis. Freshly cut wood has a high moisture content which reduces the heat value to about 2500 to 3000 BTU per pound. Other residues will have similar reductions in the heat value unless the moisture is decreased.

The estimated quantities of organic residues produced in the U.S. per year are identified in Table 14. The reported values are not directly comparable (11), since some estimate the total amount produced while others estimate the amounts considered to be collectible in practice. However, the values indicate the order of magnitude of the available material. Whether all of the material could be used to produce energy will depend upon whether collection, transportation, storage, and processing costs can be economically justified.

The agricultural residues are the largest component of the estimated residues (Table 14). Their energy potential appears attractive but must also be related to their moisture content, broad geographical distribution, and seasonal availability. Because of the latter item, the use of agricultural residues may best be integrated with other continuously available fuels.

The possibilities of producing fuel from organic residues are schematically outlined in Figure 7. The feasibility of energy generation from agricultural residues depends on factors such as: a) the amount of recoverable energy in the residues and its relation to the total energy needed in generation process, b) compatibility of the form of the energy to the uses for it, c) the availability of equipment and skills needed to maintain the process, and d) the cost of using the system and of the resultant energy.

TABLE 14

Estimated Quanties of Organic Waste Products (11)

Waste	Million metric dry tons per year
Urban	
-sewage	60
-municipal	160
Agricultural	
-cereal straws	132
-other plant residue	220
-cow manure	210
Wood	
-logging residues	50
-manufacturing residues	15

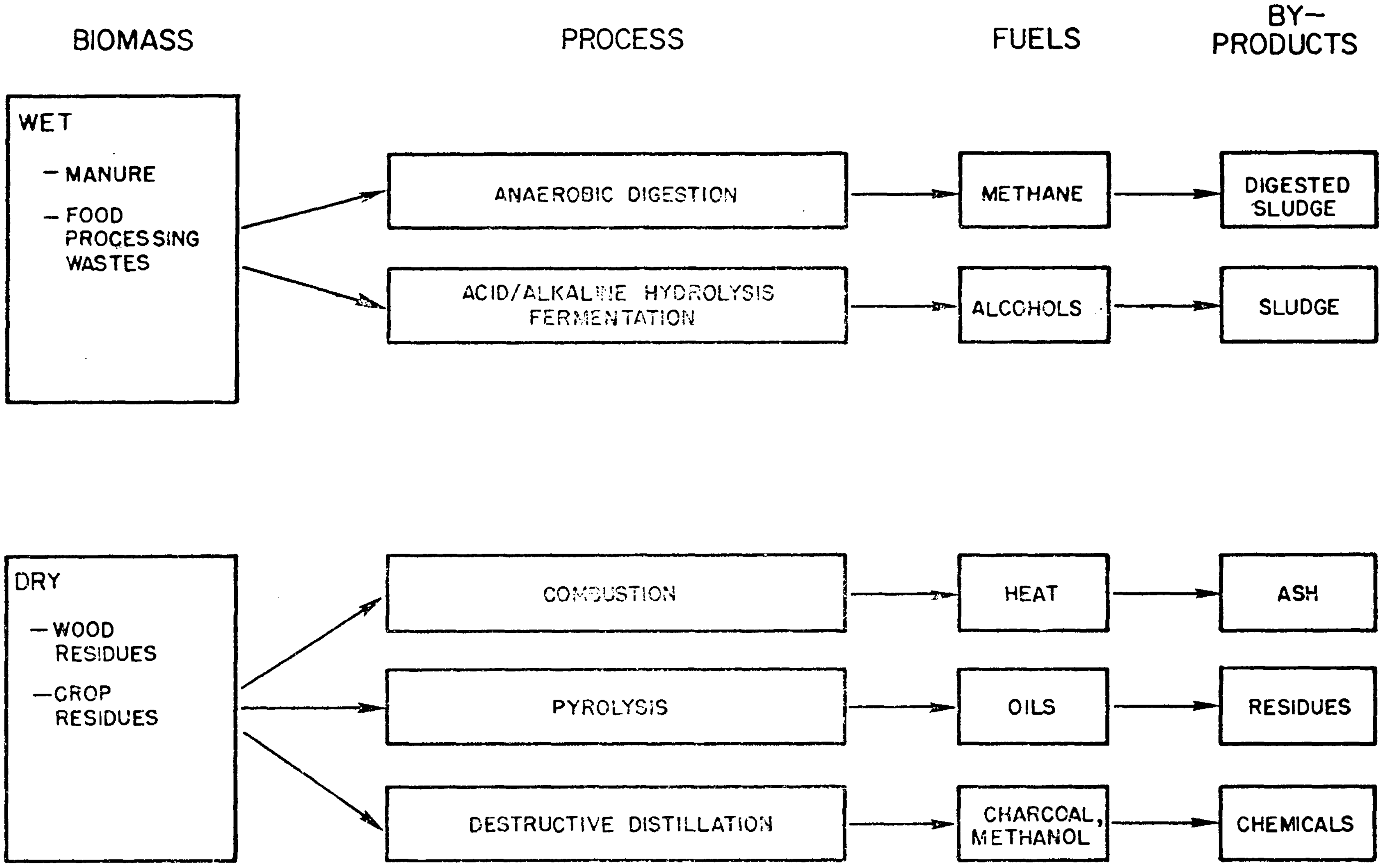

Figure 7 Possibilities of Producing Fuel from Agricultural Residues

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Two of the energy generating processes that have received considerable attention is recent years are pyrolysis and anaerobic digestion.

4.22 - Pyrolysis - Pyrolysis can be described as high temperature decomposition of organics in the absence of oxygen. Reactor temperatures range above 900°C and high pressures are common. The products are ash, oils, and gases such as hydrogen, water, carbon dioxide, methane, and ethylene.

The process is not new having been in use for many years in the production of methanol, acetic acid, and turpentine from wood plus recovery of the residual charcoal. Pyrolysis has been investigated as a potential process for several types of agricultural residues (12). Low temperature pyrolysis of egg farm wastes (woodshavings as litter, dead birds, poultry waste) was found to require only a small energy input to convert the waste to a char. The char contained 3% nitrogen, 7% phosphorus, 6% potassium and represented a 50 to 80% weight and volume reduction.

The pyrolysis of animal wastes indicated that the heating value of gases from dried beef cattle wastes, dried poultry wastes, and dried swine wastes was about 4.4×10^6, 3.8×10^6, and 3.2×10^6 joules/kilogram. The heat value of the remaining carbon char was 4×10^6 and 8.1×10^6 joules/kilogram for dry swine and dairy wastes respectively. In another study, the gas production from the pyrolysis of dry cattle feedlot manure was about 2.3 to 3.5×10^6 joules/kilogram.

A full scale pyrolysis facility using dry wood residues has been in operation since 1972 without major problems (13). The system operates at lower temperatures (300° to 400°C) and uses a unit partially open to the atmosphere. The generated gases were used to dry the input material and the char is mixed with the resultant oil for subsequent use.

4.23 - Methane Generation - The interest in non-fossil fuel energy supplies has focused increasing attention on the production of methane from the anaerobic fermentation or digestion of organic matter. Agricultural residues can be utilized for methane production. Table 15 indicates some of the agricultural residues that can be considered for this process. Some of these residues are being used as fuels or fertilizers.

Benefits from the utilization of agricultural residues for methane generation rather than their direct use as fuel or fertilizer include the production of energy resources that can be stored. Indirect benefits of methane generation include the potential for partial sterilization of waste during fermentation to reduce the public health hazard of fecal pathogens. The fermentation process will also reduce the transfer of fungal and other plant pathogens from a crop residue to subsequent crops when the liquid residue from the methane generation process is used as a fertilizer. By using some of these materials to support methane production, additional value can be gained, methane, while still realizing previous benefits. The original nutrients in the digested material are returned to the soil as a fertilizer and to improve soil structure and organic matter contact.

During the anaerobic digestion of most agricultural residues, gases containing 60-80% methane can be produced when consistently high rates of digestion are maintained. These gases can be an energy source close to the generation site. Approximately 8-9 cubic feet of gas can be produced per pound of volatile solids added to the digester when easily biodegradable wastes are digested. Lower gas production rates result when less biodegradable wastes are digested.

The production of methane from wastes is centuries old and the general technology is well known. The largest application of methane generation has been with municipal sewage sludge. The captured gases frequently are used to heat the digester tanks and may satisfy part of the energy needs at the municipal treatment plant. The process also has been utilized when energy supplies have been reduced as in several countries during and after World War II.

TABLE 15

Agricultural Residues Having Potential for Methane Generation

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-Animal wastes including bedding, wasted feed, poultry litter

-Crop wastes: sugar cane trash, weeds, crop stubble, straw, and spoiled fodder

-Slaughterhouse wastes, animal by-products such as blood, meat, fishery wastes, leather, and wool wastes

-By-products of agricultural based industries such as oil cakes, wastes from fruit and vegetable processing, bagasse, and press-mud from sugar factories, sawdust, tobacco wastes and seeds, rice bran, tea waste, and cotton dust from textile industries

-Forest litter

-Wastes from aquatic growths such as marine algae, sea weeds, and water hyacinths

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In countries where energy supplies have been hampered by low natural abundance or inadequate distribution, methane has been generated from available residues to meet existing needs. Individual family methane generating units have been used in diverse climatic and cultural conditions. For example, several thousand units are operative in Taiwan using primarily pig manure and by-products from individually owned and operated pig farms. In India crop residues and cow dung have been used in family and village operated units.

All organic wastes can be fermented to produce methane. The amount of methane which can be generated during anaerobic digestion is a function of the fraction of the total waste that is available to the anaerobic bacteria, i.e., the biodegradable fraction, and the operating, environmental conditions of the process. The more biodegradable the waste material, the greater the quantity of methane generated per quantity of waste added to a digester. Table 16 indicates the estimated gas production using wastes from various animals produced under conditions in the United States.

The biodegradable fraction of agricultural wastes will vary being a factor of how the wastes were generated and handled prior to digestion. For example, only 40 to 50% of the volatile solids of dairy cattle manure may be biodegradable and thus available to produce methane. To use anaerobic digestion effectively, the inclusion of inert material such as sand and dirt in wastes should be minimized and fresh wastes should be utilized.

Caution is advised in utilizing design data obtained from residues having characteristics different from those under consideration. The biodegradable fraction may be different and the residues may have components that may cause inhibition of the digestion process.

An important aspect to be considered with the anaerobic digestion of animal wastes is that the total volume of residue that must be handled for final disposal is equal to or greater than the initial amount of animal wastes that are to be digested because of the liquid added to obtain a solids concentration that can be mixed. Although considerable solids decomposition occurs in a digester, little reduction of the total digester volume results.

TABLE 16

Estimated Manure and Bio-Gas Production from Animal Wastes (14)

	Dairy Cattle	Beef Cattle	Swine	Poultry
Manure production (lb/day/1000 lb live weight)	85	58	50	59
Volatile solids (lb dry solids/day/1000 lb live weight)	8.7	5.9	5.9	12.8
Digestion efficiency of the manure solids (%)	35	50	55	65
Bio-gas production				
(ft^3/lb VS added)	4.7	6.7	7.3	8.6
(ft^3/1000 lb live weight/day)	40.8	39.5	43.1	110.9

(lb x 0.454 = kg: ft^3/lb x 0.062 = m^3/kg)

Residue from a digester operating on plant and animal residues will contain lignin and lipids, material protected from bacterial degradation, synthesized microbial cells, metabolic degradation products such as volatile acids and other soluble compounds, inert material in the original waste, and water. Anaerobically digested sludges can be stored and spread on land with less risk of creating conditions for odor and insect breeding problems than may exist with similar handling procedures for untreated or partially treated agricultural residues.

Practically all of the nitrogen present in the waste entering a digester is conserved. If the sludge is properly stored and, when applied to soils is immediately incorporated to reduce the loss of nitrogen by volatilization, narly all of the nitrogen present in plant residues can be available for use by subsequent plants.

Key items in the successful operation of a methane generation digestion system are: a) acceptance by the potential user; b) ability to store the gas or to use it when produced; c) sufficient demand for the gas; d) enough raw material available to meet the production requirements; and e) suitable maintenance and operational control.

The following examples indicate some of the current research (15) related to energy generation that is in progress:

-The use of organic wastes for the production of methane gas and protein feeds - The methane content of the gas from the fermentation of poultry manure reached 87% at a digester solids content of 6.5%. Utilization of the remaining nutrients in the digested effluent was achieved by the growth of bluegreen algae to provide high protein feed. One pound of protein could be obtained from 20 pounds of dry manure and the reclaimed water after algal removal was recycled. The effluent had a very high nitrogen content and met the fertilization requirements for crops.

-Solar energy fixation and conversion with algae-bacterial systems to produce methane - The study involves a solar energy conversion and waste utilization system, whereby the visible light energy component of solar energy is fixed through photosynthesis as the chemical energy of algal cellular material growing on wastes. Through the process of anaerobic digestion, variable fractions of the chemical energy of the algae cellular material will, in turn, be converted to chemical energy in the form of methane. The nutrients in wastes and recycled materials will be rendered soluble and available for additional algae growth by successive aerobic and anaerobic bacterial action.

-Utilization of livestock and agricultural wastes for feed and energy production - A study of systems for the treatment and utilization of livestock and agricultural wastes as alternate sources of animal feed, energy and fertilizer such as: a) development of physical-chemical processes for recovering undigested grain, fibrous residue and protein from livestock wastes, and b) natural biological processes to treat livestock wastes and produce energy (methane gas), fertilizer and animal feeds (single-cell protein).

-Anaerobic fermentation of organic material - Development and design of anaerobic fermentation reactors for the conversion of wet vegetable wastes to methane (fuel) gas.

-Conversion of solid waste from grapes and apples to directly utilizable heat energy - The properties of apple and grape pomace are being studied to determine factors conducive to the manufacture of briquets. Dried apple pomace and grape pomace were found to contain 8000 and 8400 BTU per lb., respectively. These values were approximately 60-65 percent of the combustion energy of commercial charcoal briquets (12,800 BTU per lb.) and sawdust fire logs (14,000 BTU per lb.). When the pomace was subjected to peroxide treatment and pyrolyzed before combustion, the BTU per lb. increased to 11,500.

4.3 - Food Production and Utilization - Certain agricultural residues contain various quantities of protein which can be recovered. In addition, the microbial treatment of wastes results in the production of microbes and a transformation of the carbon and nutrients in the waste into microbial protein. Single cell protein (SCP) has been produced by cells growing on a variety of agricultural and industrial wastes. The cells grown on these substrates are selected species of algae, bacteria and yeast.

Single cell protein production is an attractive possibility as a potential inexpensive source of nutritional protein. Microorganisms are fast growing, have a high protein content of relatively good quality, and can flourish on simple organic nutrients and a diversity of carbon sources.

Fungi, algae, yeast, and bacteria all have been produced for use as single cell protein. Fungal mycelia grow more slowly than yeasts or bacteria and have a somewhat lower protein content. They are, however, easier to harvest. Yeasts grow more rapidly than fungi but generally slower than bacteria. Yeast protein is of good quality and the concentration is higher than in fungi. Yeasts contain more nucleic acids than most fungi or bacteria but also more vitamins. Bacteria grow relatively rapidly on a number of substrates. They possess a high protein content. Bacteria are small and more difficult to harvest than fungi and yeasts.

Successful production of microbial protein requires attention be given to engineering and biochemical fundamentals. These include adequate oxygen supply, mixing, no inhibitors, temperature control, and suitable microorganisms to metabolize the substrate.

Many examples can be provided for waste recovery by microorganisms, including specific fermentation processes to produce fermented foods (16) and non-specific processes such as the activated sludge process which is essentially a treatment process. The following examples indicate some of the available information.

The Pekilo process is a process for production of feed protein from carbohydrate containing liquors through fermentation with the microfungus *Paecilomyces variotii*. The research leading to this process was initiated over 10 years ago at the Finnish Pulp and Paper Research Institute. The first full scale plant is in operation in Finland using spent sulfite liquor as a carbon source. The Pekilo protein is a safe high quality feed ingredient approved by Finnish authorities for animal feed. The protein and fat content of the dried product is 55-60% and 2-4% of the dry matter respectively.

The aerobic microbial fermentation of spent sulfite liquor produced high yields of bacterial protein having a protein content of 66 to 70% (17). Approximately 20,000 mg/l of bacterial cells were carried in the fermentation unit. Nitrogen and phosphorus may have to be added to the waste sulfite liquor to have a nutritionally based medium for the microorganisms. Cell yield was about 0.4 pounds per pound of BOD added. It was estimated that a yield of 200 pounds of cells containing 68% protein could be produced per ton of pulp. Feeding studies on rats indicated the cell material was palatable, non-toxic, and an excellent protein supplement.

Other investigations into sulfite liquor treatment have resulted in processes utilizing the liquor itself or its components such as the lignin. Vanillin, oxalic acid, tanning material, road binders and alcohol and yeast are by-products made from sulfite liquor.

Torula yeast has been produced by fermentation of the spent sulfite liquor. The protein content of such yeast constitutes about one-half its weight.

Biological waste treatment processes, such as the activated sludge process, can be a viable treatment alternative for the organic wastes of the agricultural processing industry. One of the major problems associated with such processes is the handling of the excess sludge which is produced. The handling of such sludge is both a technical and economic burden.

The waste activated sludge consists of synthesized microorganisms. The waste activated sludge from agricultural waste treatment can be used as an ingredient in a properly formulated animal diet. As an example, waste activated sludge from the treatment of citrus wastes was dried and included in the diet of broiler chicks and laying hens. The addition of less than 10% sludge did not adversely affect poultry performance. The value of the recovered sludge significantly reduced the total cost of sludge handling (18).

The following summarize other examples (15) of the type waste residue utilization that is currently under study in the United States and other countries:

-Single cell protein from fruit and vegetable processing wastes - Experiments are being conducted to study the growth rates of food organisms on selected substrates such as apple pomace, sauerkraut brine, and grape pomace under a variety of conditions. Progress to date indicates that under optimal conditions, up to approximately four pounds of single cell protein could be obtained from the waste effluents generated in the lactic acid fermentation of a ton of shredded cabbage.

-Treatment of food processing wastes and production of recoverable protein - A continuous laboratory aerobic fermentor is being used to identify the feasibility of effectively treating food processing wastes and producing protein. Results indicate that the protein content of grass straw can be increased by growing microorganisms directly on the solid substrate. Straw is first hydrolyzed by a mild acid treatment, then neutralized with ammonia to release fermentable sugar. The protein content could be increased from a natural state of approximately 4.5 percent to approximately 10 percent.

-Use of radiation mutated microorganisms for protein production from waste cellulose - Radiation experiments on _Candida utilis_ are to be conducted to obtain mutant strains capable of using nutritive solutions with a high content of furfural compounds. These furfural compounds result from a hydrothermal degradation process of plant matter frequently occurring as waste substances. Tests will be made to ascertain whether _Candida utilis_ can be genetically changed so that it can use furfurals as the sole carbon source.

-Enzymatic extraction procedures for protein recovery from crops and food wastes - The objectives are to determine optimum conditions for enzymatic hydrolysis of proteins in cottonseed meal, alfalfa leaf meal, stems and leaves of vegetables, and bean and pea processing wastes and to define optimum conditions for extraction and concentration of these hydrolysates.

-Protein concentrates from grasses for possible food uses - The objectives are to prepare protein concentrates from selected grasses; determine composition, nutritional value, and food use potential; and relate stage of maturity to yield and value of concentrate. Leaf protein concentrates that have been obtained averaged 50% protein. The filtrate left after precipitation of the protein was a rich source of energy for microbes. The residues ledt after extraction of the juice contained substantial amounts of protein and could be used as animal feed.

-Protein production from acid whey by fermentation - Fermenters convert whole and deproteinized acid whey to a feed product using Saccharomyces fragilis. No discharge of pollutants is contemplated due to planned evaporation and spray drying of the entire fermented medium.

-Fish protein isolates - Fish that is underutilized or converted into animal feeds, represents a low cost source of protein raw material that could be converted into functional protein isolates. The problems associated with the use of fish as a protein source for the preparation of protein isolates are those of isolating the protein(s), preventing adverse physical and chemical changes during processing, and maintaining organoleptic and functional stability during storage. The research is to explore the technology to prepare such isolates.

-Preservation and evaluation of marine foods - The objectives are to identify biochemical and chemical changes that take place in marine animals after capture which lead to the deterioration of marine foods, and to utilize marine species for human food, using nonconventional techniques. The practical methods of control under study could be of value to underfed countries where other protein foods are lacking, yet the fish protein is present in the nearby seas but cannot be utilized mainly because of its high perishability

An intermediate product, frozen fish emulsion, was prepared which could be used to prepare various marine foods. An improved method of utilizing more efficiently the edible portion of the red crab was devised and the enzymes degrading fish flesh, fish liver, and also the edible portion of some molluscs as the clam and the mussel were under study.

-Reclamation of protein and flavor materials from clam wash water - The objective is to convert pollutants from a clam processing facility into profitable food products. Wash water from the mincing and shredding of clams will be pulverized and clarified. The resultant mixture will be processed as clam juice. An alternate approach will be to recover the tissue particulates from the wash water and process them as a clam chowder base.

-Utilization of latent marine resources and waste products - The objective is to investigate latent marine resources and available waste products as sources of protein and other nutrients for use in animal and human nutrition. A method for production of a low fat marine protein concentrate from hake and other latent species is being developed. The marine protein concentrate will be evaluated as a source of protein for use in human nutrition. Procedures are being developed for processing and storing shrimp and crab scrap. Acidification as a means of preserving whole ground fish for use as an animal feed is to be investigated. Use of latent marine resources such as anchovy, silver smelt and krill for use as human and animal food is under investigation.

-Utilization of seafood industry waste - The objectives are to determine composition and nutritional characteristics of major seafood wastes, to evaluate visceral waste, to investigate means of separation and recovery of more valuable waste fractions, and to formulate marketable products.

-Utilization of slaughterhouse and meat processing by-products - The objective is to investigate the preparation of wholesome and nutritious protein products from slaughterhouse and meat processing by-products, for use as human food or animal feed with special emphasis on control and elimination of Salmonellae. The possibilities of blending hide proteins with the essential amino acid constituents of blood to produce better edible proteins containing Vitamin B_{12} is to be explored. Studies on the conversion of hide protein hydrolyzates into cosmetic bases also are to be carried out.

-Processing mustard seed oil into high protein food products - The objective is to find a feasible method of using mustard seed to produce a high protein nutritious food product free from the deleterious materials that occur in the seed.

-Recovery of useful materials from potato starch factory wastes and other potato processing wastes - The approach is to reduce the hygroscopicity of dried products by either sequestering or separating fructose, evaluate products with or without complexed fructose as feed, develop a method for producing high quality fructose powder or syrup, and study methods for reducing potassium levels in dried potato solubles so higher levels of dried solubles may be used in poultry feeds.

A full scale example is the processing of grape and olive waste into oil and animal feed. Oil can be recovered from grape waste and olive press waste by solvent extraction. A complex incorporating such extraction has been reported on Cyprus (19).

The general process for grape waste utilization is to remove the coarse impurities from the grapes as they are received from the wineries, following which the seeds and skins are removed and dried. The seeds are crushed, flaked, and subsequently extracted with hexane. The dried seeds contain some 7-9% moisture and 15% oil. The recovered oil is refined and the residue sold as animal feed.

The dried grape pulp has a crude protein content of about 12%, fat about 4-5% and fiber in the range of 16-18%. The dried pulp was ground and also used in the animal feed industry. The olive press waste was processed by the same equipment as for the grape waste.

The transformation of residues such as grape waste from wineries into oil, dried grape pulp, and dried seed cake was not only profitable but utilized an industrial waste which otherwise would be discarded.

The above are merely illustrations of the type of utilization and human and animal feed production that can be contemplated with agricultural residues. Numerous other possibilities exist and are under study. As noted earlier, the success of residue utilization results not only from use of the appropriate technology but also may be constrained by existing social, economic and market forces.

4.4 - Whey Utilization - The great quantities of whey that are produced annually have prompted considerable study of ways to utilize this material. Whey can be used as a partial animal feed, a feed supplement, a starting material for some chemical productions such as alcohol, and as a growth medium for microorganisms to produce organic chemicals.

Liquid whey from cheddar cheese production contains about 54% of the nutrients from milk used, and the acid whey from cottage cheese production contains about 73% of the nutrients of the non-fat milk used. Most of the whey is discharged to waste treatment plants and to streams thereby increasing the cost of the cheese production operation and national costs of water pollution control. Utilization of the whey offers possibilities to minimize pollution and to increase the nutrition of the world. Such possibilities include blending whey powder with basic food materials to produce new and/or less expensive food such as process cheese food, fruit sherbets, custards, and bakery goods.

Dehydration of whey can be accomplished by roller drying and spray drying. Cottage cheese whey is difficult to dry by the roller or conventional spray process because of its high acid content. Foam spray drying can be used with all types of whey including that of cottage cheese. After drying, the whey powder contains about 11-13% protein, 70-75% lactose and 7-8% ash.

Cottage cheese whey can contain about 10-11% lactic acid. If the whey can be fractionated, the relatively pure protein, sugar, and other material may be able to command a price considerably greater than that of the whole whey powder. Research on methods and separation and utilization of whey is continuing.

The salt content of whey, about 1%, can be a barrier to its use as a by-product. Desalting equipment, such as a combination of reverse osmosis and electrodialysis, may be used to produce a protein supplement grade of whey that may be economically competitive. The technical and marketing aspects of this approach remain to be evaluated in depth.

The following examples indicate some of the current research (15) on whey and dairy product utilization that is in progress:

-Utilization of cheese, fermented foods, and their waste products - The objectives include investigating factors contributing to excessive concentrations of hydrogen sulfide in ripened Cheddar cheese and to discover control mechanisms and developing new flavored fermented milk foods and transforming waste acid whey powder into nutritious foods for humans and animals.

-Demonstrate an ultrafiltration plant for the abatement of pollution from cottage cheese whey - The objective is to recover edible protein and lactose by ultrafiltration and reverse osmosis thereby reducing influent BOD by 99 percent and perform an operation, technical, and economic evaluation of both a 10,000 lb/day pilot plant and a 300,000 lb/day full scale system.

-Utilization of cheese whey for wine production - The technical feasibility of producing acceptable alcoholic beverages from cheese whey is under study. Experiments so far have shown Montrachet yeast to be the most desirable for whey wine fermentation. Fermenting at room temperature is satisfactory. Yeast nutrients, such as nitrogen and B-vitamins, help little in increasing the rate of fermentation. To make clear whey wine, bentonite showed promise as a clarifying agent.

-Nutritious beverage powders formulated from whey solids and vegetable proteins and/or fats - The objective is to develop and evaluate new nutritious beverage powders and improve existing products containing cheese whey solids and vegetable proteins and/or fats, thereby providing high protein food products for human use. Beverage formulations using whey solids in combination with soy, cottonseed and/or peanut proteins with or without addition of edible oils, carbohydrates, minerals and vitamins, are being developed. The effects of processing conditions on the chemical and physical properties and on the nutritive value of the final product are being determined.

-Increased utilization of cheese whey solids - The objectives include finding new uses for whey, adapting vacuum foam drying to the high protein fractions in whey, and separating the whey into components or fractions. Nutritionally improved extruded products (pasta, breakfast cereal, snacks) which contain whole whey or whey fractions and which are suitable for human use are being developed.

4.5 - Animal Feeds - The traditional method of increasing livestock production by supplementary forage and pasture with grains and protein concentrates may not meet the increased meat protein needs. Use of the grain and protein for human food will compete with such use for animal feed. Increased use can be made of the residues of agricultural and agro-industry as animal feed.

Many agricultural residues can be used directly for animal feeds such as paunch manure, fish meal, oil seed meal, whey, and vegetable processing residues. In addition, other direct and indirect approaches exist to use agricultural residues for animal feed. These include refeeding of animal wastes, production of insect protein, and production of fish.

The rumen content of cattle, referred to as paunch manure, contains a mixture of gastric juices, mocrobial flora, and remains of partially digested food. Dried paunch manure is nearly odorless and is suitable as an ingredient for animal feeds. It also is possible to use dehydrated paunch manure as a feed constituent in formulated feeds for pond-rearing of channel catfish.

Levels of 10 to 12% paunch manure were used without producing a significant reduction in growth compared to fish reared on a typical commercial feed (20). In principle, paunch and similar residues should be applicable as a feed constituent for pond rearing of Tilapia sp. and carp which are more important worldwide food fish than channel catfish.

The use of biological methods to capture the nutrients in agricultural wastes was suggested many years ago when it was proposed that house fly larvae be used to consume wastes and then be harvested as a potential protein source for animal feed. Research has demonstrated that the method can be used with poultry manure to produce a protein source that can replace soybean meal in the diet of the growing chick (21). Analysis of the dried fly pupae showed that they were high in protein (63%) and fat (15%). In addition, the method deodorized the manure, removed more than 50% of the moisture, and reduced the manure volume.

Details of these and other possibilities dealing with the reuse of animal wastes as an animal feed supplement, including problems associated with antibiotics, arsenicals, hormones, larvacides, and other feed additives, have been gathered in a detailed review (22). The review discusses the opportunities of refeeding animal wastes to poultry, swine, and cattle.

If nutritional principles are followed, a portion of animal wastes can be used as a feed supplement for animals. When adequately processed, animal waste and poultry litter may be an economic source of nutrients and should be recognized as a possible feed ingredient. To be handled in this manner, such materials would be subject to feed control laws in the same manner as are other feed ingredients. In research evaluations, feeding processed animal manures has not altered the taste or quality of meat, milk, or eggs. Potential transfer of organisms can be controlled by dehydration, drying, composting, ensiling or fermentation.

Residues used directly or processed in various ways for use as feed hold promise as a safe, valuable source of animal nutrients and energy. Further studies will be needed on the nutritional quality and feeding effects of specific processed and unprocessed agricultural residues.

In general, the nutritive value of incorporating animal wastes in feed rations is greater if the wastes of single stomached animals are added to the feed ration of ruminants and if the ruminant wastes are treated chemically before being added to feed rations. Wastes from ruminants are composed of a variety of nitrogen containing compounds, various vitamins, and undigested feed products composed primarily of cellulose, hemicellulose, and lignin. Where bedding is used, the overall wastes may include low quality roughage such as straw, wood shavings, or sawdust. The composition of manure, as well as that of the overall wastes, is dependent upon the rations fed and the bedding systems used. If the forage is the sole constituent of the ration, a large portion of the manure, about 60%, may be undigested plant cell walls. These undigested materials are resistant to natural decomposition, but contain a further potential source of energy in ruminant nutrition. If the resistant portion of ruminant wastes were treated and/or processed in a manner to allow subsequent animal digestion by the rumen microbial population, these wastes could become an available source of energy to the animal.

Chemical treatment and use of manures in this manner may offer an expedient method of reuse and volume reduction of otherwise potentially polluting wastes. Studies have shown that the digestibility of the material in animal wastes can be increased by chemical treatment. The chemical treatments that have been explored include use of sodium hydroxide and sodium peroxide which reduced the cellulose, hemicellulose, and lignin to more digestible material, and sodium chlorite which altered the lignin content. Heat treatment under alkaline conditions appears to effect hydrolysis of hemicellulose solubilization of lignin but causes little change in the chemical nature of cellulose. Under acid conditions cellulose is hydrolyzed to glucose. Hemicellulose also is hydrolyzed and chemically changed to furfural. Lignin is little changed under acid conditions.

Feeding experiments have shown that when chemically treated wastes were used in a corn silage ration, up to 25% of the dry matter was consumed by sheep equally as well as an all corn silage ration (23). Recent experiments (24) designed to increase the anaerobic biodegradability of municipal refuse have indicated that acid and alkaline treatment of the refuse at elevated temperatures did make the refuse more biodegradable. For a given pH and time of treatment, an optimum temperature existed for the improvement of biodegradability. For one hour of heat treatment the optimum temperatures were: pH 1 - 130°C; pH 3 - 175°C; pH 7 - 185°C; pH 11 - 185°C; and pH 13 - 200°C. Maximum increase in biodegradability was found at pH 13.

High temperature alkaline and acid treatment of many so-called "non-biodegradable" residues, including those from agricultural operations, industry, and municipalities, can modify the characteristics of such residues so that they are more susceptible to microbial degradation. Increased methane production, protein production, or other beneficial use can result. The relative economics of this approach, including equipment and manpower requirements, need close evaluation when this approach is being considered.

Several approaches for processing animal wastes into animal feed and other useful products have been developed. The wastelage system consists of blending 40% wet manure, at about 70-80% moisture, with dry standard feed ingredients followed by ensiling the mixture for over 10 days. Fermentation occurs in the silo and the pH decreases to near 4.0. This acidic condition inhibits most biological activity. The resultant wastelage can be fed to cattle and other animals successfully (25). About 25% of the produced manure can be used in this manure

The Ceres Ecology Corporation has developed a system to produce feeds for ruminant and monogastric animals from cattle manure (26). Three outputs can result: CI - consisting of grain and fiber particles which can be fermented into a silage product for feeding feedlot cattle or dried, blended and pelletized for range cattle; CII - a dry pelletized product containing 27-30% crude protein, 4% fat, and 25% ash, this material is fermented in the liquid phase to encourage production of microbial protein; and CIII - a compost like material suitable as a soil conditioner. These products have been used successfully in feeding trials with sheep, cattle, broilers, and laying hens. Available results indicate the products can compete economically with alternative sources of feed. CII also has been used successfully in rainbow trout rations. The system is being adapted to poultry manure.

Many experimental studies have indicated that the nutrients in manure can be mixed in rations that are consumed and utilized by animals (27). The potential refeeding value of an organic residue is in relation to its nutrient characteristics. In poultry and cattle manure, the following percentages of original ration may be recovered in the manure: 50-75% of the nitrogen, 50-80% of the minerals, and 30-50% of the organic matter. Manure characteristics vary greatly, being a function of the initial ration, environmental conditions under which the manure was kept prior to collection, and conditions used for processing for refeeding. In considering the possibility of refeeding manures, the actual manure characteristics should be determined.

Available information on manure digestibilities and chemical characteristics indicates that they may best be considered as low energy containing supplements of nitrogen and minerals, especially for wastes from animals that exist primarily on forage and hay. Levels of manures in animal rations reported as successful have ranged from 10 to 25% of the ration dry matter content. Most appropriate percentages of manure in animal rations are related to desired levels of animal performance and to the needed nutrient and energy content of the ration.

As with any feed material, proper handling of the raw material and product after processing are needed to assure a satisfactory product for refeeding. In numerous experiments, no indication has been obtained of harmful effects in humans consuming meat, milk, and eggs that resulted from animals and poultry fed adequately processed wastes. In common with all utilization possibilities, practical application of animal manure refeeding is related to the economics of alternatives such as the cost of utilizing alternative feeds.

Additional examples (15) of existing research on the use of agricultural residues for producing animal feeds include:

-Animal waste treatment and recycling systems - Cattle and swine feces will be recycled within and between species, and digestibility and palatability will be measured. Continuous recycling of wastes within species is being studied. The digestibility of fresh swine manure fed to gilts was: energy, 52.4%; dry matter, 52.7%; crude protein, 62.9%; crude fiber, 52.6%; NFE, 77.9%. Ensiling broiler litter with high moisture corn grain (1:2 ratio) reduced numbers of total coliforms and bacteria. Nitrogen utilization and digestibility by sheep fed the ensiled litter-corn mixture were very good.

-Livestock as an animal feed - Manure from feedlot cattle is being blended with other feed ingredients, subjected to lactic acid fermentation, analyzed chemically, and fed to cattle to measure nutritive value. Survival time in the fermented mixture is being determined for Salmonella typhimurium and Newcastle Disease Virus. Salmonella, Newcastle Disease Virus, and coccidea were essentially eliminated as disease entities in the ensiled waste. Beef breeding animals continued to be fed on waste containing feeds and in third generation animals, health remained excellent and unaffected by the waste containing feed.

-Organic waste materials as a feed for ruminants - The objective is to determine the nutritive value of organic waste materials such as field and horticultural crop, wood, and food processing residues as feed for ruminants and to determine accumulation of possible harmful chemical residues.

-Use of wood products in animal nutrition - The objectives of the study are to evaluate a) the possibility of using suitably prepared wood residues as sources of roughage and bulk in high energy rations for dairy cattle, b) the physical and chemical pretreatments leading to the utilization of wood residues as energy sources in animal nutrition, and c) the use of paper mill wastes as feedstuff material. Results indicate that pulp fines can substitute satisfactorily for at least two-thirds of the total ration for beef cows and ewes.

-Utilization of logging residues as cattle feed - The approach is to ascertain preferential lignin decomposition by different isolates of white rotting (delignifying) fungi; develop procedures for rapidly growing large masses of mycelium in culture for inoculum and testing for toxicity to cattle; ascertain whether substances toxic to rumen microorganisms and to ruminant are formed; and follow degradation of pilot amounts of chip and sawdust inoculated with selected delignifying fungi under natural conditions in the forest.

4.6 - Fertilizers - An important way to utilize agricultural residues is a soil conditioner and/or fertilizer. Before the introduction of mineral fertilizers about 130 years ago, manures and composts were practically the only source of nutrients added to crops. However, the availability of low cost mineral fertilizers resulted in a decreased interest in the use of organic materials as fertilizers. Nonetheless, the principles of such use of organic wastes remain valid and can be employed for better utilization of these residues.

Certain agricultural residues, especially those from livestock production and processing can be desirable as a fertilizer. Residues of vegetative origin such as vegetable processing wastes and crop residues also can increase the organic content of the soil and add to its fertility. Organic residues from agriculture contain most of the elements needed for plant growth and can supply nutrients through decomposition at a rate comparable to that needed by growing plants. The current economic situation requires that a better use be made of organic residues as fertilizers and soil conditioners thus reducing the need for inorganic fertilizers while decreasing possible pollution hazards of such residues.

Land that continues to be used for crop production without the addition of fertilizers will have the available nutrients seriously depleted. Maintenance of the fertility can be accomplished by the frequent addition of organic matter such as animal manures and other agricultural residues thus properly utilizing their nutrient and soil conditioning constituents.

Available information permits a perspective to be placed on the fertilizer potential of agricultural residues. In 1971, the total availability of plant nutrients in developing countries from various organic residues was estimated to be about 48, 16, and 39 million metric tons of N, P, and K respectively (28). This is in comparison to the 13.2 million tons of nutrients used in developing countries in 1970-71. Using a conservative estimate, waste materials from animals, plants, and human origin can supply 6-8 times more nutrients than the consumption of chemical fertilizers in these countries. Over half of these plant nutrients are from cattle and farm compost. These residues offer a potential for suitable utilization if they can be collected and properly used as fertilizers.

Nitrogen is one of the important components of agricultural residues that make them possibilities as fertilizers. Nitrogen is the principal nutrient limiting crop production in the United States and Europe. It does not accumulate or persist in cultivated soils as contrasted with phosphorus and potassium. Conservation of nitrogen in the residues and when applied to the soil represents an important utilization possibility.

The components of the nitrogen cycle (Figure 8) influence whether the nitrogen in agricultural residues will be retained and utilized by crops or lost to the environment. The manure produced by farm animals in the United States contains about 7 million tons of nitrogen. Considerable amounts of the nitrogen excreted by animals are in forms which are quickly converted to ammonia. Volatilization of the ammonia occurs readily as the manure comes into contact with the air. Phosphorus does not have the same mobility in the environment as nitrogen (Figure 9).

Greater than fifty percent of the nitrogen can be lost from these animal wastes using current waste handling procedures. On a nationwide basis, nitrogen losses from animal wastes may approach four million tons annually. This nitrogen has the potential to replace an equivalent amount of fertilizer nitrogen if the following were available: a) economically sound means of conserving the ammonia between excretion by the animal and incorporation in the soil, and b) utilizing the conserved nitrogen for crop production.

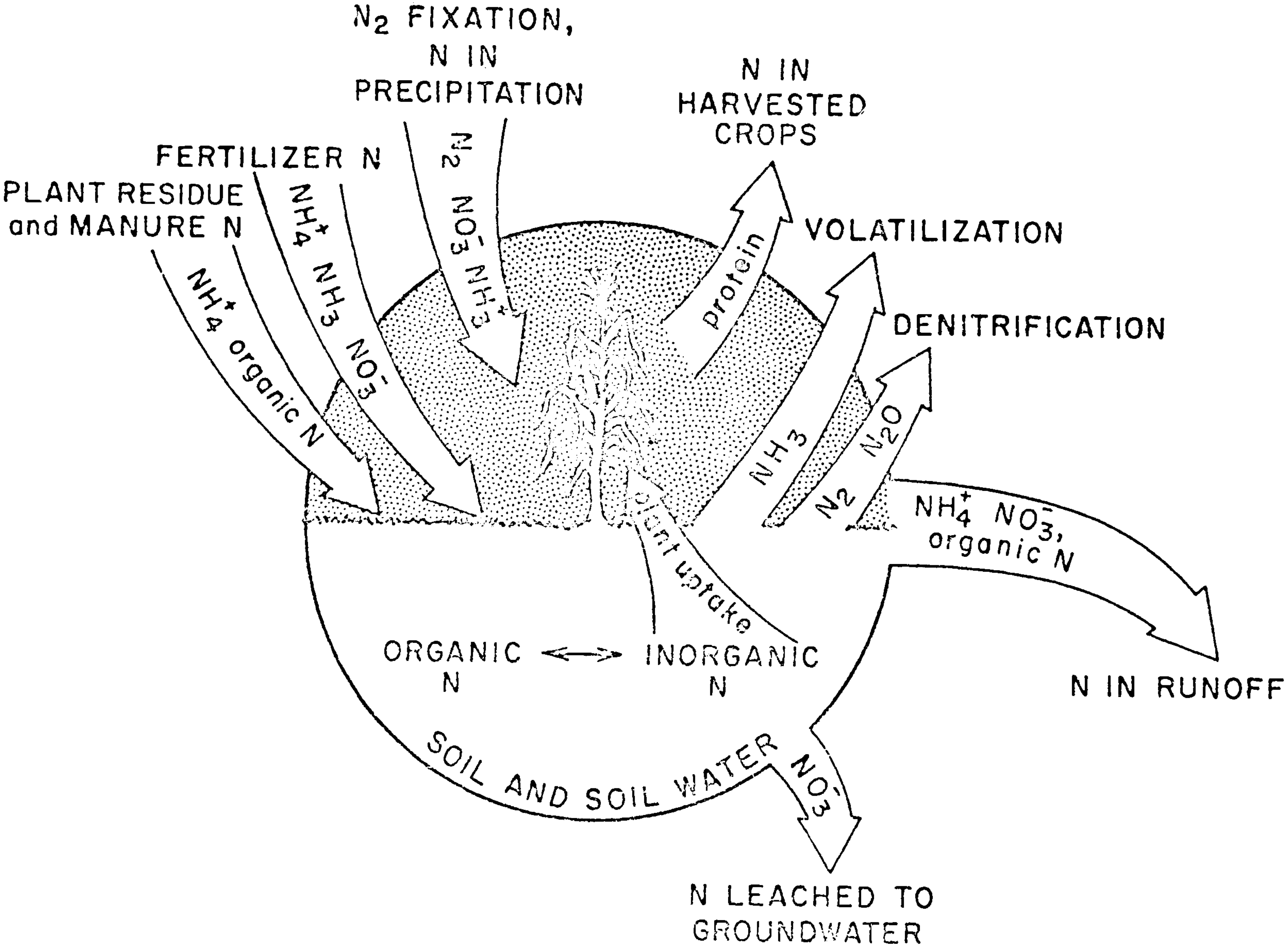

Figure 8. Nitrogen Inputs, Outputs, and Transformations

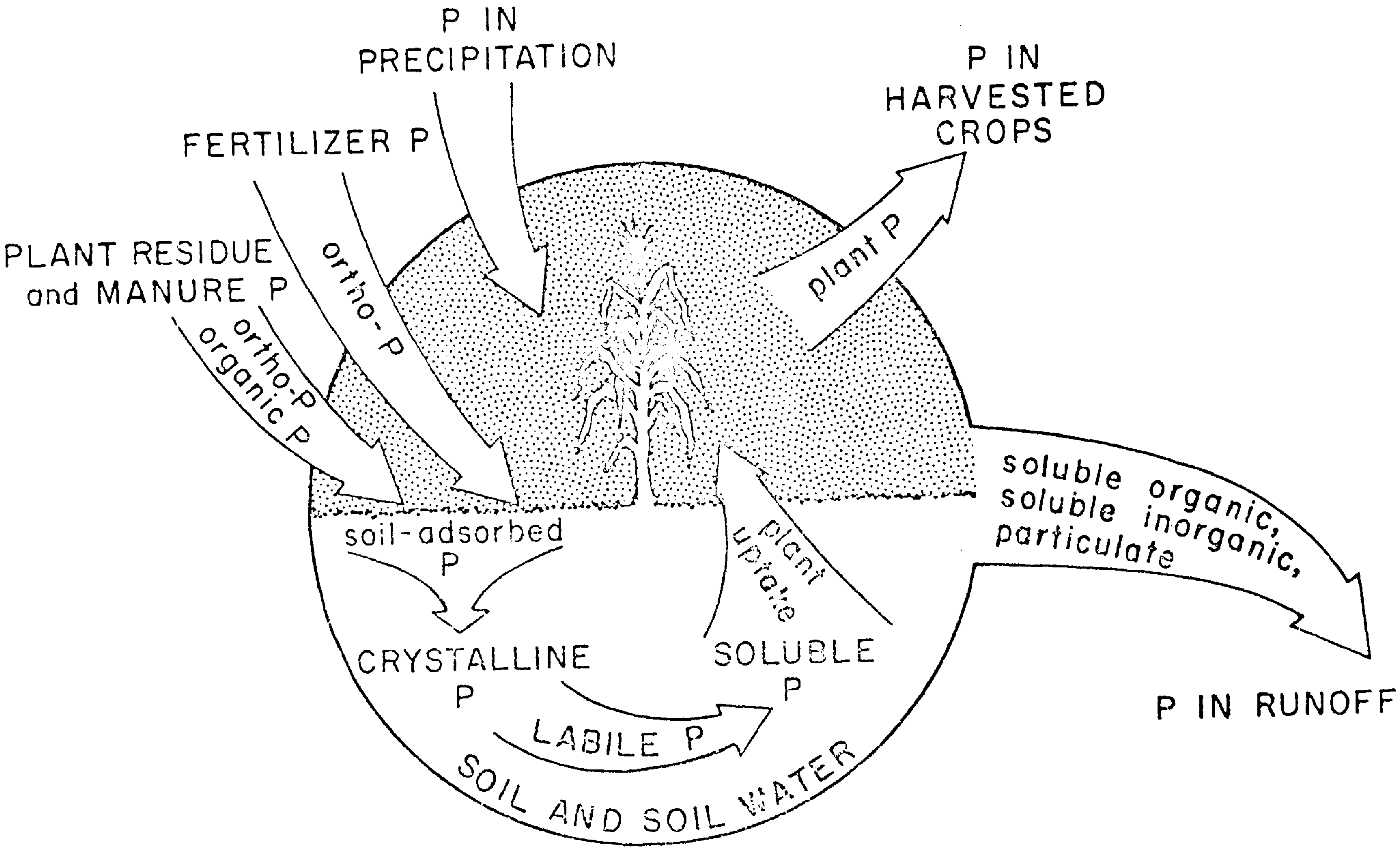

Figure 9. Phosphorus Inputs, Outputs, and Transformations

Alternatives to conserve and utilize this nitrogen include:

a) technology to conserve the nitrogen prior to land application

b) manure application rates that match the ability of crops to utilize the available nitrogen

c) manure placed below the soil surface and under conditions that do not lead to denitrification or leaching losses in the soil.

After the residues are incorporated in the soil, there are additional avenues by which nitrogen can be lost. Removal of fertilizer nitrogen in harvested crops varies from less than 25 percent for some fruit and nut crops to over 70 percent for some forage crops - with an average for all crops of about 50 percent. The nitrogen not removed is left in the soil in inorganic forms and as a constituent of the soil organic matter. The inorganic nitrogen is subject to losses by ammonia volatilization, by denitrification on poorly drained soils, and by leaching if water moves through and beyond the root zones.

Proper understanding of the nitrogen and other nutrient cycles will help better retain and use the nutrients in agricultural residues as fertilizers.

In general, one of the best use of wastes and residues from agricultural industries is to return them to the land and reincorporate them in the soil. In reality, the feasibility of this approach is influenced by factors such as: a) the economics of transporting the wastes to the land and incorporating them in the soil; b) the transmission of plant pathogens; and c) the need to avoid exceeding the capacity of the land to assimilate the residues. As an example of the latter factor, research has shown that 10 tons of dry manure per acre, applied to irrigated sorghum, provided the same crop response as when anhydrous ammonia fertilizer was used. At higher rates there were increasingly greater degrees of plant injury, in this case due to toxic levels of salts applied to the crops.

The application rates of agricultural residues as fertilizers must be determined by conditions at the local site such as precipitation patterns, natural soil fertility, crop needs, quantity of needed nutrients, and factors in the residues that may inhibit crop growth. Conservatively residue application rates should be no more than twice the rate at which the nutrients are utilized by the crops.

4.7 - Water Conservation and Irrigation - One of the approaches for waste utilization is irrigation of agricultural wastewaters to meet both water and nutritional needs of the crops. This approach is best utilized in areas with a deficit of available water during part or all of the year.

Agriculture is a major user of water in the United States, primarily for water used in the food processing industry and through the use of irrigation in agriculture. Thus a major reusable by-product of the food and fiber industry is water. These waters can be reused in the processing plants and for irrigation and recharge of groundwater. In-plant operational changes may be needed to best utilize the available water. These changes can be grouped into two categories: circulation and discharge of highly polluted water separately from the wash and cooling waters, and the elimination of some processes such as the lye peeling of potatoes which result in highly polluted water.

Land disposal of agricultural wastewaters offers possibilities for recharge of groundwater and water reclamation as well as utilization of the nutrients and organics in the wastewaters. The microbial and plant action in the plant-soil filter can remove organics, most inorganics, and bacteria. Upon reaching the groundwater level, the wastewater has lost its identity and has been renovated. The nutrients and organics can be incorporated in the crop grown on the irrigated site.

Land disposal of wastes partially restores the nutrient cycle of food and crops which is interrupted by the disposal of wastes to surface waters and to the air. For agricultural wastes, such an approach often is less expensive than other waste treatment and disposal alternatives. It can be used for both untreated and treated wastewaters.

To utilize wastewater irrigation as a long term viable alternative, the concentration of salts in the root zone of the crops must be kept below detrimental levels. A balance must be achieved between the salts removed by deep percolation or drainage and the salts added in the irrigation water. With relatively large amounts of natural rainfall and wastewaters having low salt concentrations, detrimental levels rarely are reached. Irrigation with wastewaters having relatively high salt concentrations in regions of low natural rainfall can result in detrimental salt levels in the root zone and forage or cover crop inhibition. The latter conditions should be avoided when considering or designing wastewater irrigation systems.

Agricultural wastes and wastewaters are well suited for land disposal, since most agricultural operations are in areas where land is readily available. Irrigation has been used to dispose of wastewaters from dairy and milk processing wastewaters, food processing and canning wastewaters, and treated municipal sewage. Through careful planning and control, irrigation of agricultural wastewaters can be adapted to various ground conditions and terrain. This method has been used for both year round and for seasonal operations. Competent soil science advice will prove useful when considering this alternative. Preliminary investigations may be necessary. The ability to monitor the groundwaters, the soil water percolate, the soil characteristics, and the crops that are grown is desirable. It can be dangerous to assume that because the wastes are out of sight when placed on the land, that they can be forgotten.

4.8 - Composting - Composting is a microbiological process that offers an opportunity to recover and reuse a portion of the nutrients and organic fraction in agricultural wastes. Important factors in the process include adequate mixing of the wastes, small particle size, oxygen for the microbial degradation of the wastes, time to accomplish the composting, and moisture. The composting can be done in open windrows or in enclosed environmentally controlled units. With the use of the controlled units, composting can be accomplished in 5-7 days, while in open windrows it may take 3-8 weeks or more to produce satisfactory compost.

The process of aerobic composting can be separated into distinct stages of stabilization and maturation. During the stabilization stage, the temperature rises to a thermophilic level where the high temperature is maintained followed by a gradual decrease in temperature to ambient conditions. As the temperature increases, multiplication of bacteria occurs and the easily oxidized organic compounds are metabolized. Excess released energy results in a rapid rise in temperature. The temperatures at this time can be in the 130-160°F range depending upon the method of operation. At these temperatures, the pathogenic organisms are reduced or destroyed. The ultimate rise in temperature is influenced by oxygen availability. Compost units kept aerobic reach and maintain higher temperatures than do those that do not have enough oxygen.

When the energy source is depleted, the temperature decreases gradually and the fungi and actinomycetes become active. At this stage, the organic material has been stabilized but can be further matured. During maturation, slow organic matter degradation occurs until equilibrium conditions occur. The final product is a mixture of stable particles useful as a soil conditioner. The moisture content of compost should be in the 50-60% range on a wet weight basis for optimum composting rates.

The key to a successful composting operation is to have the environmental conditions satisfactory for the organisms that exist. The major objectives in composting are to stabilize putrescible organic matter, to conserve as much of the crop nutrients and organic matter as possible, and to produce a uniform, relatively dry product suitable for use as a soil conditioner and garden supplement or for land disposal.

The operational fundamentals for satisfactory composting have been investigated over the past decades and the following factors elucidated:

-Windrow composting in the open is a simple procedure.

-Recycling of compost to the process for reseeding purposes is of little, if any, value to the process due to the sequence of organisms in the composting operation.

- -Aerobic composting is actually a semi-aerobic process requiring less aeration than the term implies.
- -Simple turning is an effective way of maintaining needed aeration. Forced aeration is not necessary and can be difficult technologically on a large scale.
- -Fly control and destruction of disease vectors occur in the process.
- -Finished compost is a low grade fertilizer, more valuable for its soil conditioning and moisture retaining properties.

The composting of dairy, beef, swine, and poultry manure has been technically possible. Both windrow and mechanical composting of these wastes have produced suitable compost when the fundamentals of the process are followed. A number of studies have illustrated the value of adding dry, large particulate material such as ground corncobs, wood shavings, straw, sawdust, and dried compost to reduce the moisture content, facilitate air movement, and reduce composting time. On-site composting of poultry manure within the poultry house resulted in an odorless, fly-free environment, and was relatively inexpensive. Solid meat packing wastes also have been composted successfully.

4.9 - Forest Operations and Pulp and Paper Production - The residues from forest operations include waste from silviculture operations such as thinning and pruning, from logging such as bark, leaves, branches and stumps, and from wood processing such as bark, sawdust, and pulp and paper processing wastes. A considerable amount of these wastes can be utilized when the economic situation is favorable. Examples include bark used for fuel, horticultural purposes, or in wood paneling; sawdust used for fuel and as a fermentation base; resin used for turpentine and fatty acid production; and pulp and paper processing wastes used as a road binder, for vanillin production, for protein and organic chemical production, and for fuel.

Paper is made from raw materials containing adequate amounts of cellulose fiber. Currently wood accounts for over 98 percent of the virgin fiber used in papermaking. There are several methods for pulping wood and freeing the cellulose fiber. Wood particles can be cooked with chemicals under controlled conditions of temperature, pressure, time, and cooking liquor composition. Wood also can be reduced to a fibrous state by mechanical means or by a combination of chemical and mechanical action.

Each paper making process will result in different waste characteristics. Characteristics of pulp, paper, and paperboard mill wastes in the U.S. are presented in Table 17.

In the chemical pulping of wood, 40 to 50% usually is recovered as the fibrous product, part of the original hemicellulose, and some residual lignin. More than half of the original organic material is not recovered as a product but results in a residue or waste for disposal. Opportunities for utilization of these wastes have been identified briefly above and in more detail elsewhere (11).

In the forest products industry, considerable material such as sawdust and bark remain as residues for possible utilization. Such residues have been used, either directly or as part of compost, as organic soil conditioners or growing media for greenhouses in Europe and North America.

Many fibrous agricultural residues and nonwood plant fibers can be used for the production of pulp, paper, paperboard and panelboard. These residues and fibers include bagasse and straw, plants and grasses (29). Of the many nonwood fibers considered for pulp manufacture, bagasse is an interesting possibility. Sugarcane is crushed in multiple mills for juice extraction. The fibrous material remaining after the juice is extracted is known as bagasse. Bagasse can be used as fuel in the boilers of the sugar factories and as a raw material for manufacture of paper. Bagasse is available in many countries including those having inadequate supplies of wood for pulp and paper production.

Straw is another abundant nonwood plant material. Cereal and rice straw is being used in many countries for production of pulp. Total production of straw pulp on a worldwide basis is about 1.36 million metric tons and has remained relatively constant (29).

TABLE 17

Summary of Waste Characteristics Resulting from Pulp, Paper, and Paperboard Mills[a]

Category	Parameter[b]					
	Flow		BOD_5		TSS	
	ave.	range	ave.	range	ave.	range
Unbleached Kraft	53	40-86	17	12-28	22	19-28
NSSC[c] - Ammonia base	35	-	34	-	17	-
NSSC - Sodium base	43	20-106	25	11-45	12	4-23
Kraft - NSSC	58	43-74	19	14-27	20	12-28
Paperboard - Waste Paper	30	5-68	11	4-20	-	3-81
Bleached Kraft						
-Dissolving Pulp	241	230-250	55	40-70	113	87-140
-Market Pulp	171	79-256	40	28-50	71	-
-Fine Papers	133	98-178	32	20-52	82	42-128
-Paperboard, Coarse and Tissue Paper	151	103-205	38	30-52	70	32-128
Papergrade Sulfite	220	208-229	127	121-134	89	81-99
Papergrade Sulfite Market Pulp	244	-	123	-	33	-
Low Alpha Dissolving Sulfite Pulp	251	203-275	134	130-137	92	-
High Alpha Dissolving Sulfite Pulp	247	-	244	-	-	-

continued.

TABLE 1' oncluded.

Summary of Waste Characteristics Resulting from Pulp, Paper, and Paperboard Mills[a] concluded.

Category	Parameter[b]					
	Flow		BOD_5		TSS	
	ave.	range'	ave.	range	ave.	range
Groundwood						
-Chemi-Mechanical	112	104-121	96	87-105	52	23-81
-Thermo-Mechanical	99	-	28	-	49	-
-Fine Papers	91	52-106	17	13-21	52	33-66
-Coarse, Molded, News Papers	99	53-115	17	10-21	49	21-78
Soda	144	118-170	43	34-52	143	-
De-Ink	92	50-162	57	17-92	172	56-208
Non-Integrated						
-Fine Papers	63	26-137	11	7-19	31	18-44
-Tissue Papers	96	43-150	12	7-23	34	22-52

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[a] from: Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Unbleached Kraft and Semichemical Pulp Segment of the Pulp, Paper and Paperboard Mills Point Source Category," EPA-440/1-74-025a, May 1974, Washington, D.C.; and

Environmental Protection Agency, "Development Document for Interim Final and Proposed Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Bleached Kraft, Groundwood, Sulfite, Soda, Deink and Non-Integrated Paper Mills Segment of the Pulp, Paper, and Paperboard Point Source Category," EPA 440/1-76/047a, January 1976, Washington, D.C.

[b] flow - kiloliters/kkg; BOD_5 and total suspended solids (TSS) - kg/kkg of product produced.

[c] NSSC - neutral sulfite semi-chemical.

Other examples of the use of such residues that are under investigation include (15):

-Wood waste products in the culture of ornamental plants - The objectives are to determine the value of wood waste products as a supplement for peat in the growing media of container grown ornamentals; the value of wood waste products as a mulch for ornamentals; the cultural requirements when utilizing wood waste products; and the quality and type of waste product desirable for growing of ornamental crops.

-Evaluation of bark for animal bedding and products foı soil application - The study will evaluate processed aspen pulpwood bark as animal bedding and poultry litter, and determine the suitability of the products as a soil fertilizer and amendment.

-Wood product utilization - The study includes the use of bark as cattle fodder, as animal bedding, and as a mulching agent. The results indicated technical success but poor economics.

-Bedding materials for stanchion and free stall barns - The investigations will evaluate the feasibility of using various wood products such as shredded bark and sawdust for dairy barn bedding.

-Paper mill by-products as a source of litter for broilers - The study will compare the use of paper mill by-products and wood shavings and determine the effect of various amounts on growth and quality of the birds. Preliminary results indicated that paper mill by-product is a suitable replacement for shavings as a litter for broilers and that there was no disadvantage in reusing litter.

5. SUMMARY

Traditionally agricultural residues have been regarded as the inevitable by-products of agricultural production and processing. With notable exceptions, the usual approach for agricultural waste management has been disposal with or without treatment. Concerns of environmental pollution and adequate food has focused attention on better use of all resources, including agricultural residues.

Continuing efforts are needed to develop technological and institutional arrangements to better utilize the residues from agricultural production. The need is to consider residues as potential resources rather than as undesirable wastes. This will require not only better use of technology and incentives but also a change in philosophy and attitudes.

As this overview has indicated, many processes are available for the utilization of agricultural residues. Other possible technologies exist in addition to those mentioned. Few novel utilization processes exist. Any novelty tends to be more in the application of the specific technology to specific wastes under different geographic, climatic and cultural situations.

The successful application of residue utilization technology will require the selection, modification, transfer and adaption of technologies to local conditions. The ability of local manpower to operate and service the various technological approaches requires careful evaluation. Where necessary, educational programs may be required to assure qualified manpower.

There is no one best approach to residue utilization. In each situation, the possible alternatives need careful evaluation with the most appropriate single technology or combination of technologies chosen to provide the desired environmental, economic, and social objectives. The latter objectives are important since even when the costs of recovery, including return from sales, cannot be brought below the disposal cost, there may be sufficient social benefit to make government subsidization of resources recovery a rational and useful policy.

Achieving better agricultural residue utilization will depend upon the local or regional capacity to develop and operate viable technologies and to utilize or market the resultant products. When considering residue utilization possibilities, aspects other than identifying suitable technologies need evaluation. The economic, legal, and social aspects of such utilization can be important constraints and also require close evaluation.

Recycling, reprocessing, and utilization of all or a portion of the wastes offers the possibility of returning such residues to beneficial use as opposed to the traditional methods of disposal and relocation. The keys to successful utilization of such residues are a beneficial use, an adequate market, suitable technology to process the residue under local conditions, and an overall enterprise that is socially and economically feasible.

The need for better residue utilization exists and suitable technologies are available. The challenge is for public and private interests to develop suitable arrangements to encourage the application of appropriate technologies to meet the obvious resource and food needs.

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Socio-Economic Aspects of Agricultural and Agro-Industrial Residue Utilization

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SOCIO-ECONOMIC ASPECTS OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

The purpose of this paper is to bring together the most important social and economic considerations which have been recently raised in the readily available publications with regard to the utilization and management of agricultural and agro-industrial residues. After the presentation of the main socio-economic needs for residue utilization, the paper deals, in turn, with demand and supply considerations. In the concluding section, the major implications for government policy are outlined.

Unfortunately, because of the lack of data, it has been impossible to quantify and compare the demand and supply of various products obtainable by residue utilization. Moreover, for the sake of brevity, no attempt has been made to examine critically the actual experience in residue utilization by any specific process or in any specific country. Finally, although various uses of agricultural residues are mentioned, e.g. as fuel or raw material for chemical and construction industries, the emphasis is on food and feed from waste because uses as a feed supplement and as a fertilizer or soil conditioner seem to offer the greatest opportunities for the utilization of agricultural residues in the near future.

1. SOCIO-ECONOMIC NEEDS FOR RESIDUE UTILIZATION

Millenia ago man was a hunter and gatherer, and there was no conception, let alone problem, of waste. He used what he required, and whatever remained was readily absorbed into the ecosystem and recycled. It was only when man began to settle the land and congregate in groups, and ultimately to live in cities, that waste became a problem. The Industrial Revolution not only exacerbated the existing problem, but also created new types of industrial waste, including materials which were foreign to the ecosystem. Today the time has come when a new type of Industrial Revolution is required - one in which the waste of the old system becomes the raw material of the new system (2, p.8). This also calls for policies which would ensure convergence of private with public interests.

Over the last 25 years the problems of agricultural and agro-industrial waste management have grown with an increase in the efficiency of farm and processing industry (2, p.58). Both animal and crop production, especially in developed countries, have been considerably intensified in order to meet the magnified demand for a good and constant quality product. However, the greater the crop yield or the number of animals reared per area of land, the greater the amount of waste produced, for instance, as straw in the case of cereals, leaves and haulms in the case of other plants, or as manure in the case of animals. Growth in processing the agricultural products has also increased the volume of residues.

Concentrated agricultural production has intensified the waste streams at the same time that the public has joined the quest for a pollution-free environment (7, p.14). Although the waste products of agriculture are not classed as toxic, when in high accumulations they can result in the same problems of pollution as encountered with factory pollution (3, p.59). Symptoms of this pollution are especially appearing near to high-density animal stocking areas. For example, lakes and inland waterways have been subject to large-scale eutrophication caused by animal manures trickling from the land which has been biologically and physically overloaded. The by-products from cereal production are also causing a pollution problem. For instance, due to the development of monocultures and specialization, the straw stem left after removal of the grain must be lifted from the ground in order to control pests and diseases and to prevent fouling of the soil for the next crop. In some countries, most of the straw produced is burnt in the field, causing smoke and fire hazards and other ecological problems. Apart from reducing fertility of most soils, removal of the straw from the field is costly and is only justified where it is to be put to use as bedding or for non-agricultural uses. In such situations, the development of upgrading methods for the recycling of animal and other agricultural wastes as an animal feed component could help to alleviate the waste problems of high-density stocking and cropping provided that any process developed was quick, socially acceptable and economically viable (2, p.60). The same considerations apply to agro-industrial residues.

Within the last few years, the concept of producing food from waste has become of great interest as a result of increasingly frequent food shortages and price rises. It appears that large production of food and feed from materials now classified as waste will be inevitable in a few decades because of the following considerations (2, p.264):

a) unlike the population growth, exponential growth of future agricultural output is not plausible;

b) engineered food would make too high a demand upon resources;

c) public pressure against pollution is justified;

d) a population dependent upon food from fossil carbon would be courting disaster;

e) largely unused organic wastes are a major renewable reservoir of carbon compounds.

a) Elaborating these points, it should be mentioned, first, that there is rather widespread doubt as to for what period even the linear increase in agricultural output can be maintained. Improvements in fertilizer application, introduction of high-yielding varieties and improvements in management practice are to a large extent exploiting once-for all opportunities and, once such practices have been widely adopted, no other similar sources of improvement will be available (2,p. 266). This point cannot be affirmed with certainty but it appears that over the next two to three decades the battle to make conventional agriculture meet the needs of a continually expanding population cannot be other than a losing game.

b) At the same time, there is fairly widespread agreement that complete chemical synthesis of nutrient from CO_2, without intervention of biological processes, is inconceivable for production of bulk foods on account of huge demands for energy and capital (2, p.267). The same is true of sophisticated systems for culturing micro-organisms from inorganic materials, such as those algal systems which depend upon artificial illumination and rapid pumping of the algal suspension. Algal systems which utilize sunlight as an energy source are in a stronger position, but practical application on a large scale will remain dependent upon reducing the technology required to very simple terms and diminishing the capital requirements to levels appropriate to developing economies.

c) As already mentioned, with the present agricultural and agro-industrial production methods, public pressure against pollution is a real and justified factor in promoting utilisation of organic wastes. As regards social justification, it is necessary to emphasize the recovery and reconditioning costs to other users of land, air and water; the reduction in environmental values for those who cannot afford such reconditioning; loss of health and beauty of surroundings; and reduced social responsibility due to frustration and lack of understanding of remedies. The effect of public pressure is indirect, however, since by penalizing pollution and creating a disposal cost it merely makes waste utilisation more attractive than it would otherwise be. The main direct incentive to waste utilisation will still be the future shortages of organic material.

d) On the other hand, the conventional production of primary agricultural and forestry products is itself an extremely wasteful process. The inputs of energy for water transport, soil preparation, fertilizer, crop-care procedures and harvesting are usually many times greater than the energy content of the output; consequently the whole of the output, including residues, should be treated as a scarce resource and wholly utilised (2.p.269).

e) It is, therefore, socially and economically urgent to recognize now that the pressures to recycle carbon without its return to the atmosphere will become irresistible and that foods and feeds must be produced from wastes on a large scale within a few decades. This change is likely to make new managerial, technological and public policy demands and will call for a high degree of flexibility of outlook in industry and government and awareness of problems and possibilities on the part of the public. Appreciation of the inevitability of this change is crucial because without it the necessary measures cannot be the subject of enterprise budgets and plans. Without planning ahead, there is a danger of drifting into serious, ever worsening shortages of conventional resources and difficulties in adapting the technologies and management methods. When such changes are introduced only from desperation there is usually insufficient time for research and development and they are accompanied by economic stresses which could be avoided.

It should be added that, apart from food and feed, many agricultural and agro-industrial residues can be utilised not only as fertilizer but also as fuel, starch, oil for chemical industry, medicines as well as for such purposes as production of construction materials, pulp and paper, etc. (1, pp.335-350). However, the existence of suitable technologies is not enough: it is necessary to examine in each case the social acceptability of the product and the economics of its production and distribution, including the social cost of accumulation and disposal. General principles of such an evaluation based on the analysis of social benefits and costs are discussed below.[1/]

2. DEMAND CONSIDERATIONS

Increasingly frequent food shortages and rises in the price of food, as well as environmental pressures, are the basis of current interest in re-using waste. However, can waste be directly converted to food which will be bought in the market? There is obviously a serious problem of public concern about what is going into human food, and sources of waste which are not in themselves foodgrade will have difficulty becoming recognized as direct food materials. Substances like cheese whey, for example, if handled under appropriate conditions of hygiene, can be considered foods as such or serve as raw materials for other food products. However, other types of food waste (not food-grade in themselves), or SCP (single cell protein) produced under non aseptic and uncontrolled conditions from fungi, yeasts or bacteria would have to be considered for use only as animal feed.

There are now guidelines available from the PAG (Protein-Calorie Advisory Group of the United Nations System) for SCP intended as food or animal feed. It is estimated that a complete testing recommended by PAG would cost about $500,000, which seems a significant part of the necessary investment (2, p.16). Such costs will act as a deterrent to the application of certain types of waste utilization schemes, but it would be irresponsible to the health and safety of future generations to forgo or lower the PAG standards.

Although the problem is purely semantic in nature, publicising the idea of food from waste could in itself be anti-productive as a result of public misunderstanding. It would perhaps be better to talk in specific rather than generic terms when describing such processes, in order to avoid the necessity of explaining how that which is clearly not food, i.e. waste, can be re-converted or reclaimed. It is obvious that many organic wastes are most unattractive materials - even offensive. Decaying vegetation, food processing wastes, mouldy materials, animal excretion, even human excretion are among the organic resources which cannot be ignored. It appears, however, that, if total organic matter is going to be scarce, it will not be possible to indulge prejudices against using these organic materials which seem disgusting. Subject to hygienic conditions being fully met, there is presumably going to be an economic pressure to utilize all forms of usable organic matter. No doubt these substances can be utilised in the community without being drawn sharply to people's notice, and this would be the best solution (2, p.273) provided that regulatory requirements do not prohibit it.

[1/] For more details, especially at micro-economic level, see reports of the Cornell University Conference on Agricultural Waste Management (3). An example of sociological research on environmental problems is presented in 11, ch.7.

Nevertheless, the objective of food and feed production from waste mut be to supply palatable cheap food which will be accepted by the indigenous population. For developing countries, the new foods and feeds should be stable and easy to sell without the need for elaborate distribution chains such as exist in the technologically advanced countries (2, p.7). However, marketability, i.e. an outlet for the product at a fair price, is an obvious general prerequisite in choosing the food and feed materials and the animals for feeding on waste products. The acceptability will vary with the product; for example, pigs bred on domestic refuse and transformed into pork products would have less sales resistance than, say, ducks bred directly on sewage and sold for the table. Microbial protein produced from the cellulose fraction of refuse and used as protein enrichment in convenience foods would be more acceptable than rabbits, which have been fed on waste, sold as fresh meat.

Market research will be necessary to aid the selection of waste for food and feed as well as of animals, but it must also be observed that to meet world food requirements eating habits will have to undergo considerable changes (2, p. 283). At the same time, it must be recognized that there is a strong tendency to conservation in food habits. This has been seen both in developing countries, where there has been consumer resistance to new foods introduced to improve nutrition, and also in developed countries, where the consumer has clung to familiar foods in spite of advertising designed to change his habits. It is, therefore, reasonable to suppose that, as far as practicable, food from wastes will be used for production of familiar food items, and passage through animals for meat and milk production will be a common application. Where vegetable or fungal foods might be used directly as sources of protein for human consumption, they will probably continue to be processed in forms which resemble as closely as possible their animal counterparts, e.g. sausages, hamburgers, etc.

However, traditional societies will eventually need to change if the projections of world population materialize. Change must, thus, come also in food habits, if only to cope with the much greater numbers of children which now survive with the aid of modern medical, health and welfare services. In the long run, unavailability of certain foods or a high price will force people to change their food habits and to look for alternatives. For instance, when in the 19th century bread became virtually out of reach for most of the working class people in countries like England it was replaced by potatoes, with all the nutritional consequences. Needless to say, a forced change from traditional foods to less appreciated ones may create social unrest among the consumers.

The conversion of waste into an acceptable food material is not the most difficult of the problems. It is susceptible to solutions by scientific study and it is encouraging that scientific interest is being generated in this area. But the world food crisis cannot be solved without also solving the problem of world poverty. People without work cannot earn money to buy the cheapest of available foods, and consequently the market for the produce will not be available. It is the solving of the social and economic issues which presents the greatest difficulty.

Although the need for an increase in the production of food and other commodities is the most urgent in developing countries, the possibilities of meeting this need in such countries are very narrow because of demand restrictions, i.e. lack of purchasing power. Thus, in Africa, the opportunities in the immediate future for making use of agricultural waste are comparatively limited (13). Some possibilities of utilization exist for wastes in sugarcane production, treatment of night-soil, game cropping, sisal, oil palm and cocoa production. It appears, however, that food shortages in Africa must be met primarily by changes in the agricultural pattern, by improved supply of primary products rather than by indirect supply of protein via animals.

Also because of market demand limitations, in South East Asia enormous quantities for agricultural residues are generated which are not adequately utilized for food production or otherwise (1). However, some of the processing operations result in effluents which cause serious pollution problems, e.g. wastes from pineapple canning, palm oil processing, rubber industry, slaughter houses, sugar and distilling plants, etc. Utilization of these wastes might become an important factor in Asian economic development. In this respect, the situation and prospects in other developing regions seem to be similar.

As regards the demand dictated by pollution, a serious health hazard arises from human waste in urban areas of all developing countries. The solution appears to be via the treatment of the night-soil to give a harmless material which provides both a liquid effluent and a solid fertilizer. This solution has been widely employed in China, where human excreta became an essential factor in agricultural development (8). Studies in China had indicated that anaerobic (oxygen-free) digestion of night-soil and manure over a 2-4 week period would destroy hookworm and schistosome ova. Thus the farmer was exhorted to store his fertilizer in closed containers over a four week period prior to its application to the soil. However, the ascariasis egg is not inactivated by the four-week storage beside the field. WHO is, therefore, against this kind of use of night-soil. Perhaps a more promising utilization of night-soil is in combination with animal manure in village plants producing biogas as well as fertilizer, thus achieving two purposes of meeting fuel requirements and retaining the soil nutrients of wastes (1).

3. SUPPLY CONSIDERATIONS

When considering the production of food from waste, due regard must be paid, first, to the proposed location of the operations (2,p.6). Waste material is available universally, e.g. sewage, waste paper, food factory effluents in the technologically advanced countries, and primarily agricultural residues in developing countries, e.g. sugar cane bagasse, olive press cake and citrus waste. A successful process will have taken into account all the local factors.

In the developing areas, where the need for additional food supplies is greatest, it is perhaps going to be most difficult to implement the residue utilization schemes. A successful operation must be assured of a reliable and adequate supply of materials, appropriate services such as electricity, water, etc., suitable labour to operate the plant, and an efficient infrastructure to permit distribution of the finished product. In the initial stages, numerous small-scale, low-energy processing plants will be needed, to save transport costs. However, waste recycle economies are marginal, especially where waste is allowed to accumulate or be disposed of at public expense, which creates a challenge to technologists to develop processes with low-cost inputs and equipment. It seems, therefore, that under the impact of continued strong pressure to protect human environment and increase food production, small inefficient plants will tend to disappear. In order to avoid a significant additional energy expenditure to treat the waste problems, a great deal of attention will have to be paid to more efficient plant and process design, and to public policy placing a cost price on accumulation and undesirable disposal. In some cases, the way will be to minimise the formation of waste in the first place, e.g. by genetic research or reduction of post-harvest losses; in others, it may entail SCP production or by-product recovery. There is no ideal solution, only the most appropriate solution for a given situation.

Economics is the overriding factor in the decision to implement any process. Although many waste streams appear to have zero or negative costs, there are often hidden costs in additional processing necessary to prepare the material for fermentation. Another significant consideration is the availability of raw material with respect to quantity and distribution in time. Therefore, in order to understand the problem of waste in the general sense, one needs to consider for each type of food the total production, distribution and consumption system.

For example, in a country with scarce land resources and a primitive food distribution system, there would be great incentives to collect and recycle at the farm level all materials which could be converted to animal feed (2, p.9). At the same time, expense or unavailability of local energy supply may dictate that part or all of the waste be converted to methane or hydrogen. In developed countries, materials which in the past served as mulch or fertilizer may no longer be utilisable with modern agricultural practices. Similarly, concentration of production facilities, such as in modern poultry houses or cattle feedlots, has created concentrated waste streams which had not previously existed but could be utilized. The same applies to industries processing agricultural products.

In general, waste streams from agricultural and agro-industrial operations can be divided into two general categories on the basis of their biological oxygen demand (BOD) or soluble and suspended solids content (2,p.10-11; 7, pp. 100-122 and 148-154):

(i) Low BOD streams, which are usually treated because of environmental pressures. Where severe economic penalties are incurred for direct disposal, by-product recovery or fermentation may appear to be the more desirable disposal route. However, because these streams are so dilute, at present the disposal by microbial processes necessitates either pre-concentration of the waste stream, or a large capital investment per weight unit of BOD disposed. Hence many food plants would not be able to assume the cost of disposal, by microbial processes or any other procedure, without raising the sales price of their product to an uncompetitive level. Low BOD streams must, therefore, have a negative cost (i.e. a subsidy) associated with their disposal.

(ii) High BOD streams or solid wastes, which may be treated because of environmental pressures. However, economic opportunities may also exist in the form of a marketable by-product which may either be recovered directly from the waste stream (e.g. whey protein) or indirectly by fermentation. It is possible that the treatment process may result in a "spent substrate" stream which will require additional processing to lower BOD to meet regulatory standards. Two possible approaches to this final stream include recycling all or part of the water within the plant, or total evaporation of the exit stream to produce solids which may or may not be added to the product. In any case, the economies of treating high BOD streams by fermentation follow those of other single-cell protein (SCP) processes, and an economically successful process will generally depend upon the local value of the substrate.

The economic considerations of high BOD waste disposal schemes present the semantic riddle of whether something is a waste or a by-product. Obviously, once a waste stream achieves some measure of value it is no longer waste, even though the original impetus for processing was the cost of disposal. In fact, the assigned value for a waste is often a question of locale, as for example, the fuel value of bagasse or sulphite waste liquor (3c, p.318). Depending upon tax laws and investment incentives, it might be more profitable for an enterprise to assign a negative (or positive) value to a waste stream at the expense of the main process.

A problem in the case of many wastes is their content of non-fermentable substances which may accumulate in the cells of fermenter effluent and which may be non-nutritive or even toxic (2, p.14). Examples include lignin degradation products, heavy metals, agricultural chemical residues, etc. In such cases, it is hardly likely that the extra processing necessary to guarantee safety would be economical from the private point of view but it may be dictated by social considerations.

In many instances, there has been considerable interest generated by wastes that offer joint-production opportunities. An outstanding example of this type ofwaste is the whey which is a by-product of cheese manufacture, containing both a high-quality protein and a readily fermentable sugar, lactose. There are a number of proposals for combined processes which recover protein and ferment the lactose to SCP for use as animal feed. The profitability of any part or all of the combined operation depends upon how one wishes to distribute the total cost of sales. Although the combined process provides the most useful manner in which the whey could be processed, it also requires the largest capital investment and would need fairly large quantities of whey for optimum scale of operations. With the recent price increases in dried milk, dried whey has become a valuable material in its own right, and in some localities it is no longer available.

In general, from the point of view of food/feed supplies, it appears that waste-recycling for feed (and perhaps with some delay for food) has great potential. The speed of its development will certainly largely depend on the prices of the more conventional foods and feeds. At present, the utilization of agricultural and agro-industrial wastes is just beginning. Detailed information on the costs of most utilization methods is, therefore, scarce and must be developed before the broad value of these methods can be determined. A variety of costs must be known: the cost of the method, the net cost as it affects the profit of the producer, and the ultimate cost to the public (3b,p.126). In some countries, especially the U.S.A., many of such data are already available (3d). Sometimes careful evaluation may prove that the process is uneconomic (4), but it could be undertaken for policy reasons such as pollution control, nutrition, employment, balance of payments, income generation and distribution, regional development, etc. (11,pp.223-236), i.e. in line with a broad concept of social welfare.

4. POLICY IMPLICATIONS

The modern world is facing four main problems: its population, its production of food, its consumption of natural resources and its environmental pollution. They are closely interrelated. Taking population as given, the utopian welfare goal is to maximise food production, minimize energy input and simultaneously protect the environment. This composite goal implies also residue utilization, but it is not at all clear that optimization of waste utilization from an energy point of view would produce the same results as optimisation from an energy point of view would produce the same results as optimisation from other economic points of view, particularly if the cost of energy is subsidised by the government.

In search for an ideal solution, various methods of waste utilization have been proposed. The oldest method of agricultural waste utilization is animal husbandry whereby livestock converts organic materials not consumable by human - and often grown on land unsuitable for direct food production - into human food (meat and milk products) and other useful products (wool, leather, glue, fertilizers, etc.). It is of interest to note that in the heavily populated areas of China much of the animal food came from three scavengers: the pig, chicken and dog which fed themselves mainly from food wastes scattered around the houses. Following this example, some writers have suggested the creation of the "city-farm", as one approach to the solution of the waste problems generated at all stages of agricultural production, processing and distribution (2, p.16). However, as is well known, no system operates in perpetual motion. No matter where the boundaries are drawn, an external source of energy will be required and somewhere along the way the system will also ultimately produce unusable waste.

In a system called "Bioplex" (2,p. 280), the biological conversion of wastes would consist of exploiting the chemical activities of living creatures in such a way that the waste from one creature becomes the food for another. In this way the productivity of any one site would be brought to a maximum whilst the waste is minimized. A further benefit would be that transport costs from one process to another are minimized and any changes due to biodeterioration during transit are prevented. It has been further pointed out (2,p.284) that microbes grown in large tanks or fermenters, or fish farms in deep silos, would be more acceptable to large urban communities than intensive animal farms, whereas goats and geese would fit more readily into a rural "Bioplex" than the relatively complex bio-engineering equipment. Although this system requires further study, it seems to deserve special attention from the agricultural point of view, especially the work of domesticating new species, fully exploiting the various possibilities for incorporation in "Bioplex" system and thus developing new ways of waste utilization.

Reasoning along similar lines, the production of increasing amounts of waste material by rapidly expanding urban communities and as a result of more intensive agricultural practices, coupled with the need for increased amounts of protein, suggests the possibility of the application of algal culture techniques for waste recycling (2,p.114). Lagoon culture of algae can produce higher dry weight yields of superior protein quality than can higher plants under similar climatic conditions if the lagoon is operated on a semi-continuous basis using optimum catch techniques. Failure to use weeds growing in water is another conspicuous example of waste, which can be contrasted with China where, in the Yangtse delta, farmers deliberately cultivate water hyacinth as a pig food (2,p. 189).

The opportunities to recycle and use the "wastes" are thus enormous and are limited only by man's imagination. Society will demand increasingly that the industries adequately utilize these wastes, since they are a valuable part of national resources. Irrespective of the system, probably the best way to ensure the proper integration of all the disciplines necessary for optimizing all waste and residue utilization would be the establishment of a National Research and Development Centre for Recycling. In such a Centre, many of the techniques would have to be looked at for their social, economic, legal and political effects.

Through such organized research work it must be, first, ensured that the new technologies for residue utilization are "appropriate", in the sense that they possess the environmental characteristic of ecological soundness (i.e. harmony with the environment), the economic characteristic of reduction of inequalities between and within countries (i.e. satisfaction of basic human needs), and the social characteristics of participation and control by the people (i.e. self-reliance) (12). In the developing countries, there would have to be capital-saving, energy-saving, employment-generating, small-scale and decentralized technologies, which are (a) based on local, renewable energy sources and natural resources, (b) capable of being grafted on to traditional skills, crafts and techniques, and (c) addressed overwhemingly to the basic minimum needs of those below the poverty line. In the developed countries, the preferences are likely to be for non-polluting and low-wasting technologies, directed towards durable products which can be recycled, and based on renewable resources.

Secondly, serious research is needed with regard to the social costs of agricultural and agro-industrial residue utilization. Until recently, little attention was given to the social cost of the discharge of wastes into the environment (5). The society tended to consider the elimination of the wastes themselves as the solution to the problem. Solid wastes were incinerated or discharged into the environment, often without the necessary care needed to reduce the potential harmfulness of these wastes. However, with very few exceptions, fermentation and other waste effluents can no longer be disposed of for no cost. Whether the waste is discharged to sewers, rivers or tidal waters, some expenditure is necessary for treatment or on a means of disposal that ensures that no harm is done to the environment (14). The social cost of waste is thus determined by the sum of its intrinsic value, in terms of recuperable material resources, plus damage to animal and plant resources brought about by the pollution and the cost of waste disposal so as to avoid pollution of the environment (5). It should, furthermore, be borne in mind that the lack of a rational system of waste-management causes the costs of pollution of the environment to be "externalized" and therefore borne by the community as a whole rather than "internalized" as a part of production costs. For this reason, the problem of recyclage and reutilization of wastes must be considered as one of public utility and interest, and a flexible programme must be established in order to determine the methods and a schedule for internalizing costs.

Within such a programme, one possible measure might be to tax the raw materials at source on the basis of the cost of conversion or disposal of the worst likely final waste or pollution effect and to pay businesses and other groups for any subsequent preventive, recovery or disposal activity, including payments to licensed disposal companies. This principle might be applied to agricultural and especially to agro-industrial enterprises.1/

1/ For a detailed discussion of problems and instruments of environmental cost allocation, see Problems of environmental economics, Record of the Seminar held at the OECD in summer 1971, Paris 1972 (10).

It appears, therefore, that the failure of the market system to combat pollution and the necessity of a more wide-spread commitment in the field of recuperation and reutilization of wastes, call for the intervention of public authorities, in the form of legislation, study, providing orientation and carrying out suitable environmental policies and educational activities in the field of agro-waste management (7,p. 454). Without government guidance it seems that private industry cannot be expected to harness waste materials efficiently and optimally from the social point of view. Most private industry acts in pursuit of short-term profits and, rather than plan the overall utilization of a resource, often selects the most profitable portions, leaving the residue unexploitable. Some government control, guidance and incentives will, therefore, be necessary to ensure the efficient scavenging of wastes in a private enterprise system. Given such action in good time it can be anticipated that industry would respond, but this again highlights the crucial need for forward planning in this area.

Adequate consideration has yet to be given to social changes associated with a shift from systems generating large amounts of waste to those minimizing waste and environmental damage. Maximization of resource conversion and conservation will require sweeping changes in social attitudes, economic and social organization (including types of inspection, enforcement and service mechanisms to firms, families and communities, changes in home and family organization and management) and in pattern of participation in public affairs. Definitions of socially approved and rewarded actions will have to be revised, covering such subjects as the use of products from human wastes, food habits, public disapproval and severe sanction of all types of waste and pollution, including individual gain from wasteful and environmentally damaging methods of exploitation. Greater inter-sectoral planning will be required, and frugality may once again become a personal virtue. The awareness necessary to support such extensive changes will not be generated without information and adult education programmes on a scale which now exists only in a few countries.

The pollution problem has so far attracted attention mainly in developed countries. Still, developing countries should take account of these considerations at an early stage before they run into the same problems. Otherwise, the danger exists that particularly the polluting industries which face severe anti-pollution measures in many developed countries would shift progressively to developing countries (9, p.238). On the other hand, in those developing countries where pollution and environmental problems have already attracted adequate attention, the concern is that they would not now over-react to existing or potential problems, but would take national optimal decisions within the socio-economic, geographical and environmental quality conditions that prevail in these countries.

Implications from fairly quickly operating rational organic waste recycling would be enormous. The wealth of national economies may well come to depend largely upon their ability to produce and reprocess organic matter. The demand for investment and ingenuity would be unprecedented in the food and agriculture industries. All sources of organic matter would be treated on their merits according to composition, whether or not they are repulsive. Ultimately, by using wastes very efficiently for food production, waste would be eliminated. From thoroughly scavenging present agro-industrial waste, a natural development would be to reprogramme agriculture to provide feedstocks for bioengineering plants. The wild lands would be harvested, too, for their crop of miscellaneous organic matter. This is probably not a preferred way of life for mankind, but it is the direction enforced by the scarcity of world resources.

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Health Aspects of Agricultural Residue Utilization

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HEALTH ASPECTS OF AGRICULTURAL RESIDUE UTILIZATION

D. Strauch*

1. Introduction

Agriculture has made phenomenal strides since the beginning of this century. In spite of the rapid increase in population agriculture has been able to maintain an abundance of quality food and fibre crops, and has a potential to maintain this abundance for future years.

These advances have benefited the consumer in many ways. However, they have been accompanied by some potential adverse effects in agricultural technology, many of which represent potential sources of environmental pollution and hazards to the health of man and animals.

The term "waste" in relation to agricultural pollution refers to any by-product or residue from agricultural operations that may adversely affect the quality of the environment or the health of humans and/or animals either directly or indirectly (1).

Difficulties in obtaining precise relationships between agricultural practices and environmental problems occur because of the widespread sources of agricultural residues and the many factors that are involved, some of which are not controllable by man. These factors include topography, precipitation, cover crop, timing and location of chemical or fertilizer application, and cultivation practices. The variability of waste discharges complicates assessment of the environmental impact of agricultural production. Agricultural wastes are often not discharged on a regular basis; food processing wastes tend to be seasonal with production a function of crop maturity, feedlot runoff is a function of rainfall frequency and intensity, fertilizer applications are timed for ease of distribution and maximum crop production, and land disposal of waste is related to need for disposal and ability to travel on the land (2).

Agriculture has often been accused of being a major polluter of various segments of the environment. Some accusations are justified, but many are based on very limited factual information and often merely on speculation (1). Available information suggests that potential environmental quality and health problems due to agricultural operations may be more dependent upon the production practices and waste management techniques used by farmers and processors than on the size of the operation, the number of animals fed, or the amount of waste involved (2). This paper will attempt to summarize the health problems that can be or have been associated with agricultural production.

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2. Residues from plant production

2.1 Silage effluents. In plant production, the residues are mainly so-called joint products like straw and leaves and stalks of beets, potatoes, and vegetables. Their utilization is generally possible via the soil or as animal feed. Public health aspects arise when such residues are processed as silage because of the production of silage effluent. This effluent is generally harmless for man and animals. But as soon as it is drained into surface waters it may be the cause of fish kills. In most countries where fish kills have been recorded, manure-silage drainage caused greater problems than mineral fertilizers. In the USA, the percentage of fish killed by farming sources rose from 8% in 1964 to 20% in 1970. In the Federal Republic of Germany and Switzerland, since 1960, up to 25 and 28% respectively of fish kills were caused by agricultural waste waters (3).

Silage effluent has a very high content of easily decomposable organic substances compared with municipal sewage. For microbial decomposition of these substrates, large amounts of oxygen are needed. The BOD_5 of these sewages ranges from 50 000 to 80 000 mg/litre. From these values a pollution load results for the effluent of one ton of silage prepared from sugar beet leaves of 15-24 kg BOD_5 which corresponds to 280-445 population equivalents. Drainage of silage effluent into ground water causes severe health-hazards (changes of odour and flavour, ink-like tint, bacterial counts of over 100 000/ml, and silting of water mains caused by iron-, manganese- and sulfur-bacteria) (4).

2.2 Straw. The surplus of straw is increasing in many countries. Consequently many farmers burn the straw in the fields. Apart from the fact that each year several people are killed and many are badly injured while the straw is burning in the fields, this method also prevents large amounts of organic substances from going into the soil which are urgently needed to maintain the biological activity and humus balance of a healthy soil. In farms where root crops are cultivated and in intensive grain-growing areas, the residues of roots and stubble plus an occasional green manure crop are not sufficient to cover the yearly requirements of humus averaging 4 000 kg of organic dry matter compared with a former value of 2 500 kg. Therefore in such areas it is recommended that straw surplus should be applied to the soil as a matter of principle (5). In other areas it is not always desirable that straw surplus be applied to the soil since it takes a long time to break down in certain soils and, if it is not removed, subsequent arable operations are hampered.

2.3 Food processing wastes. Although not a direct part of farming operations, usable products have been developed from the waste products formed during the processing of forest products, the slaughtering and processing of meat animals, the processing of dairy products, the canning of fruits and vegetables, and the processing of grain products.

Processing plant effluents are usually objectional because of high oxygen demands. The contribution of various processing industries to pollution in terms of BOD is shown in table 1. Data on population equivalents represent the pollution equivalent of the waste compared with the BOD of normal sewage (1).

The table shows that many of these processing effluents have a high organic matter content. It is well known that pathogenic microorganisms, once they are discharged into sewage with a high protein content, grow rapidly. So it was found, for instance, that in summer salmonellae quickly multiplied.

Table 1 Estimated loading of selected agricultural processing industries (1)

Processing industry	Annual Production 10^6 lb	lb BOD/ 10^3 lb processed	Potential daily load 10^3 lb	Potential daily population equivalent 10^6
Canneries	-	-	1 300	8.0
Dairy products	-	-	1 982	11.93
Meat processing	59 400	14.0	2 000	13.0
Poultry	8 200	10.0	225	1.3
Potato processing	18.4	89.7	347	2.11
Sugar production (1976)	189 600	6.0	1 600	9.6

100 000-fold in river water with a content of about 100 mg protein per litre. Since pathogens usually occur in the effluents or sludges of milk, meat, poultry, and also fish processing plants there exists a certain epidemiological problem. On the other hand, one must admit that most of this sewage in developed countries finally reaches a municipal sewerage or a sewage treatment plant. Municipal sewage usually contains considerable amounts of pathogenic microorganisms, since between 0.5 and 2% of a normal human population excretes pathogens without apparently being ill. Therefore any normal municipal sewage contains remarkable numbers of pathogenic germs which are not usually destroyed by the normal sewage treatment processes and, if the effluent is not disinfected, will reach the receiving waters and create a new health hazard for man and animals. It is not possible to discuss here the extensive complexity of sewage hygiene. But, one should mention that the question is under discussion as to whether infectious effluents from food processing plants should be disinfected on-site regardless of the fact that they will later come into contact with the still infectious municipal sewage. In any case, on-site disinfection will reduce the microbial population of the effluent and thus contribute to a reduction in the health hazards that originate from municipal sewage (14).

Table 2 shows the possible uses of food industry wastes from the point of view of hygiene and environmental protection.

3. Residues from animal production

The problem of animal wastes as a direct or indirect source of human illness or of environmental pollution has been increasing in recent years as a result of development in different animal industries and changes in the density of farm and domestic animal populations.

Table 2: Utilization of food industry wastes (12,13)

Product	Fertilizer (plough under the soil)	Animal feed	Medium for fermentation	Plant protein or respective product	Refined products
Apples, pears		x	x		x
Peas, beans		x		x	
Fish		x		x	
Grain mill feeds		x		x	
Potatoes		x	x		
Oilseeds	x	x		x	
Beet leaves		x		x	
Asparagus		x	x		
Spinach		x		x	
Starch		x	x		
Tomatoes	x	x			
Distillery, brewery and winery wastes	x	x	x		
Sugar manufacturing	x	x	x		x

Conventional methods for the disposal of animal wastes, carcasses, and manure, as well as slaughterhouseand other animal industry wastes, are now proving inadequate in many countries. The actual numbers and densities of animal populations have increased both in rural areas (with the development of ever larger animal production units) and in towns. In many countries, significant expansion has also taken place in animal-related industries with the construction of more and larger slaughterhouses, rendering plants, feed processing plants, etc. Public concern about these problems has grown in many areas and is reflected in increasing demands for more stringent measures to reduce contamination and the nuisances associated with it.

Safe means of disposing of animal wastes and dead animals are of great importance in countries with newly developing industries, as well as in areas which already have highly developed specialized industries of this type. They are essential not only for the reasons already stated but also for the control of epizootic infections within the food-producing species themselves, including many zoonoses, and for the direct protection of consumers of meat and other animal products.

Such environmental health problems have been greatly aggravated where development of intensive animal farming has not been accompanied by appropriate systems for disposal of the tremendous quantitites of organic wastes. WHO collaborates with other services in order to collect basic data for the establishment of "pollution characteristics" and epidemiological data to identify areas and populations at particular risk. These data include information on the methods of accumulating such wastes, the amounts involved, the likelihood of their transfer to other sites by natural mechanisms, and any special problems they pose to human and animal health.

In many developing countries, there is an additional problem when livestock also share the urban environment, often in great numbers, and pose major contamination and health problems for urban health agencies. The management of such horses, cattle, buffaloes, swine, sheep, goats, poultry and other species, so that they do not constitute an overwhelming environmental threat, is a formidable task for an environmental health programme (6).

3.1 Animal carcasses and slaughterhouse offal. Animal carcasses and slaughterhouse offal together with the so-called "confiscates" (condemned meat or food derived from animals) usually contain large amounts of pathogenic microorganisms, some of which are the infective agents of zoonoses. These materials also cause heavy odour nuisances, especially in warm seasons and in hot areas, if, they are not disposed of very quickly. The ideal installation for treatment and recycling of such organic wastes under hygienic conditions is the rendering plant which thus fulfills a public task of environmental and health protection. These plants also have an economic value because they produce animal feed from the residues of animal production. In the Federal Republic of Germany the rendering plants work at present with a recycling factor of 73% and it is expected that, by 1985, this value will have increased to 94% (7).

The fundamental aspects of hygiene necessary for the operation of any rendering plant have been established for a number of years. Thus, it is of paramount importance that there be complete physical separation of the "clean" area from that part of the premises where the unprocessed carcasses and offal are handled.

The majority of rendering systems will produce a sterile end project since the raw material is exposed to a high temperature for an appreciable length of time. Recontamination of the end product commonly occurs and it is necessary to ensure that the "clean" area is capable of being kept in a clean condition. It is also self-evident that separate personnel and equipment must be used for the handling of the raw and the end products, and that no other means of recontamination can be tolerated on the premises, be it dogs, cats, vermin, or insects.

In a number of countries, hides of condemned animals are removed for tanning prior to processing. This practice may present some degree of risk to public health and although it is a procedure that may continue it is necessary to take certain precautions, i.e. ensuring that personnel handling hides are not exposed to diseases communicable to man (zoonoses).

It is recommended that all condemned carcasses and offal should be consigned to processing plants or destroyed by other means that will prevent the spread of pathogenic microorganisms. Special attention in future research has to be paid to the occurrence of heat-stable toxic substances and heat-resistant micro-organisms in the products of processing plants. Legislation will be necessary to ensure this.

It is a well established fact that the rendering system of disposal of carcasses and certain other products is preferable to any other means of disposal, since it has very many advantages from the point of view of hygiene. Thus, the disposal of carcasses and offal in rendering plants should be obgligatory by law. However, it may not be possible to use this system under all circumstances unless suitable rendering plants are available in the area. If this is not the case they should be built as a matter of urgency to provide a service to the community and as a contribution to the protection of public health and of the environment (8).

3.2 Animal faecal wastes. Farming animals intensively has a substantial economic value but it can only be maintained and increased if animal health is preserved. The necessity for rational and profitable production in this type of farming is equalled by the need to ensure that neither the animals nor their products pose a threat to public health.

The most usual method of disposing of animal faecal waste is to spread it on the land as manure. The hygienic problems involved with this kind of use must be considered under two aspects:

a) Epidemiology of infectious diseases
b) General principles of animal husbandry many of which are closely related to environmental hygiene (common hygienic problems).

3.2.1 Infectious diseases. Epidemiological problems concerning large animal feedlots are closely associated with those of animal waste disposal. The incidence of latent infections increases when animals of homogeneous populations are concentrated in confinement. Most infected animals eliminate the pathogenic agent by way of the faeces or urine so that germs, ultimately, come into contact with the floor of the buildings. The fact that large numbers of pathogens are excreted has been shown in numerous studies published in the international literature (9). Results show that raw and even partially treated sewage from animal confinements possesses a high potential of micro-organisms which are pathogenic for both man and animals.

3.2.1.1 Conventional waste handling. Conventional livestock units where bedding is used do not cause a special epidemiological problem because if proper management procedures are carried out, dung heaps develop such high temperatures that pathogens that may be present are destroyed. The safety of this procedure is demonstrated by it being stipulated in many countries in the official provisions for dung disinfection for the control of notifiable infectious diseases, in terms of so-called dung packing. After three weeks the dung is considered as disinfected and can be used for agricultural purposes.

3.2.1.2 Liquid waste handling. Both intensive animal farming and modern rural livestock management have resulted in the introduction of systems for rational reasons. Straw for bedding is no longer used. Animal excreta are generally collected jointly in liquid form, the so-called "liquid manure". This mixture of urine, faeces, forage remains, and splashed water is also called slurry or "guelle". It is either collected and stored within the animal building or is drained off and kept in under or above ground reservoirs until it is used. No matter which handling or storage methods are used, spontaneous generation of heat that could entail the destruction of pathogens will not occur in this medium either in summer or in winter.

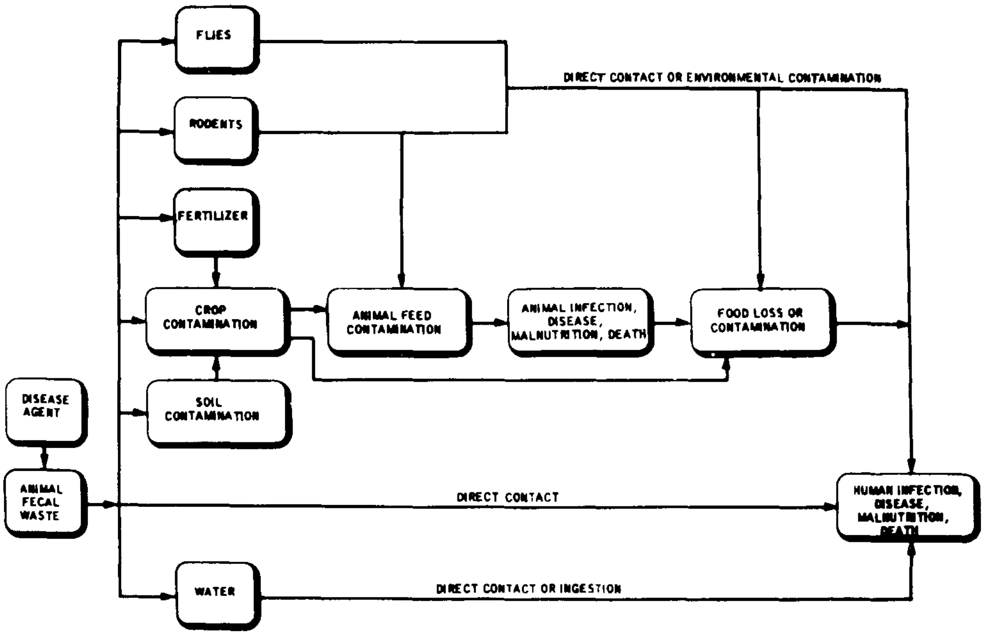
Self-disinfection. A possible measure would consist of awaiting a sort of self-disinfection of the slurry during storage. However, it has been shown experimentally that this does not. In fact, salmonella or stable forms of parasites remain alive in liquid manure for up to six months in summer and for much longer periods in winter or in constantly cold areas. Other pathogens with a viability in slurry of several month's include the viruses, especially when they are enclosed in tissue or in faecal segments. Most farms do not have the capacity to store slurry for many months. The average storage time is usually one to three months.

In the international literature, many cases have been published which prove that infection of man and animals occurs via the excrement of animals before or after it has been distributed on the land. These published examples indicate that animal faecal wastes in the form of liquid manure have an epidemiological significance for the health of man and animals which should not be underestimated. It has been found that as many as 100 000 000 leptospires may be shed per ml of urine of infected cattle. Other investigators have observed cases of leptospirosis, associated with aerosol-borne transmission from the urine of infected cattle, in farmers, veterinarians, packing-house workers, and hunters.

In acute cases of salmonellosis in calves, 10 000 000 salmonella organisms per gram of faeces may be discharged. In many countries salmonellosis is one of the major communicable disease problems. There are an estimated 2 million human cases per year in the USA and about 320 000 in the Federal Republic of Germany. Salmonellosis causes substantial losses both in livestock and in the food industry. The cost in the USA is estimated at $ 300 000 000 annually. Salmonellosis is a threat to everyone as a food-borne disease which usually originates from infected products of animal origin (9).

Figure 1 shows that there are seven direct and indirect ways by which pathogens in animal excreta pass not only to other animal production units but also to man. In other words, the land disposal of infected animal wastes can result in transmission of pathogenic microorganisms both to man and animals. Thus, the spreading of germs by means of infected slurry must be prevented. Successful prevention is only possible if the ways shown in figure 1 can be blocked efficiently. Because of the many possible ways of disease transmission, a great number of measures would be necessary to block all ways of transmission unless epidemiological measures were launched before the germs were released into the environment. Therefore it is essential that the spreading of germs by means of infected slurry should be prevented by on-site treatment of liquid manure using chemical or physical-biological methods (10).

Figure 1. Animal faecal waste/disease relationships (15)



Chemical treatment. The aims of chemical treatment are:

a) Improvement of the nutritional value of the manure for plants.
b) Improvement of the consistency of the manure for further processing
c) Improvement of the hygienic quality of the manure by disinfection which in certain cases can be connected with deodorisation.

Disinfectants have to be chosen from the point of view that they should be harmless to the crops after the subsequent agricultural application of the disinfected slurry, and that they should be allowed by the responsible authorities.

Physical-biological treatment. The aim of this treatment is to reduce odorous substances, to destroy pathogenic organisms and to produce an acceptable organic matter content in the effluent. The following methods are used:

a) Anaerobic treatment
   - lagoons
   - digesters
b) Aerobic treatment
   - lagoons
   - mechanical aeration
      - oxidation ditches
      - surface aeration
      - rotating aeration

According to recent experiences none of these procedures is completely successful. The rotating aeration succeeds in so far as hygienic measures are concerned.

c) Composting.

By the traditional method of storing in heaps or windrows the mass is reduced. For the destruction of pathogenic microorganisms, higher temperatures are necessary. This can be achieved by composting faeces with bedding or by adding substances to the slurry which support aeration of the compost (e.g. straw, municipal refuse, leaves, peat or dry compost from the return-flow of the same composting process.)

3.2.2. Recycling. There has been a major trend recently to recycle animal faeces through animal populations as a source of food. For example, poultry manure is now used as cattle feed on a large scale in many parts of the world. Such practices, while in general commendable, introduce new risks, as for example the risk that man may acquire poultry zoonoses such as salmonellosis from cattle products. The waste for recycling, therefore, has to be free from pathogenic microorganisms and the level of residues from feed additives, therapeutic agents, and toxic substances should not exceed the international standards (if there are any).

Recycling of wastes in the aquaculture of fish and shellfish as fish feed often lacks hygienic precautions. Pretreatment of effluents is essential as shown by transmission of diseases through shellfish produced in polluted waters.

Fish raised in oxidation ponds readily acquire objectionable tastes and odours from their environment and strict quality control prior to marketing is required. Cleansing of fish or shellfish involves holding the animals in fresh water for appropriate periods. Oxidation ponds are often marginal or unsuitable for fish life. Hygienic aspects are also involved in the procedure of diluting effluents or treated effluents by mixing them as "fertilizer" with estuarine or fresh water. (8)

Adequate testing of agricultural residues at the earliest possible stage should be a part of all utilization approaches. This testing should include all possible health hazards. In doing so, decisions on suitable technologies or modifications in the technology can be made in the light of the test results.

As has already been shown in the section concerning food processing wastes that municipal sewage contains considerable amounts of pathogenic microorganisms. Sewage sludge is a concentrate of all pathogens occurring in sewage. Depending on its origin it also contains toxic concentrations of heavy metals. Even if the use of animals to recycle such wastes could make a contribution to the solution of environmental health problems as well as to the campaign against human hunger, it should not be allowed at the present time. Much preliminary research is still required. For instance, it is comparatively easy, with cost the only consideration, to destroy the pathogens in the sludge before it is used as animal feed. However, as yet, there is no known reliable method of eliminating the toxic heavy metals and other toxic substances. Furthermore, all methods of dressing these sludges as animal feed have to be economical because they have to compete with other kinds of feed available on the world market.

The same hygienic principles must also be applied to sewage farming. If the sewage or sludge is not disinfected before being used for agricultural purposes, special regulations are needed concerning the crops on which it may be used, the duration and amount of spray irrigation, security distances from other fields, living quarters and public roads, and the period of time after irrigation which must elapse before the crops may be used for human or animal consumption.

Health agencies all over the world will not succeed with eradication programmes, such as those for salmonellosis and tape-worm infections, if the recycling of animal and human wastes is not kept under their control. Many agricultural people still seem to be uncertain of the danger to themselves, their animals, and ultimately to the consumer, arising from the uncontrolled and aimless use of human wastes as a soil improver, fertilizer, or animal feed.

3.2.3 Common hygienic problems

3.2.3.1 Soil and water contamination. In numerous animal production units the number of animals compared with the agricultural acreage available is excessive. Therefore all the excrement cannot be spread on the agricultural fields available without impairing the soil and plants. Large amounts of slurry and nutrients being applied over several years make it impossible for the over-stressed soil filter to retain the nutrients absorbed along with the liquid manure any longer. The application of very heavy loads of slurry to soils with relatively high water saturation levels allows liquid manure to sink into lower depths or to flow over and run off. The consequence is pollution of ground and surface waters. Thus, in north-west Germany, a nitrogen concentration of 94 mg/litre was found in ground water under fields treated with excessive amounts of slurry. This is more than double the maximum value for drinking water recommended by WHO to avoid the methaemoglobinaemia in babies whose food is prepared with it. The possibility that runoff from manured fields may cause fish kills in surface waters has already been mentioned earlier.

In some areas of the Federal Republic of Germany, the number of animals kept per hectare is extremely high and the above-mentioned danger for soils and ground waters is great. Thus, legislation is in preparation which allows only the "usual rate" of animals per unit area i.e. three "manure livestock units" (MLU) per hectare. One MLU is equivalent to a yearly excretion of 80 kg N and 70 kg P_2O_5.

The heavy manure load on the fields in some parts of the Netherlands is the reason why farmers ship their surplus of manure to other parts of the country. As the organizational basis of this transfer, so-called "manure-banks" have been established to act as a brokerage between farms with manure surplus and those that need organic fertilizers. Thus, in Holland in 1973/74 and in 1975, 75 000 tonnes and 395 000 tonnes of slurry, respectively, were transported in tank wagons to other parts of the country. But this transportation of manure of unknown origin could create an extremely high epidemiological risk for the importing farmer. Therefore an official statement from the responsible state veterinary officer is necessary to confirm that the transported manure is free from pathogenic microorganisms.(9)

Microbial water contamination. Effluent from feed lots may contain large numbers of pathogens since some animals eliminate pathogens without showing any signs of infection or illness. Thus, feed lot wastewaters discharged into rivers must always be disinfected as treatment by the settling of solids, aeration, or sludge drying usually will not eradicate the pathogens from infected liquid manures. Chlorine disinfection is the method most commonly used. When properly applied and controlled, this is an effective measure for improving the bacteriological quality of the wastewater and for protecting the human and animal population against the transmission of enteric and other diseases by this route.(9) On the other side there are concerns regarding potentially toxic substances formed during the chlorination of heavily contaminated waste treams. Other disinfecting agents like ozone are presently under investigation in various countries. In general it is to be stated that effective disinfection can only be achieved if effluents are low in suspended solids and BOD_5.

3.2.3.2 Problems with antibiotics. In the early 1950's, the feeding of diets containing low levels of antibiotics was found to increase the growth of farm animals. Commercially, this was a major breakthrough in the intensive farming of animals. However, it was soon found that the widespread use of antibiotics for non-therapeutic purposes resulted in the development of microorganisms which became resistant to antibiotics.

The situation was made worse by the fact that some bacteria became capable of transferring their antibiotic resistance to organisms which had not had contact with these antibiotics. Although scientists recognize that the transmission of drug resistance poses a real threat to disease control in both man and animals, no one seriously recommends that the use or production of antibiotics should be discontinued. However, transferable resistance is a serious problem and everybody facing it should be aware of its public health implications. Understanding the phenomenon of resistance helps to explain why some patients do not respond to the therapy. If transferable resistance proved to be more common than has been shown so far, and there is much evidence that this is so, the discharge of feedlot wastes must be considered as a massive source of resistant bacterial strains.(9)

The nonmedical and indiscriminate medical applications of antibacterial drugs have subjected most domestic animal populations in the developed countries to extensive antibiotic pressures. Products of these animals that enter the food chain of man are ideal prerequisites for the creation of ecological problems such as the administration of subtherapeutic quantities of antibiotics throughout most of a lifetime.

The effects of widespread antibacterial drug use are difficult to determine with the current state of the science. Many unanswered questions exist and basic information is lacking. Some public health investigators believe that domestic animals serve as reservoirs of pathogenic drug-resistant organisms or of nonpathogenic organisms that have the ability to transfer drug resistance to organisms that are pathogenic to man. The implications of feeding antibiotics to livestock and poultry with the spread of animal organisms on meat and meat products during slaughter, processing, and packaging are enormous. From other investigations, it has been inferred that animals cannot be a major source of resistant coli bacteria for man since he is already the carrier of antibiotic resistant coli bacteria of human origin. In either case this problem must be scrutinized very carefully in the future.

The ingestion of antibacterial drugs, their metabolites, and degradation products through the meat portion of man's food supply is a problem which can be corrected by satisfactory testing programmes as has been shown in some countries. A realistic random sampling programme with subsequent condemnation of the meat and enforcement of the existing regulations greatly minimized the residue problem in these countries.

Many countries have begun to reduce the number of antibiotics which are allowed as feed additives, especially those which are urgently needed for therapy in human medicine. Furthermore, new substances on the market are reported not to be resorbed and hence will not get into food of animal origin. The manufactureres also claim that these antibiotics do not produce transferable resistance. If this can be confirmed in long-term experiments the problem will be closer to being solved. Thus, it seems that the problems man has created in his environment by the injudicious use of antibacterial drugs in animals can be greatly reduced. Possibly some interested groups will lose markets and income if more drugs are restricted and nonefficacious uses are eliminated; however, such benefits as a reduction in public health problems and more efficient animal production will be appreciated by many.(11)

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I. TERMS AND DEFINITIONS

To facilitate a better understanding of the use of different terms and definitions frequently adopted in this paper, it is indispensable to clarify the different meanings of such terms and definitions. This is particularly necessary in a legal paper dealing with technical problems. In fact, in various glossaries, in texts on environmental law, in reports and papers of international institutions, in national laws on environmental protection, the basic terms do not always have the same meaning, and often there are substantial discrepancies between them.

For example, as concerns the term "WASTE" there are two pragmatic definitions from the point of view of economics. The first defines waste as: "matter which has no market value and which the holder no longer wants in a given place at a given time." 1/ The second one, considers waste: "any material which may have marketable value but is not utilized." 2/

In our opinion, the following definition is technically more accurate: "Any part (liquid, solid or gaseous) of a product, resulting from operation processes or from consumption, which can no longer be used for its originally intended purpose." 3/

Likewise, the term "RESIDUE", refers to wastes in general, often with different meanings such as scraps and left-overs from working processes, byproducts, and broadly, substances, materials and energies still present in something after its primary use." 4/

On the other hand; the definition of "RESIDUE" in technical terms is: "that particular substance or active principle (i.e. radioactivity) which is still active in the environment after its initial use" (e.g. DDT, TCDD). 5/

To stress our point, we refer to a report ECE, 22.11.1974 (ENV/R.24, p. 14, item 54); where the expression "residual waste products" is used to indicate what should be considered reusable.

We realize that these definitions are used conventionally, also according to subjective criteria often partially or completely overlapping in their meaning.

In law, uniform definitions are necessary to facilitate a better understanding of the subject matter and to avoid confusion in the use of the most frequent terms.

After this short introduction, we want to mention what we consider could be the final definition of some technical terms, and mean to expand further on these points during the preparatory work of the Seminar.

1/ Y. MAYSTRE General Report, ECE Seminar on the collection, disposal, treatment and recycling of Solid Wastes, ENV/SEM. 3/R.1, 3 June, 1975, p.3, item 9.

2/ J.N. WINBURNE, <u>A Dictionary of Agricultural and Allied Terminology</u>, Michigan University Press, 1962, term "waste" (1), p. 852.

3/ EEC, G.U. n.C146/6, 16th November, 1974; APHA et al., Glossary: Wastes and Wastewater Control Engineering, by W.T. INGRAM, 1969, term "waste" (3), p.366.

4/ See Intróductory Paper by FAO on the Agro-Wastes Seminar.

5/ J.N. WINBURNE, <u>A Dictionary of Agricultural and Allied Terminology</u>, terms "Residue" and "Residual effect," p. 635.

REFUSE: "any waste product of solid or semi-fluid materials". 1/

RESIDUE: a particular substance or active principle, which continues to be active in the environment after its initial use has terminated. 2/

POLLUTION: the contamination of environment (of one or more of its natural resources, such as: air surface or ground waters, soil, wildlife) by any substances or active principles of such size, condition and quality as to determine undesirable biological, chemical or physical alterations of the environmental characteristics and ecological balances, and consequent damages or noxious effects to human beings and their activities as well as to public or private property. 3/

POLLUTANT: any agent causing "pollution" (see above)

AGRICULTURAL AND AGRO-INDUSTRIAL ACTIVITY: an activity which produces agricultural commodities (plants, vegetables, crops and animals), and by way of processes and treatments, deals with the use and conservation of these commodities exploiting their full value. 4/

BYPRODUCT: any part of a product which is not utilized by the main productive process concerned. 5/

Examples:

Product:	Meat	Byproduct:	Skin, Blood	Waste:	Viscera
"	Wheat	"	Straw	"	Stubble

It is evident that the two concepts of "pollutant" and "residue" are in a functional relationship to each other, inasmuch as the former is the noxious effect of the presence of a residue in the environment.

The difference between "wastes", "goods", and "pollutants", is clearly outlined by Maystre 6/ according to whom waste is still controlled by man, whereas a pollutant is no longer subject to his control; thus its recovery from nature is no longer possible. It can only be abated or purified.

1/ See Greece, San. Reg. n.E1B 301/10.2.1964, sec. 1.1.)

2/ See Winburne, A Dictionary of Agricultural and Allied Terminology, Michigan University Press, 1962, terms "Residue" and "Residual Effect", p.536.

3/ See F.P. GRAD, Environmental Law, New York 1971, par. 1.01 (1) p.7; CILF, Vocabulaire de l'Environnement, Paris 1972, terms "Pollutant" and "Pollution" n. 315-316; DELL'ANNO, La Tutela Giuridica Contro Gli Inquinamenti Ambientali, L'Aquila 1974.

4/ See Winburne, A Dictionary of Agricultural and Allied Terminology cit. term "Agriculture".

5/ See Winburne, A Dictionary of Agricultural and Allied Terminology, cit. term "Wastes" p. 852.

6/ See p. 3-4, cit.

II GENERAL SURVEY OF EXISTING NATIONAL LEGISLATION

2.1 Two directives have been followed for a general survey of legislations governing environmental protection in various nations, and, more specifically, agro-waste disposal and reutilization. Firstly, research has been made on the legislation of various single nations; secondly a Questionnaire has been prepared and distributed, so that the most relevant problems could be adequately examined. In this Questionnaire, agro-wastes problems have been considered from two points of view: a) environment protection and human health and b) recovery, recycling and reutilization of agricultural and agro-industrial wastes with the final aim to obtain goods and sources of energy.

The Questionnaire is worth careful examination as it may offer a useful methodological approach to the problem.

The first problem taken into account was the approach of separate states to the problem of protection of the environment from pollution:

2.1.1 Does present legislation inolude an organic law for the control of pollution from agricultural and agro-industrial wastes?

211.2 If so, does it take into account pollution from livestock?

2.1.3 Is the legislative control directed to prevent air pollution?

2.1.4/1.5 To prevent soil pollution and public property pollution?

2.1.6/1.7 To prevent water pollution?

The Questionnaire then investigates whether the setting up of equipment and plants to prevent pollution is obligatory for obtaining a permit for certain agricultural activities, or if it is simply encouraged.

2.2.1 Is the adoption of purification plants or other nati-pollution measures obligatory?

2.2.2 Is the adoption of such installations encouraged by tax exemptions?

2.2.3 By loan facilities?

2.2.4 By other forms of assistance?

In order to know if the State considers environmental protection as a primary objective to be achieved by prohibiting the dispersion of wastes and by providing incentives for their reutilization, the Questionnaire includes the following items:

2.3.1 Does the legislation provide regulations with an aim to the prevention of pollution through agricultural waste management and utilization?

2.3.2 Is this utilization encouraged by tax exemptions?

2.3.3 Or loan facilities?

2.3.4 Or other forms or means of assistance?

As reutilization of agro-wastes, and especially organic wastes raises particular problems from the hygienic and sanitary points of view, more information is required:

2.4.1 Does sanitary legislation regulate disposal of wastes from agricultural operations?

2.4.2 Does it cover the utilization of livestock wastes (excrements, horns, bones, nails, feathers, viscera, fats etc.) ?

2.4.3 Can wastes be utilized for human food?

2.4.4 For livestock feeding?

2.4.5 As fertilizers?

2.4.6 For other uses?

Most infectious cattle diseases are spread by wastes and residues. In view of this, the Questionnaire makes the following enquiries on veterinary measures:

2.5.1 When wastes are utilized for livestock feeding, are special precautions taken in order to prevent and avoid the spread of infectious disease?

2.5.2 If wastes can be used as fertilizer, is adequate treatment in order to avoid the spread of infectious diseases mandatory?

2.5.3 Is waste purification treatment subject to public control?

Since the purification or reutilization of wastes may frequently not be carried out at their source, the following enquiries were made concerning legal measures concerning transportation, import and export of residues and wastes:

2.6.1 Is the transport of residues of agricultural production practices subject to authorization?

2.6.2 Is the import of wastes permitted?

2.6.3 Is the export of wastes permitted?

2.2 From the answers to the Questionnaire and the research on single legislations, it is possible to establish general trends in environmental protection, particularly in agriculture. Almost all the examined countries have a law or at least a group of norms concerning environmental protection. Only a few countries have adopted an organic law providing for environmental protection from all the possible sources of pollution (USA, Canada, United Kingdom, Denmark, Sweden, Norway, Switzerland, Federal Republic of Germany, Japan).

The same countries have enacted laws governing the protection of the environment from agricultural and agro-industrial pollution.

Certain countries have special provisions for feedlots (Italy, Federal Republic of Germany).

In other countries, norms governing agro-pollution are often to be found in laws not dealing specifically with the environmental laws, (criminal laws, water legislation, sanitary and veterinary legislation).

Air pollution control: nearly every country considered has legislation regulating air pollution control. Pollutants from agricultural activities, however, are governed in a generical manner and sometimes leave important pollution factors such as odors and noise unprovided for (e.g. Japan only, has specific regulations concerning odours and noise).

It should be mentioned that control of air pollution in countries with a market economy is affected to some extent through the mechanisms of private law when damage to private property is a direct result. In such cases the private citizen or enterprise is empowered to act through administrative or judicial action in order to impede pollution and claim damages by the polluter (Italy, Federal Republic of Germany).

Soil pollution control: National Legislation generally governs only solid waste disposal, considering the fact that underground or surface water may be polluted through the soil. Only in a few countries, e.g. Norway, Denmark and Federal Republic of Germany are there laws providing a fixed maximum to the quantity of manure that can be spread on a field.

Water pollution control: Nearly all the legislation contains provisions both for public and for private waters, if existing. The control of pollution sources is particularly rigorous for water supply systems. Moreover, in water resources protection areas, several countries prohibit the spreading of manure on the fields (e.g. Canada, United Kingdom, France, Denmark, Sweden, Greece, Bulgaria, U.S.S.R.).

Anti-pollution measures: The use of depurating plants for agricultural and agro-industrial activities which pollute is provided for in all the member countries of EEC, in Greece, Norway, Sweden, USA, Japan.

A number of laws fix obligatory measures so that pollution from agricultural activities may be eliminated or reduced (e.g. Switzerland and Finland establish a store capacity for liquid and solid manure to be dealt with).

The adoption of depurating plants is encouraged by tax exemptions (Federal Republic of Germany, Japan), or by other forms of incentives(in Moscow, USSR, the correct use and running of depurating plants is a prerequisite for the quarterly production award to industrial managers in Moscow, and in Japan financial facilitation is provided particularly for small and medium industry).

Recovery and reutilization of agro-wastes: The laws of few nations are specifically concerned with the problem of the recovery and the reutilization of agro-wastes, to avoid pollution and to reutilize available natural resources.

In most countries, this problem has been given little legislative attention and laws on the subject are at an initial stage.

Health protection: Considerable legislation provides for disposal and use of agro-wastes, so that harmful effects for human health may be avoided and that epizootic diseases may be prevented. For example, Greece prohibits the use of agricultural residues for human consumption. Hygienic problems arise in many countries when the products of agro-wastes used as animal feed may eventually be consumed by humans. (e.g. in the USA the use of fish viscera is not allowed for animal feeding,. and in Denmark strict norms fix the sterilization of products used for animal feeding). National legislations have a different approach to the use of agro-wastes as fertilizers: some of them prohibit the use of waste waters from certain sources for irrigation. (Czechoslovakia, for example, from meat processing plants, plants for processing roasting poultry and other agro-industries), others specify special treatments before spreading, or for the use of crops so treated (Federal Republic of Germany, Norway, Finland, Israel, South Africa, USA).

For public health protection, limitations are very often established regarding transport, import and export of agro-wastes.

In order to indicate the types of existing legislation, the following countries have been chosen as prototypes of different legislation:

United States of America
Canada
Union of Soviet Socialist Republics
Italy
Federal Republic of Germany
Denmark
Greece
Japan

In the course of preparing the present paper, the International Juridical Organization has carried out research on the legislation of other countries. The additional country studies, together with an introductory analysis of socio-economic aspects of legislation, were also submitted as part of the IJO report to the Secretariat of the FAO/UNEP Seminar, but for reasons of space could not be included in the present paper.

UNITED STATES OF AMERICA *

In the United States the past 10 years have been of particular importance for the development of legislation governing waste management and residue utilization in general, and of agro-waste and agro-industry management in particular.

The Environmental Protection Agency (EPA, established in 1970) has the responsibility to see that certain federal environmental legislation in the United States is enforced and effective.

At the federal level, the basic laws are the following:-

a) the Water Quality Act (1965) which requires establishment and enforcement of standards for all interstate waters;

b) the Solid Waste Disposal Act (1965) amended in 1970 as the Resource Recovery Act, states (Sect.209 (a)) that the guidelines for solid waste recovery "shall be consistent with water and air quality standards, public health and welfare considerations, and land use plans", (see National Symposium on Animal Waste Management, Animal Waste Management, Warrenton VA, 1971 p. 13), and that the Act applies to agricultural waste management systems, including animal waste management;

c) the Federal Water Pollution Control Act, as amended (1972) emphasizes the development of technology-based effluent limitations in the control of waste discharge point sources, including feedlots. All the laws provide federal supervision of pollution control. Each State is empowered to develop water quality criteria and the relative enforcement measures. These laws stress preventive as well as corrective measures. Noxious wastes are to be kept out of the water rather than reduced or counteracted.

The Federal Water Pollution Control Act, indicates three control levels and their respectively different technologies: Best Practicable Control Technology Currently Available (hereinafter BPCTCA) and Best Available Technology Economically Achievable (BATEA), both applicable to existing sources and to be applied at five-year intervals, and Best Available Demonstrated Control Technology (BADCT), for new pollution sources, all of which were to move towards the goal of elimination of the discharge of pollutants into the navigable waters of the United States by 1985. This Act enumerates a number of agricultural operations (dairy product processing, fruit and vegetables processing, seafood processing, feedlots and fertilizer processing) to be included among the point sources subject to effluent limitations. The stress however is on the aim to be achieved, not on the means to be used, and sources are to be controlled through effluent limitations.

EPA's action has been moving in this direction by evaluating all the relevant factors, particularly the costs of the three levels of technology, which have been calculated by considering capital investment, operating and maintenance costs and energy and power cost. The factors relevant to identifying the technologies stated in the Act are:- (see Loehr and Denit, Effluent Regulations for Animal Feedlots in the United States, paper presented at the International Seminar on Animal Wastes, Bratislava, Sept-Oct 1975 pg. 6).

" a) the total cost of application of the technology in relation to the effluent reduction benefits to be achieved from such application;

b) the age of the equipment and facilities involved;

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* Extracts from internal reports by P. Foster and M. Traylor.

" c) the process employed;

d) the engineering aspects of applying various types of control technologies;

e) process changes;

f) the non-water quality environmental impact including energy requirements" ;

(see Loehr and Denit, cit., pg-5-6)

The trend is then to achieve "the maximum use of technology within economic limits." (see Loehr and Denit, cit, pg. 4).

The Agency (using a procedure proposed and partly put into practice in 1971 by the Corps of Engineers) has been able to promulgate regulations for all discharges including feedlot operators, to obtain permits governing the issuing of permits by the States (1972) and governing permits issued by EPA itself (1973).

Both regulations specify that all discharges of pollutants from all point sources into navigable waterways are unlawful unless the discharger has a permit or is exempted by statute from having such a permit. (see Foster cit, pg. 20).

At the same time EPA has dealt with the specific problem of discharge of animal wastes, including those from feedlots, proposing to exempt all feedlots with less than 1 000 animal units, a proposal which was later (1973) changed, exempting all except about 4 105 feedlots from the programme. This programme has led to the "National Pollutant Discharge Elimination System" (NPDES) permit programme which has been amended (March 1976) to reach the following structures:- (see Federal Register, vol. 41 n.54, 18th March, 1976 pg. 11458).

Feedlots with 1000 or more animal units	Feedlots with less than 1000 but with 300 or more animal units	Feedlots with less than 300 animal units
Permit required for all feedlots with discharges of pollutants 1/	Permit required if feedlot- 1)discharges 1/ pollutants through a man-made conveyance, or 2)discharges 1/pollutants into waters passing through or coming into direct contact with animals in the confined area. Feedlots subject to case by case designation requiring an individual permit only after on site inspection and notice to the owner or operator.	No permit required (unless case by case designation as provided below). Case by case designation only if feedlot- 1)discharges pollutants through a man-made conveyance; or 2)discharges pollutants into waters passing through or coming into direct contact with the animals in the confined area; and After on site inspection written notices transmitted to the owner or operator.

1/ Feedlots not subject to requirement to obtain permit if discharge occurs only in the event of a 25-yr, 24-H storm event.

As a matter of fact, emphasis is on the flexibility of controls ("the case by case" designation) within the boundaries of very definite standards.

We may now examine State laws on agro and agro-industry waste management. State powers include police power which in the United States is carefully reserved to the States.

At the present time State statutes carry the heaviest burden of pollution regulations in agriculture, and each State may have its own code of pollution regulation statutes, varying from State to State as a function of its geographical and economic factors. (see Traylor, Prototypes: New Jersey, Pennsylvania, Ohio, California, Waste Management and Residue Utilization).

The structure of State pollution regulation laws are quite similar and generally have the following pattern:-

1) Statement of purpose and definitions of pollution and its expected sources, within agriculture and agro-industry.

2) Setting up of an administrative agency staffed by experts and provided with power to establish regulations, including standards and measurements of pollution, to be applied by the field officers of the agency. An administrative tribunal is always included within the agency itself where conflicts may be resolved. These tribunals are usually staffed by attorneys having special expertise for pollution control. Access is always guaranteed to the regular court system by the statutes after the administrative judicial remedies have been exhausted (which fulfills the constitutional requirement of due process of law). An example of a specific method of judicial review of pollution often applied to agriculture and agro-industry is the procedure in Pennsylvania where a pollution control enforcement official may issue a summons to the person responsible when he notes an infraction. The case is then handled in a court of initial jurisdiction in the area. Appeal through the regular judiciary system is available.

3) Establishing of sanctions of a criminal nature which may give rise to civil liability. Municipalities as well as individual citizens who provide their services for a fee are responsible for checking on infringements.

A more specific survey of State statutes shows a problem that has only recently been solved - the definition of the boundaries between agriculture and industry, especially for agro-industries. By now, a threefold distinction has been set up:-

- solid waste
- water pollution by waste
- air pollution (toxic and noxious odours and matters carried into the air by open burning).

There is a Solid Waste Disposal Act in most States which may regulate how waste must be transported, stored and processed, with possibly a difference between regulations for large and small farms. In the case of agro-industry, waste products from industrial processes must be removed from the area of production.

Regarding air pollution, the traditional practice of controlled burning is no longer satisfactory where residential developments have been set up in rural areas. Some State statutes provide means by which agriculture and forest management officials may acquire permits to burn under controlled conditions of air movement and time limitations. (i.e. in California).

One advanced example worth considering is the New Jersey statute which makes solid waste collection and disposal a public utility, so that the services rendered are publicly administered and financed like the provision of electrical service. This operation is regulated and controlled by the Board of Public Utility Commissioners as well as by the State Department of Environmental Protection.

CANADA

In Canada the responsibility in the field of agricultural and agro-industrial waste management is divided between the federal departments of Agriculture and Environment on one side, and of provincial Agriculture and Environment Management departments on the other.

Two areas of direct involvement by the federal government are tax exemptions and import/export controls.

Tax exemptions are regulated by the Accelerated Capital Cost Allowance Programme, a federal programme designed to encourage business to control pollution. Under its terms, an eligible taxpayer may write off the total cost of equipment or processes installed for the prime purpose of controlling air and water pollution over a two year period, that is 50% per year. The expenditures may cover the cost of prevention, reduction or elimination of pollution. Air and water pollution are specifically dealt with, while there is no specific regulation concerning land pollution. This programme, administered by the Environmental Protection Service of the Department of the Environment, has been extended for two years until the end of 1976. However, the pollution control assets must be acquired to abate pollution caused by operations which were in existence at a site in Canada prior to 1974. If pollution control assets are acquired for a building or plant, construction of that building or plant must have commenced under agreement in writing prior to 1974.

The Farm Credit Corporation (FCC), furthermore, administrates the Farm Credit Loans: these are credits for upgrading or developing manure management systems or for the acquisition of equipment for manure handling and storage programmes loaned to livestock operators.

In the area of export and import controls, there are no controls on the export of agricultural wastes. However, it is doubtful if any country would allow the import of untreated wastes, so the question is purely theoretical. Certainly, untreated animal wastes are not allowed to be imported into Canada, and any wastes which have been treated by composting require authorization for import from the Federal Department of Agriculture.

A general survey of the existing situation both at federal and at provincial level is offered by Table 1.

In any case, and generally speaking, a comprehensive approach to pollution control and agro-wastes management has been adopted by each province through sanitary legislation, controlling water pollution phenomena that may be dangerous for public health.

Specifically at provincial level, in a few cases legislation is rather general and may be applied to livestock operations if necessity arises. In a few provinces (British Columbia, Manitoba and Ontario) there exists a distinction between different agricultural activities, and those considered normal are exempted from regulations concerning waste management. Cooperation between interdepartment or government agencies and agricultural operators is essential: see Table 2 for more specific information. The current instruments used are codes of practices, information or guideline programmes, Certificate of Compliance programmes, etc.

In several provinces land use zoning which could effect the actual location and manure handling programmes in livestock operations has the priority. In Ontario, a Minimum Distance Separation (MDS) formula system has been adopted, which consists of three different levels for three different situations. In Quebec, regulations for land zoning are based on the soil/climate relationship to agricultural productivity.

A more detailed survey of the situation existing in Ontario shows that the Waste Management Act specifically indicates research for waste management and disposal, and the Government is empowered to make grants and loans for the development of waste management facilities in such amounts and upon such terms and conditions as the regulations may prescribe (S.3). Depositing, emitting or discharging pollutants into the environment (S.5.(1)) in an amount, concentration or level in excess of that prescribed by the regulations, is prohibited.

In case of violations or danger to public health, the Director of the Department of Environment is empowered to issue control orders or stop orders.

Any new installation or modification in plants or processes which may become a source of pollution must be approved by the Director, who must be informed of its location and technological characteristics as well as of the quality and quantity of discharges. The discharge or depositing of pollutants, noise, noxious odors harmful or dangerous to persons, fauna, flora or property is likewise prohibited.

However, such regulations are not applicable to agricultural activities, as the law expressly stipulates (S.8.(4); 14.(2); 15.(2)). In particular, the prohibition of depositing, emitting or discharging pollutants (S.5.(1)), does not concern animal wastes disposed of in accordance with normal farming practices (S.5.(2)). Likewise, existing legislation in the Provinces of British Columbia and Manitoba, provides that reasonable land disposal from traditional farm operations is exempted from certain requirements of their Acts.

According to the above-mentioned Environmental Protection Act (1971) in Ontario, the user or establishment of a waste management system or a waste disposal site are subject to the approval of the Director, subject to revocation because of violations or danger (S.31). The Director indicates the conditions (including financial grants or deposits) to be observed by the interested party. No waste discharge is allowed outside of waste disposal sites. Violations are subject to fines up to US$ 2 000.

The use of pesticides and herbicides is subject to license or permit issued by the Director of the Department, which may be revoked because of violations of laws or regulations or because of incompetence.

A procedure of compensation for damages to livestock, crops, trees or other vegetation has been provided for as well.

After the foregoing survey on a federal as well as on a provincial basis, a recapitulation of the existing laws on the subject shows the following characteristics:

- there is no lack in legislation affecting agricultural and agro-industrial waste management, whereas there is a lack of awareness of the importance and effectiveness of such laws. Generally these laws have been used in a restrictive sense and instead of using them preventively they have only brought remedy to damages already done;
- in many cases, intensive livestock operations have been dealt with as agricultural activities, not as industrial complexes; they have been exempted from industrial effluent requirements, or their discharges have not been considered as environmental polluters;
- the activity to be developed in the future shall be based on the following characteristics:
  - guidelines, codes of practices, recommended practice programmes shall develop in a uniform manner and minimum standards for livestock concerns effluent regulations shall be prepared;
  - provincial authorities shall regulate their own programmes of standards and regulatory action on the basis of national guidelines under the joint responsibility of the Federal Departments of Agriculture and Environment.

TABLE 1

LEGISLATION RELEVANT TO LIVESTOCK MANURE MANAGEMENT IN CANADA*

Province	Legislation	Administration Body Responsible for Implementation
All provinces and territories under Canadian Jurisdiction	The Fisheries Act, 1970	Environment Canada
Newfoundland and Labrador	Waste Material and (Disposal) Act '73 Stipulations for Livestock Operators**	Dept. of Provincial Affairs and Environment
	Dept. of Provincial Affairs and Environment Act, 1973	id. id.
	The Waters Protection Act, 1970	id. id.
	Dept. of Health Act, 1970	Department of Health
Prince Edward Island	Environment Control Commission Act, 1971	Prince Edward Island Environmental Control Commission
	Public Health Act, 1951	Dept. of Health and Welfare
Nova Scotia	Environmental Protection Act, 1973	Dept. of Environment
	Public Health Act, 1967	Dept. of Public Health
New Brunswick	Clean Environment Act, 1971	Dept. of Fisheries and Environment
	Water Act, 1961	id. id.
	Health Act, 1952, Regulation 66-43	Dept. of Health and Welfare
Quebec	Environment Quality Act, 1972	Environmental Protection Services (Dept. of Environment)
	Guidelines for the development of livestock production facilities ***	
	Public Health Protection Act, 1972 Regulation 15	Minister of Social Affairs (Dept. of Health)
Ontario	The Environmental Protection Act, '71	Ministry of Environment
	Ontario Water Resources Act, 1970	id. id.
	The Public Health Act, 1970	Ministry of Health
	Waste Management Act, 1970	
Manitoba	The Clean Environment Act, 1972 Regulation 34/73	Environmental Management Division Department of Mines, Resources and Environmental Management
	Public Health Act, 1965	Department of Health
Saskatchewan	The Pollution (By Livestock) Control Act, 1971 Regulation 204/74	Department of Agriculture

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* Dwyer Rigby M., A Review of Legislation affecting Manure Management in the Canadian Livestock Industry, 1975

** Draft form only as of December 1974, not legislation as yet. Intended to be amendment to Section 23 of Waste Material (Disposal) Act. 13 point stipulation programme was used experimentally during fall of 1974.

*** Programme is operated under the auspices of Environmental Protection Services, not legislation as yet. Jurisdiction - falls under Section 30, Regulations, of the Act.

TABLE 1 (cont'd)

Province	Legislation	Administration Body Responsible for Implementation
Alberta	The Clean Water Act, 1971	Department of the Environment
	The Clean Air Act, 1971	id. id.
	The Public Health Act, 1970 Regulation 297/72	Dept. of Health and Social Development
British Columbia	The Pollution Control Act, 1967	Pollution Control Branch, Dept. of Lands, Forests and Water Resources
	The Health Act, 1973	Inspection Services, Department of Health

TABLE 2

PROVINCIAL PROGRAMMES AIMED AT REGULATING OR STANDARDIZING LIVESTOCK MANURE MANAGEMENT - DECEMBER 1974*

Province	Responsible Government Agency	Programme
Newfoundland	Environment Division Department of Provincial Affairs and Environment	** "Stipulations for Livestock Operations" a 13 point programme related to the standards expected in the operations of livestock facilities is in experimental use.
Prince Edward Island	Department of Agriculture and Forestry and Environmental Control Commission.	***"Guidelines for Livestock Manure and Waste Management in the Atlantic Region" is in draft form.
Nova Scotia	Department of Agriculture and Marketing, and Department of Environment	*** "Guidelines for Livestock Manure and Waste Management in the Atlantic Region" is in draft form.
New Brunswick	Department of Agriculture and Rural Development and Department of Fisheries and Environment	*** Guidelines for Livestock Manure and Waste Management in the Atlantic Region" is in draft form
Quebec	Department of Environment	Livestock operators with a liquid manure system are required to apply for a permit to operate their facility. "Directives to livestock operators for the prevention of pollution".
Ontario	Ministry of the Environment, and	Voluntary Certificate of Compliance Programme
	Ministry of Agriculture and Food	****"Agriculture Code of Practice for Ontario". Farm Pollution Advisory Committee is responsible for assessing problem cases not rectified through government/operator cooperation.
Manitoba	Environmental Protection Branch, Environmental Management Division Department of Mines, Resources and Environmental Management	Regulation 34/73, Livestock Production Regulation. All livestock operations which fall into the size in terms of Animal Waste Units (LWU's) or into the locational aspects allocated in the regulation are required to register with the Branch.
Saskatchewan	Family Farm Improvement Branch, Saskatchewan Dept. of Agriculture	Reg. 204/74 all new or proposed expanding livestock facilities which fall into size or location categories specified in the regulations

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* Dwyer-Rigby, M.A., A Review of Legislation affecting Manure Management in the Canadian Livestock Industry, 1975

** The material is being implemented in an experimental programme form, it is not yet legislated.

*** A Certificate of Compliance Programme will be implemented in conjunction with the Guideline acceptance.

**** This Code is being revised and expanded. The new version should be available during the first half of 1975.

Table 2 (cont'd)

Province	Responsible Government Agency	Programme
		are required to apply for a permit to develop an Intensive Livestock Facility (ILO). "The Saskatchewan Intensive Livestock Operation Code of Good Practice" under the Pollution (by Livestock) Control Act, 1971.
Alberta	Department of Environment and Department of Agriculture	Voluntary Certificate of Compliance Programme. "Confinement Livestock Facilities Waste Management Code of Practice".
British Columbia	Department of Agriculture	"Animal Waste Management Guide" - Guidelines for Poultry, Swine, Dairy and Beef operators in British Columbia. Sanitation Committees are responsible for assessing problem situations.

UNION OF SOVIET SOCIALIST REPUBLICS - USSR

The directives for environmental protection through public intervention may be in large part summarized by a decree of the Supreme Soviet of USSR dealing with the "provisions for the ulterior improvement of the environment and the utilization of natural resources," issued September 20, 1972. This decree specifies and reaffirms that state ownership guarantees proper utilization of natural resources and an effective means of protection of the environment in USSR. Under these conditions planned management and rapid economic development are facilitated.

Rational utilization, conservation and renovation of natural resources which will protect the environment are a few of the provisions proposed in the XXIV Session of the CPSU, and included in the 1971-1975 five year plan for economic development.

In the 1976-1980 five year plan 1/, particular attention should be given to various directives which are designed to protect and improve environmental conditions in USSR.

Scientific and technical progress is considered a determining factor in the battle against the phenomena of waste and improper management.

A policy which unifies all sectors of the national economy must be adopted for the protection of the environment: Steps should be taken to implement techniques for the improvement of production as well as to control natural resource consumption, to increase investment returns, and to mend working conditions.

The above mentioned directives stress the importance of maximum utilization of all resources by minimizing losses, and the development of effective depuration plants in factories.

New methods have been suggested which will fight against noxious substances discharged in the air, excessive noise during production, transportation, etc., and the vibration and effects of radiation and of electrical and magnetic fields.

Forestry resources must be rationally utilized in the European part of USSR by increasing the amount of commerciable wood extracted from each individual woodland, and by accelerating the production in plants which process (through mechanical and chemical means) wooden by-products and low-quality timber. Paper pulp in the production of paper and card board must be utilized more efficiently. Technically advanced machinery which raise the rate of productivity of wood, celulose and paper are needed.

Systems and methods which will improve the fishing industry are needed as well. Again new machines, instruments and mechanisms must be developed which will mechanize and automize the fishing industry and the technical processing of fish and other sea products in order to raise the level of utilization of fish products in an assortment of foodstuffs.

Industries processing complex animal feed should increase their production by utilizing additives. The production of meat, milk, bone and fish surrogates should rise to meet zootechnical needs.

Microbiological industries must be developed and improved to assure an increased production of proteins used in animal feed, premixed products, and microbiological preparation which protect agricultural and agro-industrial activities. Scraps and by-products of food industries must be utilized more extensively as animal feed.

1/ Principle Directives of Economic Development for 1976-1980 (five year plan), Moscow, Dec. 1975.

A more organized method of food waste collection in commercial enterprises and inhabited areas, in general, should be adopted.

Livestock and poultry breeding must increase by improving maintenance conditions and nutrition and by applying the most advanced mechanical and technical systems. Veterinary assistance should also improve. Provisions for the perfection and reinforcement of services for the protection of cultivations in agriculture must be taken. Ulterior improvements for the protection of lands from fires, harmful insects, and diseases are to be made.

The principles established in the Final Act of the Conference on Security and Cooperation in Europe which ensure international collaboration in the field of "economics, science and techniques for the protection of the environment," are to be respected.

The report included in the state plan for the development of Russia's national economy for 1976 of the vice president of the Council of Ministries of the USSR and president of the Gosplan, deputy N.K. Bajbakov, 1/ establishes specific objectives for the protection of the environment and for the rational utilization of natural resources. In 1976 an increased construction of plants for the protection of water bodies from the discharges of industrial and zootechnical activities is anticipated. An increase of water reutilization and recycling by 7% in respect to 1975 is expected. The plan also contains objectives for the protection of mineral waters and underground waters. Furthermore, the number of plants which detect noxious impurities in gases freed from industrial discharges will increase.

There are numerous observations to be made concerning the legislation and the administrative structure regulating environmental protection in the USSR. The State Committee for the Planification of the Council of Ministries of the Soviet Union (Gosplan) regulates the use of natural resources while environmental control is directed by the single competent ministries.

The following laws concerning environmental protection are applicable in the USSR:

- Legal principles in agriculture, 13.12.1968;
- Legal principles in water management, 10.12.1970;
- Legal principles for public health, 19.12.1969.

The norms regulating and controlling the use of waters for agricultural activities request that all waters being publicly owned, their special use may only be permitted by a specific concession (art. 14 and 15 of Fundamental Principles in Water Legislation of the USSR and of the Federal Republics; at Vedomosti Verchovnogo Soveta, SSSR, n.50, December, 1970). "Special use" defines those activities of installations or technical constructions which alter the characteristics of the waters. This special use includes, therefore, irrigation and draining plants belonging to state organizations, colcos, sovcos and other consumers. Specific conditions control these special uses in order to avoid damage or waste. The irrigation of land by liquid run-off and drain water is permitted, provided there is also the authorization of the sanitary and veterinary authorities.

The protection of waters from pollutants of agricultural origin is also achieved by obliging the state water administrations, the colcos, the sovcos and every enterprise, organization and plant to avoid contamination of waters with animal feed and toxic substances used in the protection of cultivations.

1/ Pravda, Moscow, 3/12/1975.

The legal principles in agriculture underline that "the rational and scientifically justifiable utilization of as much land as possible as well as the increasing and protecting of the soil's fertility comprises an important capital for the entire population."

Certain articles determine the duties of the farmers as they relate to the rational utilization of the land and the concrete adoption of provisions for the improvement of the State.

The legal principles set forth both penal and civil punishments for farmers conducting anti-economical, deteriorated or destroyed cultivations, or for those who do not take into consideration the necessary provisions which protect and combat against the process of soil depletion.

Ample legislation exists also in the various Federal Republics. For example, art.223 of the penal code of the Russian Republic states that "pollution of rivers, lakes and other water bodies or sources of discharge of waters which are not purified or noxious in any way, or utilized for industrial or agricultural waste disposal, (...), which cause or may cause damage to the health of persons, to agricultural production or fisheries, as well as air pollution of harmful industrial discharges, are punishable with sentences of up to one year imprisonment or with fines of up to 300 rubles."

Even in the planned management of the economy some forms of incentives are present in the Russian system. For example, the municipality of Moscow does not facilitate financially those new industrial activities which have not obtained a special permit released by the offices of the sanitary service, with reference to the operation of depuration plants.

Furthermore, a prize is awarded trimestrally to the managers of enterprises which have demonstrated not to have violated the dispositions on the use of depuration plants.

After having examined the present conditions in Russia, it is necessary, in order to complete the picture of the problems concerning environmental protection in general, and more specifically waste management, to include a report on CMEA before reaching any conclusion.

ITALY

Italian legislation does not include specific organic regulations which protect the environment from sources of pollution in agriculture. Partially, this may be explained by the lesser harm which the agricultural pollutants may cause (most polluting substances in this field are easily biodegradable), and also the agricultural activities themselves are founded substantially on enterprises of modest dimensions managed primarily at the traditional family level in which the wastes are reutilized to fertilize the land. In the case of large extensive agricultural enterprises spread over considerable areas (i.e. mountainous regions), the problem of waste accumulation and disposal does not create a major one.

Provisions for the pollution caused by agricultural activities appear only in fragmentary form in various norms as for example in the Sanitary Laws (Testo Unico, R.D.L. 27th July, 1934, n.1265, articles 233 to 240), providing specific rules for the construction and maintenance of compost heaps in order to avoid the dispersion of liquid wastes and thus preventing the creation of swamps. Such provisions, however, are inexplicably directed towards cattle raising, while the major attacks on the environment notoriously derive from pig raising.

The same Sanitary Law (Testo Unico, art. 203) established precautionary measures for the setting up of plants and the operation of gins for textile plants (linen and hemp) and for rice culture (art. 204-215). These norms establish general criteria and leave specific regulations to the local sanitary regulations (communal and provincial).

The law dated 20 March, 1865 (art. 58) already prohibited the discharge of waters and therefore also of zootechnical liquid wastes and re-used irrigation waters into drainage trenches along public roads.

The pollution of sources of potable waters by poisoning or adulteration whether fraudulent or unpremeditated is punishable through the Penal Code (art. 439 and 452).

In 1976 a new law on water pollution came into effect (10th May 1976 n.319) which repealed all preceding norms dealing with water pollution. This new legislation establishes in effect that any discharge in public waters must be authorized by a public administration. Some perplexity was caused by the fact that the authorozation to discharge (controlled by means of depuration, decantation, etc.,) establishes limitations to the pollution standard of each discharge activity without specific reference to the total tolerance capacity of the receiving body. One may criticize the excessive leniency in the time allotted (up to nine years) to the industries to regularize their discharges. Penal procedures pending against polluters who presented to the communal administration on application to discharge within two months after this new law came into effect, were annulled. Therefore penal sanctions are avoided even though the municipality may deny the request and prohibit the discharge.

Article 844 of the Civil Code which deals with the problem of air pollution, permits the emission of fumes (odours, vapours, fumes etc.) from neighbouring properties as long as they do not exceed a standard of tolerance taking into consideration the nature of the area. In addition the Penal Code (art. 674) prohibits and punishes the emission of noxious gases and vapours unless they are expressly authorized. The law dated 13th July, 1966, n.615, which establishes norms against air pollution is scarcely applicable. The law, in fact, pertains only to activities in thermal and industrial plants and the use of motor vehicles which cause the emission of fumes, dust or gas into the air.

While Italian legislation includes a complete and organic law dealing with the disposal and reutilization of urban refuse, its normative provisions only partially regulate the disposal of reutilization of agro-wastes. Because it was created during World War II, the law regulating urban wastes (dated 20th March 1941, n.366) had as its chief objective not only municipal street cleaning and refuse collection services but also every form of waste, maximum reutilization of refuse, in accordance with sanitary and economic needs. This principle has not been very carefully applied to the present time.

The Sanitary Law (Testo Unico) and the norms on Veterinary Cleanliness (D.P.R. dated 8 February 1954, n. 320) set forth precise limitations in the utilization and transport of animal wastes in order to avoid the possible diffusion of infectious diseases.

The slaughter of infected animals is mandatory as well as the incineration or the sterilization of litter, manure or other substances in contact with infected animals.

Under the Regulations on Veterinary Cleanliness, plants which utilize animal carcasses, tanneries, hide storehouses, tallow refineries, as well as industries which process blood, viscera, bones, nails, horns, wool, feathers or bristles are subject to veterinary care.

Even the gathering of such residues is allowed only after a permit has been obtained from the responsible veterinarian of the Province, while their transport is subject to particular precautions in order to avoid the spreading of infectious diseases.

The Regulations on Veterinary Cleanliness provide norms for import and export not only of animals and meat but also of animalwastes, in order to avoid the spreading of infectious diseases. These norms may be limited by ordinances issued by the Ministry of Public Health prohibiting imports from certain countries to avoid the spread of disease.

The Ministerial Order dated 8th March, 1973 is of great interest since it provides for an organic hygienic regulation of animal feeding obtained from food wastes or other wastes. The above mentioned order (art.2) prohibits use for animal feeding of urban solid wastes. If food residues are used for animal feeding, they must be previously boiled for not less than one hour or given other suitable treatment.

According to art. 4, "centralized plants" must be used to depurate wastes and residues; by "centralized plant" is meant a complex designed to depurate wastes from different sources and furnished with installations and equipment adequate for the same. The norm is applicable to food wastes from ships and aircraft whereas no limitation is provided for food residues produced inside the farm, which may be fully utilized. Animals may be fed with raw meat, viscera, slaughtering residues and byproducts, only after they have been considered safe by the responsible Veterinary office (art.12). The abovementioned order does not apply to byproducts and wastes of cheese processing.

The processing of agricultural and agro-industrial wastes is considered as "unhealthy activity" and, according to art. 216 and 217 of "Testo Unico" on sanitary laws, is subject to special precautions in order to avoid harmful effects to the employed workers. Among the activities considered, the Ministerial Decree dated 12 February, 1971 enumerates viscera processing, production of animal glues and gelatines, tanneries, production of fertilizer from animal wastes, animal fat blending, processing of horns, nails, skins, feathers etc.

Italian laws do not provide for fiscal or financial facilities for encouraging the reutilization of agro-wastes. The financing of construction or installation of depuration plants or collecting facilities is through normal credit channels.

Special forms of credit at low rates of interest are available to farmers (credits for operational costs for one year and for property improvement for several years). Such credit facilitation has now been extended to the "regioni" after investigation and approval of the provincial agricultural inspector concerning the utility of the project and the legitimacy of the expense.

In conclusion we see that Italian law does not organically and specifically regulate agricultural activities with a view to preventing pollution of the environment. Such regulation, where possible, can only be effected through the general provisions governing protection of the environment.

FEDERAL REPUBLIC OF GERMANY *

The awareness of the necessity to shape environmental protection regulations into a separate body of laws is entirely new in the Federal Republic of Germany.

Regarding air pollution, the sharpest means of defence against harmful effects (odours, smoke, noise etc.,) is the private citizen's capacity to sue when nuisances go beyond tolerability standards or are expressly prohibited by the law.

The basic regulations are to be found in § 1004, 862, 903, 906, 907 of the Civil Code (Bürgerliches Gesetzbuch). Besides these injunctions against nuisances, private citizens are also allowed to oppose the setting up of plants, which may prove harmful or troublesome, in their neighbour's property.

Past experience has shown that the private-law way rarely leads to success because of problems such as difficulties in coordination, in the identification of the responsible disturber in a chain of cause and effect, in the recovery of existing rights, and because of the fact that the private parties are often unequally balanced, as for instance in the case of a claim against a disturbing factory.

The trend now is to aim at an institutional consolidation of the legal protection of organizations created by private citizens for the defense of their own interests and able to sue for these interests.

To a certain extent, a kind of citizen's control, in relation to single laws, is embodied in the person of the so-called factory-representative for pollution 1/ and waste protection 2/. Besides, apart from legal proceedings, citizens can turn to Petition-Commissions of Federal and State Parliament. These commissions correspond to the institution of an Ombudsman (a government offical - as in Sweden or New Zealand - appointed to receive and investigate complaints made by individuals against abuses or capricious acts of public officials).

The attempt to gather all existing scattered laws pertaining to public law, under the heading of environmental protection and to give a legal solution to all problems which, specially in cases of water and air pollution had come up in practice, was admittedly undertaken for the first time in connection with the Environmental Programme of the Federal Government of 14th October, 1971, which sets down the fundamental laws of Environmental Policy as follows:-

1) Environmental policy is the totality of all measures necessary in order to:
- secure an environment for man such as is needed for his health and the pursuit of an existence worth living,
- protect soil, air, water, plants and animals from damaging effects of human interventions and eliminate the damages or drawbacks of such interventions.

2) In principle, costs of environmental damages have to be paid by the party who causes the damage (principle of the causing party).

3) National economic production shall not be overburdened by the realization of an environmental programme. Environmental protection must be backed by financial and tax policies as well as by the necessary technical installations (infrastructures).

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* Extract - Internal Report by C. Netzer and B. Bendel

1/ Stated in Par. 53 Federal Pollution Protection Act (BImSchG) and in the 5. and 6. Executive Decree relative to the BImSchG of 14.2 and 12.4.1975 - BGBl 1S.504/727 and S.957)

2/ Stated in Par 11a of the Waste Disposal Act - AbFG)

4) The state of environment is determined by technology. Technological progress must take place in such a way as to protect environment. Burdening the environment very slightly or not at all through an "Environment Protective Technology" is one of the aims of this programme. Hereby technical progress and economic growth do not have to be hampered.

5) Environmental protection concerns every citizen.

6) In decisions relating to questions of environmental policy, the Federal Government will increasingly turn to scientific advice. For this purpose it will, among other things, call a board of environmental experts.

The last four paragraphs specially concern the role to be played by environmental education, and the need for a close cooperation between States, Governments and communities.

Subsequently a series of laws and decrees related to environment appeared in rapid succession, those already existing were worked over and expanded and fitted into the newly formulated principles.

Acts pertaining to the argument in question include:

- Act concerning disposal of waste,

(Waste Disposal Act - German abr. AbfG) of 7.6.1972 (Bundes-Gesetz-Blatt I, p. 873), last amended 21.6.1976. (BGBl. I p.1601).

- Act concerning the protection from dangerous environmental effects caused by water pollution, noises, vibrations and similar events (Federal - Pollution Protection Act - BImSchG) of 15.3.1974 (Bundes-Gesetz-Blatt I, p. 721), last amended 4.5.1976 (BGBl. I p.1148).

However, the attempts to create a consitutionally guaranteed fundamental environment protection law have so far been unsuccessful.

Environmental damages stemming from agriculture should equally be avoided particularly through the above mentioned Acts, the Waste Disposal Act and the Federal Pollution Protection Act, as also through the Water Act which appeared earlier (WHG of 27th July, 1975 - BGBl I p.1110/1386, last amended 26.4.1976 - BGBl I p.1109).

These are Federal laws valid in all states of the German Federal Republic and they have been integrated by legal state operative measures.

According to Par. 5 of the Federal Pollution Protection Act, establishments requiring authorization are to be built and to be run in such a way as:

1) not to cause adverse environmental effects or other dangers, not to cause considerable disadvantages and considerable disturbances to the community and the neighbourhood,

2) to prevent adverse environmental effects, specially through those measures which correspond to the technical possibilities of pollution limitations,and

3) to utilize residues generated by the functioning of the establishment, according to regulations and without causing damage or, provided it is not technically possible or economically feasible, to dispose of them as waste according to regulations.

According to Par. 22 of the Federal Pollution Protection Act, establishments not requiring authorization are to built and run in such a way as:

1) to avoid adverse environmental effects, in so far as the standard of technology permits,

2) to reduce to a minimum the technically unavoidable adverse environmental effects, and

3) to be able to regularly dispose of waste generated during the functioning of the establishment.

At present a decree is being prepared by the Federal Government stating the standards which an establishment not requiring authorization must come up to, in its construction and management, in order to protect the community and neighbourhood from adverse environmental effects.

In certain special cases it is therefore possible that the setting up of pollution minimizing plants be ordered. However, experiments with similar measures have not proved adequate, i.e. to reduce odours. An obligation to cultivate plants as pollution protectants can, on the other hand, have another legal origin, namely the Nature and Agricultural Protection Act which, to this extent, substitutes the other abovementioned environmental protection acts. A general Nature Protection Law for the entire German Federal Republic is now about to be completed.

Tax facilitations for income tax payment are again granted today - after the decree had been invalidated for a certain period of time - to the extent that purchase and installment of environmentally favourable property entitles the taxpayer to a certain percentage of deduction in the computation of taxation liable profits. Besides, according to the mentioned law for sewage cleaning plants, an extra deduction can be expected.

As previously stated, the Waste Disposal Act, the Water Regulation Act and the Pollution Protection Act, also serve to avoid environmental pollution through agricultural waste disposal. Private waste disposal prohibition is already a stimulus to the reutilization of residues, inasmuch as a substance still having a potential value cannot automatically be considered waste in the connotation of the Waste Disposal Act, and, therefore, is not subject to its regulations. Considering that the Waste Disposal Act does not draw a clear line - as the more recent Federal Pollution Protection Act, for instance, does - between waste and residue, in many cases there is uncertainty whether certain byproducts resulting from the agro-industrial complex are to be considered waste at all, and whether Waste Disposal Act regulations can be applied to them.

Regulations in the field of health organization start out with the fight against certain diseases and refer mainly to persons and not to things. Health protection is also amply included within the framework of waste disposal regulations, therefore there are no provisions in the special health law regulations concerning animal waste reutilization.

Epidemiological laws, particularly decrees relating to epizootic law, which have to be complied with, whenever residues are used as animal fodder or fertilizer, are mostly regulated by the same juridical subject matter and partially overlap, so that they will be mentioned jointly in the text that follows.

When fertilization is planned, it should be kept in mind that commercial circulation of fertilizers is controlled by law and that limitations can ensue also from these instructions. Within the framework of the Waste Disposal Act, the control of certain substances is included in Par. 15 concerning their processing.

According to the Epizootic Act of 19th December, 1973 (BGBl. I p.1974) last amended on 2.9.1975 - BGBl. I p.2313) the following measures among others can be enforced to protect livestock from permanent danger of epizootic diseases:

- Control of the installation and management of establishments for the commercial production and preparation of fodder which can be a vector of contagious diseases (Par. 17 Nr. 14);

- Control of the use and disinfection of food waste which can be a vector of contagious diseases (Par.17 Nr. 19);

- In mass livestock breeding, specifications concerning litter and liquid manure and fodder processing within the concern itself, and litter and liquid manure disposal as such (Par.17b Nr. 4).

On the basis of Par. 17b Nr. 4 of the Epizootic Act a decree of 9.4.1975 (BGBl. I p.885) has already been passed as protection against epizootic diseases in large pigstock raising concerns according to which, if stocks of more than 1250 head of pigs are kept in a concern, severe standards in hygienic precautions are requested also in connection with animal waste, as protection against infections.

To what extent the problem of residues will be limited in the future through the Fertilizer Law, it is not yet possible to say, because a new law is being prepared presently. For the time being, the following limitations are still valid:

- Law concerning handling fertilizers (Fertilizing substances Act) of 14th August, 1962 (BGBl.I p.558; last amended on 2.3.1974, BGBl. I p.469) and the relative

- Fertilizer Decree of 21st November, 1963 (BGBl. I p.805; last amended on 29th January, 1976, BGBl. I p.245).

According to the guideline of the Council of the European Community of 18.12.1975 concerning uniformity of legal specifications of member states for fertilizer substances, the abovementioned specifications will be thoroughly altered. Thus the jurisdiction of the forthcoming law, asopposed to the one still in force, will also apply to the so-called commercial fertilizers, i.e: litter, dung, liquid manure, fresh manure, compost and, in agriculture, plant residues. It is anticipated that the responsible Federal Minister will be authorized through legal decrees to prohibit or limit the circulation of certain fertilizing substances and therefore also of commercial fertilizers, to the extent to which it is necessary in order to protect soil fertility or human and animal health.

The problem of residue disinfection before their utilization as fertilizers is examined, for certain substances, explicitly in Par. 15 per 2 AbfG. According to this regulation, the responsible Federal Minister is entitled to require that the utilization of sewage waters, sludge, excreta and other substances such as liquid manure, dung and litter on agriculturally, silviculturally or horticulturally exploited soils, shall be subject to the examination, disinfection or disintoxication of said substances, or to compliance with certain quality standards or to any other adequate provisions that may be deemed necessary. Accordingly, two decrees are being prepared, of which the one concerning sludge and similar substances requires specific disinfection proceedings, while the draft of the decree concerning excessive utilization of liquid manure, dung and litter, lacks for the time being such requirements, but forbids, in principle, all utilization going beyond the customary agricultural fertilization. In any case, the relationship between the extent of farm land and number of animals must be respected i.e. the number of animals on a farm should be in proportion with the extent of land to be fertilized by liquid and solid manure produced by them.

Regarding the hauling of agricultural residues, especially the transport of dung, liquid manure and litter, is regulated by various administrative district and municipality decrees. The purpose here is to avoid street soiling and offensive odours when driving over local roads and streets.

Summarizing the legal regulations in connection with utilization and control of waste and residues in the agricultural complex, the main points are the following:

1) In relation to the Pollution Protection Act, technologies permitting elimination or limitation of pollution by treating, storing or otherwise influencing waste and residue as such (i.e. in the reutilization) have been hardly developed yet, so that it will not be possible in any foreseeable future to meet the very exacting legal requirements, if only for the abovementioned reasons.

2) As concerns health protection of man, animals and plants, legal measures, by and large, even though there are differences between various sections, are rather all-inclusive and efficient. The aim to protect the citizen in his physical and moral well-being, to safeguard the economic, natural and ethical bases of life for him and develop them for his sake and use, has given origin to decrees of immediate or indirect application which avoid dangers to the life or health of man through waste and residue also from agriculture and silviculture, or at least reduce them greatly.

3) In the German Federal Republic, environmental damage due to utilization and disposal of agricultural and silvicultural waste has not yet reached such importance (in proportion to industry, households and traffic) as to create the necessity to influence market mechanisms through direct or indirect interventions, price controls, import limitations or export facilitations or similar measures.

The possibility for official public intervention so far developed, with its first attempts to apply the law of torts, the possibility to punish transgressors of prohibitions and laws, and to sue the responsible party for damage, have proved sufficient so far to stimulate the development of technologies for environmental safeguard and utilization of agricultural and silvicultural residues. Besides, they have the effect of a stimulus to search for economically rewarding alternatives and to utilize them thoroughly, specially when waste and residue materials become necessary as alternative products.

DENMARK

The Environment Protection Law (1973, effective 1.10.1974) is the organic law governing environmental problems. The law covers a wide range of phenomena whose control is mostly delegated to Public Authorities. At Government level, the Ministry for the Environment has jurisdiction over problems of environmental protection and projects of land planning, both for rural and urban areas.

Regarding the control of pollution sources, land planning laws are to be considered first:

- the Land and Regional Planning Law (1973) and the Zoning Law (1972).

Even if rural area plans are at an initial stage, the regional plans, prepared by the County Councils and approved by the Ministry for the Environment, are binding for local authorities and govern the location of industrial settlements, on the basis of their possible pollutant effect. According to the Zoning Law, the country is divided into urban and rural areas, the latter being governed by precise norms prohibiting activities other than agriculture, forestry and fishery, if a permit has not been previously delivered by the public authorities.

Finally, in accordance with the Environmental Protection Law, Chapters 4 and 5, industries, plants and equipment which may cause excessive air or water pollution, are subject to a preventive permit covering their location, their installations and any constructional and operational changes. The law covers incinerators, fish meal factories, farms for animals whose skin is used as fur, slaughter houses, plants for the treatment of wastes and others.

If the resulting pollution is dangerous for human health or goes beyond the standards provided for in the permit, a stop order for the activity may be issued. In any case of pollution however, local authorities may intervene with specific orders and prohibitions concerning the general and particular activities of the plants.

A general rule prohibits the discharge of pollutants into water or their storage near waterways (see Environment Protection Law, par. 17). A permit may be issued for any discharge, direct or indirect, into waterways. Local authorities, while preparing land plans, may draw up special projects for such discharges.

Specific norms are provided for the protection of drinkable water supplies by the stipulation of protected areas, where industrial activity as well as gatherings or storage of substances which could pollute the water supply plant (e.g. the use of fertilizers on neighbouring land) are prohibited. Depuration plants for liquid run-off may be compulsory, but they are not granted economic or fiscal facilities. Discharging effluents onto the ground may be permitted by the county council, if it contains only organic substances and nutrient salts, but in practice this provision applies only to effluents from dairies and other foodstuff factories (order n. 174, 1974, par.33).

Regarding dung-hills, liquid fertilizer tanks and silage tanks, special regulations are provided in Chapter 5 of the Environment Protection Law.

Agro-wastes and animal droppings are governed by the above-mentioned basic law, on the basis both of general and of specific provisions. In particular, the disposal of sewage and dung is dealt with in Chapters 3, 4 and 5 of the Environment Protection Law and in the Order no. 170, March 19, 1974. Local plans are expected to provide for sites for the discharge or the destruction of wastes, under the control of the county councils.

Waste deposit and disposal are considered as pollutant activities, and they are subject to the control of the Ministry for the Environment through local authorities.

The Environment Protection Law (Chapter 2 and 4) provides for animal wastes to be destroyed by incineration and transported to factories which process wastes to provide animal feed. Orders on this subject are completed by regulations concerning food.

If private enterprises cannot manage wastes correctly, local authorities can issue mandatory orders on this subject.

The Environment Protection Law specially provides for containers and transport of animal wastes, under the control of Public Authorities, who are also empowered to issue orders regarding waste management and reutilization (e.g. manure heaps and similar stocks of solid manure must be sited at the minimum distance of 15 m from residential premises on the same terrain).

In Denmark, more than a half of wastes produced are destroyed by burning.

GREECE

Environmental competence is exercised by the various Ministries (Justice, Social Services, Internal Affairs, etc.), and both Central and Public Authorities.

There is no specific law governing agro-wastes. The prevalent aspect under which the disposal and gestation of wastes are controlled is a sanitary one.

The principle legislation is contained in the sanitary regulation of the Ministry of Social Services Dated 10.2.1964, "Refuse collection transportation and disposal" and in the Ministerial Decree dated 29.11.1975, "Requirements for the treatment of solid waste and food remainders used as animal food".

The regulations of the law on "Sanitary Regulation, 1940" deal chiefly with solid wastes of urban origin (refuse). Its object is to prevent unhealthy situations, such as the proliferation of animals which are carriers of infection, the pollution of surface and underground waters, the contamination of animals and the defacement of the landscape.

It includes regulations governing the modes and systems of harvesting, transportation and waste disposal (subject to the authorization of the Prefect and the Sanitary Centre). In addition it sets up local authorities with power of control.

The disposal of wastes on land is permitted provided specific measures are observed - a distance of at least 1,500 m away from inhabited areas, a reasonable clearance from water mains, a system of fencing which prevents access to animals. The discharge of wastes in the seas, lakes or rivers is forbidden (art. 5,1.1.).

Composting is another approved method for waste disposal. The conditions required are the following:-

Location outside inhabited areas;

transport, treatment and storage in a way which will avoid noise, dust, offensive odours, conditions which attract insects or rodents;

the composting product should be stable so that further decomposition or production of offensive odours is prevented and should be free of pathogenic micro-organisms, intestinal parasites or their eggs;

In cases where waste is sorted, the stabling or feeding of pigs in the disposal sites is forbidden.

Sorted fodder for the feeding of pigs should be protected from flies and should be boiled within 24 hours after sorting for at least half an hour and before transportation to the places of consumption.

Sorting foods for human consumption is completely forbidden (art. 5,1.6.).

Animal corpses should be collected and transported for burial or other suitable disposal within 24 hours after their death, at the expense and responsibility of the owner or the user. (art.6,3).

Animal manure shall be collected daily and both the stables and the surrounding area should be kept clean and free from manure, food remains etc. The floor of the stables should be made of impermeable material and should be well drained. The surrounding area should also be well drained so that any escaping manure or food remains be kept dry thus preventing the attraction and breeding of flies and other insects.

Collected manure should be stored in refuse or in dry, well-drained pits or tanks made of impermeable material at a distance of at least 10m from houses and nearer to the owner's house than that of any others.

Manure placed in pits or tanks should be covered after each deposit with a layer of soil at least 0.15m thick, and always be kept covered. Manure placed in refuse bins should be kept separate from other wastes and should be collected at least twice a week and should be transported to the fields where it should be suitably disposed of as provided by law.

Issuance of a permit is required for the operation of stables and special regulations with regard to the collection, transportation and disposal of manure should be followed.

Decree n.51/8233 of the Ministry of Social Services, dated 29.11.75, determines the kinds of solid waste that may be treated and used as animal food, as well as the processes to be followed for their treatment.

This decree also determines the regulations for buildings and mechanical facilities. Limitations as to the source of solid waste are imposed as well as provisions regarding the distribution procedures of the treated waste.

In addition, penalties for violations of these regulations are provided. Police and Health authorities are empowered to enforce these regulations.

JAPAN

A new series of laws and administrative regulations governing environment protection have been adopted in Japan during the past ten years.

On 25th December 1970 a number of laws amending the Basic Act for Environmental Pollution (1967) were passed; they specifically regulate air, water, sea, soil pollution and provide norms for noise, odours, vibrations, the use of chemical fertilizers in agriculture and so on.

On 1st July 1971 the task of restructuring the environmental sector was completed with the creation of the Kankyo-Cho (National Environmental Agency) with a consequent unification of the spheres of authority of the various previously operative agencies. NEA's main tasks are the following:

- to fix environmental quality standards, to control the enforcement of pollution control laws, to provide recommendations to the various Ministries and to make proposals to the Government.

As far as we know, the disposal and reutilization of agro-wastes is not specifically regulated; many laws, however, provide for direct and specific regulation of agricultural and agro-industrial activities.

As an example, the Offensive Odour Control Law (1971) is applicable to agricultural, forestry and fishing activities and industries (such as dead animals processing, stockbreeding factories, fertilizer blending), which produce more than one third of the whole quantity of malodours emitted in Japan. Thirteen malodorous substances are classified by this law: the density of these substances in the air is considered as an indicator of the existing odour (among these substances ammonium, hydrogen sulphide, trimethylamine are in the agro-industrial sector).

Odour control areas, designated by prefectural governments, are established by the law; in these areas, factories and other productive installations are subject to controls according to five classes of odour control standards, fixed on the basis of odours perceptible to man; the density of such malodorous substances in the atmosphere is the criterion to be adopted (e.g. the fifth class is 1.500 ppm of methyl mercaptan).

Prefectural governers may issue orders or recommendations to a factory for improving anti-pollution measures when the density of malodorous substances exceeds odour control standards. The Water Pollution Control Law (1970 n.138) and successive amendments by the Act for the Establishment of an Environmental Agency (1971) govern water pollution control, and fix standards for the whole country governing the maintenance of uniform sanitary conditions for environmental protection. These standards are differentiated as a function of the uses to which water containers are put.

The abovementioned quality standards are established by NEA, while orders and regulations issued by prefectural governments may provide for stricter effluent standards.

Plants discharging harmful substances (among which about 500 have been already classified) must present a report to prefectural governments on the basis of which the anti-pollution measures to be adopted will be decided.

Afterwards the prefectural government is empowered to impose changes in the installation and in the production or waste processing procedure or to close down the plant when effluent standards are not met.

Dumping or discharges may be prohibited when the pollution level in the area concerned exceeds fixed standards.

Violations of water control norms are punishable with fines (from 50,000 up to 200,000 yen) or with imprisonment (from three months to one year).

Regional pollution control plans, the Urban Planning Act (1968) and the Agricultural Development Areas (1969) govern urban and rural planning in Japan. These norms also provide for zoning restrictions, land development permits for designated areas. The complexity of these regulations shows how comprehensively the problem of land management and consequently the problem of agricultural pollution sources management is faced.

The Water Pollution Control Law provides for facilities to improve discharge disposal plants by appropriation of funds or technical assistance to operators. Medium and small enterprises are given special attention.

The special task of managing public funds to subsidize industries when setting up depuration plants and to help the victims of pollution is the responsibility of Environmental Pollution Control Service Corporation, established in 1965.

Japanese laws are still lacunal concerning the control of pollution from agricultural sources and agro-waste management, particularly if one considers the present day problems of the country and the ever-increasing rhythm of development both in industrial and in agricultural activities. Mechanization and the use of advanced technologies should be taken into account, and effective waste management norms must be put into practice.

EUROPEAN ECONOMIC COMMUNITY - EEC

The European Economic Community is well aware not only of rational environment-management and natural resources protection problems, but also of those problems related to waste reduction and disposal.

The Action Programme of 22 November, 1973 pointed out that farmers' activities represent a unique form of soil and landscape maintenance, while they simultaneously create situations which often affect environment itself.

The 1977/81 Environmental Programme contemplates a thorough study of the effects of agricultural activity on environment in order to gain a better understanding of the causes which damage soil, air, water, wild life and landscape, and to acquire a greater capacity to protect them.

This new knowledge will prove useful in elaborating adequate measures to enhance the favourable effects of agriculture on environment, and to eliminate or reduce the unfavourable ones which, very often, are secondary and unknown.

Particularly, pesticides application and waste disposal on feedlots, have been examined as part of this action programme. As to the application of pesticides, the reduction of noxious effects will be obtained by:

- prohibiting the use of the more dangerous products;

- controlling all treatment products before admitting them on the market;

- improving methods and means of application in order to reduce concentration and quantity of pesticides in general, and by

- developing non-chemical alternate methods of fighting pests. Concerning feedlots, their three main sources of pollution are: odours, wastes (principally excreta) and noise. To reduce pollution from wastes, measures are necessary to prevent and limit liquid manure run-off and percolation into the soil, and technical devices to reduce the emission of bad odours during waste collection, storage and utilization. These measures will consist essentially in establishing technical characteristics of waste-collecting and storage devices and in limiting waste diffusion on cultivated soil, according to sanitary criteria as well.

Action must be taken also concerning mineral fertilization to avoid waste pollution of surface and groundwaters.

A project against dispersion through a waste recovery and disposal policy and waste formation prevention, represents a specific part of the 1977/81 Programme which states explicitly (Tit.III., Chap. I., Section II): "...These problems are a matter of great concern to the Community which, for various reasons, has the duty to promote an active campaign in this field with the aim of:

- reducing pollution created by waste accumulation and treatment;

- contributing to the harmonious development of economic activities according to its EEC function, in an attempt to overcome difficulties such as unfavourable raw material costs increase, Community and Member States' dependency on supplies, and, on the long run, predictable scarcity of certain materials and their consequent price increase;

- avoiding unfair competition and trade complications which would inevitably arise if decisions concerning wastes were taken exclusively on a national level;

- improving knowledge about these problems and past experiences in the field ..."

The directive of 15th July, 1975, referring to solid wastes (excluding agro-wastes), contemplates that: "Member States shall adopt adequate measures to promote waste prevention, recycling and transformation, and extraction, from the above, of raw materials and eventually of energy, and shall further adopt any other method allowing waste reuse", and whatsmore: "that Member States shall inform the Commission in due time of any project having the abovementioned purposes, and specifically of any legal project relating to:

a) utilization of products apt to cause technical disposal problems and excessive disposal costs;

b) furthering the elimination of certain types of wastes, encouraging waste recycling and reuse, and raw materials and/or energy-production recovery from certain wastes;

c) use of certain natural resources, including the energetic ones, for purposes allowing substitution with recovery materials."

As mentioned before, besides promoting waste reuse and recycling, the EEC also intends to encourage preventive measures in order to limit waste production itself. This requires the use of materials or techniques alternative to those producing excessive wastes, or wastes difficult to reuse. Simultaneously, a campaign is planned to direct consumers towards product-consumption not entailing excessive waste formation or particular environmental damage.

An initiative of the EEC worth mentioning in this context, is the project of gathering all environmental legislation of the nine member countries according to systematic criteria, integrating this work with comments on the practical aspects of the various norms and regulations. (see bibliography).

COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE - CMEA

Information on the cooperation of the CMEA countries in the field of environmental protection and improvement, and in the related rational use of natural resources. [1]

Cooperation between CMEA countries in the field of environmental protection and of the rational use of natural resources has increasingly intensified during the past few years. In 1975, as a consequence of the cooperation under "The Overall Programme". the CMEA institutions, the Council of Plenipotentiaries and experts of CMEA research institutes drafted more than 260 projects on environmental protection from the sociological, economical and legal point of view, elaborating advanced technology processes.

At present this cooperation involves more than 360 research and planning institutions from CMEA member countries and from Yugoslavia. The interaction between economic, social, legal, technological and biological factors and their influence upon environment has been carefully considered. The economic aspect of the man-environment relationship is to be a fundamental tool in the development of economic planning, including the rational use of natural resources.

Terms and definitions of current use have been prepared in Russian, for a better comprehension of legal regulations on the subject matter, and a general report has been set up for an overall view of existing international legal norms concerning environmental protection in the CMEA countries.

Concerning "Hygienic Aspects of Environmental Protection", a classification of hazardous atmospheric pollutants has been set up by scientists and experts of hygienic institutes of the CMEA member countries. Environmental hygiene has been planned both from a scientific and a technological point of view, up to 1990. One result of the joint work of CMEA member countries experts was represented by the introduction of a practical technique for the treatment of waste gases from fluorides and chlorides.

Techniques have been elaborated to evaluate the impact of chemistry on agriculture, specially on the quality of surface and underground waters, and measures to prevent water pollution were studied. Requirements have been determined for the protection of surface and underground waters and of coastal sea areas from pollution. There has been an improvement in the methods to predict the quality of water in water bodies under the impact of contaminated waters. Studies have been carried out on the impact of discharged heated waters on the thermal and biological status of water bodies and standards have been established for water economy needs.

As a result of cooperation between interested CMEA member countries on the problem of "Disposal and Reuse of Household, Agro-Industrial, Agricultural and other Wastes", definitions of solid and liquid industrial, household and agricultural wastes have been worked out, and the concepts relating to neutralization and utilization of wastes, standardized. A common technique was elaborated to determine the physical and chemical properties of wastes and to predict the total amount of resultant household wastes and their major components.

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[1] Report by the CMEA Secretariat for the fourth session of Senior Advisors of the ECE Member Governments on Environmental Problems, Geneva, 9-13th February, 1976.

In the field of agriculture we have: better utilization of the natural economic conditions of CMEA **member** countries for the purpose of a more rational agricultural development and an increased food production, also for the improvement of livestock raising and agricultural products in general. Measures were elaborated dealing with the comprehensive solution of technical and organizational questions reducing losses of raw materials and finished products during production processes in the CMEA member countries.

A joint programme of cooperation, lasting until 1980, between member states of CMEA and Yugoslavia, in the field of environment protection and improvement, and of associated natural resources exploitation problems, has been approved in October 1974.

The programme implies elaboration of 150 subjects grouped in eleven sub-sections which include: social, economic, juridical, organization and pedagogical aspects of environment protection. As to the sanitary aspects: utilization and treatment of household, industrial, agricultural and other wastes; protection of universal resources and national use of natural resources in connection with improvement and protection of the environment, have been taken into consideration. As concerns disposal and recovery of general, industrial and agro-wastes, technological processes are to be elaborated for the collecting, transport and storage of said wastes, keeping in mind the necessity of waste disposal, including incineration.

Cooperation is well underway towards developing methods, equipment and facilities to incinerate sludge produced during the purification process of effluent waters, as well as of liquid and solid wastes from chemical, pulp and paper industries etc.

Cooperation also aims at working out definitions and standards for long term facilities to be put into production, at designing purification systems for reclamation of wastes for reuse and of industrial and agricultural wastes, including rational utilization of wastes from cattle breeding, of wood wastes and also of organic food industry wastes. The function of a coordinating centre for these problems is held by the Institute of Economics and the Organization of Construction in the city of Budapest (Hungary).

Prompted by the spirit of mutual cooperation, CMEA member countries and the Council's bodies are seeking to develop their ties with other international organizations. Currently, they are taking steps to further coordinate their activities in environmental protection and improvement, carrying them out within the framework of the CMEA. In this field ECE, UNEP and other organizations of the UN family are particularly active.

Thus, CMEA member countries are following the recommendations adopted by the 27th Session of the Council, namely to contribute actively to the expansion of cooperation with all interested countries and international organizations in dealing with environmental problems.

Along the directives of CMEA member countries, which so willingly follow a policy of broad international cooperation, the Council for Mutual Economic Assistance is firmly determined to contribute, within the realm of its own competence, to the implementation of the main principles and provisions mentioned in the Section on "Cooperation in the Field of Economics, of Science and Technology and of the Environment", in the Final Act of the Conference on Security and Cooperation in Europe, availing itself to that end of an active cooperation with the UN, ECE, UNESCO and other international organizations.

At present, scientific and technological cooperation is being organized between interested CMEA member countries and the Republic of Finland in a number of areas, involving environmental protection and improvement, including social, economic, organizational, legal and pedagogical aspects of environmental protection; protection of the atmosphere from pollution with harmful substances; elaboration of methods to forecast possible changes in water quality as well as neutralization and utilization of industrial, agricultural, household and other wastes. Not only are exchanges of information and mutual participation in various activities well underway, but proposals are also being worked out for joint development of programmes relating to the problems listed and, thereby, the first steps are being taken towards the practical implementation of the provisions of the Final Act of the Conference on Security and Cooperation in Europe to the effect that: "many environmental problems, particularly in Europe, can be solved effectively only through close international cooperation".

III. GENERAL CONSIDERATIONS AND APPROACHES TO EXISTING NATIONAL LEGISLATION

3.1 With the exception of public health measures embodied in much older legislation, specific norms regulating waste disposal are very recent. Agricultural and agro-industrial wastes, in particular, represent a new environmental problem in developed areas.

Consequently the need emerges for a new environmental policy which takes under consideration economic and technological factors. This policy tends to create managerial systems that protect the environment and optimize the reuse of material goods and residual substances.

There are very few environmental laws which deal directly with the problem of waste. Those that do exist throughout various countries are generally only "framework laws". These laws delegate to the local authorities the responsibility of waste disposal. In fact, central authorities are detached from the reality of everyday environmental problems. Rarely do these laws deal with matters of technical and administration organization, or with agreements between economic parties (public and private waste producers, users of recovered material), as these aspects of the problem are handled by local authorities and by industry itself.

Presently wastes are generally managed by small local units without an economic programme at a national level and without any coordination with the other local units. In the future this work should be done by large units covering considerable areas. For this reason the treatment of wastes must be coordinated by a large system of economic management where efficient waste treatment methods are planned on the basis of large areas.

The approach to the problem of waste management in agriculture varies from country to country according to the following characteristics:

a) Countries in which the problem is confined to the removal of wastes for the protection of public health;

b) Densely populated countries with a high degres of industrialization, mechanized agriculture and intensive livestock breeding, where the waste problem is more extensive and includes the necessity of saving natural resources and raw materials. In this case, economic considerations play an important part in the protection of the environment.

3.2 In some national laws, specific norms may be found which do not limit themselves to the protection and conservation of the environment, but which also deal with problems of agricultural production. In many countries, the establishment of extensive livestock concerns and waste disposal plants are subject to approval. These plants must operate under specific conditions, without causing harmful effects.

The following examples concerning industrialized countries may be useful:

a) The manuring with liquid, semi-liquid, and farmyard manure is relevant to the environment only in so far as it exceeds the usual level of agricultural fertilization; official control may begin only beyond that level;

b) Sewage, sewage sludge, and faecal matter may be used as fertilizers only if they meet certain conditions of hygiene;

c) Standards have been set up in many sectors of agriculture (e.g. concerning the distance animal houses should be situated from residential areas, or the content of dust emissions from silos containing chemical feed, or noise levels for tractors).

3.3 For an approach to a comprehensive environmental legislation which will achieve a deeper integration, a new philosophy of production and utilization of material goods must be developed. In fact, not only are technological solutions for manufacturing processes needed, but also an improvement in the mechanism of industrial development, achieved through incentive measures, in which the costs of environmental protection (including waste disposal) are internalized into the production system.

A deliberate connection between the system of economic incentives has become essential with the new philosophy concept. The concept "the polluter pays" implies that a social cost may be appropriately measured. Investigation must be made to determine the total socio-economic cost of environmental protection in order to establish a new price system for more rational decisions in respect to scarce natural resources.

3.4 A modern and organic system of management and reutilization of agricultural and agro-industrial wastes must be conceived along the following fundamental lines:

a) preservation of natural resources;
b) reduction of pollution and environmental nuisances;
c) saving of energy and available resources;
d) reduction of costs of agriculture and agro-industrial production;
e) reduction of costs of waste management and reutilization;
f) ensuring health protection of the personnel engaged in recovering and reusing waste materials (protective masks, gloves, special uniforms);
g) avoiding the risk of pollution or spread of infective diseases, after reuse;
h) avoiding air and water pollution in connection with recycling.

Such aims must be pursued through anti-wastage measures which tend to reduce consumption of natural resources, introducing alternative technologies which require a decreased use of same or through alternative methods (technological abstinence) involving a smaller quantity of wastes (e.g. the substitution or integration of pesticides with methods of biological warfare against crop parasites). Moreover, it may be necessary to increase the recuperation and reutilization of byproducts and refuse where technically possible (e.g. slaughtering wastes - viscera, horns, nails, feathers - to be used as fertilizers after due stabilization).

To alternate the costs of waste disposal, management and reutilization, the government may allow tax reductions or grants for waste collection and treatment plants particularly in the form of cooperatives. Public installations for these purposes might also be provided.

3.5 The role of public authorities is the same both in countries with planned economies and in countries with market economies. Public authorities must promote and coordinate activities in order to rationalize waste disposal and utilization of material goods and energies.

For this purpose, the following activities should be promoted:

a) The study of all stages of technical processes in waste recirculation (recycling, recovery and reuse);

b) the installment or promotion of plants for waste disposal, with the adoption of the most advanced technological methods;

c) the adoption of special controls to protect against hazardous wastes;

d) the establishment of emission load standards;

e) the coordination of the management of industrial, agricultural and urban wastes;

f) the organization of a system of information exchange concerning technological and economic aspects of waste management, among different countries, international organizations and institutions;

g) the utilization of mass-media in order to increase public awareness on the importance of citizens' participation and cooperation.

IV. RECOMMENDATIONS FOR A COMPREHENSIVE APPROACH TO WASTE MANAGEMENT PROBLEMS

4.1 Specific legal proposals aimed at facing the agro-wastes problem organically and rationally can be formulated or motivated only during the final report, at the end of the Seminar.

Indeed only a close interchange of experiences between technology on the one hand, and law and economy on the other, can bring forth measures adequate enough to protect environment and avoid wealth destruction in availing themselves of recovery, recycling and reutilization of wastes. However, it is possible to suggest the following recommendations:

4.2 Creation of a complete and organic domestic system for agricultural and agro-industrial wastes management. Therein a legal framework should specify the purposes, means, rulings, sanctions, incentives and local regulations (regional or municipal) which - in accordance with land-use planning - would actually regulate agricultural and agro-industrial activities as concerns waste-management and also organize a technical assistance programme, along national guidelines and, further, create and manage public collecting centres and public wastes recycling-installations.

4.3 In principle, a legislative and managerial national policy concerning agro-wastes, should contemplate:

a) a competent central authority having the task of programming and coordinating agricultural and agro-industrial wastes, and being in a position of availing itself, on the operational level, of local authorities and bodies existing in the various countries;

b) coordination between aims and means of agro-wastes management and other economic and social development programmes;

c) establishing national standards for agro-wastes as well as for commodities resulting from recovery and recycling processes;

c.1 <u>Agro-wastes</u>: standards must include:

- (i) waste characteristics
- (ii) waste release practices (as for instance seasonal restrictions in spreading manure on the soil,) or utilization restrictions (permissible dilution of wastewaters or maximum permissible amount of manure to be spread in a given area);
- (iii) codes of practice for agricultural management (good farming practices), (maximum quantity of animals in a given area),(relation with other agricultural activities in the neighbouring areas).
- (iv) Performance procedures for treatment and disposal plans.

c.2 Standards for resulting commodities (or recovered goods) should concern:

- (i) quality requirements of the products;
- (ii) permitted use (as in human and animal nutrition, fertilizers etc.)
- (iii) tolerance threshold of wastes.

d) Land-use planning according to criteria of agricultural area-zoning, and industrial settlements depending on their probable environmental impact (specially as concerns water and soil) and their compatibility with other productive settlements, as well as with other land uses; and, last but not least, according to their economic projection;

e) licensing procedures which should take into account the technical and economic aspects of non-polluting productive activity development, and evaluate the relation between the activity to be licensed and the geologic, pedologic, hydrologic and climatic features of the involved area.

f) severe hygienic and sanitary control of disposal, collecting, storage, transport, handling and recycling processes of wastes and their by-products intended for animal nutrition, or somehow connected with animal raising; equal sanitary control on any other waste reuse (also as fertilizers) requiring sanitary precautions.

g) flexible norms and the possibility for agricultural and agro-industrial activities already existing and representing pollution sources and dissipation of wastes, to conform gradually to general standards;

h) sanctions and penalties against whoever causes pollution (including the refund of damages and the reclamation of the polluted environment, whenever possible), as well as against concerns dispersing wastes which could easily and usefully be recycled;

i) fiscal and financial incentives to study and adopt techniques of recovery, recycling and utilization of agro-wastes;

j) the management of off-site agro-wastes should be carried out directly by the local or national public authority or by specialized agencies which, if private, must be subjected to a system of public licensing and control. In case of on-site management, the farmer or the agro-industrialist, should observe all the provisions issued by the competent public authorities;

k) economic and financial measures to encourage the adoption and improvement of non-waste technologies, the creation of closed-cycle agro-waste productive systems and the setting up of national agro-wastes recovery-processing-and reutilization industries which could also benefit from **mass** production economy in their organization;

l) the promotion of a more deeply rooted and widespread consciousness among the population as concerns rupology and ecology problems, by means of campaigns etc. Specalized technology courses, lectures on law and economy to be instituted for the training of waste management experts.

m) promotion of rapid news circulation concerning technological discoveries apt to limit or avoid pollution and waste formation, as well as to recover and reuse wastes themselves.

4.4 Useful international cooperation could be obtained by bilateral and multilateral treaties concerning:

a) the setting of standards for agro-wastes disposal and utilization systems, and for their transport and international trade. Working out an international wastes-code might prove useful;

b) a programme to eliminate, dispose and reutilize agricultural and agro-industrial wastes involving more than one country, if only for the sole purpose of finding elsewhere a proper utilization of those wastes considered useless or to be utilized or disposed of only with great difficulty in the country producing them.

c) the elaboration of special waste reutilization projects, coordinated and directed by specialized international institutions (FAO, UNEP, WHO, ECE, OECD, EEC, etc.);

d) periodic publication of all technical and legal information relating to the subject (Data Bank) through specialized international institutions (FAO, UNEP, OECD, etc.);

e) the promotion of an "international wastes market" in order to stimulate an appropriate exchange of wastes through information on demand and supply, prices, etc;

4.5 In examining the agricultural and agro-industrial wastes problem in modern society from the legal point of view and in viewing the aims and abovementioned solutions suggested for wastes management, one reaches the conclusion that a uniform strategy and legislation should urgently be adopted by the various states on a world-wide level. This goal could be reached both through bilateral or multilateral treaties, as well as through coordination of national legislations, once an agreement has been reached as concerns normative regulations.

Thus, taking into account recommended guidelines and general legal principles, a normative model should be worked out on an international level to which the various national legislations should endeavour to conform as closely as possible.

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Agricultural Residues and their Utilization in some Countries of South and South East Asia

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1. INTRODUCTION

This paper reviews the agricultural situation in some selected countries (India, Indonesia, Malaysia, Philippines, Thailand and Singapore) primarily to assess the availability and utilization of agricultural residues arising from processing of food and commercial crops, forest products, livestock and poultry and fisheries, and their effect on the environment. An attempt has been made to suggest some avenues of exploitation of these residues.

The dominant features of the economies of the countries of the region are their high rate of growth of population and their agricultural character. Enormous quantities of agricultural residues are generated which are not adequately utilized. Some of the processing operations result in effluents which cause serious pollution problems, such as pineapple canning wastes, palm oil processing wastes, rubber industry wastes, slaughter house wastes and sugar and distillery wastes. Serious attempts are being made to find economic uses of these wastes and some commercial/semi-commercial plants are already operating producing valuable byproducts.

After the last world war, most Asian countries started economic development programmes with emphasis on industrialization. Agriculture was assigned only a secondary role. The task of converting an agricultural society into an industrial society is not easy especially with insufficient capital response from the agricultural sector and whose poor purchasing power could not absorb the manufactured goods. Thus, raising the agricultural sector to match the industrial sector is an essential pre-requisite of a developing economy. In the countries depending on food imports, the trade gap grew so big that there was little scope for the import of capital goods needed for further development. It was this that compelled these countries to strive for increased food production which at least should keep pace with the growing population. The introduction of high-yielding varieties of foodgrains in sixties is thus not an accident.

The industry has been concentrated in predominantly urban areas and has had little impact on the rural population who continue to live on or below poverty line in these countries. The technology in most cases was imported from the more advanced countries. Several years of experience has shown that this mode of transfer of technology to overcome time gap cannot often be integrated with the social, economic and industrial needs of the society. This integration can only be brought about by developing new skills and resources and thus establishing a close relationship between technological opportunities and social goals to draw the vast majority of masses within the ambit of socio-economic progress. Excessive dependence on import of sophisticated technology will lead to a permanent 'second hand' economy.

The capital-intensive and labour-saving technology does not, in most cases, satisfy the socio-economic needs nor meet the infrastructural situation in a developing country where the capital is scarce and manpower abundant. Such imported technology leads to concentration of industry in the urban areas with the associated rural stagnation. Again, the choice of items of manufacture which are chosen do not serve the rural poor since they presently do not have sufficient purchasing power. It is therefore necessary that the technologies which are adopted or developed should be related to national priorities based on the needs of the vast majority of the people and must also involve a vast majority of the people in the production activity. It should be possible to disperse a technology in the rural areas, raise the technological competence of the rural population and involve them in value-increasing production activity. It should also be possible to produce more goods with less capital investment without in any way employing retrograde technology by presenting an alternative pattern of growth through dispersal of technology in areas of raw material availability.

2. STATUS OF AGRO-INDUSTRIES, AGRICULTURAL GENERATION AND UTILIZATION IN SOUTH AND SOUTHEAST ASIA

2.1 Cereals and Starches

2.1.1 Wheat and barley

Of the six countries reviewed, India is the only one which produces wheat and barley in substantial quantities. The production of wheat during 1973-74 was 22 million tonnes which has reportedly jumped to 28 million tonnes in 1976. The production of barley which is a crop of drier regions was 2.3 million tonnes in 1973-74 and is a staple food in some parts of Western India.

Wheat is generally consumed as a flour but barley mostly as preparations like gruel. Most of the grain is milled in small flour mills located all over the country and which produce whole grain flour. The large flour mills, however, process wheat into flour of various grits. Bran is the residue. Barley is also used for the production of beer (Indian production, 120,000 kl).

Generally wheat flour is consumed in India as chappatis (thin circular baked cakes). It is also consumed in the form of bakery products. There are 3,595 bakeries in India, of which 43 are large-scale, 343 medium scale and 3,209 small scale units producing 0.39 million tonnes of bread and biscuits. The demand of bakery products is increasing. It is placed at 0.8 million tonnes in selected urban areas alone in 1981.

Straw and bran

During harvesting, wheat and barley stalks (straw) are residues. These together with wheat bran are used as cattle fodder which is supplemented with oilcakes and gram, especially for milch cattle. With the introduction of shorter high-yielding varieties, the availability of wheat straw is somewhat reduced. Its current generation is about 60 million tonnes. The production of barley straw is around 8-9 million tonnes. Their present use as a cattlefeed is not likely to change in the foreseeable future.

2.1.2 Maize

Maize is grown extensively in almost all the countries of the region (total production, 15 million tonnes). The pattern of maize grain use differs from country to country. In India, it is a supplementary food-grain, a raw material for starch and glucose manufacture (6 factories) and as a component of poultry feed. In Thailand, almost all the grain production (3 million tonnes) is oriented towards export and in the Philippines, it is used almost exclusively as animal and poultry feed. In Indonesia, it is consumed as a supplementary food, and as animal and poultry feed.

Residues

Each hectare roughly produces 3-4 tonnes of stalks during harvesting. The ear is dehusked to recover the grain from the cob. The yields of various components are: grain 35 percent; husk and skin 30 percent; cobs 30 percent and skin trimmings 5 percent. The residue availabilities in the principal producing countries are (in million tonnes):

	Stalks	Husk, skin and trimmings	Cobs
India	18-24	5.7	4.8
Indonesia	9-12	2.9	2.5
Philippines	9-12	2.8	2.5
Thailand	10-14	3.0	2.6
Total	46-62	14.4	12.9

Thus, 75-90 million tonnes of maize crop residues are available in these four principal maize producing countries of the region.

Use pattern

The current use pattern of the residues obtained during the harvesting of maize is similar in all these countries with slight local variations. The softer stalks are invariably fed to the farm animals along with the husk, skin and trimmings, and sometimes the cobs. The harder parts of the stalks are composted. In Thailand, the usual practice is to plough the ash into the land after burning the stalks.

The cobs which have about 25 percent chaff and about 75 percent woody substance and a little pith have very little practical use at present. These are mostly burned as a fuel or added to other composting materials. These are also fed to the farm animals as a roughage. In Thailand, shredded cobs are exported. In India and Indonesia, shredded cobs are also used as a soil conditioner. Corn cobs are also used in India to produce furfural and as a moisture absorbant in stored grain.

Possibilities

The principal chemical constituents of maize stalks are cellulose (40 percent), pentosans (25 percent) and lignin (35 percent). Though several research laboratories in India and elsewhere have produced paper from maize stalks, the process has not been commercialized due to scattered nature of the raw material and the high cost of its transport. The paper also has a 'dirty' look. Various types of boards can, however, be manufactured in mini-sized plants. These are insulating boards, accoustical boards, and hard boards. These, however, will have to compete with cheaper saw dust which is available plentifully in all the countries of the region. Thus, there is very little scope for changing the present use pattern of maize stalks.

The maize cobs cannot find use as a raw material for paper or boards because of shortness of the fibre and their tendency to absorb moisture. These are extensively used to produce furfural by treatment with dilute mineral acids. It finds extensive use as a selective solvent, e.g., in lubricants manufacture, in resin production, as a plant protection chemical and as a raw material for other chemicals. Production of furfural from cobs would be better utilization of this residue than the current practice.

There are other possible uses of the maize cobs. A finely pulverized mixture of ground corn cobs and rice husk (hulls) is used as a sand blasting medium (replacing sand) for cleaning the automobile and aeronautic engine cylinders and pistons, large electric motors and generators to remove dirt and grease and for polishing moulded plastics and metal castings. The cobs can be used for the manufacture of light-weight bricks and ceramics (cob particles will burn away leaving porous product), and rug cleaners. The rug cleaners manufactured in USA contain about 66 percent by weight cob meal mixed with a non-inflammable solvent.

2.1.3 Rice

The cultivation of rice is the principal agricultural activity of the region. The six countries of the region produce nearly 80 million tonnes of paddy whose processing is therefore a major though scattered agro-based industry. The rice mills have varying capacities - from 0.5 tonne/hour of huller-sheller type to 4 tonnes/hour of modern rice mills. These operate for 200-300 days in a year depending upon the number of crops in the area. In rural India, rice is mostly produced by hand-pounding of paddy and is consumed as unpolished brown rice.

Residues

The harvesting of paddy generates approximately 4 tonnes/ha of rice stalks (straw). During milling, rice husk (20-25 percent) and rice bran (6 percent) are produced as byproduct residues. With the increasing introduction of shorter high-yielding hybrids, the availability of rice straw will correspondingly decrease. The current generation of these residues in the major producing countries of the region is given below (in million tonnes):

	Rice straw	Rice husk	Rice bran
India	140-150	14-15	1.2-1.5*
Indonesia	70-80	5-6	1.0
Philippines	12-14	1	0.25-0.3
Thailand	50-60	3-4	0.7-0.8

* 40-50 percent of the total paddy assumed as hand-pounded

Thus, the generation of rice straw, rice husk and rice bran in these countries is of the order of 270-300, 20-23 and 3-3.5 million tonnes respectively.

Use pattern

In India rice straw is used as a cattle fodder, for paper and board manufacture and as a reinforcing material in the preparation of mud plaster and mud fuska. Several mini-paper and board factories are being built.

With progressive introduction of high-yielding varieties which give lower straw yields the total availability may be restricted for the new ventures. This has been taken into consideration while expansion of pulp and paper industry was being planned in Indonesia. For example, in Java, the straw availability in the next few years will be about one-fifth of 1973 figures. The use pattern in Indonesia is: 50 percent as cattle feed; 25 percent as soil conditioner and 25 percent available for industrial applications. At present, there are three paper mills based on rice straw. The part of the plant which bears rice (locally called merang) is preferred because of low silica and high cellulose content. The plant at Letjas (cap. 15,000 tpa) uses both straw and merang while those at Blabak (Central Java: cap. 7,200 tpa) and at Pedalarang (cap. 4,000 tpa) process only merang. The last unit also manufactures cigarette paper (1,500 tpa) with imported pulp.

In addition to the above use pattern, rice straw is used as medium for mushroom culture in the Philippines and Thailand.

The quality of the husk depends upon the type of rice mill. In the huller type of equipment, the husk is obtained in fine broken state and is always mixed with some bran and broken rice. This is usually used by farmers as cattle feed or as a fuel in the rice mill itself. In the sheller-cum-huller or modern rice mills, the husk does not carry any admixture. The average composition of paddy husk is (in percent): cellulose 42-43; lignin 20-21; pentosans 19-20; ash 18-19. Ninety percent ash is silica which is present in its amorphous and reactive state.

The present uses of rice husk in all the countries of the region are: as fuel in the rice mills for parboiling, in brick kilns, and in households; as a soil conditioner, especially after partial burning; as a bedding material for poultry and livestock; as a roughage in animal feed and as a packing material, and as a building material (hollowblocks). In India a plant is operating to manufacture activated carbon from rice husk. Sodium silicate will be obtained as a by-product. An unusual use made of ash left burnt husk in India is by the washermen who mix it with soda ash and wash their laundry with the mixture.

The average composition of rice bran in India is as: water 8.5-12.5; protein 10.6-13.4; N free extract 38.7-44.0; fat 10-20; fibre 9.6-14.1; ash 9.3-14.3; and pentosans 8.4-11.4 percent. It also contains B-vitamins of the order of 544 mg/100 g. The variation in its composition is due to the type of equipment used for paddy processing. For example, the fat content of bran from huller mills is 6-8 percent, from sheller mills, 12-15 percent, and from modern rice mills, 15-20 percent. Again, the parboiled rice gives bran with relatively higher oil content.

Most of the rice bran is currently used as an animal feed. Even in India which has a large solvent extraction industry (30 plants), only 40-50 percent of the available bran was extracted yielding 90,000 tonnes of oil (1975). In the Philippines, Indonesia and Thailand, there is only one plant each. The scattered nature of its production, the consequent difficulty of collection, and the highly unstable nature of bran (fat) induces the rice miller to sell the material quickly. Rice bran is also known to catch fire spontaneously in the hot and humid climates due to enzymatic action. Hence storage over long periods and transport over long distances is generally avoided.

In India, several rice mills have installed simple and inexpensive bran stablizers where bran is heated to inactivate lipase making it possible to store rice bran for 30-40 days. The oil produced from fresh or stabilized bran has low free fatty acid content (ffa) making its use as an edible oil possible (fatty acid composition is: oleic 41-45; linoleic 28-37; palmitic 12-17 percent). Rice bran oil has 3.5-9 percent wax which is deposited during storage. It finds use in the manufacture of polishes and carbon paper.

Most of the rice bran oil in India is split and distilled to give fatty acids and glycerol. Fatty acids are used for making soaps, and in rubber and other industries. The deoiled bran is exported or used as a cattle and poultry feed.

Possibilities

Rice straw can be used as a source of pulp and paper. With its diminishing availability as more and more land goes under high-yielding varieties, greater attention is needed to the utilization of husk and bran. However, some new approaches on rice straw utilization as an animal feed are under investigation in Singapore. These include treatment of straw with alkali and subsequent ensilage, ammoniation, high pressure treatment and surface fermentation. The last is capital intensive. Alkali treatment followed by ensilage is considered promising.

The rice mills have to be modernized not only to obtain better yields and quality of husk and bran, but also to increase the yield of head rice by reducing the brokens. In India, there are nearly 83,000 rice mills of which 74,000 are huller-type, 2,000 sheller-type, 7,000 sheller-cum-huller type and only 63 modern rice mills. The situation of other rice producing countries is similar though figures are not available.

Rice husk can find variety of new uses. The manufacture of activated carbon and sodium silicate has been mentioned. Production of carbon black is another possibility which is being investigated in India. Certain types of tyres and tubes use both carbon black and silica (white carbon) in their manufacture. Rice husk carbon black may perhaps be a cheaper substitute.

In Thailand, rice husk along with coconut fibre has been successfully tested as a filtration medium to produce clean water from river water. The process has immense scope in the densely populated countries of the region where potable water does not as yet reach every home. In the Philippines, a cyclone burner has been designed which is currently under test using rice husk. Rice husk is also being used for flue curing of tobacco. Another interesting application of rice husk is the preparation of molecular sieves which is currently being investigated in India as also is the manufacture of oxalic acid from rice husk. In USA, paddy husk is a raw material for furfural as are maize cobs and cottonseed hulls.

In the manufacture of plywood ,finely ground materials like wheat flour are used as extenders during the glueing operation. Detailed investigation is needed to see if husk of the desired fineness can be used instead. Some preliminary studies have shown promising results.

Another possibility is the manufacture of silicon carbide which is being investigated in USA and India. Rice husk has the desired composition with respect to silica and carbon requirements. Since silica in rice husk is highly reactive, it will require lower reaction temperatures. Production of silicon tetrachloride required for silicon manufacture, is being investigated in USA.

The rice husk has a calorific value of 5,000-6,000 BTU/lb and an ash content of about 20 percent. Experiments in India and USA show that these characteristics can be taken advantage of in its utilization as a raw material for cement manufacture.

Indian workers have also shown that rice husk can be used for the manufacture of fire-proof and water-resistant bricks, as an insulating material, for production of producer gas and its ash as a detergent component.

There are several uses of rice husk in agriculture. It can be used as a soil builder (in the form of mulch) and for prevention of blast disease. In USA, rates up to 250 tonnes/ha have been applied. It can also be used as a supporting medium for hydroponics.

2.1.4 Millets and sorghum

Millets and sorghum cultivation in the region is restricted to India. The millets occupy an area of about 13 million ha and sorghum of about 17 million ha. The total grain yield from these crops is about 20 million tonnes. All the crop residues are currently used as a cattle fodder and there does not appear to be any scope for change in this use pattern.

2.1.5 Non-cereal starches

The two chief raw materials for the manufacture of starch in the region are maize (2.1.2) and tapioca. Another source of starch in India is the tamarind seed. The manufacture of starch from maize and tamarind is restricted to India. Tapioca, however, is a cheaper and favoured raw material even in India. Starch is used by the textile, kenaf, jute, paper, glucose and dextrose, and by the food industries.

Tapioca (cassaon)

Tapioca is an all season crop of humid tropics. Indonesia's production of tapioca (9.4 million tonnes in 1973) is next only to rice (14.7 million tonnes in 1973). In the Philippines, the production of all root crops, mainly tapioca, in 1975 was 1.8 million tonnes. Malaysia has a relatively small area under cultivation and produced 0.4 million tonnes. Thailand produced 6.3 million tonnes, most of which was exported. In India, tapioca is cultivated only in the South and to a little extent in the hilly regions of NE India. The total production in 1972-73 was 6.3 million tonnes.

The tapioca plant has an unusually high photo-synthetic potential for conversion of solar energy into starch. About 3 tonnes of roots yield about 1 tonne of meal. The roots are perishable and deteriorate within a few days of harvesting if they are not dried and adequately stored. Recently, improved methods have, however, been suggested to increase their storage life.

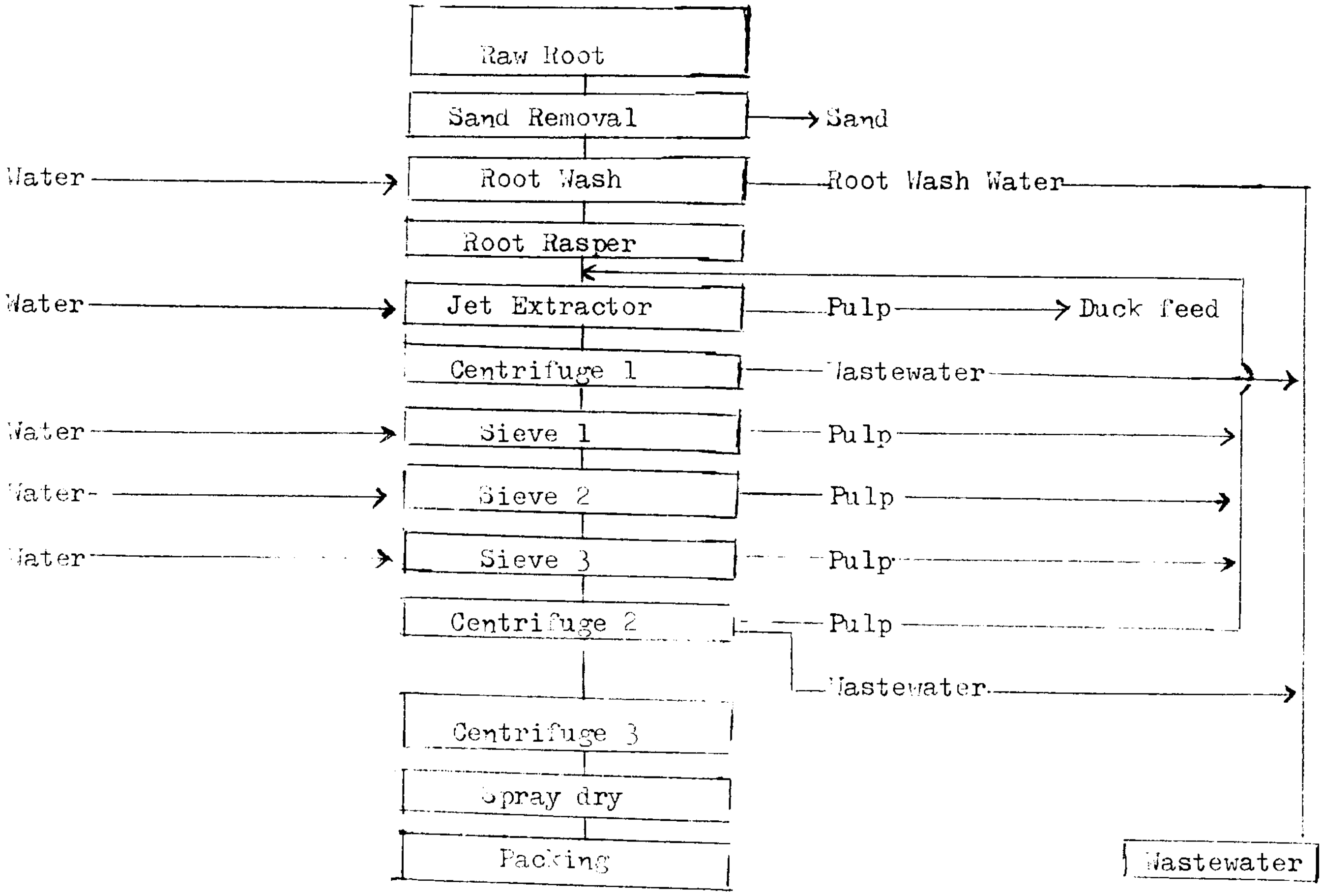
The tapioca plant is hardy and grows in sandy soil yet its uptake of nutrients from the soil is high. Small farmers in SE Asia therefore grow it on newly cleared forest areas. The new commercial varieties have 38 per cent starch in the tubers and the yield is 40 tonnes/ha.

Use pattern

Tapioca is a supplementary food to varying extents in the entire region. The major outlet is the manufacture of starch. The granulated starch called sago or pearl is exported. It constitutes an important ingredient of most of the animal feeds.

The commercial tapioca feed may be in the form of dried (usually sundried) and chipped roots of various shapes or pellets. The pellatized product is preferred since it decreases the volume, is easier to transport and is uniform. It also permits the use of dried tapioca leaves and the residual pulp for starch manufacture.

The following flowsheet diagram broadly describes the process steps in the manufacture of starch from tapioca and the nature of effluents generated.



TAPIOCA STARCH PLANT FLOW DIAGRAM

Residues

During the harvesting of roots, the woody stem of the plant is cut about 6" from the ground. The leaves along with the softer plant are fed to the farm animals. The leaves may also be dried and pellatized either alone or with dried roots. The leaves are also consumed as a vitamin-rich green vegetable. The stem is used as a domestic fuel, as a replanting material or is ploughed back.

The manufacture of pellatized tapioca does not generate any residue. Manufacture of starch does and such residues are a serious pollution problem. The effluents consist of peels, pulp and liquids. The peels have no use except as a land fill. The pulp is usually pellatized along with the dried roots. It is also sundried and sold as animal meal (1 tonne from 100 tonnes of fresh roots). The pulp composition in Thailand is as (percent): moisture 12.7; ash 9.1; fibre 8.1; fat 1.0; protein 2.5; carbohydrate 65.9.

The liquid effluents which have high suspended organic matter and dissolved solid and, therefore, high COD and BOD, are usually discharged into nearby streams. The characteristics of the two effluent streams, viz., separator and root wash water from a factory manufacturing 30 tonnes of starch per day in Thailand are:

	Separator water	Root wash water
Flow rate, m^3/day	680–1,250	760–1,600
pH	3.4–4.2	4.2–7.1
Suspended solid, mg/l	1,480–8,400	400–6,100
Settleable solids, mg/l	60–200	10–100
Total solids, percent	0.56–0.93	0.02–0.55
Volatile solids percent solids	92–98.6	59.4–90.0
Dissolved oxygen, mg/l	0	0.6–5.3
BOD_5, mg/l	3,000–4,400	200–1,700
COD, mg/l	3,100–13,900	2,000–4,850
Organic N, mg/l	19–38.9	14.5–18.2

The root wash water normally consists of cork cells, sand and clay particles. During wet season, the demand of water increases as does the quantity of suspended solids.

Possibilities

The effluents from starch industry are the major residues in the processing of tapioca. Resultant environmental pollution has been the concern of all the countries of the region and more stringent laws to control such pollution have been introduced. Several research institutes in the region have worked out schemes to utilize the high organic content of the effluents before discharge. Various types of yeasts have been made to grow on the waste waters. Torula yeast will grow well and reduce COD by about 73 percent. The yeast mass (protein content, 50 percent) had a yield of 500 g/kg of COD removed. Supplementary nitrogen (about 500 g for every 25 kg of COD removed) was found necessary. Without added nutrient, 40 percent of solids in waste waters were recovered as yeast cells in 8 hours. The total solids and BOD of the treated waste water after yeast production were 0.38 percent (w/v) and 1,800 mg/l respectively. Some institutes are experimenting on growing algae in the remaining waste water using carbon dioxide (likely to be available from yeast propagation). The growth of algae is, however, slow and harvesting expensive.

Among the new uses of tapioca which have been suggested are its protein enrichment by direct solid-substrate or a liquid fermentation using starch degrading organisms. Recovery of biomass is attractive but the economics of production of the enriched food material have yet to be worked out.

2.2 Pulses

Pulses and other legumes form an important part of diet of the region. In India, where a substantial population is vegetarian, these provide the major source of protein. The pulses usually have 20-30 percent protein which is three times the value in the cereals.

Except for soyabean, India is the largest producer of grain legumes (total area under cultivation, 22.5 million ha, production 10.4 million tonnes). Chickenpea or Bengal gram accounts for nearly one-third of the area and two fifths of the production. The average yield of pulses is low. Due to long duration of the maturity of these crops, these are generally intercropped or are cultivated on lands of marginal productivity. With the introduction of new shorter duration varieties, multiple cropping is now possible and 4-5 crops can be raised. Besides black gram, other pulses produced in India are: pigeon pea (red gram), black gram, green gram, lentil, horse gram, peas, chickling vetch (kesari dal), red bean and moth. Soyabean is a new introduction in India more as a source of cooking oil than as a grain legume. The soyabean meal, however, will be available as a rich source of protein for the human and animal diet.

Soyabean, mungbean (green gram) and peanuts are the principle legumes of SE Asian countries and are part of the traditional foods of the people. Other species consumed to a lesser extent are cow-pea, chickpea, pigeon-pea, peas and some dry beans. While mung bean and peanuts occupy more area in Thailand (80 percent of all legume crops), soyabean is the principal legume grain produced in the Philippines and Indonesia. Soyabean is consumed in a variety of ways in all these countries. Red bean is a new introduction in Thailand and Malaysia.

Use pattern

When the grain is used directly without dehusking as in several soyabean and mungbean preparations, no preprocessing is required. Milling is necessary where dehusking is to be done. For extraction of oil and for the production of soyabean meal for human and/or animal consumption, solvent extraction and other processing is used. The dehusking operation gives an yield of 80-85 percent of finished product. In India, heat puffed legume grains are also consumed as snacks or in food formulation. For this purpose, the grain is soaked in water and then toasted (250°C) for a short duration (30 seconds). Another form of consumption is in the form of flours. Recently, several weaning and supplementary foods have been introduced.

Soyabean is consumed as fermented preparations like Natta and Tahu, as milk and curd, as boiled beans, as green soyabean, in cakes and biscuits, and in other ways. Some quantities are also used for extraction ofoil and production of soyabean meal. This aspect will be dealt with under oilseeds (2.3).

Residues

All the residues generated during harvesting and processing are fed to cattle or ploughed back into the land.

2.3 Oilseeds

2.3.1 Cotton

In the region, cotton is grown extensively only in India. There are several varieties of cotton: some are local short-fibres while others have been developed by cross breeding to give a long staple. In 1974-75, 1.2 million tonnes of cottonlint was produced, and the ginning yielded over two million tonnes of cottonseed. The textile industry is one of the major industries in the country, both from the standpoint of investment and employment potential. The output of cloth in 1975 was 8,000 million meters. In addition, there are about 5,000 hosiery units in the country.

Residues

The main harvest residues are the stalks and leaves. The ginning operation yields cottonseed and cotton dust in addition to the main product-lint. Dust is also obtained in the textile factories. The processing of cottonseed for oil and cake leaves hulls and linters as residues.

The yield of stalks/ha varies according to irrigation conditions. The total availability in India is estimated at 12 million tonnes.

The processing of cottonseed produces 26 percent **hulls**, 45 percent cake, 16.5 percent oil, and 6 percent linters. Thus, if all the 2 million tonnes of the available seed is processed, the various products (in ten thousand tonnes) obtained will be: hulls 52; cake 90; cottonseed oil 33; linters 12.

The cotton dust generation is of the order of 30-33,000 tonnes.

Use pattern

Cotton stalks are currently used as a fuel. About 60-65 percent of the cottonseed is crushed to obtain oil, oilcake and other byproducts. The rest is consumed as cattle feed. Small producers directly crush the seed, sometimes, even without decortication. The oilcake thus produced carried linters and hulls. It is estimated that about 200,000 tonnes of cottonseed oil are being processed in this fashion producing 600,000 tonnes of undecorticated cake.

Cottonseed oil has a high linoleic acid content and is used as a cooking oil and in the manufacture of hydrogenated fat. The oil is refined before use with caustic soda treatment. The refining carries all the pigments (e.g. gossypol) into soapstock yielding a very dark product which is split and distilled to get fatty acids for industrial application.

Cotton linters find ready users in several alphacellulose based industries like rayon, cellulose acetate and nitrate and carboxy-methyl cellulose. These industries require short fibres (2-6 mm) which are further purified by digestion with caustic soda to produce chemical cotton. The specifications for various grades of chemical cotton are given below:

	For viscose	For Cellulose	For cellusose nitrate
Alpha-cellulose percent (min.)	98.0	98.5	98.5
Ash, percent (max.)	0.1	0.1	0.1
Fe, ppm (max.)	35	30	30
Mn, ppm (max.)	0.4	-	-

The longer fibre is used in the manufacture of surgical dressings, absorbent cotton, twines, batting material and paper.

Cottonseed hulls are mainly used as a low-protein roughage in cattle feeds. These also keep the cattlefeed porous and easy to reach the animal digestive system. Their food value equals rice or wheat straw. A small quantity of hulls are used as a fuel in the oil mills. Cottonseed hulls have average chemical composition as (percent on dry basis): cellulose 43.9; pentosans 29.5; lignin 22; ash 1.8; protein 3.3; crude fibre 49.2.

Cottonseed cake is a highly valued source of protein to the livestock. It also contains fat, carbo-hydrates and vitamins. The presence of toxic gossypol in the cake does not affect the ruminants but it cannot be fed to human beings and non-ruminant animals without the removal of gossypol. The specifications for decorticated cottonseed cake are (percent): moisture 8; protein 40; fibre 10; fat 8; ash 7. The solvent extracted meal has higher protein and fibre and lower fat contents.

The cotton dust or trash is the waste product of ginning and textile industries. The ginning mill trash also contains non-lint elements such as grass, leaves, stems and bolls.

The cotton dust is used as a fuel in the boilers or as a cheap batting material. Its characteristics are (percent): moisture 8; organic matter 70; carbon 41; nitrogen 1.4; P_2O_5 0.6; K_2O 1.2. Its C/N ratio is 29.3 and pH 6.2.

Possibilities

The main problem in the commercial utilization of cotton stalk is its bulkiness and therefore its collection and transport. It is reported that in USSR, stalks are chopped and pressed before being transported to paper/board mills.

The major difficulty in proper utilization of cottonseed in India is the unscientific belief of the farmer that seed is a superior cattle feed as compared to the cake or meal. Another factor is the growth of unorganized small-scale milling industry where large quantities of undecorticated seed is crushed. In some parts of India (Punjab and Haryana), the delinting operation is carried out in the ginning mills and the seed is made available to the users. With some incentives, it may be possible to extend delinting facilities to all ginning mills and thus make linters available to the consuming industries.

In addition to their present use as a roughage, cottonseed hulls can be used as a soil conditioner. The presence of calcium, magnesium, potassium and some phosphorous and trace elements will be beneficial to the soil. Due to high pentosan content (30 percent), the hulls are raw material for furfural manufacture in USA. When hulls are leached with water to remove tannins, the furfural yield is reported to be higher. Cottonseed hulls can be used as a source of activated carbon, charcoal and byproduct pyroligneous acids.

The composition of cotton dust indicates it will be more useful to return it to soil rather than burn it. Composting experiments in India indicate that one tonne of dust results in 0.6 - 0.7 tonne of compost in 3 weeks at a nominal cost. The quality of product is good and uniform and it lends itself to easy packaging.

2.3.2 Groundnut

Groundnut is India's principal oilseed. In 1974-75, an area of 7 million ha was under cultivation producing 6 million tonnes of groundnuts. Indonesia produced 0.3 million tonnes in 1973. Production in other countries was little. There are several varieties which are cultivated. They vary in the kernel size, shelling percentage and the quality and quantity of oil.

Use pattern

Groundnut is used as a source of cooking oil and cake and as a food component. The total oil milling capacity in India is 24.3 million tonnes comprising a large number of village crushing units called 'ghanis' (230,000) and 13,600 commercial expellers.

The harvested groundnut is sundried or sent directly to the shellers or millers where it is dried to moisture level of about 8 percent. Any storage of groundnut of higher moisture content is liable to aflatoxin contamination. The shells constitute 68-74 percent of the total weight. The kernels on processing yield about 39 percent oil, 59 percent cake and about 2 percent foreign matter.

Groundnut oil is a favoured cooking medium. Substantial quantities are also converted into hydrogenated cooking fat. It finds some use in lubricants and for canning of sardines.

Groundnut cake is used as an animal feed, as groundnut flour for human consumption, in confectionaries, as a fertilizer and for the manufacture of adhesives.

The shells are used as litter for poultry and as bedding for animals. The harvest residues are fed to cattle.

Residues

The only residue of any consequence in groundnut processsing is the groundnut shells. Due to their bulk and high transport costs, large quantities remain unutilized. Wherever shelling plants are in rural neighbourhood, shells are returned to the soil. Since they have poor burning properties, they hardly find outlet as a fuel.

Possibilities

Groundnut shells as a source of activated carbon has been investigated in India but other agricultural wastes are available more easily and cheaply and yield better quality of end-product. In USA, shell powder has been used as a carrier of pesticides and as a filler for fertilizers. Other possibilities are: conversion to briquetted charcoal; particle board; and conversion to edible protein by action of micro-organisms.

2.3.3 Castor

India is the only country in the region which produces castor and contributes about 30 percent towards total world output. Other large producers are Brazil and China. During 1974-75, 216,000 tonnes of seed were crushed yielding 77,000 tonnes of oil and 130,000 tonnes of castorseed cake. About half the quantity of the oil and cake is exported. With the introduction of new, hardy, short duration and high-yielding varieties, especially Aruna, the production of castorseed is expected to go up.

Use pattern

Castorseed is crushed for its oil and cake. The pretreated seed is expelled in hydraulic type of expellers. The oil is refined and bleached for industrial applications. The cake which still has 10-12 percent oil is solvent extracted in large capacity plants. The smaller plants do not have this facility. The yield of the oil is around 40 percent by weight of seed. The seed is usually expelled undecorticated and about 58-59 percent cake is obtained. Where decortication is carried out, 30 percent cake and about 28-29 percent shells result.

Castor oil is used in textile industry, in the manufacture of lubricants and high pressure greases (as hydrogenated castor oil), in paints and varnishes (as dehydrated castor oil) and in cosmetic and leather industries. Recently, its use in soap industry has gone up considerably. It is also used in the manufacture of hydraulic brake fluids and some perfumery. A declining use is as a medicine.

The solvent extracted castor meal has the following composition (percent dry basis): N 5.5 - 6.0; P_2O_5 2.5; K_2O 1 - 1.5; CaO 1; MgO 0.5 - 0.7; organic matter 85 - 87. It has several trace elements (Cu 27 ppm; Mn 55 ppm; B 23 ppm). Castor meal contains ricin, an alkaloid, and an allergin. The fine sharp particles of castor shell left in the meal can cause damage to animal digestive systems. Hence it cannot be used as a cattle feed even after detoxification. Its only outlet is as a fertilizer which is preferred for horticultural crops. The stems, the main harvest residue, are used as a fuel or ploughed back into the soil.

Possibilities

Castor oil is a versatile industrial raw material. Considerable efforts are being made to find new uses. Some of the recent commercial products are tallow substitutes, hydrogenated castor oil and high dielectric oils. Other possibilities are dehydrated castor oil di- and polyamides, new surface coating compositions, mono- and diglyceride derivatives and oxygenated and esterified products.

2.3.4 Sunflower (Helianthus)

Sunflower has recently been introduced in India. The high oil - yielding varieties imported from Europe have successfully adapted to the local condition but it is too early to assess their firm establishment. Sunflower's chief attractions are its being a short duration crop (80-100 days) and its high yield of seed (3-3.2 tonnes/ha). The present cultivation area of 351,000 ha, mostly in the Western and South India, is intended to be increased to 650,000 ha during the current season especially in semi-arid zones in the north and central India. With an edible oil yield of 50 percent, the seed seems to have immense scope once it takes to local environment.

The crops residues are ploughed back and the oil cake after extraction of oil is used as a cattle feed.

2.3.5 Safflower (Carthamus)

It is a minor oilseed crop of some parts of Western and South India. The total area under cultivation in 1972-73 was 416,800 ha producing 78,900 tonnes of seed which is nearly two-thirdsof that of the previous years. It is reported that the cultivation area has further decreased, perhaps due to competition with sunflower and other more remunerative crops. Like sunflower, safflower is also a single-stemmed plant and also yields similar oil which is high in polyunsaturated fatty acids (PUFA). The yield of the oil is around 50 percent.

The oilcake and crop residues are disposed of in the same manner as those of sunflower seed.

2.3.6 Rape and mustard

These oilseeds are obtained from plants belonging to genus Brassica, family Cruciferae. The oleiferous Brassica grown in India are: rai (mustard), and yellow and brown sarson (rape). In 1974-75, 3.6 million ha in India was under rape and mustard, producing 2.2 million tonnes of seed which accounts for nearly 25 percent of total oilseed production. The crop is generally sown as a mixed crop with wheat, barley and gram.

Use pattern

Most of the mustard and rape seeds are crushed for their oil and all available species are mixed before crushing. A small part also finds use as a condiment for curries and pickles. The extraction oil is carried out in the village animal or power driven rotary mills, in hydraulic presses and expellers and by solvent extraction. In most cases, a combination is used to extract the maximum quantity of oil. The rotary mills leave 10-15 percent oil in the cake, the hydraulic presses and expellers 7-8 percent and solvent extraction only 1 percent. The yields of the oil and cake are 33 and 62 percent respectively.

The oil is the principal cooking medium of northern and eastern India. It also finds small applications as oils and lubricants, and as a soft soap for textile sizing.

The oilcake is used mostly as cattle feed and to a small extent as a fertilizer.

The crop residues after harvesting are used as cattle fodder.

2.3.7 Sesamum

Sesame is one of the oldest oilseeds known to India. It is cultivated all over the country as kharif in rainfed areas and as rabi in irrigated land. During 1974-75, an area of 2.2 million ha was under sesame cultivation producing 408,000 tonnes of seed.

Use Pattern

About 20 percent of the seed is consumed in food preparations and about 77 percent is crushed for oil and cake. Animal- and power-driven multiple rotary mills are generally used for the extraction of the oil which is consumed directly for cultinary purposes. About 5 percent of sesame oil is used in hydrogenated cooking fat. It is also used in pyrethrum based insecticides.

The oil cake (oil content 9-15 percent) is used as cattle and poultry feed and is particularly rich in methionine. The cuticles contain oxalic acid. The decuticled seed meal is used for human consumption.

The crop residues are ploughed back into the soil.

2.3.8 Linseed

The genus Linum, to which Linum usitassium, the common linseed or flax plant, belongs, embraces nearly 100 species. The cultivation of linseed varieties for oil is restricted to a few countries. It is a dual purpose crop, yielding both oilseed and fibre. In India during 1974-75, an area of 2 million ha was under its cultivation, yielding 538,000 tonnes of linseed mostly through mixed cropping. The oil content is in the range of 37-43 percent. Linseed is not grown in other countries of the region.

Use pattern

The seeds are crushed for their oil and cake. The deseeded stalks are either burnt as a fuel, fed to the cattle, used for thatching purposes or for extraction of fibre.

Linseed straw which is free from immature seeds is comparable to oat straw in nutritive value.

The processing for fibre is similar to flax. The stalk bundles are cooked in water or caustic soda and the fibre separated from the core by passing through fluted rollers. A dry process for the removal of fibre is also used. The yield of dry straw is around 1.5 tonnes/ha and that of fibre is 20-25 percent of dry straw. The dry process is reported to give higher yields than ratting. The fibre length is 20-30 mm and contains moisture 9; cellulose 80.7; pectin 3.1; lignin 3.6; wax 2.4; water solubles 2.1 and ash 1 percent. Though inferior to flax, the fibre is strong and is spun as textile, generally along with other fibres. It is also used in the manufacture of ropes, twines and canvas. Linseed fibre is used for the manufacture of speciality papers. The pulp yield is 64 percent. The residue left after extraction of fibre is used as a fuel or as a cattle bedding material.

During extraction of oil from seeds, the average percent yield of various products is: oil 37.6; soapstock 1; cake 57.4; foreign matter 2; and processing loss 2. The oil is characterized by the presence of high linoleic acid content (50-57 percent). For this reason, it is mostly used as drying oil in surface coatings industry. To a limited extent it is also used as cooking oil.

Though relatively low in protein (36 percent) linseed cake is palatable to cattle and is considered as a good supplementary cattle feed due to the presence of other nutrients. The cake is also a good organic manure (N 5; P_2O_5 1.4 and K_2O 1.8 percent). A considerable portion of oilcake is exported.

Possibilities

The only part of linseed plant which is not fully utilized is the deseeded stalk. The total dry straw generated in the country is around 3 million tonnes and only a small fraction is currently used for extraction of fibre. The residue left after removal of fibre can be used for making wall board. The consumption of fibre by paper industry can be increased.

2.3.9 Soyabean

Soyabean is a minor crop in all the countries of the region. In SE Asia, soyabean is cultivated more as a food supplement than as an oilseed. The production in Indonesia in 1973 was 50,000 tonnes. Due to high inputs and poor returns the farmers are reluctant to extend the cultivation area under this crop. This may be illustrated by the area under the crop in the past four years. In 1971-72, the area covered by the crop was 45,000 ha which increased to 0.125 million ha in 1972-73. Based on this increase, the target for 1973-74 was fixed at 0.4 million ha but had to be revised to less than the previous year, viz. 92,500 ha. In 1974-75, only 90,000 ha area was under this crop producing about 70,000 tonnes of soyabean. The target for the Fifth Five Year Plan is 0.43 million ha to produce 0.4 million tonnes of soyabean. India imports soyabean oil to meet domestic demand of cooking oils (in 1973-74, 60,387 tonnes imported).

There are nine processing units in India which are equipped to extract oil and produce soya meal. A plant to process 250 tpd soyabean is also being set up by a government agency. Until the cultivation of soyabean is stabilized and the utilization of soya products is organized adequately, soyabean will continue to be an exotic crop without firm roots.

Use pattern

Soyabean is a food supplement in SE Asian diet. Very little extraction of oil from soyabean occurs. In India, both oil and protein components are intended to be utilized. Almost all the soyabean oil is consumed by the hydrogenated cooking fat industry. The meal is toasted to make it free of trypsin inhibitor and air-classified. The coarser material is used as animal and poultry feed while the finer material is used for making textured food and other items for human consumption.

2.3.10 Minor oilseeds

The monsoon region with its rich vegetation has a vast resource of as yet unexplored oilseeds. Some of these, like rubber seed, are being investigated. In India, a few others are being commercially exploited to a small degree. Their collection and the cost of transport to the usually distant processing centres are the principal reasons of their non-utilization. Only 200,000 tonnes of seeds are collected to give 40,000 tonnes of oils while the potential at a conservative estimate is 7-8 million tonnes which can produce 1.4 - 1.6 million tonnes of non-edible oils for soap and other industries. Minor oilseed processing technology lends itself to dispersal in the rural and forest areas - the source of seed. The establishment of a new industry in a dispersed fashion will be of interest to all developing countries. Some of the minor oilseeds which are being exploited in India are: mahua (Bassia latifolia, B. longifolia); neem (Malae azadirachta); karanja (Pongamia glabra); kusum (Sheleichera trijuga); and sal (Shorea robusta).

2.4 Vegetables, Fruits and Herbaceous Crops

The vegetables, fruits and herbaceous crops in the region are those which suit its tropical and semi-tropical climate. In India, temperate region fruits and vegetables are also grown. Most of the produce is consumed fresh and very little canning is done.

2.4.1 Vegetables

The vegetables and herbaceous crops grown in the region may be classified under:

Solanaceae: potato, capsicum, egg plant, tomato.

Cucurbitaceae: pumpkins, gourds, cucumber, squash, melon.

Compositae: artichoke, lettuce.

Cruciferae: cabbage, cauliflower, celery, knol-khol, mustard, radish, turnip.

Umbelliferae: carrot, anise, caraway, coriander, dill, fennel, parsley.

Liliaceae: asparagus, leek, onion, garlic.

Amaranthaceae: amaranthus.

Leguminosae: beans, peas.

Dioscoraceae: yams.

Chenopodiceae: spinach.

Malvaceae: okra, Indian red sowel.

Convolvulaceae: sweet potato.

Labiatae: rosemary, sweet basil, sage, spearmint, sweet marjorum, thyme , rue.

Tree crops: green papaya, raw jack fruit, plantains, curry leaf (*Murraya koenigi*), drumsticks (*Moringa pterygosperma*)

2.4.2 Fruits

The main fruits of the region are banana, pineapple, mango, durian, medlar, rambutan, litchi, guava, papaya, jack fruit and citrus. In India, the temperate climate also permits the culture of apples, grapes, plum, apricot, fig, strawberry, pear, peach, gooseberry and pomegranate. In addition, mulberry, custard apple, guava, lemons, sapota, litchi and date palms are grown as minor fruit crops.

Use pattern

Most of the vegetables and fruits are consumed fresh in all the countries of the region and constitute important supplementary food. The processing of fruits and vegetables is, therefore, a relatively small industry. In India, for example, 32 million tonnes of fruits and vegetables are produced annually but only 52,274 tonnes of fruit and vegetable products are produced by 1,094 processing plants.

Vegetables are rarely canned; the exceptions being tomato (as sauce, ketchup and juice), chilli (as sauce), pickles and peas. The fruits which are processed are: pineapple, citrus, mango, apple and guava. The canning of fruits generates enormous residues of high BOD and COD content and is a serious environmental problem.

Residues

In the manual harvesting and during haulage of fruit and vegetables to the market, considerable damage to the product takes place. Since the transport availability is usually uncertain, plucking before full ripening is practised in some cases. This results in loss of fruit, especially in pineapple canning. The vegetable crop residues and the damaged fruits are usually fed to the animals.

The canning of fruits and vegetables is characterised by the seasonal character of raw material, extensive use of water during processing, high solids and suspended matter content of the effluents, and the instability of the residues. Pineapple which is extensively canned in all the countries of the region, generated for example in Malaysia, 0.21 million tonnes of wastes during processing of 0.25 million tonnes of fruit in 1974.

The pineapple processing consumes about 20 per cent of the fruit; the rest constitutes the wastes. For each fruit processed, 126,000 mg of BOD ro 158,000 mg of COD is loaded on the discharge stream. The core, skin and fleshy wastes are recovered and processed for juice. The waste bran is dried (12 - 14 per cent yield) and sold as cattle feed. Pineapple wastes have also been converted into wine.. In the Philippines, the wastes are converted into wine. The pineapple wet wastes have the following composition (per cent) : dry matter: 14.3; crude protein: 1; crude fibre: 3.6; ash: 0.7; and N-free extract: 7.7. The dry wastes have the following composition (per cent) : crude protein: 9.1; ether extract: 2.75; crude fibre: 30.4; ash: 8.7 and N-free extract: 49.

Green mango is pickled. Ripe mango when processed, yields peels, stone (including kernel) and other processing wastes which together constitute 50 percent of the weight of the fruit. Mango kernel contains protein 8.5 percent, crude fibre 2.8 percent and 75 percent N-free extract. The kernel starch is edible. The kernel also has 12 percent oil. In the Philippines and Thailand, the peels are mixed with poultry litter, other fruit wastes and tapioca, and after ensilage is used as animal feed. Indian industry generates 8,500 tonnes of mango wastes which are not utilized. The total production of mango in the country is about 7 million tonnes. The total residue generation, including that from consumption as a fresh fruit, is thus of the order of 3 - 3.5 million tonnes. Mango is not canned in other countries of the region.

Banana peel constitutes about 35 per cent of the weight of the fruit which is currently thrown away. Part of it is however consumed by the cattle. In the Philippines, banana flour is made from rejects.

Citrus processing wastes except seeds are used for compounding animal feeds. In India, the peels are processed for pectin and essential oils. A small part of it is also candied.

Possibilities

Several research institutes have been working on the possible uses of fruit processing residues. The approach includes the utilization of high carbohydrate content of the effluents for SCP production. The pilot plant trials have suggested this as an economic method of control of pollution. Another microbial approach is the conversion to alcohol and vinegar as practised to some extent in the Philippines.

According to one expert, the conversion of fruit cannery wastes into SCP is not an economically viable project. In his opinion, the sugars should be converted to alcohol which will give yeast as a byproduct. Two hundred tonnes of pineapple waste will give 3 tonnes of alcohol, 20 tonnes of pineapple bran, 0.4 tonnes of yeast and 1.3 tonnes of distillable soluble wastes. The bran and yeast make a rich animal feed.

Mango seed kernel is a rich source of starch and protein and a good animal feed. The problem, however, is that of collection of seed. Currently the seed eventually finds its way to compost pits which perhaps is also a good use. If collection were possible, oil could be extracted for use in soap industry.

Ensilage of citrus and other fruit peels buried in alternate layers with straw yields a good animal feed comparable in nutritional qualities to clover and alfalfa. The citrus seed contains about 25-30 percent oil which could be used for soapmaking.

The peels, cores and seeds obtained during tomato processing, when dried to 10 percent moisture, is a good cattle feed (protein 8-10 percent; fat 10-12 percent). The tomato has skin 10 percent; stem 2 percent; core plus trim 6 percent. Tomato seed oil (17 percent by weight of the seed), a good salad oil, can be extracted.

Since the industry is small in size, and since the nature of the generated wastes vary from product to product, the environmental control by utilization of wastes requires the development of tools and technology appropriate to the scale.

2.5 Tree and Plantation Crops

2.5.1 Palms

A variety of palms grow in the tropical and subtropical climate of the region. The more economically important ones are dealt with here.

2.5.1.1 Coconut

This palm covers an area of over 5 million ha in the region (Philippines 2.3; Indonesia 1.8; India 1.1; Thailand 0.3 and Malaysia 0.2 million ha) producing about 25 billion nuts. The outermost part of the fruit is green beneath which there is thick layer of fibre (25 mm thick). The fibre (coir) is followed by a hard shell (6 mm thick) which is lined inside with soft milky white flesh (copra, on drying). The innermost recess is filled with coconut water.

Use pattern

All parts of coconut tree have known uses, though all these are not exploited fully. The major economic products are copra, coconut oil and desiccated copra, and the shell which is processed into charcoal and activated carbon. The coconut water which largely goes waste, is a refreshing drink in hot climates of the region and is partly converted into wine and vinegar. In India, the tree sap is converted to jaggery and the leaves processed into brooms, mats and baskets. The timber is used in construction of village homes. The roots are used as a herbal medicine and for making beverages.

Not all nuts are gathered. For example, in the Philippines, the total nut yield in 1975 was 10.2 billion, of which only 8.56 billion were gathered. All producing countries of the region export coconut products. The processing techniques, especially for the production of copra, oil and desiccated copra or cake, and coir and coir products manufacture are not uniformly developed in all countries and even within a country.

Residues

The principal residues are coir dust, shell, coconut water, timber and leaves. Not all husk is converted into coir. It is partly burnt as a fuel. The processing of husk for coir results in a major residue - coir dust which has absorbed moisture to the extent of 65 percent. The dust on dry basis contains about 10 percent long fibre, about 20 percent short fibre, and 70 percent pith. This residue which piles up near the processing plants has so far defied any economic outlet and constitutes a serious fire and health hazard. It is too refractory to be composted. It has been used in Malaysia and the Philippines as a medium for mushroom growth but the product has a flavour which is not liked by the consumers. In the Philippines, a small quantity is consumed by nurseries as a partial replacement of soil in seedling or saplingbags. It has also been used as a soil conditioner. The average composition of coir dust is given below:

	Wet basis percent	Dry basis percent
organic matter	8.4	91.3
minerals	7.7	8.7
fats and resins	1.6	1.8
cellulose	30.8	35.0
lignin	22-29	25-33
pentosans	6-9	7-10
N	0.26	0.30
protein	1.7	1.9
K_2O	0.79	0.9
P_2O_5	0.04	0.05
CaO	0.35	0.4

Since husk constitutes 50-55 percent weight of the nut, the region generates about 20 billion tonnes of husk annually. The status of coir industry in the region could not be ascertained with any accuracy and it has not been possible to estimate the generation of this residue. India alone generates about 160,000 tonnes of this residue every year.

Since coir dust has capacity to absorb about 40 percent water, it can be used to increase the water holding capacity of sandy soils and also as land fill for reclamation of low-lying areas. Its use as a raw material for manufacturing board is already practised in India and Indonesia.

The possibility of using rubberized coir dust compositions for flooring and ceiling boards is being explored in the Philippines and Sri Lanka. Other likely outlets are as insulation slabs, as an expansion joint filler, and as an alternate source of furfural.

Shell is used for the manufacture of charcoal, activated carbon and as a fuel. Coconut powder is used as a filler and extender in moulded plastics. Its generation in the region is estimated at about 2.5 - 3 billion tonnes. The average percent composition of coconut shell is: moisture 6.8; ash 1.3; hot water extract 1.8; alcohol-benzene extract 2; ether extract 0.2; pentosan 30; lignin 32; and cellulose 51. The ash composition varies according to habitat but is always rich in K_2O (Ca. 45 percent). With such large availability, there is great scope to extend its uses. The manufacture of charcoal with recovery of the byproducts, seems to be promising. The byproduct tar can be used for copra drying operations. The shell powder also has future in moulded furniture manufacture, and in the production of construction materials.

Coconut water has no substantial economic outlet apart from small manufacture of wine, vinegar and Nata. The yield of water varies according to its species and habitat. Enormous quantities are available for utilization. The average composition of Indian coconut water is (per cent) : water: 95.5; N: 0.5; P_2O_5: 0.56; K_2O: 6.6; total solids: 4.7; reducing sugars: 0.8 and sucrose: 1.28. Sugar content being low, it will have to be concentrated before any sugar-based use can be made. In Indonesia, preparation of caramel flavour is being attempted by evaporation of coconut water followed by adjustment of its pH. It is claimed that it can find use in the manufacture of soya sauce and bread. Work is also in progress in the Philippines on a pilot plant scale to produce dextrine, yeast, vinegar and SCP in coconut water medium. This has a potential of development of a low level technologywhich can be adopted by the farmers. Coconut water can also be sprinkled in compost to augment the potassium content. The possibility exists of using stabilized coconut water as a soft drink.

The trunk, which is currently used for the construction of village huts, is being investigated in the Philippines as a furniture wood and for the manufacture of floor tiles. The only problem is the difficulty of sawing due to its hardness and the grain direction. Coconut wood is also being used as medium for growing mushrooms.

2.5.1.2 Oil palm

Oil palm is cultivated for its value as source of oil from its fruit and kernel. The recent improved varieties yield 7.5 tonnes of palm oil per ha per year. It is a major industry in Malaysia. India has also introduced oil palm recently in Lakshdweep Islands. Indonesia produced about 270,000 tonnes of palm oil in 1972 which was mostly exported. In Malaysia, 400,000 ha produce about 2 million tonnes of oil annually. The production is expected to increase up to 3 million tonnes by 1980. The processing of oil palm generates enormous residues which seriously affect the environmental quality of the surroundings.

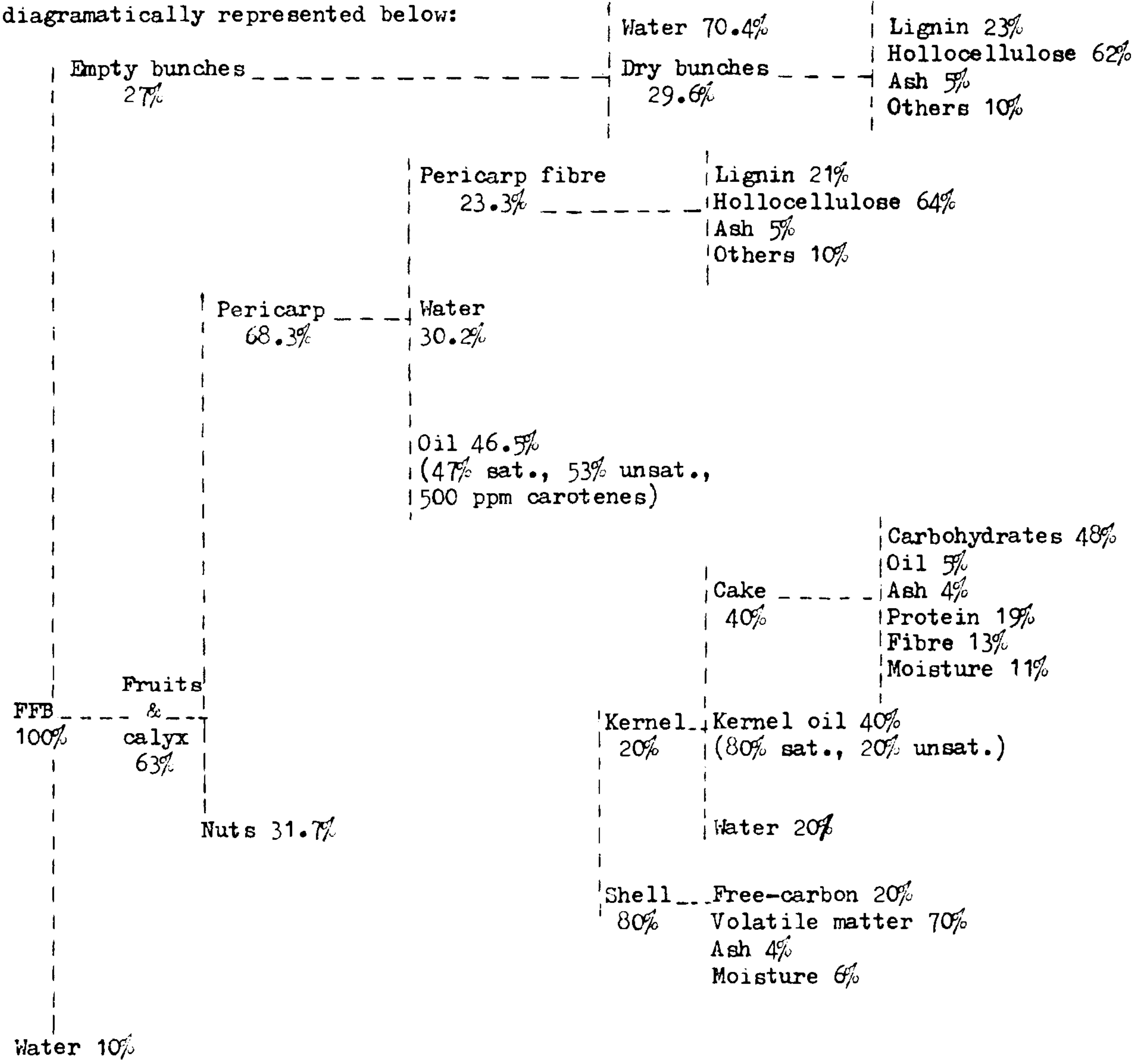
Use pattern

Oil palm and palm kernel oils are used for the manufacture of soaps and glycerol and as an edible oil. The fatty acids composition of the palm oil glycerides is (percent): myristic 0.5; palmitic 48.3; oleic 40; linoleic 8.3 and stearic 2.9. Among the edible uses are as shortenings, margarine and spreads, a cocoa butter substitute, and salad and cooking oil. Malaysian exports of palm oil are 12 percent of total export value.

Residues

During processing of oil palm fruit for palm oil, the first residue generated is empty bunches (25–27 percent of fresh fruit bunches, FFB). These are disposed of by burning in the boiler or by incineration or are returned to the field. The fruit is then pressed in a hydraulic or screw press; viscous crude oil (26–32 percent of FFB) is obtained. The solid residue is depericarped, nuts are broken to recover the kernels and the entire residue consisting of wet fibre (11–15 percent of FFB; moisture 30–40 percent) and shell (dura 16–20 percent and tenera 6–9 percent of FFB) is sent to the boiler plant. The crude oil obtained after pressing is diluted with water (1:1). The oil is then sent for purification and vacuum drying and the sludge is again diluted with water and the residual oil (20 percent) recovered in a sludge separator. The sludge waste, which now is nearly the weight of FFB and contains mostly water with high suspended matter content, is the principal liquid effluent of palm oil manufacture. In Malaysia, 2 million gallons of the sludge goes to waste.

The characteristics of various residues generated during palm oil manufacture are diagramatically represented below:



The liquid effluents have the following characteristics: pH 4.8; oil content 0.6 percent; BOD_5 18,000 ppm; COD 40,000 ppm; total solids 30,000 ppm; suspended solids 30,000 ppm; ammoniacal N 30 ppm; nitrate N 9.3 ppm; protein (on dry sludge) 12 percent; and appearance-brown, colloidal. The effluent which carries a high COD load (100 times sewage) is discharged into nearby streams causing serious ecological disturbance and pollution.

Possibilities

Several research institutes in Malaysia are engaged in finding economic uses of the residues of palm oil industry. The effect of spraying effluents on the field crops is being examined. Since the sludge waste, palm press fibre and palm kernel cake contain proteins and fibre (on dry basis, and have gross energy of the order of 17-18 MJ/kg), experiments have been carried out to study their digestibility as part of the feed of sheep. The compounded feeds were found acceptable by these animals. Tapioca chips are usually added during compounding.

Centrifugation to concentrate the effluent, adding coagulants to speed separation and settling and other mechanical separation techniques on laboratory scale have not been able to reduce BOD value below 1,000 ppm. A number of proposals have been put forward, especially in relation to the biodegradable characteristics of this effluent. It would appear that no single scheme will give satisfactory results. It may be possible to utilize the sludge by combining two or more systems such as aerobic oxidation coupled with SCP and/or algae production which again may be followed by fish pond culture or growing aquatic plants as animal fodder.

In another approach, the fibrous wastes are being investigated as potential sources of energy. About 3 million tonnes of fibrous waste in the form of shells, pericarp fibre and empty bunches are available. The average combustion value of these wastes is 7,500 BTU/lb. These wastes can generate an enormous quantity of energy. It has been estimated that a 10 t. FFB/hr capacity palm oil mill can generate 3 MW power from its 50 million BTU thermal energy per hour.

Fibrous waste has also been investigated as a source of pulp. The approximate compositions on dry weight percent basis are:

pericarp fibre - lignin 21; pentosans 24; alpha cellulose 40; ash 5.

empty bunches - lignin 20-25; pentosans 21-26; alpha cellulose 35-42; ash 5.

The ash from empty bunches has the following composition (percent): P 0.9 - 1.7; K 15 - 40; Ca 1.6 - 3.7 and Mg 2.7 - 4.8. Each tonne of empty bunches contains equivalent of 6 kg of ammonium sulphate, 1 kg of rock phosphate and 8 kg of potassium sulphate. The availability of empty bunches is estimated to be about 1 million tonnes which can yield 16,000 tonnes of concentrated NPK fertilizers.

2.5.1.3 Arecanut

Arecanut is an important plantation crop of India covering an area about 168,000 ha which produces 152,000 tonnes of nuts. The fruit is spherical (3-5 cm dia) and contains a hard nut (about 1 - 2.5 cm in diameter) which is chewed along with betel leaf in the entire Indian sub-continent.

Use pattern

Arecanut is used for chewing purposes. The leaves are used for thatching and basket making. The wood is hard and used as lamp posts or for construction of huts.

Residues

The residues of arecanut plantations and processing industry are: husk; leaves and the residual dust left after processing of arecanut.

The husk is generated at the rate of 2 tonnes/ha. Thus, about 300,000 tonnes of husk may be available for utilization. The composition of husk is (percent): moisture 5-10; pectin 1 - 3.3; pentosans 15 - 19; cellulose 37 - 49; lignin 17.5 - 25 and ash 4 - 6.

The leafsheath and leaves are available to the extent of 90,000 tonnes. Only a small portion is used for thatching, etc., the rest is thrown away. The leaf has 1.5 percent N, 0.15 percent P and 0.7 percent K.

The residual dust is obtained when arecanuts are boiled. The sediment left in the liquid is called arecanut dust. The dust is rich in tannins and has been found useful by the tanners. Its availability is seasonal.

Possibilities

It is possible to manufacture low density fibre board and high density hardboard from arecanut husk. The boards have been found comparable to those made from other raw materials. Small plants using husk and other raw materials such as tapioca stems, banana stems, and rubber wood are being set up in South India. The husk can also be a source of pulp for mixed-pulp paper manufacture. Other possibilities are insulating wood/boards, cushion material, activated carbon and microbial treatment to get fertilizer.

2.5.1.4 Other palms

There are several palms of less economic importance. These are palmyra (*Borassus flabellifer*), sago or fish-tail (*Caryota urens*) and wild date (*Phoenix sylvestris*).

The floral bunches of palmyra palm provide a sap which is a refreshing and nourishing drink (*neera*). The fermented sap gives country wine (*toddy*). The unfermented sap if concentrated yields palmyra sugar. The sap is also converted into vinegar. The fruit is small, jelly-like and edible. The stems and leaves are used for construction of village huts.

The sago palm leaves are used for making ropes and brushes. The pith yields a flour called sago and is eaten. The sap is fermented to give toddy. The wild date palm also yields sweet sap which is converted to sugar or wine.

2.5.2 Sugarcane

Sugarcane is cultivated as a commercial crop on a fairly large scale by almost all the countries. The processed sugar is also exported. Sugar is manufactured in large plants and sugarcane juice is converted into brown sugar or jaggery in the rural areas.

In India, there are 251 sugar factories with a total capacity of about 5 million tonnes. About 1 million tonnes was exported during 1975. Indonesia has 57 sugar factories producing about 1 million tonnes of sugar. Production of the Philippines in 1975 was 3.3 million tonnes. Malaysia has 16,000 ha under sugarcane cultivation and produced over 1 million tonnes of sugar in 1974. The sugar production capacity of Thailand is 20,000 tpd.

The sugar industry generates three principal residues: bagasse, press mud and molasses. Commercial applications of these are known. Liquid effluents from sugar and alcohol industries are pollutants of high BOD.

Use pattern

Sugar is used as a food item and as a raw material for chemical and biochemical industry. Bagasse is mostly used as a fuel in the sugar industry. Molasses is a raw material for the production of alcohol and other fermentation products, and also as a component of animal feeds. It finds minor use in tobacco industry.

Residues

The only crop residue, cane tops, is fed to the farm animals as maintenance diet. The tops are also incorporated in commercial animal feed compositions which also incorporate up to 20 percent of press mud.

The bagasse is largely consumed as a fuel by the sugar mills. In Indonesia, about 7-9 percent of the total bagasse is also consumed by locomotives. Due to the shortage of energy resources, the present use pattern is unlikely to change. Bagasse which is not used by the sugar industry is being used for the manufacture of paper, fibre boards, furfural and in animal feed compositions. The physical and chemical characteristic of bagasse vary according to the cane used, and the type of equipment used in expelling juice. The characteristics of Indian cane are as: av. fibre length 1.4 mm; av. fibre dia 18 microns; ash 1-2 percent; lignin 18-20 percent; cellulose 54-58 percent; and pentosans 24-26 percent.

In Thailand, where bagasse is not used for paper manufacture, 1.8 million tonnes of bagasse are available. It is understood that several paper and pulp plants will utilize this resource. In Indonesia a 45,000 tpa capacity plant is being built.

Molasses is used for the production of alcohol, yeast and animal feeds. One tonne of cane yields 20-25 litres of molasses. Production of alcohol results in high BOD effluents. In Indonesia these effluents along with sugar factory streams are led to paddy fields where they have increased the yield of rice.

Each litre of alcohol produced from molasses yields approximately 10 litres of spent wash which is acidic in character (pH 4.5) and has high BOD (50,000-60,000 ppm). The total solid content is also high (10 percent), mostly inorganic in nature. Other characteristics of spent wash are: volatile solids 40-60 g/l; COD 65,000-95,000; total reducing sugars 0.5 percent; total N 900-1500 ppm; ash 3-5 percent; P_2O_5 100 ppm; and K_2O 37 percent of ash.

The press mud is currently utilized as an animal feed component and as a soil conditioner.

Possibilities

If alternate sources of energy are available to the sugar mills, large quantities of bagasse would be available for the manufacture of pulp, paper and boards, furfural, activated carbons and other products. The prospects, however, are not bright. The bagasse usually has moisture 50 percent; fibre 30 percent and pith 20 percent. The pith can continue to be used as a fuel while the depithed bagasse can be used for the manufacture of pulp and paper.

Along with other cellulosic wastes, bagasse can be used as a source of energy for enzymatic and microbial reactions to produce SCP and sugars. Sugars can also be produced by acid treatment of cellulose and converted into alcohol.

The distillery spent wash must be treated before discharge. Anaerobic units are known to generate methane (73 percent), carbon dioxide (25 percent), and other gases like hydrogen sulphide (2-3 percent) at the rate of 8 ft^3/lb of organic matter. In this manner, BOD is reduced by 90 percent to a level of 2,500-3,500 ppm. On the average, the volume of gas generated is 20 times the volume of the spent wash. The discharge from the anaerobic units can be sent to oxidation ponds where BOD level of effluents can be further reduced to 100 ppm.

The final effluent can be used as irrigation water or evaporated for recovery of potassium salts. It can also be treated in sand filters to reduce BOD level still further to 35 ppm. Another method adopted by some distilleries in India is solar evaporation of spent wash in open shallow pits. The dry cake is sold as a fertilizer.

In addition to the present use as animal feed component and as a soil conditioner, the press mud can be extracted to recover sugarcane wax.

2.5.3 Fibre crops

Fibre crops like cotton, flax and various palm fruit husks and leaves have been described. Other commercial fibre crops yielding bast and leaf fibres are described in this section.

The bast fibres are obtained from jute (Corchorus capoularis and C. olitorius), kenaf (Habiscus cannabinus), ramie (Boehmeria nivea), and sunn (C. Juncea), and leaf fibres from abaca or Manila hemp (Musa textilis) and sisal (Agare sisalana). Other fibre yielding plants are: kapok (Ceiba pentandra) which gives fibre from seed pod and grows throughout the Region, and sida (Sida rhombifolia) which is native to the Philippines. Jute is cultivated extensively in India and Bangladesh and to some extent in Thailand, ramie and abaca in the Philippines and Indonesia, kenaf in Thailand, India and Bangladesh, and sunn in India. Sisal grows wild in India, Indonesia and elsewhere in the region. It is a perennial plant.

All bast fibre yielding plants are single stemmed and grow to various heights (2-5 m). The fibre strands consisting of overlapping fibre cells, held together with natural gum, are located between the central woody stem and the bark.

The processing of bast fibre from all these plants is similar. The main operations consist of retting, stripping and grading and finally baling for the manufacture of finished goods. Retting is a time-consuming but critical step in the extraction of fibre.

Abaca plant looks like a banana plant with 3-6 meter stalks (12-30) radiating from a central rooting system. Abaca fibre, however, is very much stronger than that of banana. The fibre runs along the sheath in abaca lying in its outermost layer. The mature stalks are cut, the fibre layer cleaned by pulling the fibre strip under a knife pressed against the strip, and air-dried avoiding sun and rain. The fibre yield is 2-3 percent of weight of the stalk.

The sisal fibre is embedded longitudinally in the agave leaves (1-2 m long; 10-15 cm wide) The fibre layer is 5-7 mm thick. The fibre is removed from fresh leaves by scraping away the pulpy material in a mechanical decorticator. The fibre strands are washed and dried. In Indonesia, the dry fibre strands are further cleaned by brushing them against a rotating drum. Fibre from Sansevieria, a perennial of India and Sri Lanka also is extracted in a similar manner.

The average composition of various fibres is:

	Cellulose percent	Moisture percent	Ash percent	Lignin and pectin percent
Jute	63	10	0.7	24
Kenaf	66	10	1.0	22
Sida	81	10	0.5	6
R mie	91	-	0.7	-
Sunn	80	10	0.6	6
Abaca	64	12	1.0	22
Sisal	77	6	1.0	15

Use pattern

The extracted fibres are used for the manufacture of textiles and other goods. The bark and leaves of kenaf and jute have minor uses in basket-making. The stem is too hard to be eaten by the animals and is generally wasted.

Residues

The availability of jute sticks is about 2.5 million tonnes in India and that of kenaf stem about 1 million tonnes in Thailand. Thus enormous quantities of residues from all fibre plants are available. The average analysis of jute sticks is (percent): Holo-cellulose 78.6; alpha-cellulose 39.3; pentosans 19.5; lignin 21.9; and ash 0.6. The cellulose content of residues of other fibre plants is satisfactory for their use as a source of pulp for paper and board industry. There are several small plants operating in India using jute sticks as a raw material for mixed pulp. In Thailand and the Philippines there are plans to build paper and board plants.

Possibilities

The possible uses being explored are the manufacture of mechanical pulp, paper and straw board, hard boards, rayon grade pulp and charcoal. The main problem in their economic utilization will be collection and transport.

The residual leaf and juice after extraction of sisal fibre can be a source of wax and hecogenin. This occurs in enticle part of the leaf to the extent of 15-20 percent which is extracted in India in a small way.

With present processing techniques for the extraction of sisal fibre, hecogenin, a steroid, present to the extent of 0.1 percent, gets resinified. Modified methods have therefore developed to overcome this difficulty. Hecogenin is raw material for a variety of hormones.

2.5.4 Rubber

Natural rubber in the region is obtained from the latex derived from perennial tree, *Hevea brasiliensis* which was planted during the colonial period. Malaysia, Indonesia, Thailand, India and Sri Lanka are the chief producers. Rubber contributes about 30 percent towards Malaysia's total export earnings and is its major agro-based industry producing about 1.5 million tonnes of product. The production in other countries is less (Thailand 0.2; Indonesia 0.24; India 0.13 and Sri Lanka 0.1 million tonnes).

It takes about 5 years for a rubber tree to become ready for tapping. The tapper cuts the bark almost down to cambiumto allow the latexto flow which is collected and transported to the processing unit. In Malaysia, the unit may vary from the 5 kg/batch of the cottage industry to a large modern processing plant.

Use pattern

Till recently, the main materials produced were primary products like block rubber, sheet rubber, crepe and the latex concentrate. The manufacture of rubber goods such as tyres, footwear, conveyor and transmission belts is being introduced in all countries. India, which is relatively a small producer of rubber, has 19 factories manufacturing bicycle tyres and tubes (30 million tyres; 25 million tubes) and 13 producing automobile tyres and tubes (6 and 5.5 million respectively). The small and large-scale footwear manufacturing units turn out 1.6 million pairs of rubber and canvas footwear. Belt production in 1975-76 was: conveyor 4,600 tonnes and transmission 2,500 tonnes.

Residues

Rubber latex contains about 30 percent of non-rubber constituents. During processing of rubber, these are washed away into rubber serum. Large quantities of water are used for this purpose. The effluent generation of an average 20 tpd factory is estimated at 410 kl. These effluents constitute a serious pollution problem. The general characteristics of the effluent are: pH 4.86; total suspended solids 340 ppm; total solids 1 880 ppm; volatile solids 1 440 ppm; steeleable solids 190 ppm; COD 2 180 ppm; BOD 1 040 ppm; ammoniacal N 85 ppm; and total N 150 ppm. Several methods have been suggested to economically treat these effluents which vary in quality and composition according to the process employed, quality control and supervision. Some factories give partial treatment (ponding, pitting or filtering) before discharge of the effluents, to recover suspended latex. The acidic nature of effluents is due to the use of formic sulphuric and phosphoric acids during processing.

The concentrate factory has a large amount of total solids. The skim serum produced has the following characteristics: pH 4.77 ppm; total solids 42 550 ppm; volatile solids 36 410 ppm; suspended solids 2 850 ppm; COD 32 690 ppm; BOD 13670 ppm; total N 4 620 ppm; ammoniacal N 3 430; albuminoid N 755 ppm; total sugars 500 ppm; reducing sugars 409 ppm; and Al, Ca, Cu, Fe, K, Mg, Mn, Na, P and Si, 1.6; 6.0; 4.0; 2.0; 618; 61; 0.6; 11; 61 and 8 ppm respectively.

The non-rubber constituents are proteins (1 per cent of fresh latex); lipids (1 percent of latex) which are mostly phospholipids (60 percent of total lipids); querbrachitol (1 percent of latex); sugars; and inorganic chemicals (0.5 percent of latex). Minor constituents are carotenoids and nucleosides.

The rubber seeds resemble castor seeds in appearance; they are larger and heavier (2-4 g.) The seed kernels possess a flavour resembling hazel nut and have the following average percent composition: moisture 8.5; crude protein 17.6; ether extract 48.5; carbohydrates 22.9; ash 2.5; Ca 0.12; and P 0.43. The seeds contain a cyanogenic glucoside and a specific enzyme, linase. The seeds contain an active lipase. The kernels contain a semidrying oil (40-50 percent). The lipase hydrolyses the oil in the stored seed. The seeds should, therefore, be heated before storage to inactivate the enzyme. The oil is inferior to linseed oil as a drying oil and is chiefly used for soapmaking. The characteristics of the oil are: acid value 4-40; soap value 190-195; iodine value 132-140; and hydroxyl value 12-32; and unsaponifiable matter 0.5 - 1 percent. The component fatty acids are (percent): oleic 17-30; linoleic 33-39; linolenic 21-26; palmitic 7-11; stearic 8-12; and arachidic 0.3 - 1.3. The cake or meal is used as a fertilizer or animal feed. The meal analysis in percent is: moisture 5-6; oil 4-6; protein 30-34; carbohydrate 40-44; fibre 7-12; and mineral matter 5-6. The seed shell has 57 percent fibre, 6 percent protein and is used as a roughage.

In Malaysia, 133 tons seeds are reported to yield 16 tons oil and 30 tons meal. The annual production is 30 000 tons oil, 50 000 tons meal and 198 000 tons shells.

Rubber wood finds use as a fuel, as an inferior timber and for furniture making. Not all wood is utilized (Malaysians use pattern: total use 60 percent; furniture and timber 25 percent and fuel 35 percent). In Malaysia, two plants (cap. 400 000 tpa) export chips to other countries. At 3 percent replantation basis, the availability of rubber wood in Malaysia is estimated at 6-7 million tons (1 ton = 50 m^3).

Possibilities

Apart from developing the potential of rubber seed and wood as a source of economic commodities, the major attention is being devoted to the solution of environmental pollution problems created by the rubber processing industry. The multipronged effort includes microbial degradation of wastes, their use as a medium for growing of yeasts, algae and fungi, as a seedling material for latex coagulation, as a fertilizer, and as a source of chemicals.

The yeasts grow well on the effluents (75-1 scale trials gave a yield of 5-6 g/l). Experiments on growing algae along with fish in treated effluent have given satisfactory results. The skim serum has been used as soil stabilizer for maize, soyabean and groundnut increasing the crop yields by 75, 89 and 27 percent respectively. The isolation of querbrachitol, various enzymes, proteins (as an animal feed) and inorganic salts are other possibilities which are being investigated.

The rubber wood has adequate strength, is easy to machine, has negligible distortion when dry and is durable. Thus, it is an ideal furniture wood. Its characteristics are: SG 0.55; modulus of rupture 60 kg/cm^2; impact bending strength (22.7 kg hammer) 61 cm; compression parallel to grain 330 kg cm^{-2}; shearing strength 112 kg cm^{-2}; radial hardness 442 kg; tangential hardness 446 kg; and end hardness 485 kg.

Proper utilization of rubber seed can augment resources of oil for soapmaking and paint manufacture. The meal/cake and shells can provide supplementary animal food.

2.5.5 Tobacco

The Nicotina plant is cultivated for its leaves which on curing yield tobacco. It is an annual, 50-150 cm high, with a pubescent stem, slender branches and fleshy leaves with uneven surface. Several varieties are planted in the region. The plucking of leaves is carried out according to their end use. The harvested leaves are cured. The techniques used are: flue curing, air curing and fire curing. Several physical and chemical changes take place in the leaf during curing. The average moisture content of the leaf is reduced from the original 80-85 percent to 10-15 percent during curing. Leaf enzymes play an important role in determining the biochemical changes during curing. The concentration of nicotine varies according to the variety (1.5 - 4 percent). Almost all the countries of the region produce tobacco, principal producers being India (447 000 tons), Indonesia (59 000 tons) and Philippines (57 000 tons).

Use pattern

Cured tobacco leaf is converted into cigarettes and cigars or exported. In India, it is also used for making snuff, chewing tobacco, bidis and hookah tobacco. The stems and stalk are considered useful by the farmers due to their K content and nicotine content. These along with pods are usually used as a fuel. Limited quantities of tobacco seeds are extracted for their oil (oil content 35-40 percent) which is a semidrying and edible substance.

The present capacity of cigarette manufacture in India is 624 billion pieces which is being increased to 1 000 billion pieces by 1978-79. There are 18 units currently producing cigarettes. Cigar, bidi, snuff and chewing tobacco are manufactured on cottage scale. In the Philippines, tobacco supports nearly 2 million people. Cigars and cigarettes are also manufactured in Indonesia and Thailand.

The bidi is the cheapest Indian smoke which is prepared by wrapping tobacco in a specially prepared leaf (usually of Diospyros melanoxylon, Bauhunia racemosa or Butea monosperma. The present production is estimated to be 120 billion pieces.

Residues

The tobacco stalks and leaf scrap are the only crop residues. Leaf scrap occurs when diseased or substandard tobacco leaves are produced and it is burnt. Some stalks and scrap leaf are used for agricultural purposes, the rest are either burnt or allowed to rot. Their use pattern in India is: agricultural use 40-50 tons; destruction of leaf scrap 2-4 tons; and burnt as a fuel or otherwise wasted 31-34 tons. Thus sufficient quantities are not available for paper and pulp manufacture. The availability of stalk in the Philippines and Indonesia is of the order of only 75 tons. Since N and K are important constituents of these residues, their use in agriculture may be encouraged.

During cigar and cigarette manufacture tobacco dust is generated, which has nicotine content from 3-8 percent depending on the tobacco used. Bidi tobacco has high nicotine content. The stalks and midribs also have nicotine (1-3 percent). In India, nicotine is extracted in the form of nicotine sulphate. The process employs a petroleum solvent and steam distillation.

Possibilities

In the Philippines, cultivation of different species of mushrooms on tobacco midribs is being investigated. The initial results are encouraging. In India, manufacture of oxalic and nicotinic acids from tobacco wastes is being investigated. If nicotine recovery process is simplified, tobacco may be grown solely for this purpose. Tobacco waste could also be reconstituted into leaf sheet.

2.5.6 Tea, coffee and cashew

2.5.6.1 Tea

Tea is principally grown in India and Indonesia. India is the largest producer in the world producing about 500 000 tons. The green shoots are plucked from the bush, cured and further processed to give green tea, black tea, oolong and instant tea. The largest production, however, is of black tea. Enzymes play important part in the processing of tea. Indonesia produced 48 800 tons in 1972.

The wastes from tea are generated in the form of fluffs, stalks and sweepings. It is estimated that about 10 million kg of tea waste is available in India. Some tea waste is used as a fertilizer by the tea planters. It is also burnt to prevent adulteration but more and more is being used for the extraction of caffeine. For extraction of caffeine, the tea waste is mixed with lime, the liquid extract is then further extracted with an organic solvent. Crude caffeine obtained after recovery of the solvent is further purified by repeated crystallization. Spent tea waste which still contains 20-25 percent tanning is used as a cattle feed or fertilizer. It can, however, be used for the production of tanning agents, soundproof bricks and activated carbon but no investigation seems to have been made in these directions. Work on conversion of caffeine to theophylline has been done and a viable process seems to be available.

2.5.6.2 Coffee

While coffee is produced by almost all the countries of the region, large production is only in India (86 000 tons) and Indonesia (23 000 tons). The bulk of coffee in India is produced from Coffea arabica, though other varieties are also becoming popular. The berries are dried, dehulled, graded and cured. Cured coffee beans are roasted and powdered. Coffee is also available in the form of flakes or tablets. Decaffeinated coffee and soluble coffee are also manufactured.

Coffee husk obtained during dehulling operation is a major residue of coffee industry. Husk is generated in India to the extent of about 60 000 tons. The average percent composition of husks from C. arabica and C. robusta is given below:

	C. Arabica	C. Robusta
Ash	6.5	4.4
Protein	9.2	9.0
Crude fibre	39.1	38.0
Water extract	25-35	30-40
Caffeine	0.3 - 0.6	0.2 - 0.5

Currently the husk is composted and used as a manure on the plantation. It has been used as a nutritious roughage. The raw coffee contains 10 percent oil and wax. The bean oil has the following characteristics: S.G. 0.94; soap value 160-180; iodine value 79-98; unsaponifiable matter 6-10 percent; saturated acids 37-40 percent; and unsaturated acids 51-54 percent. It may be worthwhile to explore the possibility of extracting the oil before roasting.

The tannins extracted from husk and the organic acids produced by fermentation of husk are reported to be useful in tanning industry. Coffee parchment gives a 13 percent yield of furfural.

2.5.6.3 Cashew

On the 8 South American species of Anacardium, A. occidentale has been introduced in India and other countries of the region producing cashew products. An erect, spreading evergreen tree, growing upto a height of 12-13 m, produces a curious fruit, known as cashew apple which has a kidney-shaped nut attached to it. The nut is processed for its kernels, producing cashewnut shell liquid, a phenolic substance and shell as the byproduct residues. The fruit itself is fleshy and juicy. It is astringent when raw but sweet when ripe. It is edible and yields the well known wine, cashew fanny.

India has nearly 400 000 ha of area in South and East India under cashew. The annual production of kernels is around 150 000 tons. India imports about 170 000 tons of raw nuts. The annual export of kernels is around 60 000 tons. About 7 000 tons of cashewnut shell liquid is also exported.

The cashew processing consists of heat treatment of the nut and manual cracking of nut to recover the kernel. Heating is usually done in a cashewnut shell liquid hot bath which also extracts most of the shell oil. The residual oil in the shell is extracted with a solvent. The spent shell is either used as a fuel or composted.

The shell liquid (CNSL), which is 25 percent by weight of shells, has a phenolic acid, anacardic acid, as its chief constituent which is decarboxylated to cardanol during the processing. If cashewnut is mechanically broken to recover the kernels (as is done in Tanzania) followed by solvent extraction of the shells, CNSL has anacardic acid mostly intact. CNSL has many uses in paints and plastics, in the manufacture of brake linings and as a foundry core binder. Cardanol is recovered by distillation for use in light coloured paints and varnishes.

Cashew apple has the following percent composition: moisture 86.2; protein 0.8; fat 0.6; carbohydrates 11.9; mineral matter 0.2. Vitamin C is present to an extent of 261.5 mg/100 g. Each tree on average yields 35 kg of fruit, and each fruit gives 20-25 ml of juice having 10.4 percent solids (94 percent sugars, mostly invert sugars). Since raw juice is rich in sugar, it could be a good raw material for alcohol industry. It is converted into vinegar or cashew fanny. The production of cashew apple in India is estimated at 30 million tons.

The peelings obtained during the preparation of kernels for the market contain some broken kernels and brown testa, constitute about 12 percent by weight of kernels, and are used in poultry and animal feed compositions. The testa has 42.5 percent total extractable solids and 23 percent total phenols. The main constituents are catechin and epicatechin (6 and 7.5 percent of testa respectively). The availability of testa is about 2 500 tons in India and could be exploited as a source of tannins.

The wood is reddish brown in colour and is used for making packing cases and charcoal. The bark has 9 percent tannins and the leaves 23 percent. The tree yields a gum which exudes as a stalactitic mass. The bark, leaves and gum have not found any application.

2.6 Forestry

The exploitation of forest resources is a typical example of primary processing in the region. Logging is a major forest-based industry tuned, excepting India, to export. The associated industries are sawing, plywood manufacture chipping mills and match manufacture. A sizeable volume of wood is used as a domestic fuel as firewood or charcoal.

The pattern of industrial utilization of wood (8.3 million m^3) in India is (percent): timber 33.25; plywood and boards 6.89; mining 8.71; transport and communications 9.25; wood working 7.19; packaging 8.59; pulp and paper 13.30; rayon 9.67; and matches 3.14.

The plywood manufacture in 1975 was 33 million m^2 and of fibre and particle boards about 25 000 tons. Safety matches are manufactured in 5 large plants and innumerable small plants (total capacity 11 000 million boxes of 50 sticks each). The production of various other products in 1975 was: paper and paper board 829 000 tons (to be increased to 1.4 million tons by 1978-79); rayon pulp 106 000 tonnes (230 000 tons in 1978-79); cigarette tissue paper 8 500 tons (22 000 tons in 1978-79); speciality papers 10 000 tons. The minor forest industries are production of lac (about 800 000 tons), tanning materials (40 000 tons, mainly from Aacaias) rosin and turpentine (mainly from Pinces longifolia), katha (from the heartwood of Acacia catechu) and essential oils (sandalwood, lemongrass, citronella, palmarosa, vetiver and linaloe).

Logging is a big industry in Indonesia with an annual capacity of 35.7 million m^3. The sawing capacity is 7.2 million m^3. Logs and sawn timber are mostly exported. Plywood is manufactured by 25 units (capacity 2.16 million m^3) and chips by 4 units (capacity about 1 million m^3). Most of the chips and some plywood are also exported. The wood wastes, which are currently not utilized, are planned for use in new projects for expansion of pulp and paper industry. Two plants (one each in Sumatra and in Central Java) use pine wood as a source of pulp with respective capacities of 200 000 and 58 000 tons. The other 3 plants (total capacity 650 000 tons) use hardwoods. It is planned to use saw dust in the integrated mills to produce excess pulp to feed the scattered and non integrated small units in Sumatra by 1983-84.

In the Philippines where logging is also a big industry, extensive programmes of reforestation and utilization of wood waste have been introduced. There are 22 paper and board mills producing 226 000 tons of paper and 143 000 tons of board. The largest mill has a capacity of 157 000 tons of paper and board and utilizes the wood wastes from logging, sawing and plywood manufacturing industries. Apart from their export, the logs and timber are used for the manufacture of veneer, plywood, chip boards, charcoal, activated carbon and pulp and paper, and as construction materials. The bark of some species is extracted for tanning materials.

In Malaysia, timber contributes about 16 percent towards export earnings. The production of saw logs and timber during 1976 is expected to be 16.27 and 3.68 million m^3. The minor forest products include cane and the latex for chewing gum (from Dyera costulaca) which are exported.

The Thai forest industry is almost wholly logging for timber and firewood. Of the total about 3 million m^3 of log production nearly one-third was used as a fuel. The export figures suggest that extensive illegal logging is practised. The charcoal production is reported to be about 250 000 tons. As elsewhere in the region, the production methods are primitive with no recovery of the byproducts. Sawdust is mostly used as fuel and to a little extent in fibre board manufacture. All the 4 plywood manufacturing plants are located in Bangkok, with only one using wood wastes. One-fourth of the forest is under bamboo which is the source of pulp to the existing relatively small paper industry (cap. 25 000 tpa). There are plans to instal new paper mills using various types of raw material to produce newsprint, writing paper and pulp (total capacity 400 000 tpa). An interesting feature of these schemes is the use of rubber wood as a source of pulp. Amongst the minor forest products, yang oil is important.

Residues

Logging is the chief forest industry which generates enormous residues at two stages of processing operations. The first source of residues is the felling operation in the forest which produces leaves, bark, lops and tops, and trimmings. The residues are variously estimated between 30 and 60 percent depending on the nature of end use and whether the felling is legal or illegal and include abandoned logs. These are mostly used as a fuel or for small scale production of charcoal. The second operation which also generates enormous quantities of residues is sawing and manufacture of plywood and other products. The residues in this operation consist of bark, off cuts, waste veneer, shavings, chips, saw dust and trimmings and are of the order of 40-50 percent of the input. The saw dust is used for pulping, as a fuel, as a packaging material, as an insulating material and for the manufacture of boards. The chips are used as a fuel or for the manufacture of chipboards. The other residues are used as a fuel.

It is difficult to estimate the total residue generation by the forest industry in the region. It is obvious that large quantities are available for utilization. As an illustration, a rough estimate of the residues generated in India is given below:

Lops and tops	3.0 million m^3
Bark from veneer logs	0.3 million tons
Saw mill wastes	2.0 million tons
Plywood wastes	0.2 million tons

The residue generation in S.E. Asian countries will be more where the logging is much more extensive.

Possibilities

The average waste on felling of trees has been computed as follows (percent volume of timber removed):

> stumps 8; tops 14; branches 13; butt trims 2; abandoned logs 3, and damaged residual tree 40.

Thus timber removal results in 80 percent of its volume as waste. If the damaged residual tree is not taken into account, there is still 40 percent of volume as a waste. As stated earlier, in some countries, the figure is as high as 60 percent mainly due to indiscriminate felling and thus inflating the figures, especially the abandoned logs.

The general pattern of residue generation in a saw mill is (percent of input): saw dust 16; slabs 7; edgings 7; trim 5 and rejects 17. Thus 52 percent of input results in residues.

Since wood is likely to continue as a source of domestic fuel, it will be advantageous to convert waste wood and saw dust into briquettes which may be carbonized to produce briquetted charcoal. The obvious advantage of such conversion is the recovery of byproducts during carbonization. The consumer also has smokeless fuel which does not add to the atmospheric pollution. The market for briquetted charcoal will only be in urban areas since the rural population gets free firewood in the region. The technology for making briquetted charcoal and charcoal from lops, tops and chips is available in India. In the Philippines, various methods have been developed to produce charcoal in the backyard and the designs of plants based on the utilization of byproduct gases as a fuel are available. On the average, 100 tons of wood on carbonization yields 30 tons of charcoal and 45-50 kl of byproducts liquor. The liquor can be processed to give acetic acid (4-5 percent of wood), methanol (about 2 percent of wood), tar (7-11 percent of wood) and some acetone.

Wood waste, particularly saw dust, is used to some extent as a raw material for pulping and for hard board manufacture. Saw dust represents about 10-16 percent of the total wood waste (or about 55 percent of wood processed). The saw dust pulps (soda, sulphite, sulphate, mechanical and dissolving) are generally inferior in strength to those produced from chips. Their industrial potential is therefore confined to filler pulp. Since the demand of pulp is ever-increasing, the industry should be encouraged to use wood waste, especially sawdust as a raw material.

The off-cuts (10-15 percent of log volume) are currently used mainly as a fuel, for production of decorative articles and in chip board manufacture. Due to their scattered availability, it may be of advantage to set up mini chipboard manufacturing plants in the forest areas.

Tree bark (8 percent of tree volume) is a source of tannins in some species. It is generally used as a fuel or allowed to rot in the forests. Apart from producing briquetted charcoal, it can be used for the production of various types of boards. In the Philippines, a process has been developed to produce these boards by utilizing the phenols present in the bark as binders.

The use of wood wastes as a soil conditioner has been suggested. Wood waste for this purpose is formulated with other wastes and the composting accelerated by addition of ammonium nitrate, superphosphate and limestone. One composition contains (kg): saw dust 227; grasses or straw 136; farmyard manure 91; ammonium nitrate 10-16; super phosphate 9-14; and limestone 14-18. The composting is done for several months under conditions of adéquate moisture. In another composition, the use of ammonia, phosphoric acid and potassium sulphate has been suggested. The resultant compost has been found useful for forest nurseries in the Philippines.

Waste wood was used as a source of producer gas during the last war. With the present energy crisis, this outlet of wood waste needs to be re-examined.

2.7 Livestock and poultry

The region has a large cattle and buffalo population mostly located in India. Of the total cattle population of about 200 million, India accounts for 176 million, and of buffaloes, 53 million out of a total of about 64 million. In India, there is very little consumption of beef (due to religious taboos), there is therefore a high of growth of cattle and buffalo population. The bullock is the work animal in contrast to S.E. Asia where buffalo is used for this purpose. While beef and pork are the main sources of meat in S.E. Asia, mutton (from sheep and goats) is the principal meat of India. There are few pig farms in India. The large cattle farms provide only milk. Wherever milk industry is organized, the milk from the village backyard farms is also collected at conveniently located chilling centres and sent eventually to pasteurizing plants for bottling to meet the urban demand of milk and milk products. Both cow and buffalo supply milk in India in contrast to S.E. Asia, where buffalo is not exploited for this purpose.

The poultry industry in all countries consists mainly of chickens with a relatively small population of ducks. Though there are a few commercial farms, the birds are largely raised in the backyard. In Singapore where land for cultivation is limited, poultry is an integral part of vegetable and pig farming.

Residues

The livestock and poultry wastes may be classified as:

- animal shed/feedlot wastes
- slaughterhouse wastes
- carcass of dead and fallen animals
- poultry litter and other wastes.

Since the animals are generally located on the farm itself, the excreta is generally disposed of as a farmyard manure. In India, the dung is also dried into cake and wastefully used as a fuel. It is estimated that the Indian cattle and buffaloes annually generate 1 335 million tons of dung and 370 million tons of urine. The percent composition of dung is: water 70-80; organic matter 18-20; and mineral matter 2-5; Its C:N ratio varies from 20 to 35:1 depending upon the feed.

The cattle dung has (as percent): nitrogen 0.2; P_2O_5 0.1; and K_2O 0.15. Urine has (as percent): nitrogen 0.6; P_2O_5 0.1, and K_2O 0.5. Their annual potential as soil nutrients for India is:

Waste	N	P_2O_5	K_2O
cattle dung	2.67	1.33	2.0
cattle urine	2.22	0.04	1.85

Except in commercial farms, the animal sheds do not have any bedding material. The urine is therefore mostly wasted causing pollution in the surrounding areas. The dung, however, is largely composted except in India where its utilization as a manure is only to the extent of 33 percent. Thus considerable nutrient potential is lost in wasting urine and burning nearly 265 million tons of dung.

To meet the fuel requirements of Indian farmers and yet retain the soil nutrients of dung and urine, a small biogas plant has been introduced which produces methane (along with other gases) during anaerobic fermentation of animal excreta. The spent slurry contains about 1.5 percent nitrogen, 0.4 percent P_2O_5 and 2.2 percent K_2O. It can be directly used as a manure. One ton of fresh dung (containing 0.25 percent N) is expected to give 2 000 cft of gas and 730 kg of manure having 1.37 percent N.

The most advanced biogas plant is located near Manila which recycles pig waste to produce biogas and fertilizer. The gas is used to generate steam for the rendering plant, pump water, provide refrigeration and may generate power in the near future. The byproduct sludge of the biogas plant is used as a land fill to reclaim land for agricultural purposes and the effluent after dilution is partly used for algae and fish farming, the rest being sent to rice fields and vegetable garden

In many S.E. Asian countries, the pig waste is fed into fish ponds where aquatic plants and scavanger fishes are also grown. Any overflow is sent to cultivated land. The aquatic plants and fish are periodically harvested and the pond silt is also taken out and, along with pig waste, used as a fertilizer for rice and other crops and also for growing pig feed. The pigs supply meat. Thus, it is a symbiotic situation.

The slaughterhouse wastes are the byproduct of meat production. These residues consist of blood, fat, guts, bones, horns, hooves, useless meat, glands and organs, and hides and skins. The pattern of utilization of these residues varies within the region.

India slaughters annually 37.3 million goats and sheep, 1.44 million cows and buffaloes and 0.7 million pigs (1970 figures). The animal fat is extracted and used for cooking and soap manufacture.

Blood forms about 8 percent of body weight of an animal. Actual quantity obtained after slaughter is however less. The annual availability of blood in Indian slaughterhouses is about 55 000 tons, about two-thirds of which is wasted and the rest used as a fertilizer or animal/poultry feed.

The cow guts are mainly processed for export (as casings for sausages, etc.) but since these are not collected and processed in time, considerable wastage occurs. The sheep and goat guts are processed for their use in musical instruments and sport goods. These are also exported. Gut manufacture is a cottage scale industry and mostly done by hand.

The total potential of bones in the country is 450 000 tons of which only 136 000 tons are collected, mostly from dead carcasses. Slaughterhouse bones are usually sold along with the meat. Fresh bones yield appreciable fat which is recovered. Bones are used for the manufacture of bone meal, glue and gelatine. The steamed bone meal contains: moisture 7 percent; Ca 32 percent; P 15 percent; fat 1 percent; F 0.06 percent; and acid insoluble 1 percent. Bone meal is used as animal and poultry feed. It is also used as a fertilizer. Bone sinews are exported.

Glue and gelatine is produced by 14 factories located principally in Bombay and Calcutta. Hide trimmings, horns, hooves, bones and blood albumin are the raw materials used. Horns and hooves are used for the manufacture of buttons and combs. Neats foot oil is also produced from hooves.

Only 40 percent of the inedible offal is used as dog meat; the rest is wasted. The waste meat availability is estimated to be 12 000 tons which can be processed into meat meal of the following characteristics: moisture 4.2 percent; crude protein 53.9 percent; crude fat 24.3 percent; and ash 15.1 percent. It has great value as an animal feed.

Various animal glands are collected and processed as hormonal extracts. The hides and skins are processed to give leather.

The estimated generation of slaughterhouse residues in India is (in tons): fat 26 800; guts 48 400; blood 30 000; glands 36 000; Oesophagus 4 000; bladder 1 300; waste meat 22 700; tail stumps 150; horns 4 400; hooves 7 000; and bones 22 000.

Indonesia has 12 large slaughterhouses and many small ones. In 1973, 720 000 cows, 199 000 buffaloes, 2.97 million goats, 1.46 million sheep and 1.8 million pigs were slaughtered. The extracted fat is used for cooking. Blood is eaten or used as animal feed. Hides, skins and cartilage also form human food. These are also converted into leather. Bones are crushed and exported. Glands are not processed and hair is thrown away.

In Malaysia all slaughterhouse wastes are intended to be utilized when the smaller slaughterhouses are closed by law. The present use pattern of slaughterhouse residues includes production of bone meal as an animal feed, and conversion of all other animal residues to fertilizer in the rendering plants. There are plans to produce meat meal.

The pattern of slaughter waste utilization in the Philippines is generally similar to that in Indonesia. In addition, the rendering plants convert animal residues into fertilizer.

It has been estimated that about 8-10 percent of the livestock die due to various causes in India. The percentage mortality in other countries of the region is likely to be similar. Based on 8 percent mortality, the number of carcasses annually available in India is (in millions): cows 13.6; buffaloes 4.0; sheep 3.3; goats 5.0; and other animals 6.1. The carcass can provide economic products like hides and skins, tallow, bones, meat, manure, etc. The potential is not fully utilized in any country of the region, though some rendering plants do process some carcasses.

Poultry litter has not found much use in India and Indonesia except for its use as a fertilizer. The feathers also do not find much outlet In the Philippines, the litter is fed to fish ponds and is also used as a fertilizer. The feathers are converted into animal feed and fertilizer after liming and autoclaving in rendering plants.

The poultry manure contains considerable calcium. It has a moisture content of 75-80 percent and total solids 20-25 percent (volatiles 15-18 percent; ash 5-7 percent). On a dry basis, the percent composition is: volatile solids 75-80; ash 20-25; crude protein 37; carbohydrates 35; fats 1.3; Ca 9.3; P 1.5; K 5.9; Total N 88.2; and organic N 11.8 of total N. Other characteristics are: pH 6.9 - 7.4; C/N ratio 8-12; BOD 30 000 - 35 000 ppm; and COD 150 000 - 160 000 ppm.

In Singapore and Malaysia, in addition to the above-mentioned conventional uses, poultry litter is converted into animal feed by ensilage. The poultry litter is sprinkled with water to bring moisture to 40-45 percent level and fed into silos for ensilage for 3 weeks. The fermented litter is then fed to beef and milch cattle along with supplementary diet consisting of pelleted tapioca, oil palm pericarp or pineapple waste. The weight gain in beef animals is reported to be as high as 750 g - 1 kg per day. Several commercial plants are being established in the two countries.

Possibilities

With the break-through achieved in the recycling of poultry litter as feed for ruminants, pigs, poultry and fish, considerable work is being done on the recycling of livestock waste itself in Singapore. A feature of the concept is that it permits not only the use of animal wastes but also crop and food industry wastes providing a variety of processed animal feeds. The technology for the manufacture of a few animal feeds is already available and includes treatment of poultry litter and livestock waste by drying, lactic acid fermentation, sterile or semi-sterile fermentation to convert manure into SCP or other protein concentrated feeds and also the use of crop residues like cereal straws, rice husk, sugar cane crop residues, leguminous crop residues, oil palm residues, cannery residues and vegetable wastes. With the introduction of such a technology it will be possible to organize the neglected livestock industry on modern lines with higher and cheaper meat production even in the absence of arable land, as in Singapore. It shall also release cereals and vegetable proteins for human consumption in addition to abatement of pollution problems.

The production of biogas from cattle farm wastes has obvious advantages. It presents an alternative to wasteful burning of dung in India. It also provides rich fertilizer for farm use. The capital requirement for a small plant is low but still too high. Larger plants, shared by the village community, will be more economical. For this purpose, a large cattle-shed rather than many small individual sheds will be required. This will need considerable extension work to convince the tradition-bound farmers of South and S.E. Asia. The combining of animal manure with night soil in these plants will provide more gas and fertilizer and also provide hygienic disposal for human excreta and needs to be explored further.

Cattle yard wastes can be best conserved by anaerobic composting with alternate layers of fodder wastes (including weeds and other farmyard wastes). In India a battery of three pits has been used which also receive urine and washwater from the cattle yard. In the Philippines, addition of straw and other farm wastes during anaerobic fermentation was found to increase the yield of methane. Further efforts are required to improve fermentation techniques and to produce an improved low cost equipment design.

The economic advantages of recovering byproducts from slaughterhouse wastes are obvious. The collection and storage of these wastes under hygienic conditions is a pre-requisite for developing this industry. The slaughterhouses should be modernized.

The technology for carcass utilization is known. It only needs an intensive effort to make use of it to recover the valuable products.

2.8 Fisheries

Fishing has been traditionally a widely engaged occupation of the people of South and S.E. Asia. Modern commercial fishing requires organization, transportation, refrigeration and other pre-requisites of handling a large fish catch. Since the countries of the region still depend to a sizeable extent on the traditional fishing gear, the total annual catch from this fish-rich area is only around 6 million tons. Modern fishing vessels have recently been introduced to increase the size of the catch. The government is helping in the mechanization of boats and in providing preservation facilities to encourage deep sea fishing. Inland fishing is also vigorous which provides the population with staple food. Fish is eaten fresh or as cured fish. Frozen, dried or canned fish and frog legs constitute exports.

In Thailand, the trash fish catch is very high due to small mesh of the nets and also due to close-to-shore fishing. Trash fish are converted into fish meal along with the canning wastes generated by two modern and innumerable small canning plants. Trash fish are also fed directly to duck. Shark is processed for shark liver oil. It is claimed that the fishery industry does not generate any residues which are not utilized. The treatment given to liquid effluents of fish canning plants or mode of their disposal could not be ascertained. Out of an annual catch of 1.5 million tons, 88 221 tons was exported in 1974. The trash fish catch during this year was 0.69 million tons.

In the Philippines, the total fish catch is about 1.5 million tons. The trash fish content is around 10-12 percent which is wholly converted into fish sauce and fish paste. Of the edible fish, 60 percent is consumed fresh and 40 percent is processed. Processing wastes are converted into fish meal by small manufacturers. Shark is processed for shark liver oil and the residue converted into fish flour which is exported. The sea shells are heated in lime kilns to obtain quick lime, converted into jewellery or other articles, or exported.

In Indonesia, the annual catch in 1973 was 1.3 million tons and the exports 52 178 tons consisting of frozen shrimp, frozen frog legs, other frozen fish and salted jelly fish. Indonesia also imports large quantities of canned fish to meet the domestic demand.

In Malaysia and Singapore, the fish catch is relatively small. The Indian fish catch is about 1.4 million tons. Fish trash, scrap and other wastes are converted into fish meal and fish manure. Fish oils are extracted from sardines and shark liver. Shark skin is converted into leather. The processing centres are scattered and all the residues are not utilized.

Residues

The fishery industry generates the following residues:

- surplus fish due to heavy landings without corresponding shore facilities;
- processing wastes; and
- trash fish.

In S.E. Asia solid wastes are utilized in the form of fish meal, duck feed, fish sauce and paste and as a fertilizer. In India the utilization is only partial. Due to the scattered nature of the processing units, accurate figures of the quantum of residues are also not available. According to a rough estimate, the annual residue availability is as (in tonnes): prawn shell and head waste 40 000; lobster wastes 800; fish wastes (tuna, seer, mackerel, sardine, pomfret) 3 000; frog wastes 5 000; shark liver residues 2 000; and squilla 100 000.

The prawns and shrimps when processed into frozen headless fish, cooked frozen fish, semidried fish or dry fish pulp generate residues such as shells and other left-overs. A small part of the residue is currently converted into fish meal or manure; the rest is dumped in the waters. The approximate composition of the residue which contains about 77 percent moisture is (on percent dry basis): ash 38; protein 40; chitin 10 and fat 5.5.

Possibilities

Trash fish and fish processing wastes can be converted into fish meal in India as is done in all S.E. Asian countries. Trash fish can also be converted into fish sauce and paste as is practised in the Philippines. With enormous fish wastes available, India produces only 5 000 tons of fish meal. The present method of production, namely sundrying and powdering, is also inefficient and unhygienic leading to contamination of product with pathogens and sand.

The prawn shell and head wastes can also be processed for the isolation of glucosamine hydrochloride (GAH) which is a rare sugar of interest to pharmaceutical industry. Another useful product obtainable from these wastes is chitosan, which has outlet as a textile sizing agent, for clarification of wine and water or as an adhesive. It is possible to manufacture liquid fertilizer from these wastes.

The main problem which faces the utilization of these wastes is the collection, preservation and storage since the units are scattered.

Data on the volume and nature of effluents from fish canning industry are not available. It is reported that proteins from blanch liquor can be isolated.

The trash fish apart from their use in the production of fish meal can be a source of fish protein concentrates which can be incorporated in various diets to fortify protein content or of fish protein hydrolysate (protein content 30-40 percent).

Another possible use of waste fish is the production of fish ensilage as animal feed. The fish waste is mixed with molasses (as a source of carbohydrate) and subjected to ensiling. Curing of fish, widely practised in S.E. Asia is another possible use.

The frog wastes constitute about 65 percent of the weight of the frog. The waste can be defatted to recover the oil and the rest converted to frog meal (yield 12-14 percent) which is similar to fish meal in percentage composition (moisture 6; protein 60.6; fat 8.4; ash 22.0; acid solubles 0.5; CaO 6.2; and P_2O_5 5.4). The frog oil is obtained in a 6-8 percent yield (S.G. 0.9107; soap value 194; IV 95; acid value 0.47; and unsaponifiable matter 2.55 percent).

2.9 Marine algae: (Algae or sea weeds are primitive group of plants without true roots)

Algae or seaweeds are primitive group of plants without true roots, stems and leaves. Depending upon their pigment, they are classified as:

- green algae (Chlorophyceae)
- brown algae (Phacophyceae)
- red algae (Rhodophyceae), and
- blue-green algae (Myxophyceae).

The first three occur in abundance in the seas of the region. Though their use as a source of agar and algin, as a fertilizer and as an animal feed is known, there is no organized collection of seaweeds. Only the seaweeds washed ashore are collected and processed. There have been no surveys to assess the availability of seaweeds.

The present capacity of agar manufacture in India is 100 tons which is likely to increase to 300 tons by 1978-79. Several plants to manufacture sodium alginate have been set up. The south and west coasts of India have a potential for the manufacture of 20 000 tons agar and 2 000 tons sodium alginate.

The potential uses of some of the species available along the Indian coasts are described below:

Gelidiella and Gracilania species have been investigated as a source of agar which is colloidal carbohydrate present in the cell walls of certain red algae and is a mixture of two polysaccharides. The yield of agar varies between 12-45 percent, the high-yielding ones being Gelidiella acerosa and Gracilania lichenoides. Algin is also a polysaccharide which is water-insoluble and alkali-soluble and which constitutes the cell walls of brown algae. Both agar and algin are used as stabilizers, emulsifiers, thickeners, body-producers and gelling agents in food industry, and in textile, paper and paints industries.

Some green and red algae are rich in protein content and contain essential amino-acids and iodine (16-30 percent protein content on dry basis). Protein concentrates prepared from these algae can be compounded with other foods to increase their nutritional value. In the Philippines and Indonesia, seaweeds are common food items and agar is extracted for export. Seaweeds are also eaten in Indian coastal areas.

Because of their high mineral content, the seaweeds can be used as supplementary diet of animals or they can be used as a fertilizer in sandy soils where water retention is desirable. Seaweeds and aquatic plants can be composted along with farmyard manure.

2.10 Aquatic plants

There are large numbers of plants of the hydrophytes and hygrophytes group which grow in the monsoon region. Hydrophytes are tender, soft and, compared to their bulk, light. Most, like Hydrilla, are rootless. Their reproduction is usually through the vegetative method and is rapid.

Water hyacinth (Eichhornia crassipes) is a perennial , persistent and pernicious weed, with long fibrous roots, short stem, spoon-shaped leaves and lilac flowers and is difficult to eradicate. The dense formations of this weed have impeded the flow of water for irrigation and navigation canals. It has choked ponds and lakes. It has interfered with pumping of water and poses a health hazard by harbouring insects like mosquitoes in its dense root system.

The fresh plant contains (in percent): moisture 95.5; N 0.04; ash 1.9; P_2O_5 0.06; and K_2O 0.2. The dried plant has 28.71 percent K_2O, 12.8 percent CaO and 7.0 percent P_2O_5 which makes it an exceptionally rich source of potassium.

The dried plant is burnt with other agricultural residues as a fuel and the ash is used as a manure. Since the plant is rich in potassium and phosphorous, its composting along with dry leaves and grasses provides a manure superior to farmyard manure.

The plant has a protein content of only 0.9 percent. The fat and carbohydrate contents are also low (0.6 and 5 percent respectively). It is therefore uneconomical as a cattle fodder. It can however be used in combination with other animal feeds. Its use is reported to increase milk yield by 10-15 percent in milch buffaloes but the milk has correspondingly low fat content. One Ha can annually yield about 250 tons of fodder.

The paper and boards made from the dried water hyacinth plant do not have satisfactory characteristics. Some paper and boards are made in India by mixing jute and cotton and jute fibres (8-10 percent on weight of pulp). The economics however depend on the cost of collection.

Several methods of industrial utilization of water hyacinth have been suggested. These are: sacharification by acid digestion followed by fermentation; gasification, and bacterial fermentation. All these yield 100 kg of potassium chloride per ton of dried material. In the first alternative, each ton of dried material gives about 60 litres of ethanol and 200 kg of residual fibre (7 700 BTU), and **the** second 38-45 kg ammonium sulphate and 1 100 m^3 of gas of low heating value (H_2, 16.6; CH_4, 4.8; CO 21.7; CO_2, 4.1; and N_2, 52.8 percent). The bacterial fermentation per ton of dried material gives about 800 m^3 of gas (600 BTU). The commercial possibilities of these alternatives have not been proved. The cost of transport and drying of a material with 95-96 percent water content is likely to be very high.

3. SOME END PRODUCTS FROM AGRICULTURAL RESIDUES

3.1 Animal and poultry feeds

The region has a large livestock population to support farming activities and to provide food for its ever-growing population. The animal fodder resources are limited by the availability of land. This has created a wide gap between the traditional fodder availability and the current requirements. In India, this gap has been estimated to be of the order of 26 million tpa which is affecting not only the farming operations but also the projected development of dairy and meat industry.

The traditional animal feed are straw, green fodder, grass, oil cakes and brans. Not all these are equally palatable or nutritious, and the animal diet is usually unbalanced. The cereal straws are generally deficient in digestible protein, poor in energy and minerals, and unpalatable. Their palatability and nutritional value can be enhanced by a caustic soda solution spray by about 25 percent, yet this is not practised widely. The straws from oilseeds and leguminous crops are palatable and nutritive (digestible protein 3 and TDN 40 percent).

The cereal processing waste like rice and wheat bran and maize grit, gluten and husk is palatable and nutritious but the rice, coffee and groundnut husks are not.

The addition of molasses and urea (1 percent) improves the palatability of these husks. The groundnut husk digestibility can be increased from 19.7 percent to 54.9 percent by caustic soda treatment. Where groundnut husk is used as bedding material for broilers, the digestibility improves further to 71.2 percent because of the presence of droppings (66%). The groundnut skin is highly nutritious (protein 18%, TDN 65%).

Pineapple cannery wastes (60-70% of input) can be commercially formulated as a complete animal feed or as a supplementary diet. The wastes should be subjected to ensilage treatment rather than fed directly. Likewise, other fruit processing wastes can be used as animal feed. Citrus wastes, which constitute 45-60 percent of the fruit, has high digestibility (88-92%) but is low in protein and fat. A typical analysis of dried crude citrus pulp waste is (in percent): ash 4.3; ether extract 3.5; crude fibre 13; crude protein 6.2; nitrogen free extract 63; and dry matter 92. It has digestible protein of 2.3 percent and total digestible nutrients of 74.9 percent. The use of cashew apple, mango and tomato wastes as animal feed has been discussed earlier.

The animals like to forage on grasses and leaves, pods, thorns and tender branches of several trees. These sources of animal fodder are not collected commercially nor have any detailed studies been made on their nutritional value. Some of these plants, like _Cossia toria_ are not eaten by the animal in green state but are palatable after drying and preferably after ensilage. The wood wastes can be utilized for animal feeding _via_ bedding material for poultry followed by ensilage.

Oilcakes and oilseeds are traditional animal feed components. These should however be used in quantities in keeping with their nutritional value and palatability.

Molasses, press mud and bagasse, the byproducts of sugar industry, are well known ingredients of animal feeds. In commercial feed compositions, supplementary nitrogen in the form of urea is usually added.

Except for brewer's yeast, the residues from distilleries, wineries and breweries are not utilized at present. The effluents are a source of pollution. The liquid sludge can be a substrate for SCP which can be incorporated in animal feeds.

The possibility of using oil palm and rubber processing wastes as animal feed has been discussed. The utilization of these wastes for this purpose will depend on the economics of the process.

Seaweeds which have a high mineral content (ash 33%) but low protein (10%) can be used as part of the supplementary diet of the animal. Fish meal is an accepted animal diet of high nutritional value especially for poultry and pig.

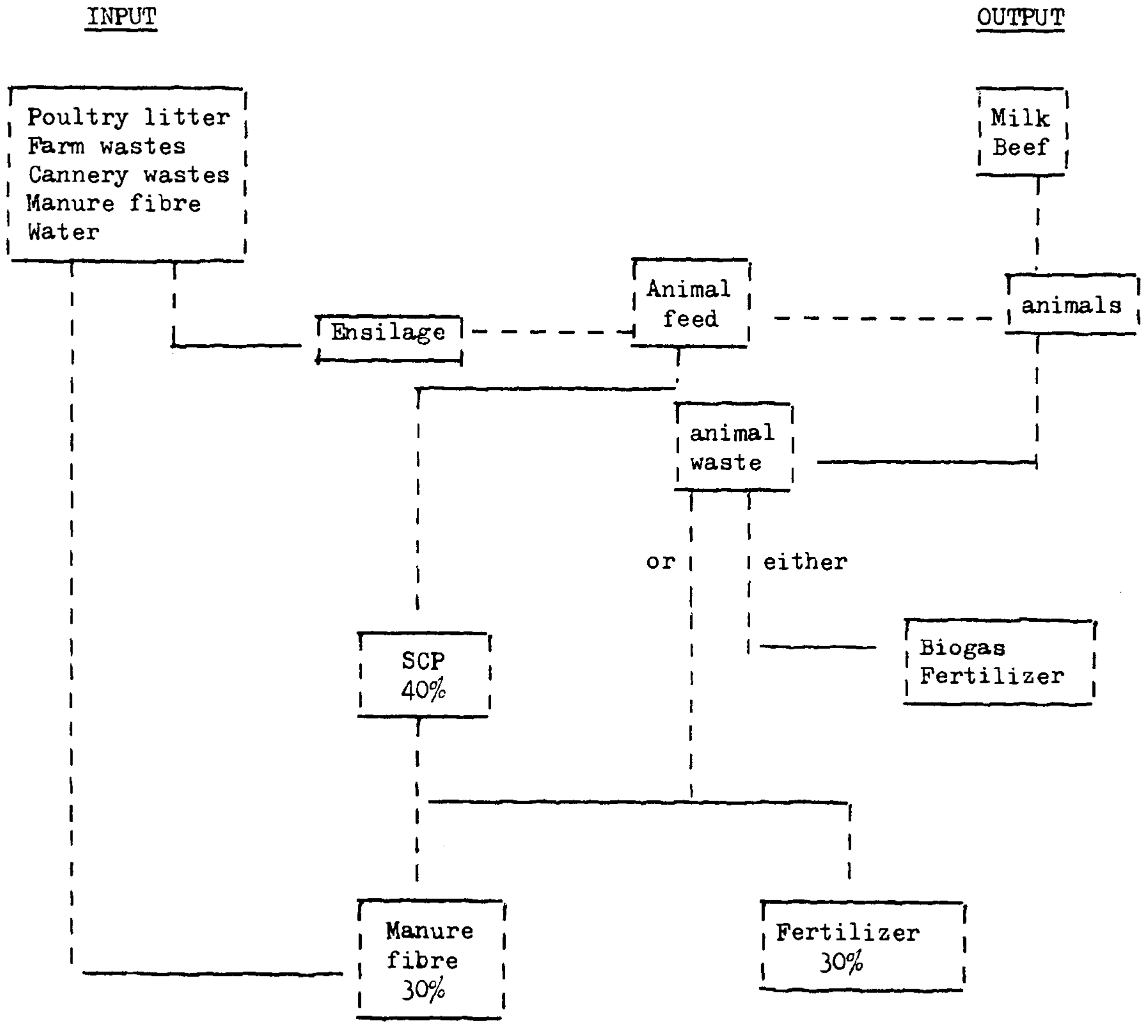
The slaughterhouse wastes like meat scrap, tankage, blood, hoofs and horns are being processed for their use as animal feed. Poultry feathers can also be processed and recycled as supplementary ration for the broilers. Silk worm pupae after recovery from cocoons and penicillin mycellium (protein content 28%) can be used as a supplementary diet for the poultry and animals.

Egg shells have the following average percent composition: moisture 1.22; crude protein 5.77; total lipids 0.35; total ash 92.52; Ca 32.30 and P, 1.05. With 94 percent calcium carbonate content, egg shells are a good source of calcium in an animal diet.

The food grain damaged during storage by insects, rodents and other pests is not fit for human consumption due to the presence of uric acid (9-10 ppm). It however retains other nutritional properties and provides the same gross energy. Experiments have shown that it can be safely used in poultry diet after testing for the absence of any fungus growth.

The recycling of organic wastes for the production of animal feeds creates new opportunities for commercial enterprise. The attractive possibilities are due to the availability of cheap and abundant raw materials, the simplicity of equipment and ensilage treatment, small land requirements (as compared to pasture land) and low capital investment. Another advantage of producing animal feed by ensilage is that a balanced diet will be available due to a studied nutritional knowledge behind each composition. The raw materials which have been extensively studied to produce wholesome and acceptable feed are poultry litter and cattle dung. The one based on poultry litter is already being commercialized in Singapore and Malaysia. Different types of bedding materials for poultry have been tested including cereal straws, sawdust and hulls. The ensilage could also include supplementary food ingredients of organic or inorganic origin. The equipment consists of a crusher or shredder, a horizontal mixer, 3 conveyors, one bucket elevator or blower, 2 silos and one forage box. For a 1 500 cattle feedlot, the capital investment is reported to be US$ 100 000 but the process is adaptable to smaller farms of 50-100 heads with lesser investment costs. The technology is being offered by several commercial organizations in S.E. Asia.

The recycle of animal wastes can be combined with the production of SCP or biogas. The cycle which has not yet been commercialized is shown below:



3.2 Pulp, paper and boards

Agricultural fibres have been a source of paper and board for a long time. World demand of pulp and paper is increasing, posing a problem of raw material availability. Wood has been the chief raw material all over the world. Some alternative cellulosic raw materials are available in the form of agricultural residues such as straws, husks, kenaf and jute wastes, bagasse and sawdust. Some of these are already being used in South and South East Asia for the production of pulp, paper and boards.

The approximate analysis of depithed bagasse, rice and wheat straws, and jute and kenaf wastes shows that these raw materials are of low lignin content (21-25%), high pentosan content (18-26%) and of an average cellulose content (51-57%). Bagasse and kenaf wastes have a low ash content (1.2 and 0.5% respectively) while rice straw has a high ash content (18.6%). Short fibres are obtained in all cases. The cereal straws are being used as animal fodder; their availability for pulp and paper industry is thus limited. With the progressive introduction of short high-yielding varieties, the yield of straw per unit area is also decreasing. Nevertheless, the straws are available in some areas in reasonable quantities. Bagasse is mostly (over 90%) used as fuel by the sugar mills. The excess quantities are available for alternate uses. Jute and kenaf wastes and saw dust are available in large quantities.

A major problem in the utilization of crop residues for pulp, paper and board manufacture is their scattered availability. The lightness of these materials adds further costs to their collection and transportation to mill site. Even a small sized paper mill will daily require 100 tons of raw material. Collection of such enormous quantities close to mill site is not possible. Setting up of mini-paper mills is, however, a feasible alternative.

A 1 500 tpa speciality paper manufacturing will require a capital investment of about US$ 100 000 using jute/kenaf wastes/paddy straw, cotton linters, tailor cuttings, paper wastes, etc. The fibre plant or cereal crop residues are mechanically chopped to 5-7.5 cm length and digested with 6-10 percent caustic soda. The digested pulp is washed free of alkali, bleached with sodium hypochloride in a beater, and refined. The cotton linters are similarly treated but under milder conditions. The cotton rags and cuttings are also converted into pulp in a beater and bleached. The three pulps are then blended in different ratios, and processed to produce the following ultimate product mix:

	tons/year
Writing/printing paper	700
Wrapping/kraft	500
Filter, drawing, bond, grease-proof papers, etc.	300

Bagasse has been tested as a source of rayon grade pulp using a caustic soda and sulphate process. In both cases, about 34 percent yield of bleached pulp was obtained (alpha cellulose 92-96%; pentosan 2-25%; ash 0.12% and brightness (MgO = 100) 86).

The residues like abaca wastes, sunn hemp and its wastes, flax wastes and hemp (Cannabis sativa) wastes can all be used in a similar fashion. In the Philippines, chemical pulps from the fibres of Giant Cavendish-banana (Musa Cavendishu Lamb) have been produced.

Timber and wood processing industries generate enormous quantities of residues. In addition, the coconut industry produces residues like husk and shell which are not wholly utilized. In India, the utilization of husk for coir production is only to the extent of 50 percent of all nuts collected.

Fibre boards are manufactured using various agricultural residues. The lime process is used in all the countries of the region. The pulp yield from bagasse, kenaf/jute waste, wheat and paddy straw is reported to be 65; 80–82; 62 and 55 percent respectively. The breaking length is the highest for bagasse and the lowest for rice straw.

Fibre boards from wood wastes are manufactured by a wet process where wood is first converted into fibre and then pressed into board. The dry process is simpler and cheaper and utilizes saw dust or similar materials which are mixed with binders and pressed. The boards produced by this process, which is amenable to small scale manufacture, are hard, dense and uniform (density 1.16–1.37 g/ml; bending strength 2870–7147 psi; water absorption (24 hr) 4.4–21.6%).

Coconut husk has resinous material which gives it a unique self-bonding property. Thus, satisfactory boards can be prepared from the husk of mature coconuts (using only 0.5% by weight binder as compared to the usual 6–9% with other raw materials).

Binderless fibre and particle boards can be produced from the conventional raw materials according to a process developed in India. The characteristics of the boards prepared from sawdust and bagasse are:

	Sawdust	Bagasse
Bending strength (kg/cm^2)	130	150
tensile strength (kg/cm^2)	75	80
bulk density (kg/m^2)	1.3	1.3
water absorption (%, 24 hr)	5–10	5–10

The total investment of a 10-tons per day particle board manufacturing plant is estimated to be around US$ 25 000.

3.3 Fatty acids and glycerol from "minor" oilseeds

Many of the seeds produced by the forest trees are sufficiently oil-bearing to be of great economic value. Their non-utilization or insufficient exploitation is due to several factors. In some cases, the economic potential of these seeds is not known. There are problems of collection in remote forest areas which make the cost of collection high. The processing plants are distantly located. The cost of freight becomes prohibitive.

The extent of availability of oil-bearing forest seeds is large and the question of their exploitation deserves a closer look. A case study on the economics of production has been made which illustrates the advantages of mini-plant approach. Andhra Pradesh in India was chosen for this study. Three alternatives to process 40 tpd of oilseeds have been examined.

The comparative data for the three alternatives is given below:

	Alternative 1	Alternative 2	Alternative 3
	Single plant with solvent extraction units	Single plant with expeller units	Mini plants complex
Total investment* (Rs million)	11.46	8.38	5.63
No. of persons employed	91	112	338
Investment/person employed, Rs	126 000	75 000	17 000
Value of daily production, Rs	92 200	88 700	88 700
Annual returns, Rs. million	10.4	10.7	10.9
Annual returns, investment rat.	0.91	1.28	1.94

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* US$ 1 = *Ca*. Rs. 9

It is clear that despite the higher value of daily production, Alternative 1 appears to be the least economic (Returns/investment ratio only 0.91) while Alternative 3 is socially and economically the most desirable. The project in this case will operate in the heart of rural area providing direct and indirect benefits to the community as a whole. The returns/investment ratio is also highly favourable (1.94). Besides, this provides perhaps the only practical method of utilizing the otherwise unutilized resource of minor oilseeds and manpower.

3.4 Furfural

Furfural, a light yellow liquid, is a solvent for removing gum-forming compounds in lubricating oils and diesel fuels. It is also used in the manufacture of plastics for paints and resins, for refining of vegetable oils, for the intermediates and as a pesticide. It is produced from pentosan-rich agricultural wastes like sawdust, bagasse, hulls and stalks by acid hydrolysis of pentosan. The theoretical yield of furfural from various raw materials (in % dry basis) is given below:

Oat meal 22; maize cobs 22; cottonseed hulls 20; bagasse 17, maize stalks 16; groundnut shells 14; and rice husk 12.

Other potential raw materials with high pentosan content are: wheat straw, rice straw, soyabean stalks, and vegetable fibre plant residues.

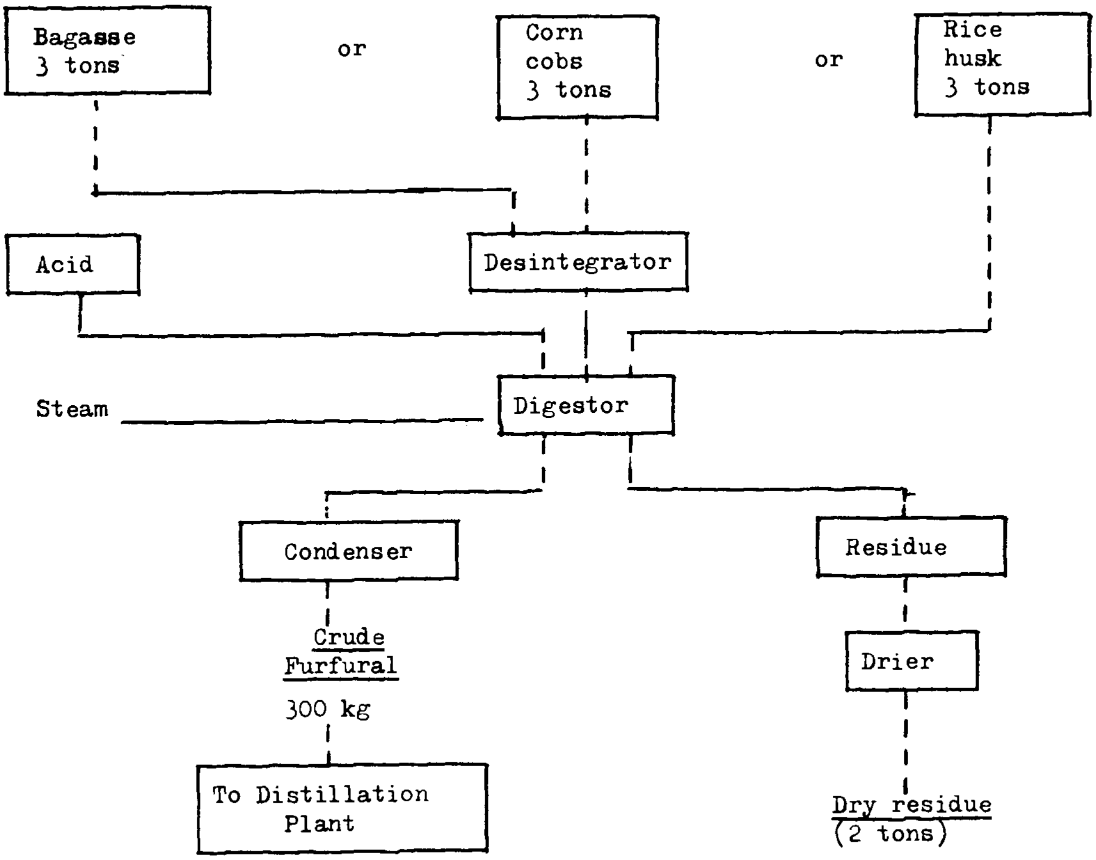
The process consists of crushing and air-drying of the raw material, hydrolysis at room temperature followed by heating to about 250°C, and recovery of furfural by sweeping with steam or inert gas. Small quantities of acetic acid and methanol are also produced.

The spent residue which is about 7 times (on dry basis) the weight of furfural produced can be used for various purposes. A typical analysis of spent corn cobs (on % dry basis) is: protein 2.8; fibre 51.4; N-free extract 38.5; ash 3; K_2O 1.02; SiO_2 1.26; and P 0.11.

The raw materials for the manufacture of furfural are all of rural origin and if large plants (e.g. 6000 tpa capacity) are to be set up, large quantities of bulky raw materials have to be transported to plant site (for every ton of furfural, one requires approximately 8-10 tons of raw material). The employment potential of large plants is also unfavourable. It is thus appropriate to carry out an exercise in scaling down of the technology to bring it to an economically viable level which could be operable as part of a rural economy. The merit of establishing small units besides providing gainful employment to a larger number of people is the dispersal of technology which by itself has many intangible advantages.

The project can be integrated with mini plant complex for fatty acids and glycerol manufacture (7.3) and five mini plants (cap. 300 kg pd) to produce crude furfural can be located at the same sites. The crude furfural likewise could be distilled in the central distillation plant located near fatty acids distillation plant. The following flowsheet diagram describes the process:

Basis: 300 kg crude furfural
per day
No. of units: 5
Location: Mini Fat Splitting Plants



It is estimated that each mini plant for producing crude furfural will require a capital investment of US$ 27 000. Thus, 5 mini plants will have a total capital investment of US$ 135 000. The distillation plant will have additional capital investment of US$ 100 000. The total capital investment of the complex thus works out to be US$ 235 000,- The gross return per annum is expected to be around US$ 260 000,-

3.5 Dehydrated castor oil (DCO)

Introduction

The manufacture of dehydrated castor oil is different from that of other treated oils in that there is substantial evolution of volatile decomposition products during its preparation. Since the dehydration of castor oil involves the splitting off of the elements of water, accompanied by fission of fatty chains which results in production of aldehydes and free carboxylic acids, corrosion due to the presence of the free fatty acids poses a problem. In addition, an efficient condensing system is required to handle the water vapour (about 5 percent on the weight of castor oil used) and the other volatile organic compounds evolved during the dehydration.

The actual plant required will depend on the quality of DCO to be produced. Where pale colour and high quality is not required, even an open fire could be used. But to produce pale coloured DCO of superior properties, special precautions are necessary. Since DCO is susceptible to oxidation and polymerisation, it is essential to exclude air from the reaction vessel by means of either inert gas or vacuum. The latter also helps in rapid removal of the volatile products formed and enhances the speed of dehydration. The heating of the oil has to be so carried out that there is no local overheating, and the temperature is uniform throughout the product. This could be done by having a jacketed vessel and by using a suitable heating system, i.e. either having oil in the jacket which could be heated by immersion heaters, or by circulating hot vapours of suitable oil through the jacket. Efficient stirring is important, specially when insoluble solid catalysts are used, so that there is intimate contact between oil and catalyst. The heating surface provided should be as large as convenient, since this would enable lower temperatures to be used for heating, due to the large surface available for heat transference. The reaction kettle should preferably be constructed of stainless steel, or aluminium and its alloys; stainless steel is essential when acids or acidic salts are used as catalysts. Arrangement for rapid cooling of the product helps in improving the quality of the DCO obtained.

Pre-treatment of raw materials

a) Castor oil

For ordinary grade of DCO where pale colour is not important, raw castor oil can be used (free from mucilage) and for pale coloured DCO, the best grade (first special) of castor oil (light in colour and of low acid value) should be used.

b) Sodium bisulphate (fused)

Sodium bisulphite and sodium sulphite of technical grades can be used. The catalyst sodium bisulphate and the sodium bisulphite and sodium sulphite are used in the form of a slurry with castor oil or DCO, the order of addition being sodium bisulphite, sodium sulphite and sodium bisulphate separately.

Reactions details

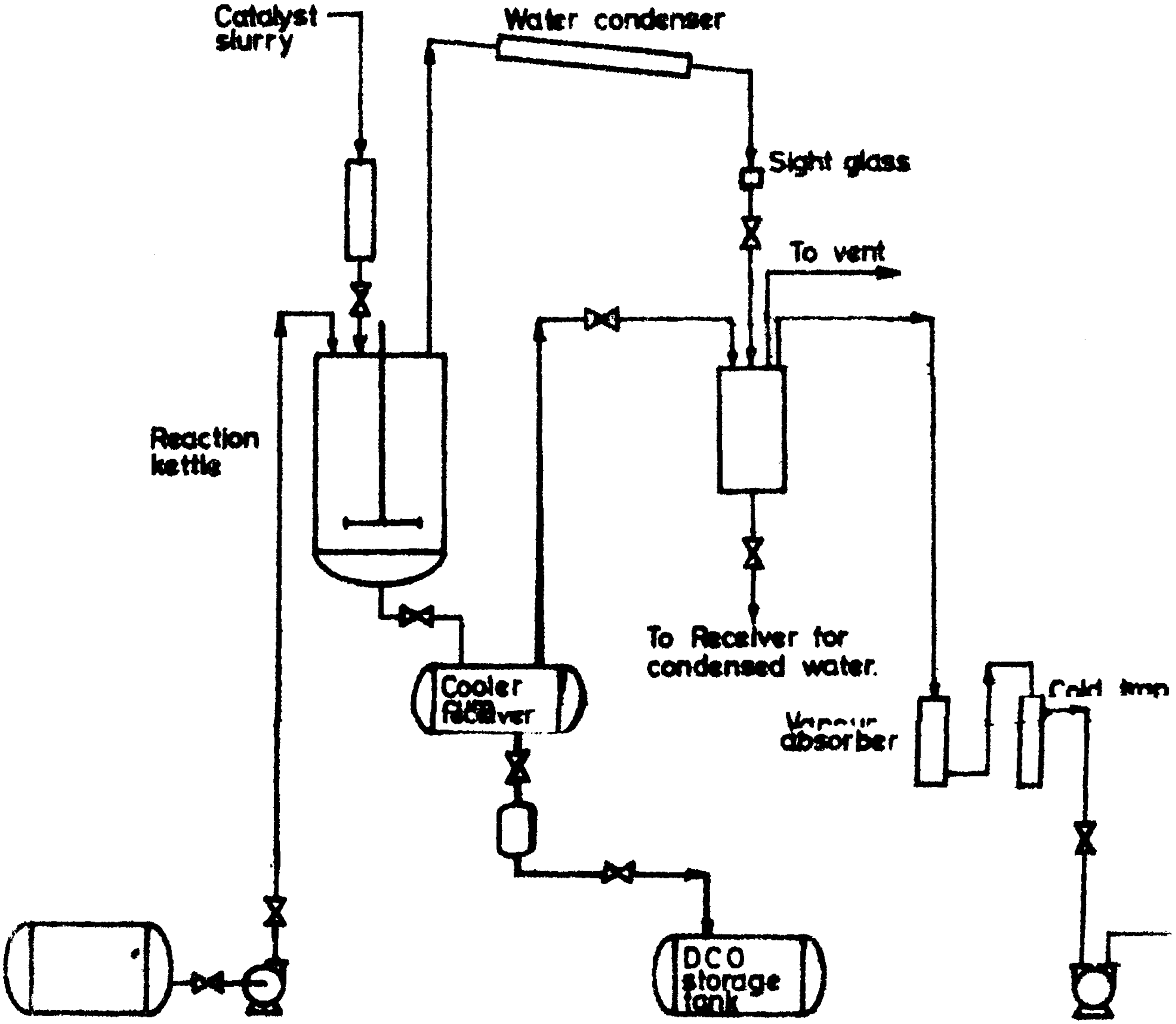
The processing of castor oil into DCO is as follows: (a) Sodium bisulphate catalyst.

The castor oil is fed into the reaction vessel and heated rapidly with stirring and under vacuum of 28 inches of mercury by gauge to a temperature of 225-240°C. During this period the sodium bisulphate (1.5%), sodium bisulphite (0.5%) and sodium sumphite (0.5%) are separately made into slurries by grinding with straight or processed castor oil (DCO). As soon as the castor oil attains a temperature of 240°C, the slurries of sodium bisulphite and sodium sulphite are sucked in under vacuum, followed by the slurry of catalyst. Heating is carried out for the required period (30-35 min), as determined in a test run, for the DCO to attain the minimum viscosity. The product is then discharged into the cooler under vacuum and after cooling to 60°C, it is removed into an open vessel, from where it is pumped into a filter press. The filtered oil is collected and stored in tanks. Flow-sheet for the manufacture of DCO is shown on the following page.

3.6 Charcoal

Charcoal is obtained by carbonization of wood which is carried out by heating wood under conditions of controlled supply of air. The object is to reduce wood to form carbon by removing other constituents in the form of gases and other volatiles (smoke) which can be condensed to yield useful byproducts. Charcoal burns smokelessly on account of removal of these volatiles.

The conventional method for producing charcoal in South and South East Asian countries is by heating wood in earth kilns or in simple pit kilns where wood (usually sound hardwood) is piled into stacks and then covered with earth to give a firm enclosure, not too tightly packed to allow a slight inlet leak of air and an escape for the volatiles. The kiln is then lighted at the bottom. The heat first removes the moisture and then carbonizes wood into charcoal. Since the air supply is limited, uncombusted volatiles escape as a dense smoke. It requires 3 weeks to convert 200 m^3 wood into about 1.5 tons of charcoal. A battery of several kilns



FLOW-SHEET FOR THE MANUFACTURE OF DEHYDRATED CASTOR OIL (DCO) is used. Improved designs use masonary structure but advantage of earth kiln is its "portability" to site of raw material. The technology is simple but wasteful. All the valuable byproducts are dispersed into the atmosphere causing considerable pollution.

The beehive-type, vertical type and tunnel-type ovens provide recovery of byproducts like methanol, acetic acid and acetone. When pinewood is used for carbonization, valuable pine tar is also obtained. More efficient carbonization techniques employ an internally-heated system and are continuous in nature. The process is described below:

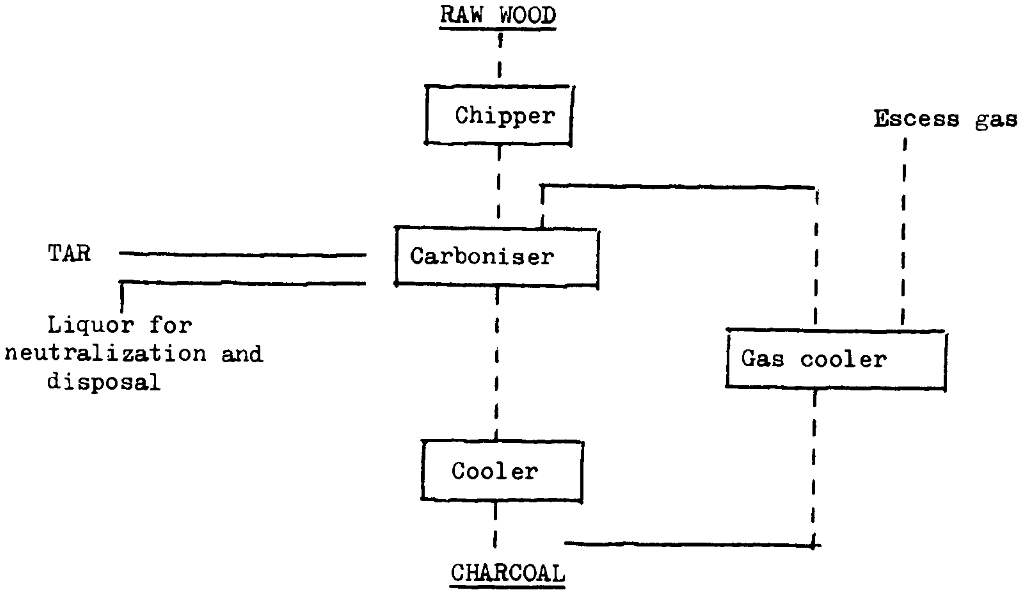
Product standard

Charcoal	(1) Moisture	8-10%
	(2) Ash	3-5%
	(3) Volatile Matter	10-15%
	(4) Fixed carbon (by difference)	79-70%

Raw material standard

Hard wood	(1) Moisture	10-15%
	(2) Ash	1-2 %
	(3) Volatile Matter	70-75%
	(4) Fixed carbon (by difference)	19-8 %

The wood is cut into about 50 mm cubes and fed into the bunker. From the bunker it travels down the dryer section where it comes in contact with the hot gases of carbonization. From the drying section the wood travels down to the carbonization section where the carbonization is effected by hot combustion gases from an oil-fired furnace. The wood gets carbonized into charcoal which travels down and gets cooled by the cooling gas admitted from below. The cooled charcoal is discharged and quenched with water and sent for storage. The vapours of tar and pyroliqueous liquor produced during carbonization are sucked along with the products of combustion from the furnace through a dust and drum separator and a tar separator by means of a fan. The dust separates out at the dust and drum separator. The tar condenses in the tar separator. The vapours of pyroliqueous liquor then pass through a spray cooler where they are neutralized with a spray of sodium carbonate lye. The gases free from condensable components are used partly as cooling gas and partly let out as excess gas. The tar obtained is stored separately.



The plant which will have a capacity of 100 tons of wood chips/day will produce:

Charcoal for sale	30 tons/day
Tar for sale	8 tons/day
Liquor for sale	40 tons/day

The raw materials and utilities requirements are given below:

Raw materials:	Wood chips	100 tons/day
Utilities:	Power	200 KVA
	Steam	100 Pounds/hr
	Furnace oil	nominal
	Water	1000 gallons/min
	Sodium carbonate	500 kg/day

The cost of the erected plant will be around US$ 250 000.

The charcoal produced will not only serve as a domestic fuel but also will be suitable for many industrial applications like production of carbon bisulphide, calcium carbide, silicon carbide, activated carbon and in metallurgical industries.

3.7 High protein flour from groundnuts

Oilseeds are being cultivated mainly as a source of oil. Oil-seed cake is being used mostly as cattle feed or as fertilizers. The advantage of using groundnut flour as a source of protein for human beings is the fact that the protein in the groundnut is not associated with any inherent anti-nutritional factors and being bland, it blends easily with different types of food products.

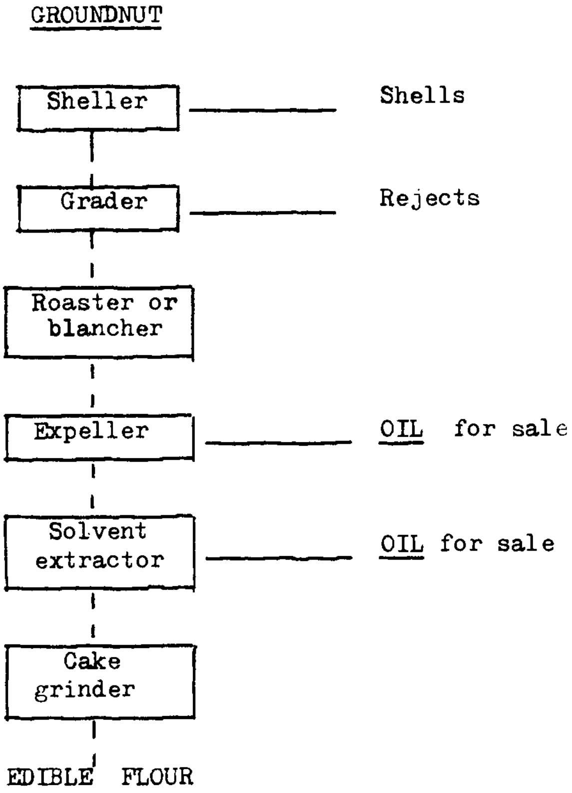
Product standard

Protein content	Min. 50%
Oil content	Max. 1%
Fibre content	Max. 7%
Moisture	Max. 7%
Sand and silica	Max. 1%
Aflatoxin content	Max. 50 parts per billion
	100% to pass 100 mesh

Raw material standard

Groundnut - oilseed quality max - Moisture 7%
Hexane - Food grade

The groundnut is shelled to remove husk, cleaned to remove stones and graded to remove infested seeds. Then the nuts are roasted and bleached to remove red cuticle and germs. The decuticled seeds are hand-picked for removal of discoloured and fungal infested seeds. The good clean white kernels are subject to breaking and cooking to condition the kernels for oil extraction. The cake from the expeller is flaked and solvent extracted using food-grade hexane. The deoiled meal is desolventised and ground to flour for packing.



Plant Capacity

Groundnuts (in shell) handled	9000 T/Y
Expelled oil for sale	2670 T/Y
Solvent-extracted oil	225 T/Y
Edible flour	2940 T/Y

Raw materials and utilities

Groundnut in shells	30 tons
Solvent hexane (for losses)	240 litres
Steam	13 000 kg
Power	1 600 KWH

Plant area

35 m x 70 m = 2450 m^2

Investment

Land and buildings	US$ 40 000,-
Plant and equipment, erection, etc.	" 140 000,-

4. CONCLUDING REMARKS

The dominant features of the economy of the region are:

- its high annual population growth rate (2.2-3.3%) and high density of population in fertile plains;
- the phenomenon of 'rural push' caused by a continued disruption of rural balance and the vast disparity between urban and rural wages resulting in non-uniform growth of urban population;
- the monsoon dependency of most agriculture;
- rice is the most outstanding crop with associated off-season crops, chiefly cultivated for subsistence (Thailand is the only exporter of rice in the region):
- the high percentage of small holdings (using labour-intensive and inefficient farming techniques) making it difficult to introduce modern agricultural practices;
- high post-harvest losses especially due to inadequate and poor storage facilities;
- the popularity of fishing and fish culture but inadequate attention to livestock farming except in Singapore where combination farming of vegetables, livestock and poultry is practised due to limited availability of land;
- the production of commodities obtained mainly by primary processing, e.g. palm oil, rubber, coconut, sugar, etc., and inadequate development of secondary and tertiary processing industries;
- the uncontrolled denudation of forests for lumber and fuel causing land erosion and floods;
- the generation of enormous quantities of agricultural residues (e.g. in the region rice alone generates: rice straw 270-300; rice husk 20-23; and rice bran 3-3.5 million tons);
- the non-utilization or inadequate utilization of these residues either due to their dispersed availability and therefore due to the problems of collection and transport to processing centres or simply due to lack of technological information; and
- the capital-intensive and labour-saving technologies now being introduced do not, in most cases, satisfy the socio-economic needs nor meet the infrastructural situation in these countries where capital is scarce and manpower abundant.

The traditional balance between agriculture and rural handicraft was disturbed in South and South East Asian countries during long periods of colonial rule. The encouragement given to feudal type of economy resulted in the reversal of natural process of socio-economic change and the base of economy in these countries continues to be agriculture. Whatever processing industry exists, it is engaged only in the manufacture of primary products. Recent efforts to correct these distortions in economy by rapid industrialization with inadequate attention to agriculture and agro-industries has only weakened the agricultural base. This experience shows that only the strengthening of the rural economy can lead to successful industrialization.

For a healthy economic growth, these countries require an annual investment of 12-15 per cent while annual saving is of the order of 5-6 per cent, with the exception of India (12-13 per cent in 1975). The agriculture is unable to generate enough savings and the industry has still to develop in order to generate enough savings. The agriculture also cannot develop further, because there is not enough to invest.

This vicious circle can be broken and the balance in economy restored by developing industries in the areas of raw material availability through appropriate dispersal of technology. Farm wastes are cheap, abundant, and renewable resources. Their utilization will not only stabilize the rural economy but also put an end to 'urban pull'. It will also result in increased purchasing power of the people and hence increased savings for proper economic growth.

In order to set up agro-based industries, especially those based on abundant agricultural residues, the availability of capital, technology and skilled manpower will have to be considered. Mini plants in the rural areas will not require much capital investment and these can be set up within the present rate of savings. The appropriate technology for the product manufacture may either be available within the developing countries or elsewhere, or it may have to be quickly developed. The necessary skills can also be acquired by training programmes within developing countries. Thus, a plan for technology and experience sharing within the developing countries is the first step towards restoration of economic stability and progress.

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Survey of Agricultural and Agro-Industrial Residues in selected Countries in Africa

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SURVEY OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUES IN SELECTED COUNTRIES IN AFRICA

by

W.R. Stanton

I. GENERAL OBSERVATIONS ON RESIDUE UTILIZATION

1. Introduction

One of the distinctions between a developing and a developed country lies in the difference in the capital available. This capital is in the form not only of monetary resources, but also institutions, raw and manufactured materials and equipment , and the size of the skilled cadre of the population. Where these resources are available, the distinction disappears and equal opportunity is presented to both types of community from the point of view of utilization of secondary commodities. Under these circumstances, whether the secondary commodity is used or not depends entirely on economic and social constraints. There must be an economic incentive to utilize the waste, although the term "economic" may be somewhat artificial in that as the waste is often a polluting factor, failure to utilize the waste by a sector of the community or industry causes pollution, so that the economic criteria might be in fact a legal necessity to abate that pollution.

The further restriction imposed on waste utilization by social and ethical considerations should not be overlooked however. Communities are averse to handling certain materials and yet others are averse to using products derived from those materials, even though on the biological, physical and chemical grounds they can be shown to have no harmful effects.

2. Ecological distribution

It is not entirely a matter of chance that the developing countries have more than the average share of geographical situations and raw material disabilities. This is a consequence of the long term evolution of man and its roots can be traced back to the origin of agriculture and the origins of civilization. By definition civilization is a consequence of the partial release of man from spending the full daylight hours in the daily round and common task of food production and housing and yet we still find that much of the world is in the position where it is this activity which chains man to a low-level of output and lack of diversification of effort.

A developing country can import skills at a price. It can also import excess raw materials for processing at a price and also equipment. It can if necessary overcome the logistics of collection of the raw material. It can borrow money. The country can but often finds it difficult to release the processed waste material on the world market, or it can alternatively operate a protected economy with respect to the particular good. Whenever the social constraint on utilization of waste materials is more difficult to overcome and traced to its logical conclusion, it is found that this social and cultural restraint has determined the particular pattern of crop productivity.

In dealing with waste, one is dealing with a multidisciplinary venture impinging on all aspects of economic life of the community. Rarely can a waste be considered purely as a technical problem, dependent on the specific research having been done and appropriate processes developed.

The question of agro-industrial residue utilization may be viewed in the light of the following criteria, all of which are inter-dependent and need to be understood and integrated.

TABLE 1

Factors to be considered in residue utilization

- Types of the waste
- Logistics of supply and collection of the secondary materials
- Economics of disposal and treatment
- Socio-political aspects of utilization.

3. Waste Characteristics

The different types of waste are considered in Table 2. In this table the waste have been classified according to whether they are liquids, slurries or solids and the factors that may affect utilization possibilities. The liquid sample is divided into those liquids which contain suspended solids, whether actual solids or immiscible droplets such as those of oil, or colloidal solids and those without suspended solids. It is often a desirable feature to fractionate the waste into appropriate sub-fractions with a more limited biochemical or chemical availability for ease in processing.

TABLE 2

Types of Waste*

Liquid	with suspended solids without suspended solids	dilute, concentrated
Slurry		
Solid	structured unstructured	
With mineral/dirt contaminant		
With toxic metal contamination		
With organic toxin contamination		
With biological/microorganism contamination		
Hot/ambient		
High carbon	fermentable non-fermentable	
High N		
High P		
High special nutrient components		
High inert fraction (silica/silt/clay)		

---

* from the point of view of treatment

A difference in structured and unstructured solids is that the structured solids may require comminution or separation on the basis of particle size. This may result in the separation of the physical and chemical characteristics of the components.

A slurry, that is a solid mixed with liquid mixture which can be poured, is a very common form of waste but may be one of the most difficult to process. A typical slurry is that of cow-dung , but others may be high mineral slurries in the form of sludges from the industrial processing.

In all these types of waste there is the question of the dilution factor. In liquids this dilution factor is usually water, though it may be an oil. Similarly, with solids the dilution factor maybe due to inert matter such as sand, clay or other inert mineral matter or it may be in the form of contamination such as bark and cork particles, lignin components in an otherwise useful cellulosic residue. One of the most important features which constrain the use of cellulosic waste is the presence of included silica in the material.

To some extent, contamination and dilution are the same but a waste material may be affected by both. The contamination may be in the form of mineral contamination such as sand which is a nuisance in starch production or dirt, a contamination which affects filtration in that it provides a component of heterogeneous particles which may not respond to the normal separation mechanism.

Contamination may mean more than just dirt in that it can be in the form of toxic metal particles or toxic metal salts or non-salts such as compounds of arsenic or cyanide. The presence of this type of material can completely preclude the use of the waste for anything more than land-fill.

A further form of toxic contamination is that due to organic compounds and the range of these is increasing greatly. Many of them are strongly resistant to biological degradation and cause toxicity to man, plants, livestock in very low concentrations. These toxins may arise during waste storage, standing, or in transportation prior to treatment. Finally, there is contamination from microorganisms and larger organisms such as human parasites and insects and even rodents.

A further form of contamination lies in the temperature of the waste. A hot effluent may either be disadvantageous or advantageous. If it is to be processed biologically the effluent may need to be cooled and if the quantity is very large it may not be sufficient to allow it to stand in lagoons as the cooling process may take a long time.

Another set of criteria to be considered is the nature of these agriculture and agro-industrial wastes. It was mentioned in the early part of this review that the structuring of the solids was important and also the presence of suspended or immiscible solids in a liquid. However, further down the scale in size it is important to consider how finely divided the waste material is and whether it is amorphous or crystalline. The differences arise in treatment if the individual components form heterogenous aggregates or if it is possible, in the process of classifying the components according to size and gravity, to also separate them chemically. If the latter is possible this renders the whole question of processing of the waste much simpler.

At the heart of analysis of residue utilization possibilities is the chemical composition of the residues. This includes recognition of the presence of an important component which is to be salvaged or is the basis of a fermentation process; recognition of a minor component, in terms of quantity, which nevertheless may make the whole waste much more valuable; recognition of the carbon to nitrogen ration; recognition of the presence of appropriate nutrients; and recognition of the presence of special vitamins and growth factors. An inert fraction can affect the utilization or it may absorb a component which would otherwise make the material useful. Inert fractions also can alter the physical characteristics of a residue. Detailed information on the characteristics of a residue is essential to the determination of appropriate and environmentally sound technologies.

4. Logistics

To meet the economic criteria for utilization, an analysis must be made of the logistical problems in collecting and storing the commodity prior to processing. This requires both a spatial and a temporal analysis. As indicated in the country reports, potential uses for wastes have been identified but the wastes are only available for short periods of the year and this uneven temporal supply can preclude their being used profitably.

These logistic considerations are tabulated in Table 3.

TABLE 3

Logistic Considerations in Waste Disposal

Dispersed } evenly
Dispersed } unevenly

Concentrated

Seasonal

Aseasonal

Polluting if not treated, or removed

Non-polluting if not treated, or removed

Other economic considerations, of which logistics forms a part, are listed in Table 4.

TABLE 4

Economics of Waste disposal/treatment

A. Costly to dispose of if not treated
Can be disposed of at little or no cost

Costly to collect
Cheap to collect

Costly to store in relation to value of end-product
Cheaply and easily stored

B. Market of indefinite size for products recovered
Market of limited size for products recovered

C. End products part of an 'alternative demand group'
End products unique

End products part of world trade
End products restricted to selected localities

D. Existing market
Market to be developed

The economics of residue utilization and treatment are of obvious importance. Is it costly to dispose of these wastes if they are not treated? Alternatively, can the waste be disposed of at little or no cost?

Another question is the cost of residue collection. The hygienic collection and disposal of sewage is a costly process and it is for this reason that it has not been applied in most of the developing countries.

Economic operation of a processing plant depends on a steady supply of the material to be processed. Since most waste materials are not furnished with absolute regularity, storage is required and can be a limiting factor in the economic viability of a process. This is specially true of large scale agro-industries in which large quantities of waste are generated on a daily or seasonal basis. Dry solid wastes are relatively easy to store but even these can deteriorate during storage or can furnish a health hazard. Liquid waste demands a tanking or ponding system together with pumping system which can be costly to construct.

Having identified the waste and collected it to a suitable point for processing is only part of the difficulty. The residues may occur in very large quantities which would certainly affect the domestic market for allied products and their utilization may result in products that can affect the international market. The question which has to be asked is: Is the end-product of the waste processing commodity in an alternative demand group, or is it a unique product? There are many end-products of agro-industrial waste processing which are comparatively unique. Searching for uniqueness is an important part of agro-industrial residue utilization.

Although there may be a large international trade, the commodity may be restricted to certain geographical localities and uses. A market survey is then important in assessing the ultimate viability of a large project.

Even if a market for the end-product does not exist, this does not mean necessarily that the waste should not be utilized. This situation pre-requisite is to generate tests for the necessary market before seeking capital for the venture.

5. Other aspects

Finally, there are a series of hurdles which the successful operator of a new venture must overcome before that venture becomes viable. In overcoming these obstacles, governmental organizations can prove very useful. This group of factors has been called the social, political and legal aspects of waste utilization. (Table 5)

TABLE 5

Social, Political and Legal Aspects of Utilization

Ethically) acceptable waste for handling
) not acceptable

Capital available

Skills and/or a tradition of techniques available

Surplus (under-employed) labour available

Resistance to reform/change

If a waste material has an ethical restriction on its use either by the local processing of the material or by the country destined as the market for that material, the processing will not take place.

Large scale waste disposal may demand large capital inputs and this in turn requires international confidence in the stability of a particular country since amortization may be required over a number of years in order to make the project viable.

It is not sufficient to satisfy only the earlier criterion. It is necessary to provide a cadre of skilled manpower from both external sources and local recruitment to operate a specific process. This difficulty can be overcome with time.

In a developing country an alternative approach is to recognize that there is always a pool of underemployed or unemployed labour and that the transplantation of a technology direct from a developed country might be quite inappropriate. It may be more appropriate to reorientate unit processes in order to make best economic use of this pool of under-utilized manpower.

II. THE SURVEY

1. Introduction

This report is a survey of the occurrence and utilization of agro-industrial wastes in Africa. The survey considers the significance of these wastes in the territories visited, the problems presented by their production and opportunities for obtaining a useful product arising from their existence. As far as possible a standard pattern has been adopted in reporting so that a comparison can be made between the commodities occurring in different agrarian situations.

It must be noted that the philosophy covered by this report has fundamental restrictions imposed on the way in which it can be transformed into technologies. These are firstly, that the population in the different situations surveyed determines, both from its density and qualitative characteristics, the opportunities which may be presented for product utilization and the form in which techniques may be applied. Secondly, it is accepted that agricultural patterns are an integral feature of the culture of specific populations, but that these patterns may not necessarily make the best use, from a biological point of view, of the land available in terms of advancing the material welfare of the people living on that land. Both constraints are not completely immutable and it is to be hoped that, by highlighting them, notice of their significance will be brought to the attention of national economic planners. Technologists cannot perform economic miracles by embarking on modes of development which ignore these constraints.

2. Human and other Biological and Social Characteristics common to the Territories covered by the Survey

To assist in understanding the factors affecting agricultural waste management in the survey areas, the individual country reviews are preceeded by an overall review of the Region, circum-saharah Africa, indicating the similarities and differences which occur between the different territories. With the exception of Tanzania, all the territories covered by the survey have a boundary on the Sahara, or have sub-saharan conditions. Parts of Tanzania are climatically sub-saharian. Planning the survey and its subsequent execution have been based on this common agro-ecological zonation. The basic characteristics of each of the territories visited, in terms of population and land area, according to the latest statistics available, are listed in Table 6.

TABLE 6

Land and Population

	Africa	Algeria	Egypt	Ghana	Kenya	Nigeria	Sudan	Tanzania
Land (Million ha)								
Surface area	3 031 181	238 174	100 145	24 854	58 264	92 377	250 581	94 509
Land area	-	-	-	23 002	56 925	-	237 600	-
Arable	211 287	6 240	3 720	1 993	1 454	22 795	7 092	15 192
Permanent Crops	211 287	552	132	1 581	216	22 795	42	1 059
Permanent Meadows and Pastures	792 203	37 416	-	11 237	3 944	20 720	24 000	40 202
Forests and Woodland	634 251	2 424	2	2 447	1 935	31 069	91 500	31 074
Other Land	1 393 440	191 542	97 291	7 596	50 715	18 793	127 947	6 982
Irrigated land	-	270	2 852	12	14	15	1 407	40
Population								
Population (1973) million	384.1	16.1	38.0	10.3	12.4	61.2	17.9	14.7
Annual increase (1970-73)	2.8	3.2	2.2	2.7	3.6	2.7	2.5	2.7
Population density/km^2 (1973)	-	7	36	39	21	65	7	15
Per capita Income (1970-71) $	210	295	210	239	141	167	125	97

Source: FAO 1975. (1) Production Yearbook 1974, Vol. 28-1, Rome; (2) Statistical Yrbk.'74.

The average population density varies from the relatively high figure for Nigeria to an extremely low population density for the Republic of the Sudan. With the exception of Ghana, the distribution of population is extremely uneven and, in practically all the territories surveyed, there are areas of overpopulation. The limits of growth appear to have been reached in at least two territories if the present agricultural pattern is continued.

From the point of view of the crops encountered, there is a clear division between those bordering the Mediterranean (Algeria and Egypt) and the other territories 'south of the Sahara.'

The two Mediterranean countries are culturally part of the Mediterranean Arab World, whereas the other countries visited may be classified collectively as 'Africa south of the Sahara'. Agro-ecologically the Sudan is part of the latter group, though culturally partly 'Arab World'.

With the exception of Egypt and to a less extent Algeria, the industries may be described as almost entirely agricultural, the agrarian situation being peasant farming or collective-farm agricultural economies. The latter system is a comparatively recent development, but has implications for the management of crop processing. Several of the territories are in the process of radical agrarian reform but all, with the exception of Nigeria, are extremely short of capital with which to undertake any form of industrial revolution. This statement even applies to Egypt, which has a much longer industrial history than that of the other territories.

Although there are areas of high population density, only in Egypt and Nigeria is their development of the true conurbation with all the inherent dangers that this incurs, though Algeria has towns which are very restricted in their ability to spread. The population influx and extent of juvenile unemployment are reaching dangerous proportions.

The danger of excess population is not confined to the human population, but may also be applied to that of the livestock. In several of the territories overpopulation of livestock is a serious problem, growth of which requires restraining with equal expedition to that of the human population. Some of the governments are adopting such devices as 'cattle banks' and the purchase of excess stock at the beginning of the dry season.

3. Commodities

Agricultural statistics are notoriously difficult to collect and in some of the territories visited, the estimates-of-production figures are only a guide. The only relatively accurate sector in the statistics is that for the import and export of materials associated with agriculture. The population of these territories is not known to within a greater accuracy than ± 5% and food production for particular commodities may depart as much as 25% from the estimate.

The commodities (crops) encountered and the territories in which they occur are listed in Table 7. It was found desirable when asking questions about waste utilization, to proceed systematically in the discussion through the list of possible crops. This procedure frequently resulted in the eliciting, from the local counterpart, of information which would otherwise have gone unrecorded.

Table 7 is headed 'commodities', since it is with the latter, rather than the crops themselves, that one is concerned in considering a residue utilization. This was particularly apparent for countries such as Egypt, where a major source of utilisable residues arose from materials originally imported. Further, sources of biomass, other than crops, may give rise to commodities which have a potential for processing into useful products.

TABLE 7

Production of Commodities

Animals	Africa	Algeria	Egypt	Ghana	Kenya	Nigeria	Sudan	Tanzania
Livestock 000 head								
Horses	3 579	150	32	4	2	248	20	-
Mules	2 179	210	4	-	-	-	1	-
Asses	10 877	315	1 480	25	-	710	664	161
Cattle	148 130	950	2 160	1 100	7 400	10 918	14 000	12 098
Buffaloes	2 150	-	2 150	-	-	-	-	-
Camels	9 410	190	110	-	330	18	2 620	-
Pigs	7 182	4	16	340	78	865	7	23
Sheep	148 769	8 100	2 080	1 600	3 200	7 545	11 900	2 850
Goats	116 838	2 400	1 278	1 600	3 600	22 390	8 600	4 500
Livestock Products 000 ton 1/								
Beef and veal	2 278	30	126	21	114	187	187	115
Mutton and lamb	629	41	29	5	9	22	77	11
Goatmeat	348	9	17	5	10	63	6	17
Pork and pigmeat	289	-	2	6	5	29	-	-
Horsemeat	4 714	117	389	81	171	434	312	165
Edible Offals	734	111	63	6	35	76	54	23
Cow milk (fresh)	10 119	342	620	9	721	284	1 320	620
Goat milk	1 336	118	8	14	40	-	471	44
Sheep milk	640	116	19	-	13	-	149	-
Wool greasy	191	14	3	-	2	-	14	-
Wool scoured	89	6	2	-	1	-	6	-
Cattle hides (fresh)	358	5	13	2	2	34	18	23
Buffalo hides (fresh)	12	-	12	-	-	-	-	-
Sheepskins (fresh)	115	5	4	1	2	5	11	2
Goatskins (fresh)	74	2	3	1	3	18	1	3
Raw silk and waste	25	-	10	-	-	-	-	-
Poultry and Products								
Chicken 000 head	436 319	15 600	25 800	10 000	14 600	81 000	20 960	19 800
Hen eggs 000 ton	659	12	67	7	18	102	18	16
Other poultry 000 head (ducks and turkeys)	10 184	49	3 869	-	-	-	-	2 293
Poultry meat 000 ton	569	30	84	8	21	53	11	14
Honey ton	26 736	1 400	7 000	-	-	-	-	-
Fish 2/	4 800	31	80	196	29	-	-	168
Plants 000 ton								
Cereals	67 921	1 346	7 908	877	2 118	7 806	2 527	1 031
Wheat	8 534	850	1 984	-	100	6	235	91
Rice	7 595	5	2 400	107	33	356	7	160
Barley	4 770	450	99	-	21	-	-	1
Maize	26 766	5	2 550	480	1 600	1 100	20	550
Oats	206	33	-	-	4	-	-	-
Millet	9 051	-	875	120	360	2 800	470	100
Sorghum	9 290	3	-	170	-	3 500	1 795	130
Roots and tubers	79 920	310	870	4 700	1 395	27 017	1 748	3 902
Potatoes	3 299	310	750	-	215	27	25	95

1/ Animals slaughtered within country, irrespective of origin

2/ 1973

TABLE 7 (cont'd)

	Africa	Algeria	Egypt	Ghana	Kenya	Nigeria	Sudan	Tanzania
Plants (cont'd)								
Sweet Potatoes	6 192	-	75	-	540	210	495	300
Manioc	47 541	-	-	2 900	640	10 000	1 100	3 500
Taro	3 397	-	45	1 200	-	1 780	-	-
Yams	18 643	-	-	600	-	15 000	128	7
Pulses	4 832	48	342	10	310	880	71	185
Beans	1 153	2	15	-	-	-	3	130
Broad beans	685	19	234	-	-	-	17	-
Cow peas	995	-	6	-	830	-	-	10
Chick peas	341	14	5	-	-	-	2	25
Other pulses	1 660	13	82	10	310	50	49	20
Soya beans	85	-	-	-	-	65	-	2
Groundnuts in shell	5 540	-	30	125	3	600	991	35
Castor beans	68	-	-	-	2	-	19	15
Sunflower seed	323	2	-	-	3	-	-	12
Sesame seed	553	-	23	-	3	65	271	11
Linseed	103	-	23	-	240	-	-	-
Seed cotton	3 869	2	1 320	-	16	197	661	249
Cottonseed	2 495	2	840	-	11	130	432	159
Cotton Lint	1 345	1	480	-	5	65	229	83
Olives	1 021	152	8	-	-	-	-	-
Olive Oil	178	18	-	-	-	-	-	-
Coconut	1 533	-	-	280	81	90	-	300
Copra	153	-	-	8	5	9	-	28
Palm kernel	750	-	-	40	-	300	-	3
Palm oil	1 144	-	-	65	-	450	-	2
Tomatoes	3 340	132	1 630	115	220	-	-	-
Pumpkins, squash, gourds	745	-	350	-	-	-	-	-
Egg plants	257	-	220	19	-	-	-	-
Green peas and beans	296	46	150	-	-	-	-	-
Water melons and melons	2 545	206	1 410	-	-	-	-	-
Grapes	2 711	1 000	167	-	-	-	-	-
Wine	897	177	380	-	-	-	100	-
Sugarcane	53 669	-	7 150	300	1 800	670	1 150	1 397
Sugarbeet	2 240	230	-	-	-	-	-	-
Raw centrifugal sugar	5 826	26	605	9	133	38	118	124
Orange	2 921	385	725	90	-	-	1	-
Tangerines	421	132	96	-	-	-	-	-
Lemons and limes	197	16	80	30	-	-	-	-
Grapefruit pomelos	172	5	-	-	-	-	-	-
Other citrus	385	-	-	-	-	-	52	30
Apples, pears, peaches, pulms, apricots	807	61	55	-	-	-	-	-
Sisal	375	-	-	-	80	-	-	157
Tobacco leaves	240	6	-	2	-	12	-	15
Rubber	250	-	-	2	-	80	-	-
Bananas	4 206	-	100	27	-	-	10	720
Tea	152	-	-	-	53	-	-	12
Coffee	1 390	-	-	4	70	4	-	55
Tobacco	240	1	-	2	-	11	-	15
Cocoa beans	1 027	-	-	386	-	230	-	1

TABLE 7 (cont'd)

	Africa	Algeria	Egypt	Ghana	Kenya	Nigeria	Sudan	Tanzania
Plants (cont'd)								
Figs	163	58	12	-	-	-	-	-
Mangoes	460	-	80	4	-	-	-	150
Pineapples	670	-	-	30	45	-	-	37
Almonds	35	5	-	-	-	-	-	-
Cashewnuts	375	-	-	-	16	-	-	150
Roundwood Coniferous	12	-	-	-	0.9	-	-	0.2
(million m^3) Broadleaved	297	-	-	10.1	10.6	59.8	21.1	32.5

Source: FAO, United Nations, 1975
(1) Production Yearbook 1974, Vol. 28-1, Rome: 328 pp.
(2) Statistical Yearbook 1974, Rome: pp.144

In Tanzania in particular there appears to be an unutilized element in the game culling in the overstocked, but underpopulated areas of the country. Many products of the trees of the dryland forest are 'gathered' rather than grown. These dryland forests, miombo woodlands, sahel and guinea savannas in particular generate a number of secondary products.

From the wetlands and waterways there are weed monocultures currently dominant and a nuisance in blocking the waterways to traffic and fishing. Such plants, as members of the Cyperaceae and the water hyacinths (Eichornia crassipes) may form the only unutilized plant mass in a particular area.

The total biomass is, in most of the African territories surveyed, in short supply. The action of grazing cattle on lowland areas and then kraaling that cattle on upland areas is one of the time-honoured method of transferring biomass back to the point where it is required. It was necessary to be continuously on the lookout for classical biomass conservation and product utilization methods which are so inherent in the agricultural system as to pass unnoticed.

4. Economics of Utilization

A number of factors contribute to the value of potential secondary products resulting from residue utilization. Of primary importance is the ratio of land area to biomass available. The same commodity may have a different value in different territories, due to differences in the cost of collection and transport to an appropriate processing point.

Establishment that there is a 'market' for the processed products from the wastes is of paramount importance and unless this exists, the residue will not be utilized. However, other logistic and technical factors may enter into consideration in utilization, one of the most important being the interaction of the scale of activity with the type of technology required to process the product. Another is the quality of the product, in terms of contamination of various types, and therefore the burden of processing the product to an improved commodity. These restrictions apply to both solid and liquid secondary products.

In general, those products yielding high value byproducts, or having a potential of processing into special products or human protein food, have the highest value. The solid and slurry ligno-cellulose fractions, with a high degree of mineral contamination, and the mixed dilute effluents have the lowest value.

5. Demarkation of Agro-ecological Zones

Agro-ecological zonation of the territories visited is hampered by differences in approach adopted by the territories and the state of the art of classification in the different territories, though a uniform system has been adopted by Papadakis (1966) for the West African territories. For the purpose of this survey it is convenient to divide the territories into Africa, south of the Sahara, including the Sudan, and 'Africa north of the Sahara' respectively.

In comparing the opportunities for applying the principles of crop ecology, there is a great distinction between the discrete situation which occurs in the Mediterranean countries visited and in the northern Sudan and the more flexible situation occuring in the savanna woodlands and forest lands of East, Central and West Africa.

For the latter territories current research on cereals and legumes, particularly that applied to the introduction of novel species and types and destined to extend the cultivated land by making better use of the low rainfall areas, such as that being conducted by the International Institute of Tropical Agriculture, is likely to have a profound effect on future agricultural productivity and hence the primary and secondary commodities available.

Two major trends were specifically noted. First, it appears that the expansion of maize cultivation at the expense of sorghum and other millets has reached its limits and that it is likely that the reverse trend will develop in future years.

Second, for the grain legumes, which are an integral part of the cereal cropping systems, the introduction of new varieties and new husbandry systems, which will furnish a reliable high yield, will help meet the increasing demand for vegetable proteins. These grain legumes systems are likely to diversify from the standard groundnut and cowpea systems, which have dominated the agriculture of Savanna Africa in the first part of this century. At one time, it was thought that the soya bean itself offered the best means of providing improved legume protein supplies and there is still much scope for the expansion of soya bean cultivation in Africa, together with its incorporation in acceptable African foods. However, recent research has shown that there are other legumes, such as Psophocarpus and Dolichos, which can also fulfill this role and these may have a higher reliability under African climatic conditions. While the above speculations are part of a longer term view, nevertheless they are important in considering the types of commodity and commodity residues which will be available and the techniques for the utilization of which are already being elucidated in other parts of the world. Typical examples are legume milks, enriched bread and biscuits and the 'tempe' and 'oncom' fermentations. The application of these new developments is dependent on agro-ecological information, much of which has yet to be gathered.

6. Country Reports

The country reports are set out in the order of countries visited.

6.1 Egypt

Egypt is characterized by having its population concentrated on a fixed area of irrigated flood plain. The agricultural population is engaged in practising a system of agriculture which has largely remained unchanged for five thousand years. Similarly, this agricultural system has supported a population similar in numbers over thousands of years and it has only experienced an explosion in the last few decades. This population explosion is of extreme concern to the authorities and action is being taken to stem it.

Agricultural research is being devoted to extending and improving the irrigated area and to production of new irrigated lands from desert areas, especially near the coast. There is evidence that, under the present shifting sand dunes of the coastal area, there existed formerly irrigated land on which the desert has now encroached.

A comprehensive study of the desert ecosystems of northern Egypt is being conducted to improve their utilization. The Nile is still the lifeline of the Egyptian agricultural system and, in spite of industrial development, it remains remarkably unpolluted.

In contrast to the research to develop more land, urban and industrial development are consuming the agricultural silt-land in the area around Cairo and Alexandria.

In recent years Egypt has become a net staple food importing country, particularly wheat, although it was classically regarded as the granary of the Mediterranean. In reviewing the imports of commodities, it was found that tobacco was also an entirely imported product. This latter phenomenon is, however, an administrative decision as it enables the authorities to keep control over the revenue derived from tobacco products, though it deprives farmers of a very high value crop for which the land is eminently suitable.

Approximately one-third of the total land area is devoted to fodder crops to feed the livestock, much of which is used for draught and transport purposes. The reduction of this draught animal population would result in the releasing of land for the production of vegetables and vegetable protein crops, such as grain legumes rather than fodder legumes.

Thus, in contrast to the situation found in the other territories visited, in Egypt the available wastes (and those which were causing problems) were limited to a small number of products derived from the agricultural industries. All cellulosic materials were in short supply, as they are used both for fuel and fodder. Specialised agro-industrial wastes such as date stones and mango stones were encountered. Another source of specialized highly seasonal waste is that of the food canning industry. The problem with food canning residues is that each commodity occurs over a very short season and the total amounts are small when considering utilization of these byproducts.

6.1.1 Sugarcane Processing

Sugar in Egypt is mainly derived from cane and all the byproducts currently are being processed, or utilized as cellulosic wastes with the exception of vinasse (stillage). Research is being done on this byproduct. Sugar production is the monopoly of one company, the Société des Sucŕéries which currently has sixteen factories in production and a further one in the stage of commissioning.

Of particular relevance to waste processing is that a major byproduct, since 1965, is fodder yeast. This product is Saccharomyces ceremiseae and is of human food grade. It has been tested for food grade quality by a number of European countries, but is not yet used directly as a human food in Egypt. Molasses is used as a feed stock for the fermentation industry which produces alcohol, vinegar, carbon dioxide, glacial acetic acid, food yeast, sugar derivatives (EGYFOAM for fire extinguishers) and secondary products derived by the further processing of the primary products. The vinasse is the only unutilized component, together with a series of factory effluents from the secondary processing of the fermentation byproducts. At present these are discharged without treatment, or further processing. The concentration in terms of BOD of the vinasse is 30 000 - 40 000 mg/l.

Apparently the sugar company has a United Nations grant for study of the production of Torula yeast from the vinasse. The project is still in the research stage. Molasses is also supplied to the antibiotics industry, but the byproducts (e.g mycelial waste) of this industry are not, as far as the author was informed, used in any way.

An interesting feature of Egyptian molasses is that it is relatively high in potassium. The residues of fermentation could theoretically be used for the production of potassium salts, but no economical method was apparent.

The bagasse is used for the production of hard board, paper pulp and the wax is also extracted.

6.1.2 Tobacco-dust

From the imported tobacco leaf, tobacco is manufactured both from the blade and the midrib. The latter is softened, flattened and then shredded along with the leaf. The tobacco dust, which is a processing residue, is not utilized, although there is a full-scale process available internationally for reconversion of this into a leaf-like material known as 'reconstituted homogenized tobacco powder.' This reconstituted product is produced by adding water to the milled residues and formation of a paste. The paste is then rolled into sheets and the sheets are subsequently shredded. At the present time this process is not being applied because of lack of capital and the government is not giving high priority to the application of capital for this purpose. The capital required would be of the order of two million US dollars. At present the tobacco dust is therefore used as a fertilizer and a cheap insecticide. The monopoly of tobacco production is held by the Southern Tobacco Company.

6.1.3 Starch Wastes

A potentially useful waste, produced in relatively small quantities, is that from starch products by the Egyptian Starch Products and Yeast Company in Alexandria. This factory produces 36 tons of rice starch per day, which is preferred for many industrial processes such as textile sizing. It appears that 6 tons per day of starch is lost in the processing and is discharged in the effluent water. The company has been doing research on this effluent with the National Research Centre in Cairo. It might be possible to improve the extraction efficiency by altering the machinery or adjusting the flow-sheet of the process and, in view of the value of the end product, this would add to the profitability of the factory. Small quantities of fibre are produced and these are used for animal feed.

6.1.4 Canning Industries

The major producer of these products is the Nassra Canned Food Company, which has a total of 7 factories spread out between Cairo and Alexandria.

Apparently, an Italian Company is interested in producing oil from mango seeds, but the investigation is still in the research stage. At present, date and mango seeds are burnt.

Some of the orange peel is used in marmalade manufacture. Machinery was being installed for the extraction of the peel oil, which is used in fruit juice manufacture. Extraction of pectin from the pulp was not done and none of the liquid waste from the manufacture was used.

An unusual waste is that of guava seeds, which make a valuable cattle feed after being milled.

The only other waste produced in relatively large quantities is that of tomato, which is produced at the rate of 800 tons per year. Production occurs over five months of the year, but at present no treatment is given to this waste.

6.1.5 Animal Product Wastes

These appear to be fully utilized in Egypt, with the exception of whey from the production of Egyptian type cheese. This whey cannot be treated by the normal whey processes because it contains 14% salt. The high salt content is a pre-requisite for the fermentation of the bacilli and the early stage of the fermentation, and it is not possible to add the salt after the separation of the curd. At present, there is no satisfactory method for the processing of this waste. Desalting and protein recovery from the whey is possible but it may not be profitable. Salt tolerant yeast might be applied (such as Saccharomyces rouxii) to fermentation of the whey, though this would require further research work and a determination that the yeast could be marketed profitably.

6.1.6 Research Relevant to Agricultural Production

From limited visits to institutions, there was the impression that there is a long established tradition of research in Egypt. Many of the senior people have taken part in international agency exercises and acted as consultants for the UN agencies. They have also served for long periods in universities abroad. There is a large reserve of manpower available to conduct the research and there is a general awareness of the problems and how to deal with them. However, the capital resources to conduct research and apply it are scarce. As in most countries, there is a communication gap between one institution and another. There are many collaborative research projects with outside agencies; this helps augment institutional funds and there is, in this manpower resource, a potential for the export of technical expertise.

6.1.7 Conclusions

Egypt is running into a severe problem of overpopulation with respect to production. It also has long established and deep-rooted traditions in agriculture, government and higher education institutions. There is an interest amongst research workers and government to collaborate in projects associated with biomass conversion and agricultural waste product recovery. It is recommended that this potential of expertise be exploited.

6.2 The Sudan

If any one country can claim a broad representation of much of the conditions in the countries of Africa it is the Sudan. Estimates of the population vary from 14 to 17 million and agricultural statistics for production are only available for the crops for export.

This vast territory, one of the largest in Africa, consists of half pure desert and half a composite of savanna woodland, eastern and western pockets of mountain vegetation, a small coastal area bordering on the Red Sea and a rain forest derived area in the south.

It possesses a large area which is seasonally flooded in the centre, a strongly developed perennial river system, as well as seasonal rivers (wadis) especially in the western part of the country.

However, it possesses no large fresh water lake areas, unlike the countries further to the south.

The population is scattered through the country. It is more concentrated in towns in the north and scattered throughout the countryside in the south. The people are culturally varied.

The systems of agriculture range from true nomadism through shifting cultivation to highly intensive irrigated-agriculture systems. There is a surplus of low-grade cellulosic residues, particularly in the south, though there is a seasonal shortage of fodder in the upland grazing belt in the middle of the country.

The southern half of the country has a potential for both upland and irrigated agricultural development. This is already being exploited with the aid of internationally supported teams of agricultural specialists.

The agricultural pattern for animal husbandry is determined by the broad tsetse belt, which runs across the centre of the country. It is to the north of this belt that the main cattle growing area lies and the area supports a population of 4.5 million with a cattle population of 6 million.

6.2.1 Waste Problems and Opportunities

At present, due to the highly dispersed and relatively small population in relation to the land area, there are few problems due to the presence of quantities of wastes, the one exception being the night soil. The 'Gobar' process might be applied to this material. The main southern towns where the night soil was a problem were Juba and Wau (each of 20 000 people) and Rumbel and Tong (each of 5 000 people). The night soil is disposed of by trenching outside the towns. However, this is a labour consuming method and makes no use of the fertilizer value of the night soil.

The direct discharge of night soil into ponds, as is done in Southeast Asia, is likely to cause a health hazard as water is extremely scarce and the pathogens arising from this action would undoubtedly be spread by the process. Moreover, any open fresh water areas are an immediate attraction for the vast herds of cattle which are allowed to wander freely during the dry season and all fences would be trampled and the fresh water areas polluted.

There might be a possibility of generating salt water oxidation ponds to take the effluent from the gobar plants (where it was not suitable for irrigation water) and culture algae and fish under salt water conditions. If necessary, plant and animal species are available in the salt lake areas of the lands to the west and south such as Lake Chad and the salt lakes of Kenya. The salt water would inhibit the pathogen problem and would also make the waters unattractive to cattle.

In the new irrigation schemes in the neighbourhood of Wau, sugar cane, cotton and rice, are being cultivated. These are beginning to produce seasonal surpluses which have a potential for processing.

The processing of sugarcane products is well documented. Similarly, rice hulls have been the subject of much experimentation and the scheme at Aweil, which is 6 000 acres in extent, generates about 1 000 tons of wastes per annum.

6.2.2 Wastes from Cotton Growing

Not much waste is derived from the harvested cotton. The seed is either exported whole, or the expressed seed is used as cattle cake. However, due to the need for an overall control of the bacterial disease caused by Xanthomonas malvacearum, the black-arm disease, all plants are destroyed at the end of the growing seasons. This costs the Gezira Board, the body which controls cotton growing in the main irrigated cotton growing area, over a million Sudanese pounds per annum in disposal measures. There are about two million tons of this material, as there is one ton of oven dried residue of cotton stalks produced by each feddan of cotton plantation. 1/

It might, within the framework of the sanitary measures needed for the control of black-arm, be possible to consider the ensilage of the whole haulms (after chopping) at the end of the season for the cotton crop. This ensilage would take place when the cotton is largely green. It would use some of the surplus molasses. This is an alternative to the present practice of allowing the cattle to graze off the tender parts of the cotton plant and then expensively lift and burn all the rest. This procedure would overcome the problem of the acute shortage of any form of fodder towards the end of the dry season, since in the Gezira area there are no trees at all and, even further south where more cotton is grown, the tree population is very small.

6.2.3 Sugarcane

There are 0.5 million acres of land under sugarcane. Of this production the sugar itself is fully utilized, the bagasse is being used for fuel but [illegible] of the molasses is wasted.

1/ 2.2 feddans approx. 1 hectare

6.2.4 Wastes from Sorghum

Another cellulosic waste which is that from the sorghum production in the middle belt and the south. This is produced under dry land farming conditions. The fields of sorghum are 20 miles or more away from the village. At present these sorghum residues are left in the field for cattle, or are burned. They are potentially available for processing.

6.2.5 Forestry Waste

Although these do not present a problem at the present time, better use could be made of the small-section timber, since only the trunk and tree seeds and pods are used. The main source of these materials is from the leguminous trees, but other families of tree are also involved.

6.2.6 Future Developments: New Crops and Cropping Patterns

There are great possibilities for developing the productive capacity through farming of the upland areas and extending the irrigated area. A few crops are being started such as castor bean, near Port Sudan, and sunflower. A curious feature of the latter crop is that the Tokero people complain that the act of processing the sunflower seed gives them asthma. No reference to this condition has been encountered before.

There is also a move to change from pure stands of cotton to cotton interplanted with legumes, in particular crops of the genus Dolichos. This diversification will not yield much of a direct waste as the pods and the haulm are a valuable cattle feed, but their use will supplement the very low protein of the dry grasses (2.5%), which limits production of the cattle at the present time. As far as the statistics indicate, there is only 1% take-off economies where the take-off could be 50%. Thus, improved production of grain and fodder legumes would improve the utilization of the cellulosic waste from the Gramineae.

6.2.7 Animal Product Waste

There are a variety of wastes generated in small quantities and a few in large quantities such as blood, manure and slaughter house washings, in the course of cattle slaughtering. At present, the industry is not sufficiently organized to make good use of these.

6.2.8 Conclusion

One of the greatest post-harvest wastes at present is in the form of losses from insects in stored grain. Other wastes are present in too small quantities or too unsuitable situations to bring into the economy at the present time. However, there is an enthusiasm for agricultural development generally and particularly as the new land schemes develop, there is likely to be a need for better utilization of these materials.

6.3 Kenya

Kenya possesses a wide diversity of products ranging from pyrethrum, tea and coffee of the extreme highland areas, to cereals and cattle on the plateau and coconut and tropical lowland crops down by the coast. As with the other territories visited, Kenya generates a variety of agricultural wastes in small quantities. Much of the cellulosic waste is used for fuel, which is scarce over most of Kenya, and in the remaining areas the residues are too scattered to be worth considering from the point of view of processing.

A recent trend in the marketing system of cattle has lead to the loss of byproducts in the cattle industry in that, due to price control at government slaughter houses, 50% of the cattle is slaughtered privately and the wastes from this slaughtering process are dispersed.

6.3.1 Coffee Waste

Coffee production generates utilizable solid and liquid wastes and studies have already been made on the processing of these materials. Apparently, a feasibility study was conducted by the Kenya Coffee Board for the production of charcoal briquettes from dried coffee pulp, but no further action was taken.

A feasibility study was produced for the coffee board for the production of a yeast from the pulp, but no further action has been taken on this study.

6.3.2 Sugar Production

Sugar production is a major industry and there appears to be some wastage of molasses and all the bagasse is burnt at the present time. There is no any action being taken to recover the wax. Further information may be available from the East African Industrial Research Organization on these projects.

6.3.3 Milk Production

As milk is 80% consumed as liquid milk there is little processing waste from this industry, although the industry itself is a major industry.

6.3.4 Sisal Wastes

The main industrial crop studied was sisal. This is an important crop in both the highland and lowland area but interest in it has sagged in recent years due to the low prices which have prevailed. This has culminated in the closing of the high level sisal research station. Nevertheless, there has been an FAO study on the utilization of the solid waste from sisal processing and the possibility of applying the proposed method for processing sisal waste is being considered by the Kenya Sisal Board.

On the Kenya sisal estates the water supplies for processing sisal are adequate and there is no incentive to change the extraction process to one which is more economical of water and which would produce a more concentrated effluent. Such an effluent would be amenable to subsequent fractioning processing for protein separation and fermentation of the remaining liquor into a fodder yeast.

The quantity of material handled by a sisal estate is large in that any one hectare may yield up to 40 tons of fresh leaves per annum, of which the output is only about one ton of fibre. The whole of the solid residues is at present allowed to rot in heaps. In the past, some attempts have been made to feed this material to cattle.

6.3.5 Research

Pertinent research at the University of Nairobi, Faculty of Agriculture, Department of Food Science, included the production of fodder yeast from molasses and pineapple residues; the production of passion fruit seed oil; the production of pectin from passion fruits and citrus peel; and the nutritional value of local leaf extracts. Such activities can make a very useful contribution to the natural product processing economies of the east African common market area and act as a base for short term training courses.

6.4 Tanzania

Tanzania is the largest territory in the East African community with a total area of 960 000 sq. kilometers, which includes the 1 660 square kilometers of the islands of Zanzibar and Pemba. There are also 50 000 sq kilometers of inland lakes. The population is approximately 30 million people mainly of African origin with small Asian, Arab and European communities concentrated in Dar-es-Salaam and Zanzibar.

From an agro-ecological viewpoint the limiting factor is rainfall and, although there are no truly desert regions, large areas of the territory have very low and variable rainfalls which, in the absence of cultivation, develop a sparse deciduous woodland. The most productive areas of the country are around the margins, the north-east-coast area, the slopes of the mountain Mount Kilimanjaro and alongside Lakes Victoria and Nyasa.

Cattle production in the central area is restricted by the presence of the tsetse fly. The major cash crops are sisal, cashew nuts, cloves, cotton, coffee, groundnuts, tea, cane-sugar and tobacco. Maize and sorghum are the main cereal staples, and in some of the more humid areas cassava provides an important element in the diet. Grain legumes such as the cowpea are grown throughout the territory. In appropriate areas coconuts, fruits and vegetables are grown. Meat production from cattle is small, although priority is being given by the government to the development of the industry. In addition to sea fisheries there is extensive fresh water fish production, especially around Lake Victoria. At the present time, the country is undergoing extensive agrarian reform, with a view to developing cooperative groups of villages for joint enterprises.

6.4.1 Agricultural Wastes

At present, there is no extensive utilization of agricultural wastes. Most of the cellulosic waste is either burned or consumed locally by livestock. A major problem in Tanzania is lack of transport although maize is sent from the northern territories to Dar-es-Salaam for milling. Thus, the byproducts of milling are not made available to the areas of their origin, since these byproducts are not returned to the villages with the flour.

There is a major animal feed and dairy development project under the auspices of the United Nations, which includes 70 large demonstration sites and 50 villages schemes. The team has conducted a survey on crop wastes of potential value for livestock feed, but the report of this survey has not yet been released. At present there is little development of improved pastures and pasture research has a low priority in the governments research scheme. There isalso no local seed production industry to support the development of improved pasture.

Earlier work has shown that a number of pasture legumes,such as 'stylo', 'siratro' and Glycine javanica are possible crops, but this research has not yet been applied. The lack of a local seed industry could be overcome to some extent by importation of seed of North Australian legume species, as these have been shown to be suitable for culture in Tanzania. The improvement of this aspect of agriculture would enable better utilization to be made of the cellulosic residues in stock feed. None of the agricultural or agro-industrial waste generated in Tanzania apparently causes any health problem at present.

The residues which appear to offer the earliest opportunity for utilization are those of coffee, molasses and cereal processing. The residue from sisal processing requires further research on the fibre extraction to produce a liquid fraction which can be subjected economically to further processing before it can be regarded as animal feed. A small amount is used to extract the hormone precursor hecogenin.

6.4.2 Molasses

At present there are 25,000 tons of molasses produced each year which are wasted due to lack of transport. The main centre of production is Arusha, though other mills also produce molasses. At Arusha only 800 tons of molasses are used at present on the pilot stage of an FAO project, but they have a molasses urea minerals plant planned which will consume larger quantities of molasses. This, together with urea, will assist in the better utilization of many crop residues.

The urea for the treating of molasses is imported, although there is a factory situated near Tanga which converts urea and other fertilizer raw materials into compound fertilizers.

A curious feature encountered in assessing the possibility of utilizing molasses is that the Tanzania Sugar Company sells its molasses at 176 shillings per ton ex-works, whereas the Kenya Sugar Corporation sells its molasses for manufacturing purposes at 50 shillings per ton. The Shell Company is already operating a MUM (molasses-urea minerals) plant in Kenya. This produces 6,000 tons of products per year. It was started in 1973 with 4,000 tons and there has been a gradual increase in production ever since.

6.4.3 Copra

At the present time, 90% of the copra and cotton seed cake produced is exported and therefore there is very little available locally. The copra cake locally available amounts to 1,700-1,800 tons. Coconut production is declining and there is a high market value of the fresh coconuts.

6.4.4 Coffee Processing Waste

Coffee processing waste is one of the major potential wastes. Some 9,000 tons of this are rejected yearly. The National Milling Corporation has looked into the possibility of using the dried pulp for feeding, but this programme is still in the research phase.

6.4.5 Caustic Soda Treated Bagasse

To improve the utilization of the cellulose fraction of sugarcane, caustic soda treatment has been considered, but no action has been taken to apply this well-known process so far.

6.4.6 Brewery Wastes

Brewery wastes and the wastes from extraction of pyrethrum occur, the former in substantial quantities, but the latter is only a few tons. Neither of these wastes are used at the present.

6.4.7 Cotton Seed Cake

Cotton seed cake is used for feeding at Lake Victoria area, but it is reported to be expensive.

6.4.8 Game

Amongst the animal waste encountered, which have possibilities for processing, is that derived from the culling of game in the western Tanzania. Apparently, 6,000 tons of elephant meat is wasted per annum because of the difficulties of extracting the fresh meat from the point where the animals are killed. A chemical preservation or salt and starch fermentation process for the meat might be used to preserve it as a basis for animal feed, since it is a high-grade protein. This has a chance of being a profitable venture. It is recommended that investigation is given to preserving this meat and other similar animal products.

6.4.9 Conclusion

While experts are aware of the possibilities of waste utilization, their main aim at present is to increase production and, although much of the information needed to achieve this is available at the experimental level, transfer to full-scale projects and the farmer is required.

6.5 Nigeria

Nigeria has the largest population of all the territories visited on the survey. It is also the territory in the most rapid state of transition, having benefitted from the influx of money derived from oil revenues. Within its boundaries is the International Institution of Tropical Agriculture.

One of the residue management problems of Nigeria at the present time is reducing post-harvest losses of agricultural products, particularly in the North, rather than abating any pollution which might arise from the discarding of agro-industrial and agricultural byproducts.

In northern Nigeria, there is an overall shortage of cellulosic byproducts suitable for animal feed in the dry season. This problem has been enhanced during recent years by the growth of the animal population, particularly due to the improved water supply in the stock raising areas of the far north. The situation has been aggravated by the recent series of droughts which have occurred in the Sahel zone of the West African territories during the last few years.

Growth of the northern towns has resulted in wide-spread scavenging of the suburban areas for wastes for fuel, resulting in a broad deforested area around such towns as Kano.

6.5.1 Palm Oil Processing Wastes

The palm oil industry generates some 50,000 tons of palm Kernel oil shell waste and much of this could be used for processing of charcoal.

6.5.2 Sugarcane Byproducts

As a consequence of the development of a sugar industry from sugar cane grown on the banks of the Niger River above Jebba (Kanji dam), Nigeria now has an industry for processing byproducts of sugar. Molasses is used for fermentation at a factory at Jebba and produces a food yeast and alcohol. The bagasse is used for fuel, but there are plans for using it for pulp and paper.

6.5.3 Cocoa Pads

A major waste of the forest areas of West Africa, particularly Nigeria and Ghana is the pods from cocoa cultivation. It is possible to produce a pectin from these pods, but this process has not been commercially applied. The pods are accepted as food by cattle, but in order to ensure that they consume sufficient quantities it is essential to dry the pods first and then pelletize them. The Buhler Company of Switzerland has been experimenting with this process of pelletization, but ithas not yet been commercially applied.

6.5.4 Food Processing Wastes

Among the food manufacturing wastes are those of the breweries and is one of the most serious food production wastes.

One of the most interesting processes encountered was that of the development of a small scale still for improving the efficiency of distillation of the local palm wine. The whole apparatus can be built very cheaply and now the design is authorised by the government and is in commercial production. This 'intermediate technology' development seems to be one of the most promising new developments to come within the brief of the survey. The still is applicable to the production of alcohol from a variety of sugary wastes.

Fruit processing is not well advanced in Nigeria, though there are tomato factories at Zaria in the North and at Gombe in the Middle Belt.

The Federal Institute of Industrial Research has a programme for the study of liquid effluents from breweries and other food industries. One particular project is studying the production of SCP using *Geotrichum candidum* with cassava as the substrate. Using a small fermentor, the yield efficiency was 0.48 units of protein per unit of carbohydrate.

The waste from gari manufacture (fermented, gelatinized cassava product) is used by the villages directly for animal feed. It is debatable whether commercial gari is competitive with that produced in the villages.

The University of Lagos has been studying the production of ethanol from local carbohydrates and palm wine with emphasis on the conditions of fermentation and the additives required to give the end product a satisfactory organoleptic constitution. A waste product, cocoa shell powder, is used as a colouring matter for the distilled liquor.

In view of the relative adequacy of carbohydrates in Nigeria and the problem with storage of valuable proteinaceous products, particularly fish, it would appear that utilizing enzyme active starchy materials produced by germination or fermentation, to preserve fish by a lactic fermentation could be possible. There would appear to be potential market for this type of product in Nigeria, as the taste and texture is consonent with that of local diets.

6.6 Ghana

Ghana is a relatively coherent territory with a balance between forest and savanna. Research on agricultural waste utilization appears to be well coordinated by the government's Council of Scientific and Industrial Research (CSIR).

Agricultural Industries do not appear to be causing a serious pollution problem in any part of the territory, even though the country is extremely environment conscious.

No situation was encountered in which full scale utilization was made of agricultural secondary products, but interest was expressed in the following subject areas: night soil processing; saw-milling wastes; sugarcane wastes; avoidance of situations giving rise to the appearance of aflatoxin and other mould toxins; the conversion of woody material into pulp and paper; the production of algae and the use of water weeds; the use of palm oil shell and mangrove wood; the use of starch and starch wastes, starch food conversions using local material; the production of phenol: resins for glues from local materials; the production of pectin; the production of secondary products from sugar; the production of furfural.

Ghana is a net cereal importing country and it was reported that wheat bran would be a useful animal feed material if freely available. At present it was pelletized and re-exported in return for foreign exchange.

6.6.1 Cocoa Pods

Unique research was being conducted on the extraction and testing of cocoa pectins. The more valuable pectin is from the mucilaginous pulp encasing the beans. The pod also contains pectin which can be removed by steaming and then squeezing out the mucilage. The value of this pectin is as high as that from the mucilage surrounding the beans due to differences in molecular composition of the pectins from the two sources.

The husks are a cattle food, which is eaten with relish, although the digestibility is not very good. Intake of husks can be improved by sun or hot air drying down to 60% moisture and then chopping, grinding and pelletizing.

For plant hygiene on the cocoa plantations it is essential to dispose of the pods. The most economical way is to dry the pods to a condition whereby they can be burnt and then to use the ash, which is high in potash, as a fertilizer. Ghana cocoa production is a cottage industry and it is difficult to organise waste processing on a large scale.

6.6.2 Food Scarcity

In Ghana feed is becoming scarce and expensive for the non-farming community. The cost of basic food stuffs, particularly fish and other protein foods, has risen by a factor of three in the last two years. This scarcity is a major incentive to process all possible materials to supplement the present food supply.

6.6.3 Other Agro-Industrial Wastes

For the future, there is a programme for the rapid development of the oil palm acreage. This will result in byproducts for processing. The total acreage of new schemes under implementation at the present time is nearly 100,000 acres.

Due to the Volta dam project, inland fisheries are being developed. Increased supplies of fish will in turn generate increased quantities of fish byproducts.

6.6.4 Conclusion

The organized research and development, the technical competence and the awareness of the potential value of new processes augurs well for the introduction of new techniques toward better commodity utilization.

6.7 Algeria

Algeria is a territory in which there is little room for expansion of the cropped area. It is clearly demarcated into four agricultural zones. These are the coastal zone, the mountain plateau zone, the sub-Saharan zone and the Saharan zone. These are occupied by intensive agriculture and horticulture, extensive agriculture, limited dryland agriculture and grazing, and desert respectively. The large estates, situated on the richest land, have been divided into small individual holdings (10 ha), or cooperative farms. The highland area has remained largely unchanged. The dry hinterland has possibilities of improved cropping, especially in increasing the culture of low rainfall tolerant legumes. However, fodder is in short supply and there are no substantial cellulosic wastes available for secondary processing. The desert area contains oases in which date and cereal production occurs. Here also the quantities of waste are negligible.

The main source of agricultural residues is the coastal zone.

6.7.1 Residues Occurring in the Coastal Zone

Sugar beet tops are wasted and could be used by ensilage, using some of the molasses from the sugar extraction. This technique is not practised.

Vines undergo regular pruning throughout the growing season and the green residues from these are available for stock feed, or for ensilage. They do not appear to be used for this purpose at the present time.

Some of the straw from wheat and other cereals is being used for paper. The remainder is used directly for stock feed or is burned. However, stocking is limited in this area and the use limited for feeding.

There are no wood residues. All trimmings are used for fuel and wood is overall in short supply. Pinus halepensis and Cedrus species are being planted to replenish the supply of timber.

There are substantial residues from citrus production. There appear to be possibilities for utilization of citrus products for the production of pectin, peel oil, single cell protein and animal feeds.

A wide variety of grain legumes are grown in all three agricultural zones, but no large residues are produced. Miscellaneous residues which appear to exist are:
a) Marc, the solid residue left after expressing the juice out of the grapes for the manufacture of wine, b) Market garden residues, miscellaneous vegetable material, and c) residues from olive oil, sunflower oil and safflower oil production.

III. GENERAL CONCLUSION

From the survey it will be seen that, with certain agro-industrial exceptions such as starch and sugar production; the opportunities in Africa in the immediate future for making use of agricultural waste are comparatively limited. In the Sudan and south of the Sahara a diversity of wastes have been found which could be better utilized. For instance in the Sudan irrigated area, there are possibilities of processing the residues from crop and sugarcane production on both a large and a small scale, but the treatment of night soil and the recovery of methane fermentation products appears to be especially favourable for small scale enterprises.

Undoubtedly, as the irrigated areas under rice develop, this cultivation will give rise to opportunities for better utilization of the residues from rice production.

Tanzania is still coming to grips with the problems of the actual production of crops and the problem of pollution arising from agricultural waste is not serious. The two exceptions to the absence of utilizable wastes were: game cropping and sisal. It appears that modern techniques can be applied to non-refrigerated harvesting of game products by the setting up of temporary mobile processing units. This would provide a valuable contribution to the protein supply of the country. With the increased supply of fertilizers there will be a development of more intensive cereal production, particularly of sorghum, and this will give rise to cellulosic residues which may be utilised in ways other than the present one of burning.

In both Kenya and Tanzania, sisal is a crop with a future, if it is regarded as the basic crop of a plantation agricultural system employing intercropping in a period immediately after the cut. The sisal harvest itself should be regarded as a biomass rather than a source of fibre alone and it is recommended that further investigation is conducted into the method of extracting the fibre, principally by counter-current washing and filtration or centrifugation of the liquor, to give more concentrated fractionated liquors of greater utility for subsequent processing.

In West Africa the crops that provide opportunities for the utilization of secondary products are oil palm and cocoa. In Southeast Asia current research is extensive on the utilization of the non-oil fraction of the palm fruit and it will not be many years before it is desirable, both from economic and anti-pollution viewpoints, to apply the techniques in West Africa. Similarly, it has been shown in Southeast Asia that the rubber plantations can provide other products than the rubber latex concentrate, ranging from algal and other single cell protein products to the utilization of the rubber trees themselves.

Three products were identified in cocoa production, from the pods and from the mucilage surrounding the seeds. These are pectin, dried pelleted cocoa pod for animal feed and the ash of the cocoa pod as a fertilizer and a raw material for industrial chemical use such as soft soap.

It was noted that, throughout the territories surveyed but particularly those south of the Sahara, there was marginally a shortage of food in general, as distinct from a protein shortage. Radical changes in the agricultural pattern would need to be implemented in the near future to meet this need for food directly, by improved supply of primary products rather than by indirect supply of protein via animals. Grain legumes is the group of crops which can best provide an effective total utilization of the biomass grown.

A serious health hazards arise from human waste and protein residues. There is a potential health hazard arising from the agro-industrial effluents. In the Sudan the authorities are fully aware of the health hazards presented by the absence of sewage system in the towns and no doubt this is also a problem in the small communities. The solution appears to be via the treatment of the night soil to give a harmless material which provides both a liquid effluent and a solid fertilizer. Where fresh water is scarce, the possibility should be investigated of discharging the high B.O.D. effluent into salt water at appropriate oxidation pond loading rates and producing fish and other aquatic products. Alternatively, the liquid can be used for irrigation after anaerobic fermentation.

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Energy from Organic Residues

by B.A. Stout & T.L. Loudon

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ENERGY FROM ORGANIC RESIDUES

by

B. A. Stout and T. L. Loudon[1]

SUMMARY

Energy is an essential ingredient for human existence. Increasing energy prices and uncertain supplies have focussed attention on alternatives. More effective use of organic residues, a renewable source, is one alternative.

This paper reviews technologies available for conversion of organic residues to more useful solid, liquid or gaseous forms. The feasibility of various conversion technologies--both wet and dry processes--is examined.

Generally, wet material such as manure lends itself to methane generation by anaerobic fermentation. Is this process practical and economically feasible? Several studies indicate it probably is not presently a viable alternative in the U.S., but the search for improved processes and management techniques continues.

In less developed countries, the thousands of small-scale digestor units in operation indicate anaerobic fermentation is practical. Each application must be analyzed individually considering the supply of feedstock manure, cost of collection, the demand for methane and its relative value compared with other fuels, climatic conditions, and operator skills.

Several dry processes are available to convert organic residues directly to heat or other fuels (solid, liquid or gaseous). Municipal wastes can be used to generate steam, but this approach is less attractive for agricultural residues because of their limited or scattered supplies, the higher moisture level of some agricultural residues and competing uses for residues on the land or for animal feed.

Conversion to liquid or gaseous fuels by pyrolysis has been investigated but has not proved economically feasible.

Perhaps the most attractive dry conversion process is combustion in a limited air supply to generate producers gas (largely hydrogen and carbon monoxide). Producers gas may be burned directly or used as a fuel in an internal-combustion engine (with considerable reduction in power).

The cost of collecting agricultural residues is a formidable obstacle for all processes. The most practical use of organic residues results when they are concentrated from another use and thus become a "free" by-product.

Although growing crops specifically for fuels is widely discussed, no examples are known where the practice is cost effective.

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INTRODUCTION

Energy is the basic driving force in man's development. The history of civilization is to a large extent a story of man's progress in harnessing energy. Some major events that have occurred include: controlled use of fire; domestication of animals; use of sails; windmills and water mills; controlled mechanical energy from thermal energy; the ability to store and transport energy; and the development and use of electrical energy including nuclear generation. Efficient use of energy is the key to maximum productivity per person and resultant high standard of living.

The relation between energy consumption and level of development has been analyzed. Figure 1 illustrates a rough correlation between per capita energy consumption and gross national product. Cook (19) argues that high energy consumption is a prerequisite for high output of goods and services. But with limited petroleum supplies, how will world-wide energy needs be met (Fig. 2)? Recognizing that petroleum supplies are finite, what alternative fuel sources are feasible?

The purpose of this paper is to explore the use of organic residues as alternative fuel sources. Both wet and dry conversion processes are considered including anaerobic and alcoholic fermentation, combustion in excess air or in a controlled atmosphere, pyrolysis, hydrogasification and hydrogenation. An attempt is made to assess the feasibility of each process.

Agriculture's Energy Needs

Agriculture is essentially an energy conversion process -- the transformation of solar energy and fossil fuel products (fertilizer, diesel fuel, pesticides, etc.) to food and fiber for man. In the U.S. and other advanced countries, 12 to 16% of the nation's energy is consumed in the food system (production, processing, transport, marketing, final preparation). Agricultural production accounts for about 3% of the total (10, 38, 79).

Energy use in the developing countries is much greater than one might think. When food, fodder and wood are included, annual energy use per capita is 5 to 10 million kcal (51). If only commercial energy (oil, coal, hydropower, etc.) is considered, perhaps 1 to 4 million kcal/person/yr is consumed in the less developed countries (LDC). This compares with 13 to 50 million kcal/person in Europe and North America (Fig. 1). See Table 1 for a rough indication of energy use in five less developed areas of the world.

Economic accounting is more highly developed in most countries than energy accounting. If one considers the percentage of disposable income spent for food, the range is about 20% in the U.S. and as much as 80% in some LDC's (66). About one third of the fossil energy use in the LDC's is in the food system (250,000 kcal/person/yr). Overall, Pimentel (66) estimates that the food system currently uses 25% of the world's fossil fuels.

Energy Sources for Agriculture

The most important energy source for agriculture is the sun. Through photosynthesis, billions[1] of metric tons of organic material are produced. Some plant material is eaten directly (grains, fruits, vegetables, etc.); other fibrous materials must be converted by ruminant animals leaving sizeable quantities of residues, manures and often other unused wastes.

Controlled crop growth requires external energy to prepare the soil, irrigate, plant, control weeds, harvest and prepare the crop for use as human food. Yields can be enhanced by adding more energy as fertilizer.

Manpower continues to be a major energy source for agriculture in many LDC's. But man is a poor energy source. His energy capacity is extremely limited. A healthy adult can exert about 1/10 hp on a continuous basis -- the equivalent to the electrical energy needed to light a 75 watt bulb. If this rate of energy is expended for a 10-hr day, 750-Wh or 3/4 kWh will be developed.

If electricity costs 4 cents/kWh man's energy is worth about 3 cents/day. To achieve a reasonable standard of living, man must use his head (decision making, etc.) or his dexterity to perform tasks of greater value not easily done by machine.

Man is creative and learned early to domesticate animals to supplement his limited energy capacity. Later, man developed the concept of selective mechanization to extend his energy capacity, produce more and improve his standard of living.

As petroleum supplies diminish, alternative fuel sources must be found to provide the cultural energy needed to produce adequate food supplies for the expanding world population.

Availability of Organic Materials

Land Areas

The present annual production of biomass on the land areas of the world has been estimated at 100 billion metric tons, dry weight (1). This has an energy equivalent six times greater than the current world-wide energy use. There are two major approaches to biomass utilization as an energy source: 1) to grow a crop specifically for direct use as a fuel or to produce a fuel; and 2) to collect by-products or wastes for use as a fuel or for fuel production (78).

Studies of the feasibility of growing crops for fuels are numerous. Energy ratios of 12 to 25 are possible with the present U.S. agricultural production (72). These ratios refer only to biomass production and do not include the energy required to transport it from the production site to the consumer or conversion losses.

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[1] 1 billion = 10^9

Roller (72) concluded that climate, land and water availability, economics of agricultural production and marketing all combine to cast doubt on the feasibility of growing organic matter for fuel under U.S. conditions. They point out that collecting residues may be more practical but cautioned the competition for residues for return to the soil or cellulosic production is formidable. Other competition important in LDC's includes food for animals.

Table 2 gives biomass yields from selected species grown in different parts of the world (44). Anderson (3) estimated that U.S. organic wastes total 800 x 10^6 metric tons/yr (Table 3). He calculated a recoverable oil potential of 27 x 10^9 l and a gas potential of 38 x 10^9 m^3 representing about 3% of the total annual oil or gas use. Downing (22) calculated the energy value of crops in Canada (Table 4). He also calculated output/input ratios for various crops ranging from 4 to 16 (Table 5).

Go (32) reported the demand for coconut charcoal (derived from controlled burning of coconut shells) is increasing. Japan reportedly imports 7,500 metric tons annually from Sri Lanka. The Phillippines is interested in developing a coconut charcoal industry as well.

Graham (33) plotted biomass yields as a function of solar flux (Fig. 3). Yields up to 90 metric tons/ha per year are shown.

Wood is a major fuel throughout the developing world (Table 6). It is estimated that over 95% of households in developing countries, where woodfuel is readily available, use it as a primary source of fuel for cooking (62). FAO (11) estimated that of the total world production of wood (2,525 x 10^6 m^3 in 1974), 46% or 1,173 x 10^6 m^3 were used for fuel.

Another major source of organic residue is animal manure. Table 7 summarizes the numbers of livestock in various parts of the world (9). Table 8 tabulates manure production for various species. Although some manure is used productively as fertilizer and some as fuel in LDC's, some is left unused. Considerable energy can be extracted from manure and it will still retain much of the fertilizer value.

Marine Based

Mariculture is the harvesting of plants from the sea. The giant kelp, Macrocystis pyrifera, is abundant, accessible and capable of biological conversion to methane. This giant seaweed commonly reaches 70 m in length and grows two thirds of a meter or more per day (60). It is native to waters whose temperatures average less than 20°C.

Kelp bed densities vary in different parts of the world. Biomasses up to 22 kg/m^2 fresh weight have been reported in the relatively thick California beds; while, for example, Indian Ocean biomasses range from 95 to 606 kg/m^2 with an average of 140 kg/m^2 (59).

Fresh kelp contains about 85% water and has about 70% volatile matter, on a yearly average. A simple digestion system will convert 40% of the volatiles; one kilogram of digestible organic matter yields 0.41 m^3 of methane (CH_4).

One proposed ocean food and energy farm consists of a network of kelp supporting lines extending out from a central processing station (83). The kelp plants are harvested twice a year by special ships and drained of excess seawater. The plants are then taken from the ship to the processing plant and shredded. Each hectare is expected to yield about 740 to 1,240 wet tons of harvested organic material per year (41, 43, 83).

The shredded kelp is fed to the digestors and converted to fuel gas. Effluent from the digestors may be further processed to yield fertilizers and animal fodder.

A 40,500 hectare mariculture system could produce 7.4×10^8 m^3 CH_4--about 0.04 percent of the total U.S. energy consumption in 1970. A system 1,120 km in diameter would be needed to satisfy 100% of the total U.S. energy consumption.

There are 36×10^7 square kilometers of ocean on the earth but only 56 to 70% of this is "arable" surface water. Since kelp cannot reproduce in water above 20°C, mariculture farms could not exist within 20° of the equator. If waters above this latitude were incorrectly farmed the oceans could become a mat of kelp fronds and serious ecological damage might result. However, because of their enormous energy potential, mariculture systems warrant serious consideration.

CONVERSION PROCESSES

Fig. 4 shows some alternatives for converting nonfossil cellulosic material (carbon) to gaseous or liquid fuels. The feedstock material (organic residue) has an energy content of 2,200 to 5,600 kcal/kg (Tables 9, 10) with 3,300 or 3,900 kcal/kg (6,000 or 7,000 BTU/lb) of dry matter being most common. The typical products (methane, carbon monoxide, hydrogen, oils, etc.) have heating values of 8 to 14,000 kcal/kg (Table 10). Heat contents of gaseous products range from 1,200 to 8,900 kcal/m^3 (Table 10).

Dry (Non-biological) Processes

Combustion in excess air

A common example of combustion in excess air is incineration. The basic purpose is usually to dispose of a waste product (e.g. forest residue or municipal wastes) (70). Recently, several cities have installed incineration processes in which the heat generated is used to produce steam to generate electricity (19). Particulate control is essential to avoid air pollution. In an agricultural context, incineration is not very practical. It's costly and often there are more attractive alternatives.

Combustion in a controlled atmosphere

Gasification is the process of burning carbon (e.g. an organic residue) in a packed bed with a limited air supply at temperatures above 1,090°C. The typical products of combustion called "producers gas" are listed in Table 11. The heat content of producers gas ranges from 1,200 to 1,400 kcal/m^3. A comparison of heating values of various fuels was given previously (Table 10).

With a suitable nozzle, the hot gas can be burned somewhat like natural gas. In this application, the conversion of crop residue to useful energy is 85 to 90% thermally efficient. In addition, the gas can be cooled, filtered and used as fuel in a spark-ignition or diesel (dual-fuel) engine. The conversion of crop residue to cold, clean gas is 65 to 75% efficient.

Producer gas technology has a long history and is well developed. A bibliography by Nowakowska and Wiebe (61) covers the development of gas producers up to 1944. Lincoln (47) presents a modern review of alternative fuels for vehicles. Stationary gas producers burning coal or coke for fuel were first used in Germany.

During the 40's, research on gas producers was widespread in Europe with the advent of war and fuel shortages. Both stationary and portable gas producers were manufactured. Small stationary producers were developed and sold for manufacturing firms to insure consistent gas supplies (7). The Power-Gas Company began to design and install gas producers in countries where coal and oil were scarce. These stationary gas producers used a variety of crop residues and wood (4).

In Sweden, where automobiles were extensively powered with wood, one trailer-mounted gas producer indicated that 100 kg of wood was equivalent to 76 liters of gasoline (5). Perhaps 700,000 vehicles were adapted to producer or suction gas generators and they used many forms of fuel including coal, coke, charcoal, wood and coconut husks. Stationary gas generators have been designed for and operated with just about every conceivable form of cellulose, including rice hulls, olive pits, straw, camel dung, cotton seed hulls, sawdust, walnut shells, etc.

More recently, Porter and Wiebe (68) at the USDA laboratory in Peoria, Ill., tested corncobs in a small gas producer with promising results. When coarsely ground cobs were used, a gas with 1,415 kcal/m^3 was produced from cobs whose heat content ranged from 4,370 to 4,521 kcal/kg with an average of 4,442 kcal/kg (ovendried).

Conversion of farm tractors to producer gas was studied extensively in Australia. Operational problems, field trials and economics were discussed by Roberts (71). Bowden et al (16) discussed fuel consumption, power output and the effect of high and low compression pistons. Producer gas and kerosene were compared in terms of power output, cylinder wear and economics. Freeth (28) discussed conversion of tractors to burn producer gas. Most Australian producers were cross-draft types using charcoal as fuel. On the other hand, the Soviets used wood or straw downdraft gas producers. A discussion of these latter producers appears in a 1945 edition of Gas Oil Power (8).

As stated previously, considerable attention was given to the development of gas producers for cars, trucks and buses. An article reviewing eight different gas producers appeared in Automobile Engineer (6). A discussion of gas generation principles and the application to small gas producers is given by Lowe (49) who also detailed several commercial models.

The Canadian government became interested in portable gas producers and, as a result, commissioned a series of tests on commercially available European models. As a further result, a detailed report by Allcut and Patten (2) in 1943 reported on a study of 12 gas producers in which both bench tests and vehicle tests were conducted. Gas generation, composition and kcal content are reported in detail for repeated tests on each producer.

Filtering of producer gas prior to its use in internal combustion engines is essential to avoid excessive wear. Most filters on portable gas producers consisted of either sisal tow, coke or fabric or a combination of these.

Apparently, these filters require considerable attention because they often plug with dust, tar or condensate, thus increasing the pressure drop required and reducing the volumetric efficiency of the engine.

One concept -- the wet washer -- had considerable success. Water, containing a suitable wetting agent, and used in a device similar to an oil bath air cleaner. This wet washer was used after the gas was cooled. In addition, the water dissolved certain gaseous impurities such as ammonia and sulfur compounds. By using such a cleaning method reduced cylinder bore wear to 0.0025 cm every 4,800 to 6,400 km (6).

The bulky, wet cleaners are not the drawback for stationary gas producers that they are with portable producers. Most gas can be cleaned satisfactorily in a stationary producer by simply using a wet scrubber, many of which are on the market for stack gas cleaning.

Horsepower is reduced from 40 to 50% when gasoline engines are converted to producer gas. It is not possible to get the same amount of energy into a cylinder with producer gas as it is with gasoline.

In a 1947 issue of Diesel Progress, Lustig (50) described a stationary gas producer using ground-up vegetable matter to supply fuel for dual-fuel engines. This gas producer was built by the Wellman Engineering Company of Cleveland, Ohio, and a long series of tests were carried out using a Bruce MacBeth 4-cycle engine. This article notes that "...Brazilian engineers attended the tests made on the gas producer, anxious to find an effective means of utilizing waste vegetable matter."

Although nearly all experimental work on gas generators ended in the 1940's, Sweden continued to develop the gas producer. Fig. 5 shows a gas generator developed by Nordstrom (58) for use with wood.

A laboratory downdraft gas producer was designed and built by the Agricultural Engineering Department of the University of California in 1975 (39). A cutaway view of the producer is shown in Fig. 6. A 4-cylinder air-cooled engine has been run on the gas successfully with little modification. Emission tests when the engine was under full throttle at 2,200 rpm indicated that hydrocarbons were as low as 25 ppm and CO was as low as 0.05%.

The engine was connected to a 3-phase induction motor and by applying torque to the electric motor it was able to generate electricity, thereby putting power back into the grid.

Tests will continue as technologists strive to develop satisfactory designs for gasifying crop residues and automating the operation.[1]

Heating in the absence of oxygen

Destructive distillation and pyrolysis are two processes carried out by heating organic materials in the absence of oxygen. The resulting thermal decomposition produces combustionable gases and a solid nonvolatile residue.

Destructive Distillation - Bituminous coal is subjected to destructive distillation in large quantities to produce coke, coal tar and coal gas. Large quantities of wood were formerly subjected to destructive distillation to produce charcoal, methanol, acetone and other chemicals. Such destructive distillation processes could not compete economically with synthetic methods but some charcoal is still produced by destructive distillation.

Pyrolysis - A more modern term for essentially the same destructive distillation process is pyrolysis (Fig. 7). Pyrolysis involves heating organic material at high temperature (540 to 1,090°C) in the absence of oxygen for several hours. Various proportions of gas, oil and char are produced depending on the temperature, pressure and length of treatment (23). One commercial pyrolysis process for municipal wastes produces either 159 l of fuel oil or 170 m^3 of gas in excess of heat inputs to the process. The gas is a mixture of primarily methane, hydrogen, carbon dioxide and carbon monoxide and has a heat value of 7,120 kcal/m^3 (23).

The pyrolysis processzusing animal manure yields gas with a heating value of 2,670 to 4,450 kcal/m^3 or about 560 to 830 kcal/kg of dry matter. Engler et al. (24) reported after studying three processes for converting animal waste to a useful energy form that pyrolysis was the most promising. The resultant synthesis gas could be used to provide: 1) a clean low-Btu gas for power generation; 2) a starting material for ammonia synthesis; 3) a starting material for methanol production.

A plant was designed conceptually and its profitability analyzed. The capital investment required for the plant capable of handling 907 metric tons of manure per day was $6.07 million and annual operating costs $2.54 million.

Assuming there would be no charge for manure transportation, costs were estimated at $1.27/metric ton. Utilities, labor costs, maintenance and administrative costs were included. The sales price of gas required for profitable operation was calculated. The price ranged from $1.00/MSCF (thousand standard cubic feet)[2] for a 454 metric ton of manure per day (T/D) plant to $0.29/MSCF for a 9,000 T/D plant.

To make a 16% return on investment at 1973 gas prices, a 900 T/D plant would have to sell gas for $4.02/metric ton. Thus, significant improvements in the process or changes in the cost of producing synthesis gas would be needed for manure pyrolysis to be economically feasible.

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[1] The summary of development of producer gas technology (pp 5-7)is adapted from Horsefield and Williams (39).

[2] MSCF = 28.3 m^3

Another study (30) concluded that a pyrolysis process for a 40,000 head beef cattle feedlot would cost \$6.17 per metric ton of 80% moisture manure. This would be \$25.30 per head of livestock and is not considered feasible at this time.

Conversion under pressure

Hydrocarbonization involves conversion to an oil or gas by subjecting organic materials to high temperatures and pressures. The process may be further sub-divided into hydrogasification which yields gaseous fuels and hydrogenation to produce oils and solid fuels.

Hydrogasification - is the process used to convert coal to pipeline gas. Manure and hydrogen may be fed into a reactor at 34 to 68 bars and temperatures of 500°C. A low Btu gas is produced which can be further processed to be 95 to 98% methane with around 8,900 kcal/m^3 -- the same as natural gas (27, 52).

A major deterrent in the application of this process is the large amount of water that must be removed. Consequently, the most likely application is in treating manure low in moisture content. Although laboratory experiments and economic feasibility studies have been conducted, there are no known commercial operations in which manure is converted by hydrogasification.

Hydrogenation - (another high pressure and temperature conversion method) is available to convert organic matter into oil. The reaction involves heating the raw material at 240 to 400°C and high pressure (102 to 272 bars) in the presence of carbon monoxide, steam and a catalyst. About 330 l of oil are produced per metric ton or organic input (12, 23). Costs of a large-scale plant are unknown, but construction and operating costs will be high due to the requirement for high pressures.

Wet Processes

Anaerobic Fermentation

Description - One way to use agricultural and agro-industrial waste materials is to produce biogas containing methane by anaerobic digestion of organic wastes. This process is the anaerobic equivalent of aerobic composting but much less heat is liberated in anaerobic digestion than in composting.

Methane production through anaerobic digestion is a two-stage biological process. First, soluble carbohydrates are converted to organic acids by acid forming bacteria. Second, bacteria (we call them the methane formers) use the organic acids to produce methane (CH_4) and carbon dioxide (CO_2).

Possible Substrates - Many different organic waste materials have been used as the feed material for anaerobic digestion. Table 12 is a compilation of the results achieved with a variety of different agricultural wastes (61). With the possible exception of materials like sawdust (which is primarily cellulose), almost any organic waste material can serve as a component of the substrate for an anaerobic digestor. The suitability of materials for gas production depends on the carbon to nitrogen (C:N) ratio which should be below 35 for optimum production.

Recent research on anaerobic digestion has been done using animal manures as a substrate. It falls in the desired C:N range and is a material which, in large livestock production facilities, is easily collected in quantity. The major use of manure throughout the world is for fertilizer or energy through direct burning. Anaerobic digestion stabilizes the nutrients and nearly all the N, P and K value remains in the digestor effluent so the process provides for both energy extraction and maximum nutrient retention for use on agricultural soils.

The use of crop residue as a substitute for anaerobic digestion has not been researched as extensively as has manure. The C:N ratio of crop residue or even mixtures of crop residue and manure are generally too high for satisfactory biogas production. The ratio can be reduced by adding human excrement including urine or chemical nitrogen (51).

Klass et al. (45) reported successful biogas production using grasses in small-scale digestors but indicated that grasses must be finely chopped and that scale-up technology is not readily available. Lecuyer (46) assessed the use of water hyacinths for biogas production and found it was technically feasible but not economically viable. Furthermore, the process may not be acceptable in some areas because a large area would be needed for water hyacinth production.

Biology - The methane process requires a group of acid-forming bacteria existing symbiotically with the methane-forming bacteria. The steady state reactions of the two-stage process may be written (77):

1st stage $$\text{Complex Organics} \xrightarrow[\text{Bacteria}]{\text{Acid-forming}} CO_2 + H_2 + \text{Organic Acids} \qquad (1)$$

2nd stage $$\text{Organic Acids} \xrightarrow[\text{Formers}]{\text{Methane}} CO_2 + CH_4 \qquad (2)$$

$$4H_2 + CO_2 \longrightarrow 2H_2O + CH_4 \qquad (3)$$

These reactions must occur simultaneously and if the reactions become unbalanced, the digestion process fails.

The diagram shown in Fig. 8 was developed by McCarty (57) as a schematic representation of the two-stage process described previously. This diagram is a great simplification of the methane forming process, but it indicates there are many paths and bio-chemical reactions between the complex organic wastes and the end product, methane.

Temperature is crucial to the process. There are two sets of methane-forming bacteria: the mesophyllic organisms which have an optimum environment temperature of 35°C and the thermophyllic organisms having an optimum temperature of 54°C. Because of the problems associated with maintaining the higher temperature as well as heating cool material to 54°C before it is introduced into the digestor, the mesophyllic process has been considered the most promising. Generally, methane production decreases rather drastically as temperature drops below the optimum level. A rule of thumb often used is that methane production drops 50% for every 11°C decrease in temperature below the optimum level.

Additional design factors which must be determined are loading rate and detention time within the digestor. Loading rate is usually expressed in terms of the amount of volatile solids (VS) input to the digestor daily per unit volume of digestor. Miner and Smith (54) indicate loading rates from 1.6 to 5.9 kg VS/m^3/day have been generally satisfactory. Most loading rates expressed in Table 12 also fall within this range. Detention times used with these loading rates range from 10 to 18 days for continuous flow digestors.

Start-up procedures for an anaerobic digestor process can take several weeks. The start-up period is critical because if the acid-forming bacteria become too active before methane formers begin to function, too much acid may be produced driving the pH below the range acceptable for methane-forming bacteria and the methane production may never really get started. Therefore, check pH frequently during start-up and keep it above 6.7 to achieve a balanced digestion process.

Equipment - The equipment required for methane production consists of an oxygen free digestor, a gas collection device, input and output equipment, a controlled heat input system, and in some cases agitation and scum prevention are necessary. Fig. 10 shows a diagram of the necessary components. The organic material must be broken up before it enters the digestor; therefore, choppers or shredders are required for the pretreatment process. The digestor may be designed for gas production using a batch process where the digestor is filled and the total volume of material left inside to digest for a set period of time before the digestor is opened, emptied and the next batch started.

Alternatively, the digestor design may include input and output equipment and the system be set-up for periodic (often daily) removal of a portion of the slurry and addition of an equal volume of organic material for digestion. Agitation and scum prevention are needed in this type of continuous flow digestor.

The batch process requires less equipment since a daily input-output system is not needed, but gas production is not uniform. It starts from zero when material is first added, slowly rises to a peak and then tapers off. Fig. 9 shows a typical batch process production curve.

The continuous flow process involves substrate input and some digested sludge output everyday. Gas production is much more uniform, but reliable input-output equipment must be provided. Since methane digestors are not sold commercially as a package item, problems are generally experienced with the hardware of the system. Many researchers (Hein *et al*. (36); Booram *et al*. (15); and Parker *et al*. (64)) have reported mechanical difficulties with input-output pumps and recirculation hardware, but the degree of difficulty depends on the solids content.

The continuous flow process is the system of choice for uniform gas production. An alternative is to have several batch digestors at once site and load them alternately so that one is always at peak production. The system should be simple. For small village or farm installations, plungers can be used to force the daily feed into the digestor and simple overflow or hand-operated vacuum devices used to remove a daily volume of digested sludge. Where pumps and valving systems are desirable, consider only heavy duty, non-clog equipment. Fig. 11 shows a schematic of a simple, manually operated continuous flow digestor.

Skills Required - The mechanical skills required for operation depend on the digestor design. Where a manual input-output scheme is used and where agitation is done manually rather than mechanically, the mechanical skills required for operation are minimal. They include being able to mix and measure the required input material, manage the gas storage and utilization systems to maintain proper material balance, and prevent explosive conditions.

Skills required which are related to bio-chemical processes involve pH and temperature monitoring and control. Generally adequate fermentation rates can be achieved with pH in the range of 6.7 to 7.6 (63). While this is a relatively wide range, pH control may be difficult with village-level technology and close attention is needed to stay within the range. If pH paper can be made available and assistance given to digestor operators to assure its proper use, adequate pH control can be achieved. Without relatively long experience pH could get outside the desirable range before the operator realizes something is wrong within the digestor.

The most frequent problem encountered will be the digestor becoming too acid (pH dropping below 6.7) during the start-up period due to an excess of acid production over methane production. If the pH is known to be decreasing and approaching the lower limit, the situation can often be corrected by adding lime or bicarbonate of soda. While pH is not as responsive an indication as a direct measure of the volatile acids present, it is the index which must be used for operations which do not have the services of a well-equipped chemical laboratory.

The Gas - The gas produced in anaerobic digestion of organic material is a mixture of mostly methane and carbon dioxide with small amounts of other gases present. Fermentation of animal waste or other substrates with a C/N ratio around 30 will generally produce a mixture containing about 60% methane. Table 13 gives ranges of the composition expected in biogas produced from farm wastes.

In a well-functioning digestor, the biogas produced can generally be expected to have a heat value of about 5,340 kcal/m^3 at atmospheric pressure. For comparison, natural gas has a heat value of 8,900 kcal/m^3 and a liter of gasoline contains about 8,000 kcal.

Converse and Graves (18) formulated the data in Table 14 to compare the potential energy in biogas produced from various manures with the quantity of other fuels required to yield the same amount of energy.

Utilization of Biogas - The success of a biogas production unit depends on making beneficial use of the gas produced. Methane (CH_4) which generally makes no more than 60 to 70% of the gas as it comes from the digestor is the compound having energy value. The remaining fraction is mostly CO_2. Gas utilization may involve direct use of the total gas mixture including impurities or it may involve purification steps to remove: 1) CO_2, thereby increasing the energy value of gas per unit volume; and 2) hydrogen sulfide (H_2S) to decrease corrosiveness of the mixture.

The CO_2 content can be reduced by bubbling the gas through a water scrubber with pH controlled to keep acid conditions from developing in the scrubber. Lime may be added to control pH, but in some cases none is needed as there may be sufficient ammonia in the solution to maintain neutral pH (32). Hydrogen sulfide can be removed by passing the gas through iron-impregnated wood chips (18) or iron filings. A suggested design for an H_2S removal filter containing iron filings is shown in Fig. 10.

The amount of gas produced depends not only on digestor size and volatile solids loading rate but also on the temperature within the unit and the biodegradability of the feedstock. If temperature is not controlled and fluctuates with the seasons, so will the gas production rate. If temperature is controlled, a certain portion of the energy provided is used to heat the digestor and not available for beneficial use. Therefore, gas utilization must be planned with the expectation of lower amounts during cold periods.

Researchers who have evaluated biogas or purified methane storage concluded that it is not practical to compress and store gas produced by small digestors in farms (18). Nor can significant quantities of energy be compressed into small enough tanks to make use of biogas in mobile engines or tractors and other vehicles practical (18). Therefore, major use of the gas must be at the production site.

The use at the production site may be through such things as space heaters, stationary engines or crop dryers or cook stoves. Other possible uses include electricity generators or low grade (low temperature) heat production.

When planning space heating remember net gas production may be lowest during periods when heating needs are greatest. Stationary engines to be run on methane should be high compression engines designed for this application. Full engine power can be realized only if carbon dioxide is removed from the biogas mixture to increase the energy content of the gas going to the engine. Longer engine life can be attained if hydrogen sulfide is also scrubbed out of the gas before use.

Methane driven stationary engines have a variety of uses but two likely uses are for pumping irrigation water or for electrical generation. If one is going to depend on biogas for irrigation pumping, a reliable supply of gas will be needed.

The quantities of gas required can be determined as follows:

$$hp = \frac{Q\ w\ h}{33{,}000\ E_p}$$

Q = stream size in gal/min
w = specific weight of water (8.34 lb/gal)
h = total head (ft)
E_p = pump efficiency (about 0.7 for well designed pumps)

$$kw = \frac{Q\ w\ h\ (.0098)}{E_p}$$

Q = l/sec
w = 1 kg/l
h = meters
E_p = pump efficiency

Example

Let's consider what is required to lift a flow rate of 100 gal/min (6.3 l/sec) a distance of 20 ft (6.1 m) for a surface irrigation system:

$$hp = \frac{100\ (8.34)\ (20)}{33{,}000\ (0.7)}$$

hp = 0.72
1 hp-hr = 2,546 Btu

$$kw = \frac{6.3\ (6.1)\ (0.0098)}{0.7}$$

kw = 0.538
1 kWh = 860 kcal

If engine efficiency is 20%

1 hp-hr output requires:
2,546/0.2 = 12,730 Btu input
For .72 hp output:
0.72 x 12,730 = 9,166 Btu/hr input

1 kWh output requires:
860/0.2 = 4,300 kcal input
For .538 kw output:
$0.72 \times 4{,}300 = 2{,}313.4\ \frac{kcal}{hr}$ input

$$\frac{9{,}166\ Btu/hr}{600\ Btu/ft^3} = 15.3\ ft^3\ \text{of}\ \frac{biomass}{hr}\ \text{input}$$

$$\frac{2{,}313.4\ kcal/hr}{5{,}337.7\ kcal/m^3} = 0.43\ m^3/hr$$

If the pump were operated for 10 hr/day, 91,660 Btu or 4.3 m^3 of biogas would be needed. This would require the manure from 26 or 27 mature pigs being fed a U.S. finishing ration. Makhijani (51) estimated the cost of a community biogas scheme to produce gas which would be used by individuals as fuel for irrigation pumping plants. His estimates are given in Table 15.

Feasibility and Economics - It is technically feasible to produce methane through anaerobic digestion of animal waste (76). Studies show that if the C:N ratio is correct, it is feasible to produce methane from other farm crops and residues (45). Much less information is available on digestion of crop residues than on manure.

Most information (see Table 12) about the performance of digestors was derived from the study of small-scale laboratory digestors. The extent to which this information can be directly used to predict performance of digestors scaled-up to handle the wastes from a farm or a village is not well established.

Limited experience with farm-scale digestors suggests there are problems to be overcome to increase the reliability of physical equipment, and to decrease the amount of management time and capital investment required (15, 20).

Studies in the U.S. show methane digestors are not economical for farm installation with present technology and energy costs (15, 25, 55, 77). (This situation appears more favorable in LDC's.) However, these studies charge the entire cost of a digestor and its operation against energy production, whereas if the substrate being fed to the digestor, is animal waste a portion of the cost might well be charged to pollution control and waste handling convenience.

The economic attractiveness of anaerobic fermentation for a specific installation depends on the size of the operation, cost (and availability) of other forms of energy, and benefits to be derived by operation of a digestor such as water pollution control, fertilizer nutrient conservation, odor control and protection of human health.

Williams et al. (84) considered the economic feasibility of operating anaerobic digestors on U.S. beef and dairy farms. He did not charge the cost of the digestor to that of energy production but rather to waste handling. For a 100-cow dairy operation, his figures show that the cost of electricity would have to be at least 3.5 cents/kWh before one could afford to run and maintain a digestor. We are about at that level of electrical rate now in the U.S.

Williams' data also show that for a 1,000 head beef feedlot, producing methane and generating electricity will be financially beneficial if excess electricity over that required to operate the farm can be sold to the power company. However, power companies are not yet interested in buying power from small producers.

Makhijani (51) reported that the cost of energy from a village scale digestor is comparable to electricity at 6 cents/kWh. He indicated that when foreign exchange requirements for other energy sources are considered, energy from locally produced methane is the cheaper alternative. Further, the use of farm-or village-scale digestors in developing countries may provide a sanitary means of human waste disposal and conserve valuable nutrients for use on cropland.

Combine the energy required for puming irrigation water (based on the calculation presented in the section, Utilization of Biogas) with the cost of biogas per million Btu's (as estimated in Table 15), the cost of operating an irrigation pump on biogas would be $2.25 per acre-foot of water pumped. This is comparable to using a gasoline engine if the cost of gasoline is $3.02/gal (3.785 1).

The economic feasibility of using agricultural residues for biogas production depends on the particular set of circumstances and must be evaluated on an individual basis. To achieve reliable gas production, careful management of the digestor is imperative.

Alcoholic Fermentation

Transformation of sugars, largely encountered in agricultural plants, into alcohol by fermentation is common in the food and beverage industry. The starch content can also be transformed into ethyl alcohol, with an intermediate enzymatic action generating sugars. Therefore, the "vegetal alcohol" produced world-wide comes from plants rich in sugars or starch, such as sugar cane, sugar beet, vinasses, cassava, potato and maize.

But organic residues do not generally have a high sugar or starch content. Hydrolysis of lignin and cellulose is necessary to change these molecules into sugars. There are two ways to practice hydrolysis: 1) acid hydrolysis, with or without heating (glucose yields are about half the weight of cellulose); and 2) enzymatic conversion (cellulose derived from a fungus) which has a better glucose yield since all of the cellulose in the organic material is transformed (28).

The process then continues by fermentation of the sugars and alcohol distillation leaving an aqueous residue comprised mainly of lignin.

Ethyl alcohol is a good liquid fuel, whose caloric value is about 5,600 kcal/l. It can be used in spark-ignition engines either alone or in mixture with gasoline without big changes in the output power (37). Adaptations on a commercial car are minor.

A recent study using acid hydrolysis on straw reports an efficiency of 24% in the best cases (14), therefore, technical improvements on hydrolysis are necessary. The only large-scale plant currently using acid hydrolysis is in the U.S.S.R.

Alcohol production with sugar or starch-rich plants is more widespread. In some countries it is a means to control extra production, but the so-produced alcohol is not yet economically competitive with alcohol obtained from petroleum (14, 53).

Brazil has developed a large program of alcohol production, through sugar cane and cassava especially cropped for this purpose (67). Typical yields are 66 l of alcohol per metric ton of sugar cane (or about 3,000 l/ha). Cassava (which can be planted on poor land) provides 180 l/metric ton (or about 2,200 l/ha). Brazil already uses 200,000 m^3 of alcohol as engine fuel by mixing it with gasoline (80 percent gasoline, 20% alcohol). National plans are to produce 2,300,000 m^3 of alcohol, mainly with sugar cane.

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Definition of Terms

1. Biogas - The mixture of gases resulting from anaerobic digestion of organic matter (mostly methane and carbon dioxide with traces of ammonia, hydrogen sulfide and other gases).

2. Biomass - The total organic matter produced by plants (may be limited to above the ground or harvestible portion).

3. Cultural energy - Energy added to solar energy in the form of fuel, fertilizer, agricultural chemicals; an energy subsidy; includes energy required to grow seeds, manufacture implements, construct buildings, produce fertilizers, etc.

4. Energy ratio - Food energy produced divided by cultural energy input.

5. Gasification - The process of burning carbon in a packed bed with a limited air supply. The primary products are hydrogen and carbon monoxide.

6. Low Btu gas - Gas from coal or organic residue having a heat content 1,330-2,670 kcal/m^3 (150 to 300 Btu/ft^3), eg. producers gas, not suitable for mixing in pipeline with natural gas.

7. Pipeline gas - Gas from coal or organic residue suitable for mixing with natural gas in a pipeline, heat content approximately 8,900 kcal/m^3 (1,000$^+$ Btu/ft^3).

8. Producers gas - The products of combustion from the gasification process.

9. Substrate - The input material or feed for a biological fermentation process.

10. Synthesis gas - A mixture of methane, hydrogen and carbon monoxide.

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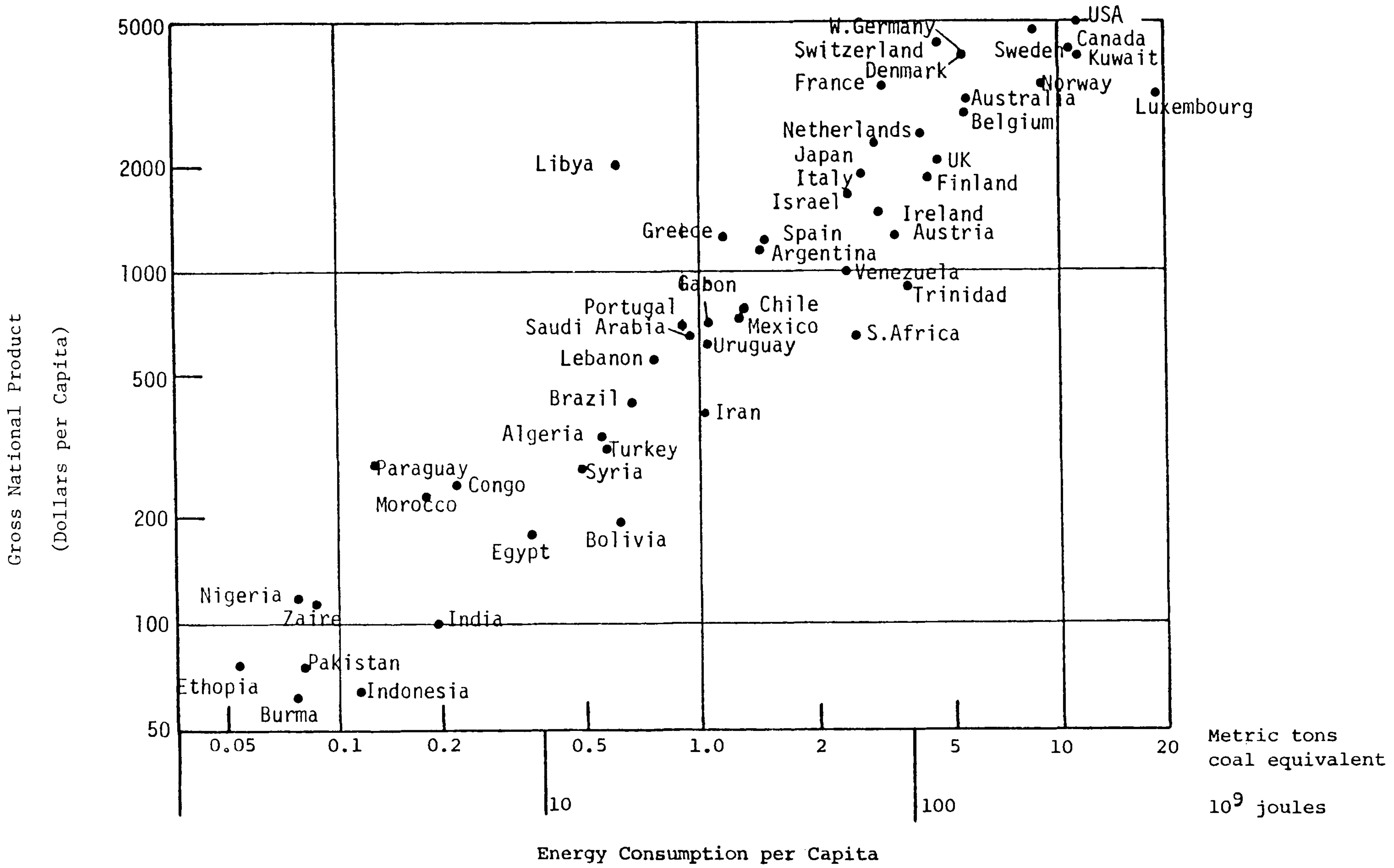

Fig. 1. Relationship between GNP and energy consumption per capita for 51 countries--1971 data (42).

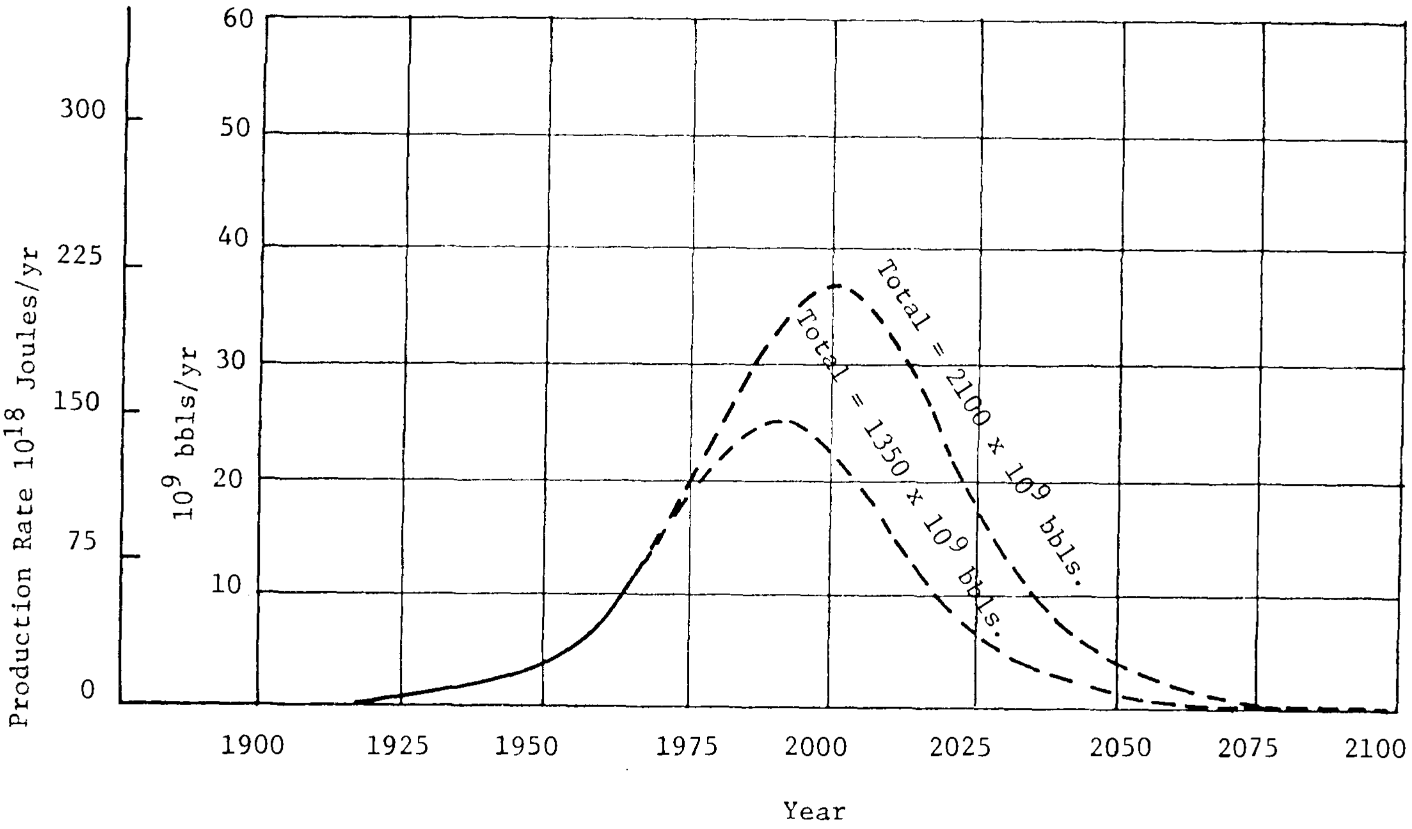

Fig. 2 World petroleum production and potential reserves according to two different estimates. Hump-shaped curves indicate projected use scenarios if the rate of use is proportional to the amount of resources remaining. Half of the world supplies are projected to be consumed by 1990 or 2000 (40).

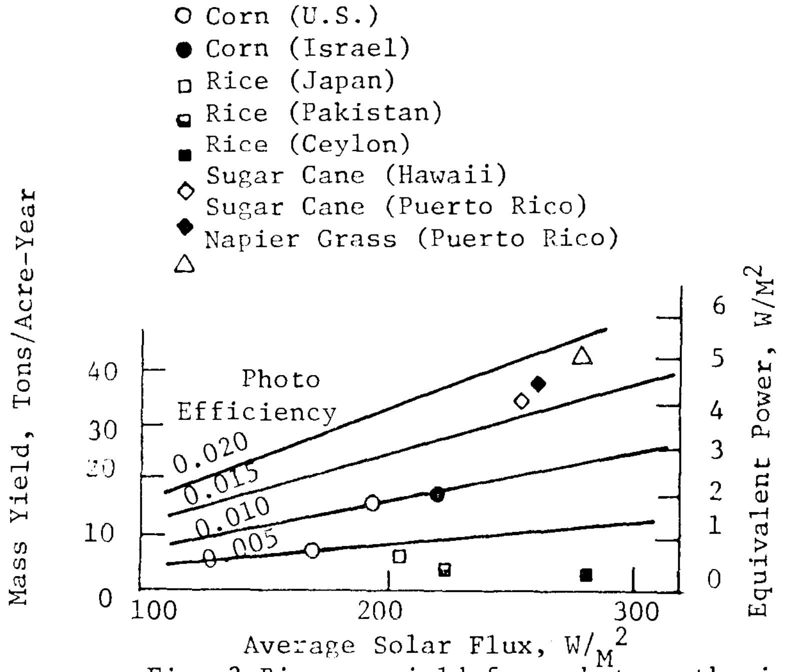

Fig. 3 Biomass yield from photosynthesis (33).

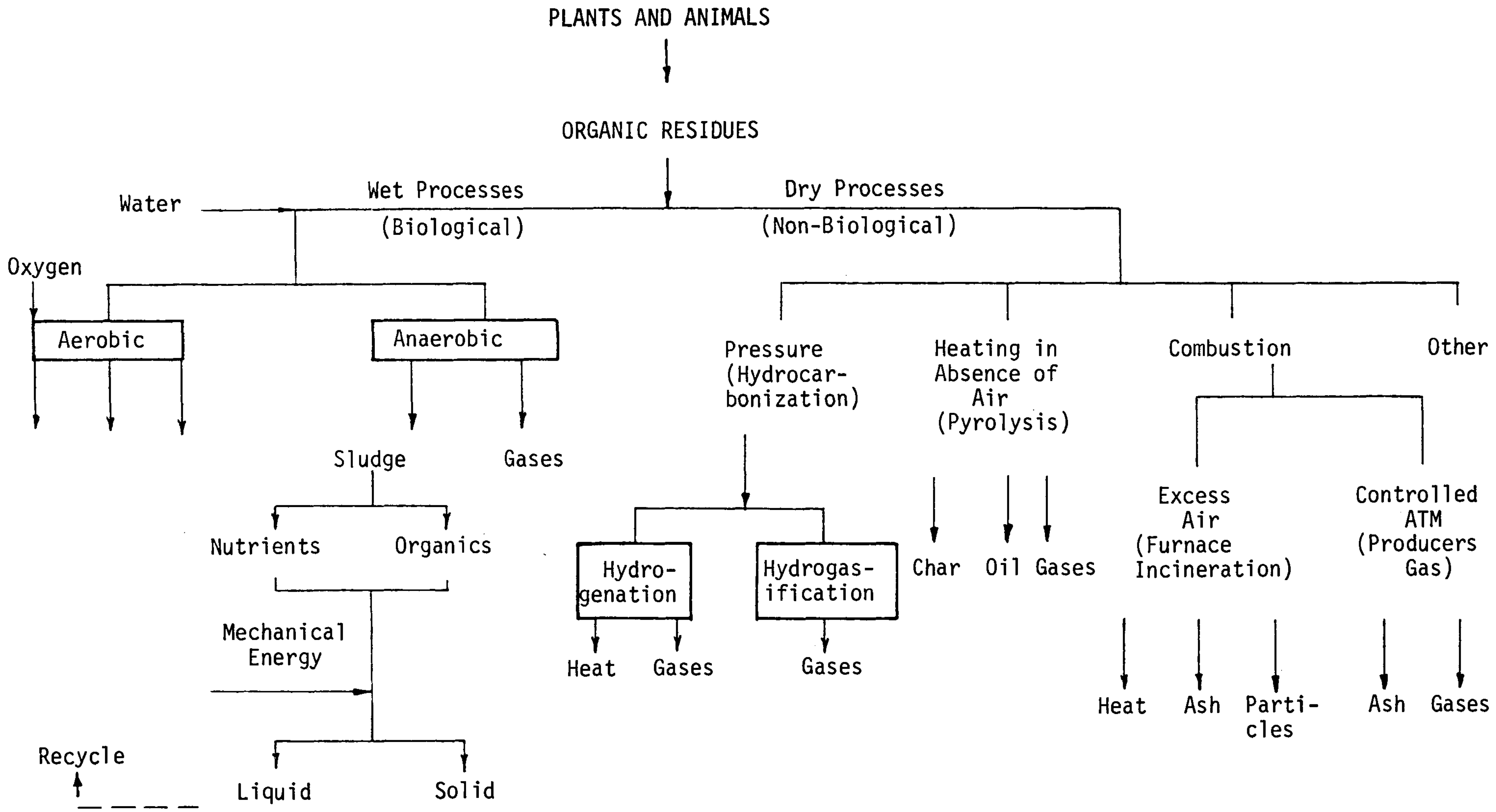

Fig. 4 Process alternatives for converting organic residues to gaseous or liquid fuels

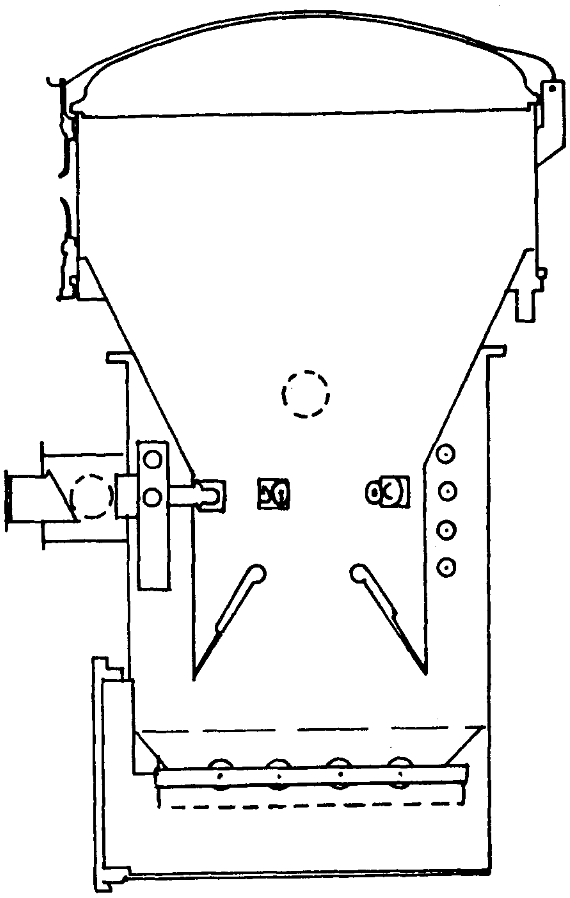

Fig. 5 Modern downdraft gas producer developed in Sweden for use with wood (39).

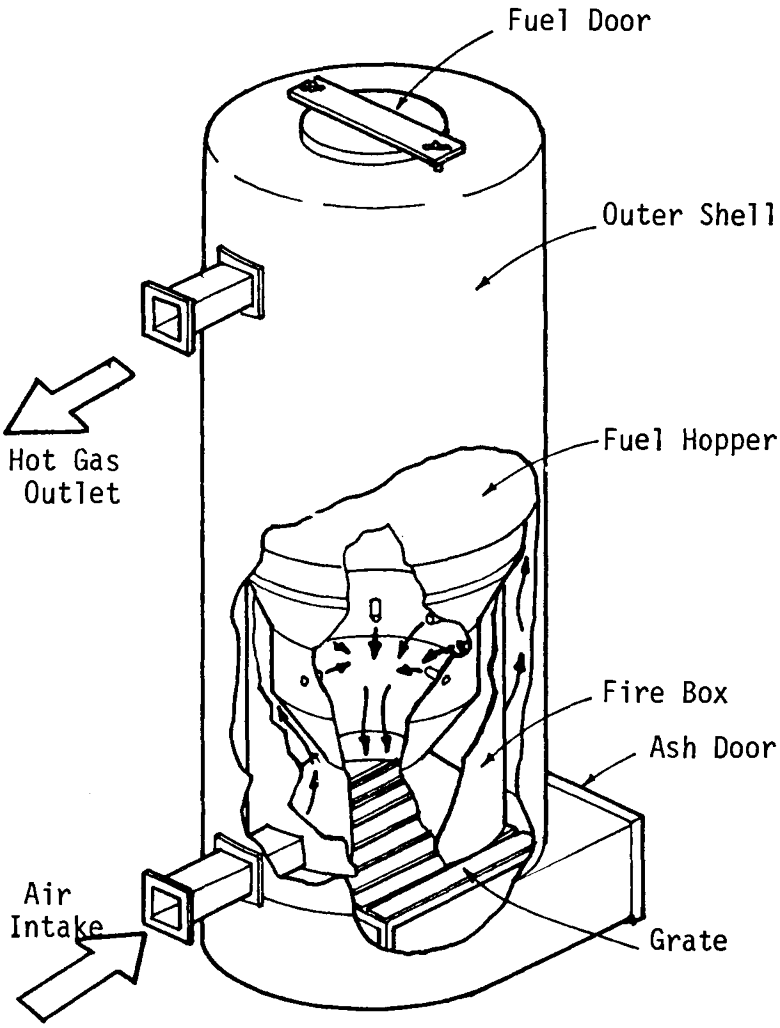

Fig. 6 Experimental gas producer for use with crop residue developed at the University of California, Davis (39).

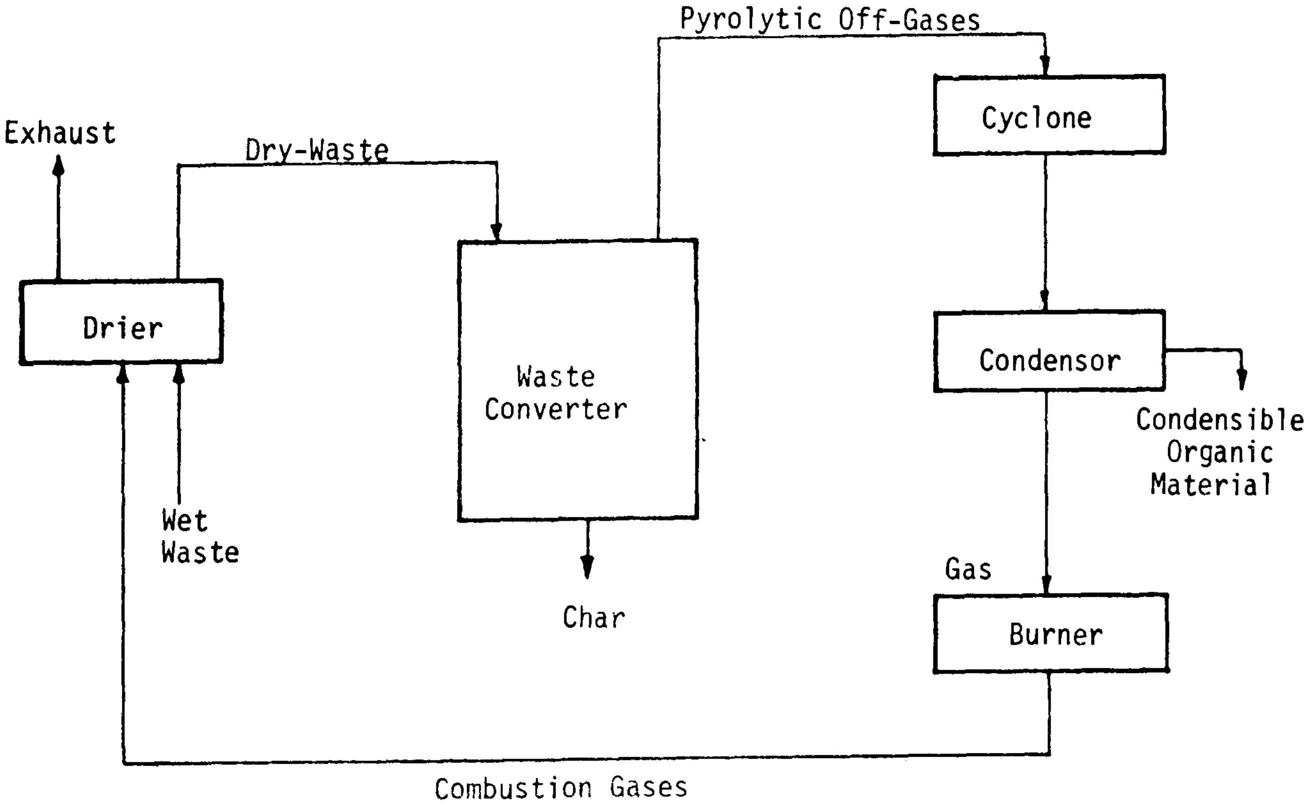

Fig. 7 Flow diagram of pyrolysis system.

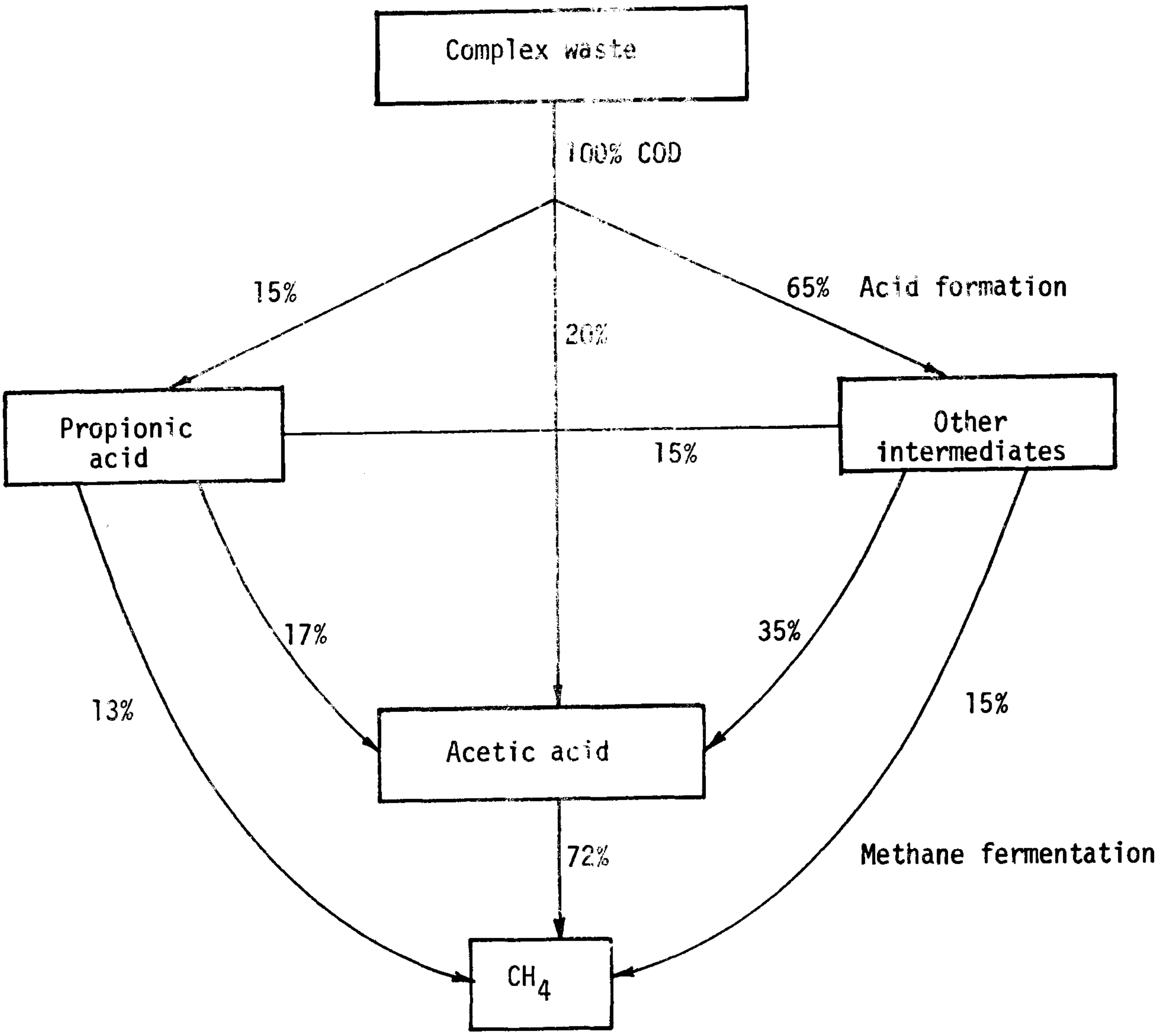

Fig. 8 Methane fermentation of a complex waste (57).

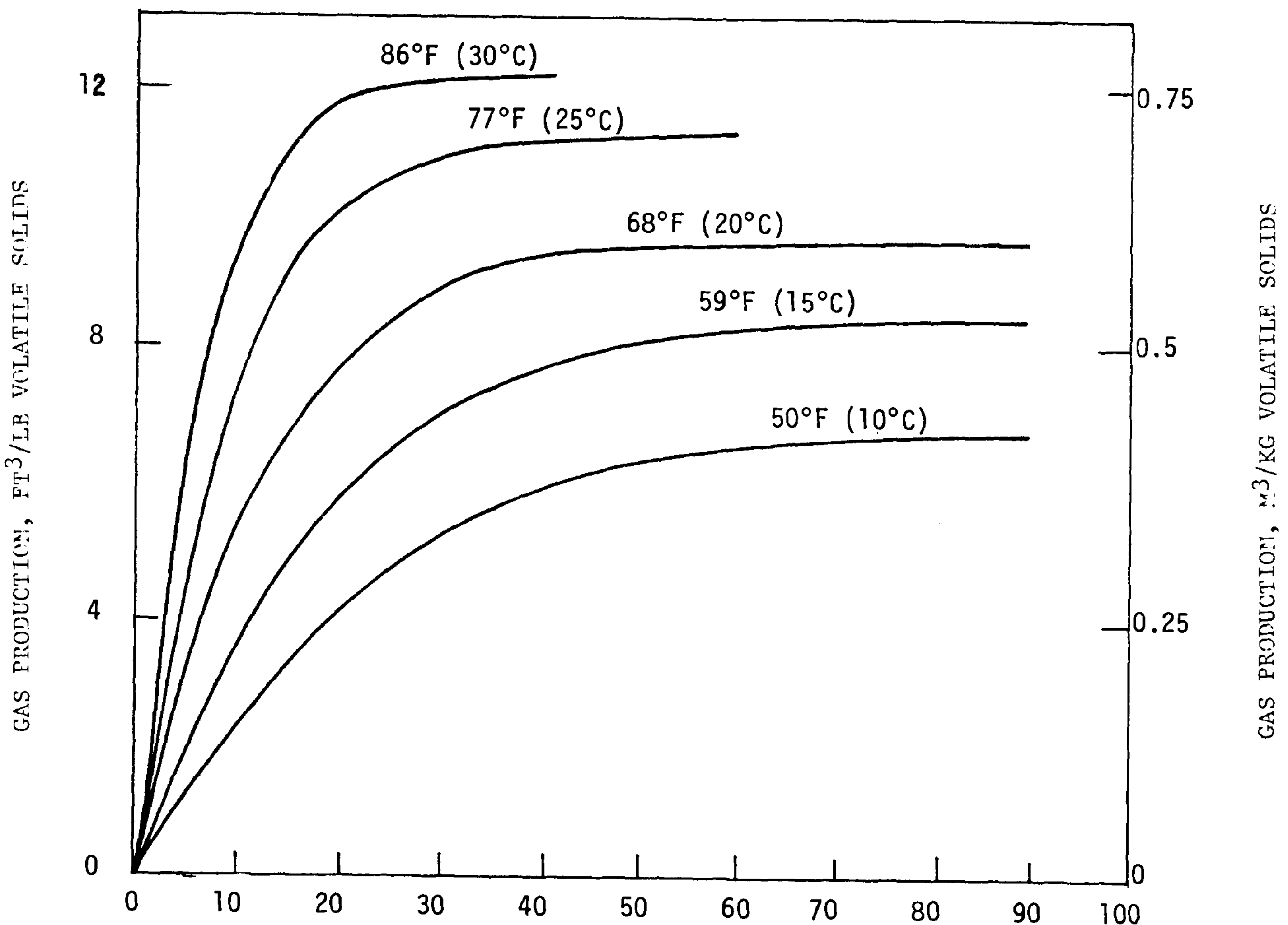

Fig. 9 Gas production from batch-fed anaerobic digestor when operated at temperatures from 10° to 30°C (76).

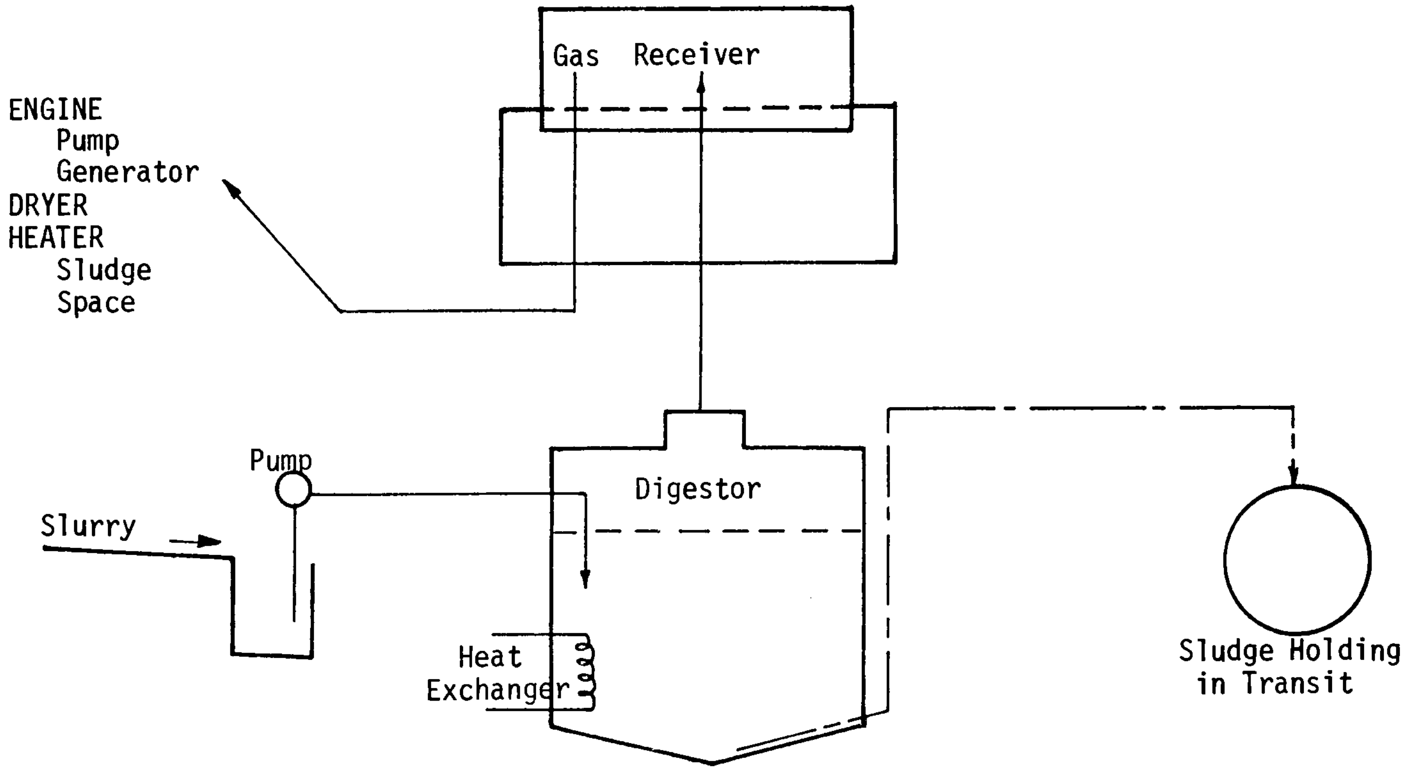

Fig. 10. The bio-conversion system.

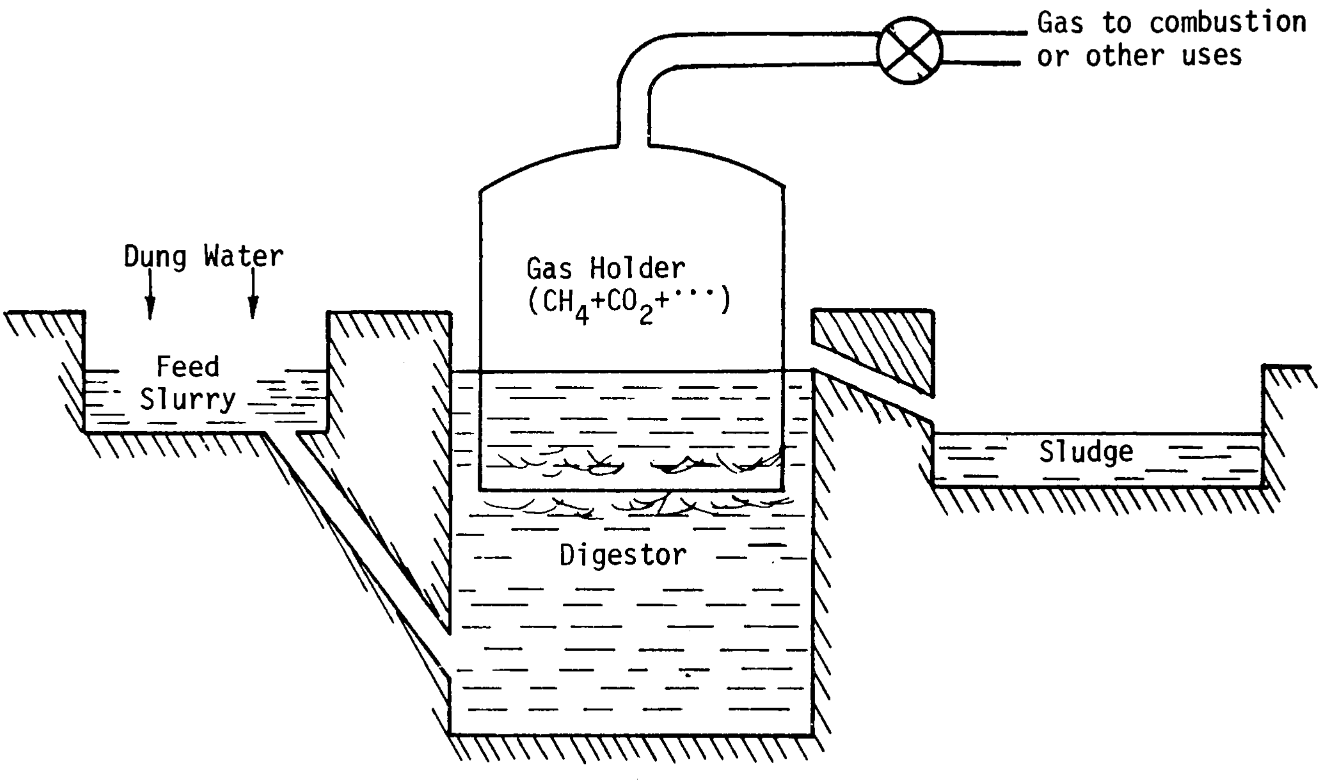

Fig. 11 Schematic of a biogas plant.

Table 1. A rough sketch of energy use in a few prototypical villages of the third world (a)

Energy Use	India (East Gangetic Plain)	China (South Central)	Tanzania	Nigeria	Mexico (North)
Principle sources: wood, food, crop residues, grazing land (except North Mexico)					
1. Domestic Energy use per capita			(10^4 kcal/yr)		
a. Useful energy	5	25	28	19	40
b. Energy input	101	504	554	378	429
2. Agricultural energy use: farm work, irrigation, chemical fertilizers					
a. Per capita					
Useful energy	13	35	2	4	340
Energy input	194	209	58	60	1030
b. Per acre					
Useful energy	18	68	1	5	156
Energy input	270	436	40	76	479
3. Energy use per capita in transportation, crop processing and other activities					
a. Useful energy	2	3	1	1	3
b. Energy input	86	81	18	23	91
4. Subtotal per capita energy use					
a. Useful energy	20	63	31	24	383
b. Energy input	381	794	630	461	1550
Commercial Energy Sources					
1. Oil, coal, hydro, etc.					
a. Useful energy	13	40	5	4	76
b. Energy input	63	202	25	18	378
2. Total energy use					
a. Useful energy	33	103	36	28	459
b. Energy input	444	996	655	479	1928

(a) These numbers are rough estimates, particularly with regard to the breakdown of animal labor into field and non-field activities.

Source: (51).

Table 2. Plant productivity data

Location	Plant community	Annual Production(a) metric tons/ha
Sweden	Enthrophic lake angiosperm	7.2
Denmark	Phytoplankton	7.8
Mississippi, US	Water hyacinth	11.0-33.0
Minnesota, US	Maize	24.0
New Zealand	Temperate grassland	29.1
West Indies	Tropical marine angiosperm	30.3
Nova Scotia	Sublittoral seaweed	32.1
Georgia, US	Subtropical saltmarsh	32.1
England	Coniferous forest, 0-21 yr	34.1
Israel	Maize	34.1
New South Wales	Rice	35.0
Congo	Tree plantation	36.1
Holland	Maize, rye - two harvests	37.0
Marshall Islands	Green algae	39.0
Germany	Temperate reedswamp	46.0
Puerto Rico	*Panicum maximum*	48.9
California	Green algae	49.3-74.2
Columbia	Pangola grass	50.2
West Indies	Tropical forest, mixed ages	59.0
Hawaii, US	Sugarcane	74.9
Puerto Rico	*Pennisetum purpurcum*	84.5
Java	Sugarcane	86.8
Puerto Rico	Napier grass	106.0
Thailand	Green algae	163.6

(a) Dry organic matter.

Source: (44).

Table 3. Estimates of available organic wastes in the U.S., 1971

	Total organic wastes generated	Organic solids available
Source:	10^6 metric tons/yr	
Manure	181	23.6
Urban refuse	117	64.4
Logging and wood manufacturing residues	50	4.5
Agriculture crops and food wastes	354	20.5
Industrial wastes	40	4.7
Municipal sewage solids	11	1.4
Miscellaneous organic wastes	45	4.5
Total	798	123.6
Net oil potential (10^{10} liters)	17.5	2.7
Net gas for fuel potential (10^{10} m^3)	24.9	3.9

Source: (3).

Table 4. Energy values of crops in Canada

	Canada	Ontario	Saskatchewan
Crop energy (10^{12} kcal)	275	59	89
Crop energy (10^6 kcal/ha)	7	18	5
Available crop residue (10^{12} kcal)	59	7	28
Available animal waste (10^{12} kcal)	145	51	17

Source: (22).

Table 5. Energy on specific Canadian farms

Farm no.	Hectares	Crops(a)	Precipitation cm.	Yield 10^2 kg/ha	O/I ratio
1	250.9	B.O.R.S.	48	26.9, 25.1, 13.8	4.21:1
2	388.5	W.B.S.	38	21.5, 26.9	5.50:1
3	518.0	W.S.	33	13.4	4.19:1
4	121.4	Br.-A.	48	1.8 metric tons	6.7 :1
5	121.4	A.	38	1.8 M.T., 3.6 M.T.	16.2 :1

(a) Crop Rotation Abbreviations: B-Barley, O-Oats, R-Rapeseed, S-Summerfallow, W-Wheat, Br-A-Brome Alfalfa, A-Alfalfa.

Source: (22).

Table 6. Woodfuel consumption in some developing countries

Country	1973 GDP per capita	Percentage of GDP derived from subsistence sector	Use of woodfuel per capita/yr		Woodfuel use out of total timber	Population using woodfuel	Charcoal use out of total woodfuel	Urban Population
	£		m^3	kg	%	%	%	%
Tanzania	40	30	2.3	1630	96	99	4	7
Gambia	50	25	1.6	1090	94	99	26	23
Thailand	80	20	1.4	1000	76	97	45	15

Source: (62).

Table 7. Livestock numbers, 1973

	1,000 Head						
	Horses	Mules	Asses	Cattle	Buffalos	Camels	TOTAL
Africa	3,751	2,201	10,714	149,276	2,283	10,226	178,451
North & Central America	15,374	3,194	3,397	182,001	7	8	203,981
South America	16,530	5,889	5,190	199,109	145	--	226,863
Asia	14,179	2,310	20,306	348,088	121,130	4,081	510,094
Europe	6,770	902	1,646	129,294	422	--	139,034
Oceania	585	--	5	38,739	--	2	39,331
USSR	7,075	3	540	104,006	429	230	112,283
	64,264	14,500	41,797	1,150,512	124,417	14,548	1,410,037

Source: (9).

Table 8. Manure production data

Animal	Fresh manure per 1,000 kg liveweight (kg/yr)	Assumed average liveweight (kg)	Fresh manure production assumed per head (kg/yr) (except item 7)	Assumed moisture content of fresh manure %	Nitrogen content percentage of dry matter	
					Solid & liquid wastes	Solid wastes only
1. Cattle	27,000	200	5400	80	2.4	1.2
2. Horses, mules donkeys	18,000	150	2700	80	1.7	1.1
3. Pigs	30,000	50	1500	80	3.75	1.8
4. Sheep & goats	13,000	40	500	70	4.1	2.0
5. Poultry	9,000	1.5	13	60	6.3	6.3
6. Human feces without urine	-	40 to 80	50 to 100	66 to 80	-	5 to 7
7. Human urine	-	40 to 80	18 to 25 kg dry solids/yr	-	15 to 19 (urine only)	-

Source: (51).

Table 9. Energy content of plant biomass

Plant	Plant part	Percent H_2O	kcal/kg
Sugarcane (a)	Bagassee	12	4,041
Sugarcane (b)	Bagassee	52	2,220
Bamboo (a)	Cane	10.5	4,106
Buckwheat (a)	Hulls	10	4,215
Chamise (c)	Leaves	0	5,411
Chamise (c)	Stems	0	5,245
Coconut (a)	Shells	13	4,196
Beech (a)	Wood	13	4,166
Birch (a)	Wood	12	4,206
Oak (a)	Wood	13	3,986
Oak (a)	Bark	7	4,517
Oak (b)	Bark	0	4,645
Pine (a)	Wood	12	4,416
Pine (c)	Bark	0	5,012
Fir (c)	Bark	0	4,890
Spruce (c)	Bark	0	4,851
Redwood (c)	Bark	0	4,635
Oilseed crop (d)	Seed	--	4,995

(a) Handbook of Chemistry and Physics, C. D. Hodgeman (Ed.), p. 1945. The Chemical Rubber Publishing Co., Cleveland, Ohio (1962).

(b) Steam: Its Generation and Use, Babcock and Wilcox Co., New York, N.Y. (1963).

(c) R. C. Rothermel and C. W. Philpot, 1973. Predicting changes in chaparral flammability. Journal Forestry, Vol. 71, No. 10 (October 1973).

(d) R. S. Loomis, et al., 1971. Agricultural productivity. Ann. Rev. Plant Physiol. 22:431-468.

Source: (44).

Table 10. Energy content of certain fuels

Fuel	Heat value (a)		
	kcal/kg	kcal/liter	kcal/m^3
Producer gas (b)			1,397
Hydrogen			2,403
Carbon monoxide			2,812
Pyrolysis gas (c)			
Municipal			3,337
Feedlot			4,450
Bio-gas (d)			5,517
Methane	13,243		8,846
Natural gas			8,899
Propane	11,983	6,095	22,390
Butane	11,778	6,794	29,189
Cattle manure			
Air dry	2,775		
Dry matter only	3,735		
Volatile solids only	5,051		
Softwood	4,995		
Coal	7,215		
Alcohol, methyl	6,383	4,241	8,525
Alcohol, ethyl	9,269		
Diesel, No. 1	10,878	9,005	
Kerosene	11,006	8,729	
Gasoline	11,267	8,263	
Fuel Oil, No. 2	11,183	8,856	

(a) High heat value includes latent heat of evaporation of resultant water vapor.

(b) Hot coal + blast of air ($2C + N_2 + O_2 \longrightarrow 2CO\ (N_2)$).

(c) From Resource Science, Inc., Santa Ana, January 1974.

(d) Also called manure methane or swamp gas.

Source: (26).

Table 11. Typical gas analysis from downdraft gas producer using wood

Gas	Range % by volume
CO_2	9.5 - 9.7
Hydrocarbons	0 - 0.3
O_2	0.6 - 1.4
CO	20.5 - 22.2
H_2	12.3 - 15.0
CH_4	2.4 - 3.4
N_2	50.0 - 53.8

Source: (39).

Table 12. Anaerobic treatment of agricultural wastes

Waste	Temp °C	Process loading kg VS/m^3 day	Hydraulic detention time (days)	% VS reduced	Gas prod. m^3/kg VS added	% CH_4	Process used
Slaughter house	33	1.8(a)	-	-	-	-	Two stage with solids return
Pear	35	1.6-7.4	.5-1.0	-	-	-	Two stage with solids return
Whey	37	2.1	6	-	-	65	Single stage
Beef cattle	23	1.6-6.4	10-20	-	-	-	Lagoon
	35	1.4	10	71.0	.56	58	Single stage
	35	2.9	10	53.0	.55	57	Single stage
	35	4.3	10	44.3	.74	52	Single stage
	35	5.8	10	55.5	.71	53	Single stage
Dairy manure	-	2.1-3.5		10-15			Single stage
		.6					Unmixed
		1.2					Mixed
	35	1.6	12	45.3	.06	77	Single stage
	35	1.6	20	44.7	.05	79	Single stage
	35	2.9	12	37.8	.04	77	Single stage
	35	2.9	20	53.3	.07	74	Single stage
Dairy bull	-	3.8	10	18-26		61-66	Single stage
Swine	-	3.8	10-15	49-61		58-61	Single stage
	35	4.0-8.0	10-20				Single stage
Poultry manure	-	2.7-5.0		50			Single stage
	35	1.4					Single stage
	35	2.9	10-15	57-68		52-58	Single stage

(a) Loading calculated based on ratio BOD_5 to VS equal to 1.0

Source: (69).

Table 13. General composition of biogas produced from farm wastes

Gas		%
CH_4	Methane	54-70
CO_2	Carbon dioxide	27-45
N_2	Nitrogen	.5 - 3
H_2	Hydrogen	1-10
CO	Carbon monoxide	.1
O_2	Oxygen	.1
H_2S	Hydrogen sulfide	Trace

Source: (29).

Table 14. Approximate daily production and heat values for biogas

Livestock 454 kg body weight	Approximate biogas production m^3/ day (20°C)(a)	Approximate heat value kcal	Approximate Equivalents			
			Liters gasoline(b)	Liters diesel fuel(b)	m^3 natural gas(b)	kg propane(c)
Beef	0.9	4,500	0.57	0.53	0.51	0.4
Dairy	1.3	6,800	0.87	0.76	0.77	0.6
Poultry broilers	2.6	13,900	1.74	1.59	1.56	1.2
Poultry layers	2.0	10,900	1.36	1.21	1.22	1.0
Swine	0.8	4,400	0.57	0.49	0.48	0.4

(a) Assumes biogas containing about 70% methane or a heating value of 5,339 kcal/m^3

(b) Heating values: gasoline, 7,990 kcal/l, diesel fuel, 8,860 kcal/l, natural gas, 8,900 kcal/m^3

(c) Propane, 11,660 kcal/kg

Source: (18).

Table 15. Cost of a community biogas scheme for irrigation

Capital Costs	Dollars
Digestors and gas holders (400 m^3/day capacity (a)	\$ 10,000
Compressor and engine	2,000
Land cost	500
Extension services, etc.	1,500
40 cylinders (0.03 m^3 capacity for irrigation fuel distribution) (b)	5,000
	\$ 19,000
Annual Costs	
Interest on capital	2,280
Depreciation (5%)	950
Cost of dung and crop residues (at \$2.00/metric ton) (c)	800
Labor and maintenance	1,000
SUBTOTAL	5,030
Sale of gas plant residues on the basis of nitrogen content (\$400/metric ton nitrogen)	1,000
Net annual cost for 1 x 10^9 Btu of gas	4,030
Cost per 10^6 Btu of compressed gas about (d)	\$ 4.50 (\$17.86 per 10^6 kcal)

(a) 400 m^3/day capacity enables production of about 1 x 10^9 Btu of methane per year (150 m^3 of biogas per day) on a schedule compatible with irrigation needs for a three crop per year cycle. The energy could irrigate from 10 to 100 ha depending on local conditions.

(b) 0.03 m^3 methane at 200 kg/c^2 is enough to power a 5 hp (3.7 kw) pump for four hr.

(c) 70% assumed to be dung and human excrement, 30% crop residues. Not all the available dung and human excrement can be used because gas output fluctuates seasonally. The dung and excrement not used are assumed to be composted.

(d) 10% of the gas is used for compression.

Source: (51).

Food from Waste and Nutritional Considerations

by George D. Kapsiotis

UNEP/FAO/ISS.4/09

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FOOD FROM WASTE AND NUTRITIONAL CONSIDERATIONS

1. INTRODUCTION

All of a sudden society found itself confronted by the energy crisis, by environmental pollution and by all kinds of shortages: food, water, fertilizers, etc. The shortage of food and the practically uncontrolled population growth posed the stark problem of survival for proliferating mankind. Apprehension is rapidly mounting at a rate faster than a geometric progression.

The struggle to produce more food has been intensified in all conceivable directions: plant genetics, animal husbandry, exploration of marine and inland water fish and animal resources, tissue culture, chemical synthesis, bio-engineering and food technology for food production and scavenging nutrients and food from effluents and wastes.

This paper concerns itself with the nutritional aspects - whether positive or negative - should food scavanged from or produced from waste be directed to human feeding. While the question of production of feeds from waste will be handled by others during the Seminar, this paper will discuss the implications of wholesomeness and safety of products derived from animals fed on feeds developed from waste, and intended for human feeding. Throughout the paper the assumption is - correct or not - that food is produced from waste economically, thus economic feasibility aspects will not be touched upon.

2. TYPES OF WASTES AND RECOVERY OF NUTRIENTS

The wastes with potential for processing and transformation into edible products fall into two general categories:

2.1 Effluents and other wastes of the food industry containing nutrients which can be recovered by physical and/or chemical processes. Typical examples in this category are:

(a) the whey of the cheese processing industry, which can be concentrated and dried as such, or its two main components which can be separated by ultrafiltration, for example, into two products: protein and lactose, or should there be no market for lactose, it can be converted enzymatically to galactose-glucose syrup which may find easy acceptability as a sweetener. The protein - dried material - can find ready application in food enrichment processes.

(b) the recovery of the potato protein from effluents of potato starch mills by ultrafiltration and concentration by reverse osmosis.

(c) the isolation and recovery of protein through regenerated cellulose ion exchangers from milk whey, effluents of abattoirs, soya concentrate plant, gelatine plant and fish, meat and vegetable processing streams. Also, the recovery of fat and proteins from fish, poultry and meat processing plants effluents. The fat and suspended material is removed by air flotation. The bulk of protein is recovered by flocculation and the rest through an ion-exchange bed. These last products however are intended for animal feeding.

(d) direct scavenging and up-grading into food under appropriate hygiene conditions of muscle material from the bones of fish after filleting and from the residues of the meat and poultry industry.

2.2 Effluents and other wastes containing nutrients which can be transformed into food products through bio-engineering processes. Some examples in this category are:

(a) Fermentation of the whey lactose - following the separation of the protein - into food grade yeast.

(b) Food yeast production from molasses.

(c) Symbiotic fermentation of effluents of potato starch, cassava starch and maize starch industries and conversion of the starch and other carbohydrates into biomass of Candida or Torula yeasts. The process consists of the symbiotic growth of two yeasts: the first, Endomycopsis, produces the amylases necessary to break down the starch to sugars and the second, Candida Utilis or Torula, which grows on the sugars as soon as they are produced.

(d) Production of fats by fermentation.

(e) Production by fermentation of food materials essential to the food industry such as acetic, lactic and citric acids as well as amino acids, i.e. lysine and methionine.

3. NUTRITIONAL CONSIDERATIONS

The use of nutrients, recovered from waste, or food products developed from them, in human feeding, is apt to face adverse reactions both from the regulatory authorities entrusted with the protection of the health of the consumer and from the consumer himself. Equally concerned is the public or private prospective investor involved in the creation of the facilities, or in the production of nutrients or foods from waste and in their distribution. For the two former it is imperative that convincing evidence be provided that the nutrient or the food is wholesome, that it is nutritious, that it is free from pathogenic and other micro-organisms and that it does not present any toxicological hazard when eaten. Forthe investor it is essential to know what conditions: legal, nutritional, microbiological, toxicological etc., the final nutrient or food should fulfill in order to satisfy the regulatory authorities and the prospective consumer. Only then would he be able to decide whether or not the process and/or the extent of investment required will be an adequately remunerative venture. It is therefore essential that agreed-upon procedures be established which would satisfy all the parties involved: regulatory authorities, industrial concerns and the consumer. To this end, the United Nations Agencies interested and involved in activities relating to the improvement of the nutritional status and health of populations in their member countries requested the then Protein Advisory Group (PAG) of FAO/WHO/UNICEF to look into the matter and provide the needed advice. The PAG, renamed recently Protein Calorie Advisory Group of the United Nations System, has been studying the problem through ad hoc working groups. Up to now the PAG has issued three Guidelines:

(a) PAG Guideline No. 6 for Pre-clinical Testing of Novel Sources of Protein;
(b) PAG Guideline No. 7 for Human Testing of Supplementary Food Mixtures, and
(c) PAG Guideline No. 15 on Nutritional and Safety Aspects of Novel Protein Sources for Animal Feeding.

In addition to this last guideline, the International Union of Pure and Applied Chemistry (IUPAC) has proposed a similar procedure which might be considered as a protocol whereas the PAG procedure is a guideline proper. The PAG Guideline No.15 aims at providing a checklist of possible tests, not a rigid set of required ones. Should a published guideline constitute a compendium of mandatory tests the acceptance of any new product would be precluded. And this for very good reasons. Firstly, at present costs, a rigid test covering all the requirements of the Guidelines may well cost over US$ 600,000. This is well justified if there are reasons for believing that a novel source of a food ingredient such as a microbial protein may present well-founded doubts concerning its safety in use. For possible investments up to $20 million or more a private concern or a public enterprise may think twice before investing. On the other hand the regulatory authorities of the country concerned will not grant the necessary licences for the production and use of the nutrient or food in question unless convinced beyond any possible doubt that the consumers' safety is in no danger.

The importance of testing the feed products, particularly those recovered by fermentation processes from waste materials, is particularly warranted due to the potential danger that mutations in the strain of the culture may appear or toxic metabolites may develop in the biomass which, while not affecting the animals fed on them during their short life term, might find their way into the food products derived from these animals, i.e. meat, milk, eggs. However, such elaborate testing procedures need not necessarily be applied to every new product: processes which might have detrimental effects have to be excluded, but the novelty of a process with its incognita will determine the extent and type of testing required. Sound judgement must be made on the product and product characteristics and on the novelty of process and risks associated with toxicity, pathogenic microorganisms and of course nutritional value. PAG Guideline 6 states that "Products intended for incorporation into animal feeds may not require as extensive testing as is suggested for human foods, but foods derived from animal sources must be considered from the viewpoint of the possible presence of residues in meat, milk or eggs transmitted from animal feeds". The minute traces of residues or contaminants in such foods cannot be identified by means of laboratory animal feeding studies. The detection of such substances suspected of being present would necessarily depend on highly sensitive analytical procedures. A new dimension which PAG considers to be of extreme importance is the testing for allergic reactions in addition to acceptability testing in humans of foods derived from products from animals fed with novel feeds.

My reason for insisting and elaborating on the PAG Guideline 15 is that there are indications that it is probable that the bulk of nutrients recovered from wastes, or derived from them, would be used in animal - including fish - feeding.

Guidelines 6 and 7, as their titles indicate, refer to the testing of novel foods for humans. While both Guidelines are essentially concerned with novel sources of protein, the testing procedures recommended apply also to foods as such, and specifically to nutrients and foods recovered from and/or processed from wastes. These procedures cover generally three areas i.e. safety, nutritional value and acceptability and tolerance.

4. SAFETY AND WHOLESOMENESS

The safety and the wholesomeness of nutrients and/or food products derived from waste materials can be predicted from information regarding the source, the processes used, the chemical and physical properties, content of microorganisms and their metabolites and the toxicological effects on laboratory test animals. The sanitation with respect to the source of the waste material and the aesthetic as well as the potential pathogenecity should also be taken into account. Serious problems may be raised by the content of non-fermentable or non-economically separable substances, such as lignin degradation products, heavy metals and agricultural chemical residues which may be toxic. The identity of the waste material has to be well defined and its reproducibility has to be well established and monitored. Should wide variation in the nature and components of the waste material occur, either seasonally or at unpredictable periods, the parameters of safety and wholesomeness might change drastically, the final product might not be the same, or the process might prove inadequate and uneconomic.

The recommended tests and procedures to be used for recovered nutrients or processed products may comprise:

4.1 Chemical analyses for proximate composition of the nutrient or the food product, for its content of non-protein nitrogenous components, for the presence of contaminants, residues of pesticides or solvents (depending upon the source of the waste material), for naturally occurring or adventitious toxins, and for food additives subject to tolerance limits.

4.2 Microbiological examinations for viable microorganisms, pathogens and non-pathogens, aerobic and anaerobic, vegetative and spore forming. In the case of products of microbial origin consideration should be given to the composition of the substrate on which the organism is grown.

4.3 Toxicological evaluation - Growth depression or any other adverse effect observed in the course of short-term nutritional assays should be viewed in the light of possible toxicity of the waste material source. In order to avoid confusing nutritional insufficiency with toxicity in safety evaluation studies, the basal diet to which the test material is added should itself be nutritionally adequate for normal growth and development of the animal species employed. Naturally occurring toxicants found in plants include carcinogens, goitrogens, lathyrogens, cyanogenetic glucosides and estrogens, the presence of which must be excluded from any waste material intended for the production of nutrients or food products. Waste materials exposed to warm, humid conditions which induce fungal growth must be examined for the possible presence of mycotoxins, such as the aflatoxins. Single cell proteins produced by growing micro-organisms on substrates of waste materials must be evaluated to establish the non-pathogenecity of the microorganisms or their metabolites, or possible mutagenicity into toxigenic forms. The spontaneous mutations of strains on a continuous fermentor could be a serious hazard should the end product be for human consumption.

5. NUTRITIONAL VALUE

The nutritional value can be predicted first from its chemical composition with particular emphasis on the amino acid content and availability and then by means of short-term rat feeding tests designed to estimate the efficiency of absorption and utilization of its nitrogen content. The presence and amount of non-protein nitrogenous components as glucosamines, amides and amines should be determined, particularly in the case of products derived from animal sources.

In single cell protein the content of nucleic acids should be determined as in many cases it can reach levels up to 15 percent. The high nucleic acid: protein ratios found in microorganisms may give rise to high blood levels of urea and uric acid and possibly to the accumulation of uric acid calculi in the kidneys. There are methods to reduce the content of nucleic acids in a biomass. This will have an effect on the cost and on modifying the functional characteristics but the PAG also draws attention to the possibility that when a biomass is treated in order to reduce its nucleic acid content this may lead to unforeseen human effects.

Although not relevant to the evaluation of the nutritional quality or safety of novel food products, it would be expected that studies on their functional characteristics (solubility, viscosity, wettability, etc.) would be conducted to establish their technological utility as food or food ingredients.

The chemical examinations yield valuable information for predicting safety and nutritional value. However, they cannot be considered substitutes for biological appraisals of protein quality through short-term growth responses of rats to the ingestion of the test food. It is not the purpose of this paper to discuss the various methods used, but a listing of some of them might be useful: Protein Efficiency Ratio (PER); Net Protein Ratio (NPR) and Net Protein Utilization (NPU); Nitrogen balance procedures; functional or metabolic studies.

6. ACCEPTABILITY AND TOLERANCE

Any undertaking involving human subjects should be preceded by the tests mentioned above and the satisfactory evidence derived from them on the safety and the nutritional value of the nutrients or foods obtained from waste. Human testing, according to the PAG Guideline 7, will fall into the following four main categories:

a) Acceptability and tolerance tests
b) Growth tests
c) Nitrogen balance measurements
d) Other criteria, essentially of a physiological nature, i.e. serum albumin, plasma amino acid and enzyme levels etc.

Whether the human testing has to be extended to cover all these four categories will essentially depend on the types of analytical data and experimental evidence obtained during the array of tests for the evaluation of the nutritional value and the safety for human use of the products. The tolerance and acceptability tests are quasi mandatory, whereas the tests falling under the other three categories are needed when the evaluation had left areas requiring further terminal testing.

It is unlikely that products developed from waste would stand as foods by themselves and that they would be offered to the consumer as such. The most probable way is that they would be used as ingredients to staples or other conventional foods to improve their nutritional value and/or replace partly or totally imported or expensive commodities constituting parts of the food. Therefore, another parameter has to be introduced in the tolerance and acceptance, that is the acceptance and willingness of the consumer to buy and use the food containing ingredients derived from wastes.

Finally, before attempting to introduce into consumption such foods, the food regulations in a country have to be adapted so that procedures for testing the wholesomeness, and for controlling the quality in general, be designed and promulgated for the protection of the consumer and prevent unfair trade practices.

The preparations for adapting food regulations, being a lengthy procedure, have to be arranged long before commercial ventures are to be initiated.

Microbiological Conversion of Wastes with Special Reference to the Application to Developing Countries

by W.R. Stanton

UNEP/FAO/ISS.4/10

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It is stressed that the present report is a personal statement, although it is presented by the author in his capacity as a Member of the UNEP/UNESCO/ICRO Panel on Applied Microbiology. The author is indebted to Members of the Panel for discussions and documents relevant to the subject of utilization of agricultural residues. Discussion has also been held with Prof. A. Fiechter (E.T.H. Zurich), Prof. Bullock (Manchester) and a number of commercial institutions.

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Patent Coverage

Many of the processes described herein are partially or totally covered by patent rights. Further, no detailed published data is available on some of the processes most likely to have an impact in the next two decades (see Appendix I). Patent coverage is a mutual protection to the inventor and developer and should not discourage the latter from considering such processes. Commercial companies are anxious to see their processes developed and are therefore willing to co-operate in exploitation. However, the choice of process is a matter for the local developer and should be based on a comparative assessment. Detailed citation of patents was not possible in this review, but the writer will be pleased to supplement the information herein upon specific enquiry (see Appendix I for examples).

Summary

Microbial processes for abating pollution or the recovery of useful material from agro-industrial residues are only one sector of an array of options for by-product processing. Only under special circumstances do they compete economically with chemical processes for the production of industry's bulk simple organic chemicals.

Employment of microbiological processes should be viewed as part of the strategy of planning agro-industrial development. The ability of these processes to assist the strategist lies in the special features they possess for making complex transformation of materials with a minimum expenditure of energy and a high degree of selectivity.

Application of microbiological processes to novel situations is not simple. However these processes have evolved in the past alongside agriculture and food technology and current advances in allied disciplines, both in the sciences and social sciences, have provided many opportunities for extending the harnessing of the microbe.

The report pays special attention to the strategy of microbial degradation of ligno-cellulose; the recovery of fungal yeast, bacterial and algae products from effluents; the digestion and liquefaction of solid residues; the conservation of animal products by lactic fermentations and the treatment of noxious wastes, excreta and dilute wastes by variations on the oxidation pond process. Attention is drawn to the fact that currently the rumen is the central processing unit of one of the most widely used, and successful, small-scale processes.

Hazards of microbiological processing are noted but the ability of microbial processing to detoxify, preserve and repel pathogens is also mentioned.

Low capital investment, use of local raw materials, low energy requirement are advantageous features of microbial processes which aid their successful incorporation into the economy of small communities.

Extension work and training are roles of the International Agencies such as FAO and more particularly of the specialist body, the UNEP/UNESCO/ICRO Panel on Applied Microbiology. This Panel now has a world-wide network of permanent centres and a regular programme of Regional Training Schemes at which special attention is given to the microbiological processes applicable to the products and residues of agro-industry.

Ultimately the processes are required to be commercially viable. Industry can provide various services and items of equipment although the type of product and market may differ from that of large-scale usage.

In discussions after the paper special attention was paid to toxic hazards, commercial viability of processes, the effect of world shortages of fermentation materials such as nitrogen and phosphorus.

Section 1: INTRODUCTION

1.1 Microbiological Process Feasibility

For the application of a microbiological process a special set of criteria needs to be considered. There is a great danger in opting for such processes on the grounds of apparent simplicity, economy in the use of energy and low capital cost.

The 'simplicity' may be the unwritten skills of generations of people operating a village process and interference with, or modification of, any part of the process may upset the system as a whole. Nevertheless, by a process of technological evolution, village processes have been selected for robustness and can be modified. Examples of this type of change, currently under study, are the transfers which have taken place in the last 2,000 years (or perhaps more in view of recent archaeological finds in Thailand) between the hearth of Far Eastern food technology in China and Southeast Asia. In these transfers the technique has remained, but both substrate and organism have changed. The important consideration is that, because of its inherent merits, the process has survived.

1.2 A check list of factors to be considered

Listed below is a table (Table 1) based on a set of questions originally formulated by Imrie (1976) which need to be answered in the formulation of a new microbiological process with special reference to the production of SCP for animal feed. The purpose of the original check list was to form a prelude to a management game for teaching post-graduate students in a UNEP/UNESCO/ICRO (Bangkok 1976) training course. Too often has a country attempted to adopt a process on the basis of 'sales talk', or because it happens to operate in another country where it had been seen by a visitor and he had returned home both full of enthusiasm and with the power to direct its adoption.

The list raises questions to guide to assessing the scope and limitations of a **process for microbial use of carbohydrate waste.**

Table 1

Potential of Agro-Industrial Wastes as Raw Materials for Fermentation A Critical Assessment*

*The following questions are a development of the thesis introduced by Loehr (UNEP/FAO/ISS, 4/02 - Jan. 1977) at the symposium and iterated in the author's introduction to his paper on the survey of agro-industrial wastes in Africa (UNEP/FAO/ISS, 4/07 - Jan. 1977)

A. FEEDSTOCK

a) Carbohydrate

i) soluble or insoluble, therefore will it need treatment before fermentation?

ii) Sugars normal, or abnormal? Some sugars are not fermentable by most SCP organisms.

iii) Concentration: is there enough carbohydrate in the waste to support an economic fermentation without C-source supplementation? Remember that for best growth C:N ratio must be optimized (also see section on Nitrogen).

b) Fat (Lipid)

- i) Will this interfere with fermentation by chosen micro-organisms?
- ii) Is there any advantage in choosing an organism with lipase activity?
- iii) Rancidity?

c) Nitrogen

- i) What fraction is 'crude' protein in contrast to 'useable' protein?
- ii) What is the C:N ratio?
- iii) What is potential toxicity of N. fractions?
- iv) What is the amino acid spectrum in comparison with that of a reference protein?

d) Other components

- i) What other components might interfere with use of waste as a feed? Polyphenols and tannins in some fruits are known to inhibit digestive enzymes of ruminants. Cyanide compounds may be present in the raw material. Will they be destroyed or merely released?
- ii) Can the potential SCP organism break down these inhibitors? Is it itself inhibited by them?
- iii) Will the secondary compounds act as supplementary growth factors for an organism which can metabolize them?

B. ECONOMICS

a) Cost

- i) If the waste now has a zero value, what will it cost once a use has been found for it?
- ii) If it is an enviornmental pollutant, what does it cost to treat it or remove it? Is that a 'negative' value to the main product processor?
- iii) Will you have to pay for its collection and shipment to your plant? (see section on Availability)

b) Availability, Abundance

- i) Is the waste seasonal?
- ii) How much is produced at any one place?
- iii) What total quantities are available?
- iv) Must it be collected and processed before it is available to you?

c) General

- i) Why ferment it? Maybe the waste can be used as an animal feed, either on its own, or by mixing with something else.
- ii) What are the socio-economic advantages/disadvantages to using the waste? For use the waste may require changing the farmers' attitude to agricultural practice. This may be difficult.
- iii) Are there any political considerations to the use/non-use of this waste? (or social or ethical barriers?)

C. MICRO-ORGANISM

Primary Screening

a) Protein Content of Cells

If it has to compete with alternative protein sources for animal feed the product must be capable of being compounded to an adequate protein level.

b) Growth Rate

An efficient process will require a rapid growth rate to minimize retention volumes.

c) Carbohydrate Conversion Efficiency

If one is paying for the waste, then an efficient conversion of carbon to cell dry weight is a consideration, as distinct from transport bulk storage factors for a 'no cost at site' material or a 'negative cost' pollutant.

d) Calorific Value

This must be at least equal to that in alternative animal feeds at the same price after compounding.

e) Toxicity

(This is a very complicated question since it is toxicity at the point of consumption by human beings which is the ultimate criterion. This question therefore affects choice of organism, process and animal food.)

D. PROCESS TECHNOLOGY

a) Supplementary Nutrients

- i) Does the feedstock for its fermentation derived from the waste require supplementing with additional nutrients? What are they? Are they available locally?
- ii) How much will it cost to supplement the feedstock?

b) Selective Advantage or Medium

- i) Does an organism have a selective advantage in growing on this substrate? This may be because the substrate inhibits other competitive organisms, or because the chosen organism produces conditions which do not favour competitors. Thus *Aspergillus niger* will produce a rapid shift in pH of substrate toward 2.0, which effectively prevents competition.

  High growth rates and high innoculation rates can be used to give an organism a competitive advantage.
- ii) Can the organism grow in high salinity? Sea water could be used as the liquid phase for the substrate in water deficient areas. Salt has been traditionally used as a fermentation directing agent.

c) Growth Rate

As a general rule one should select the faster growing of two organisms, if other parameters score equally well. Remember that the overall rate of protein production from a manufacturing unit is directly proportional to the growth rate of the organism, since this is the rate-limiting step in the whole process. (see self-selection processes under 'continuous culture' and 'effluent treatment'.)

d) Temperature Tolerance

Favour an organism which grows well at temperatures near the ambient for the local climate. Preferably an organism that has a wide tolerance to temperature changes. Remember microbial growth is exothermic and cooling water may not be available at the temperature needed.

e) Yield

For an optimal yield of biomass, on the basis of the carbon and energy supplied, the other nutrients must be supplied in balanced proportion to allow rapid growth and prevent the accumulation by the organism of excess storage carbohydrate and lipids. The critical yield, in terms of economics, is the amount of biomass produced per unit of substrate added to the medium. This means that the chosen organism must be capable of growing under conditions of balanced carbon and nitrogen limitation rather than that of limitation due to other nutrients.

f) Protein Content

It is not true that it is best to select the organism producing the highest yield of protein. The final value of the protein must be considered in the light of the total cost of preparation per unit weight of nutritional protein. The ultimate criteria being the overall economy of the process and utility of the product.

g) Effects on Quality of Post-fermentation Processing

It costs money to separate and dry micro-organism from a fermenter. How easy is it to separate the cells from fermenter broth? Some organisms form a "Cake" resistant to drying and this impedes drying efficiency. Some organisms retain water and require high temperatures to remove it. This may influence quality adversely. Why not feed the whole broth or solid?

h) Nutritional Value

The organism is being grown to be eaten by animals. It should have good nutritive value. (This contrasts with the philosophy applied to a number of secondary product fermentations used for food by man.)

i) Acceptability

If the product is unacceptable to animals you have wasted your time.

j) Safety

The micro-organism must be non-toxic, or liable to give rise to **toxins** or toxic strains, and not cause allergies or other effects during handling and compounding. It should not change adversely the marketable characters of the animal flesh after slaughter. The product of the fermentation should not contain any toxic material which can pass unchanged through the animal fed on it to the human recipient. (This is a hazard in the use of fungi which is discussed later in the paper.)

E. PROCESS ENGINEERING

a) Type of Fermentation

i) Continuous cultures seem attractive because of the high productivity per unit volume. Remember that this means, in liquid culture, a high dilution rate and in turn higher separation costs per unit of dry cells produced. A 'fed batch' process may be preferable, or a fixed substrate process not requiring a fermentation.

ii) Does the country have the engineering technology and infrastructure to support a sophisticated process?

iii) Is any one prepared to make the high investment in plant for a sophisticated capital intensive process?

iv) How does one reconcile continuous culture with a discontinuous supply of waste material?

v) Continuous cultures are sensitive to minor changes in substrate composition. How will this be reconciled with an infinitely variable waste input?

vi) Continuous processes are normally highly automated. How does this degree of automation fit with the labour policy of the country? Perhaps creation of new jobs is more important than a capital intensive/machinery intensive process. (A sewage system is an example of a possible non-automated continuous culture fermentation system which can utilize waste carbohydrate to produce fungi, yeasts, bacteria or algae. The relative merits of various systems are discussed at the end of this paper.)

b) Separation

The nature of the organism will decide this to a considerable extent. Bacteria may need centrifugal separators, which are made by relatively few countries. They will need to be imported.

Yeasts may need centrifugal separation, although other techniques are available, e.g., flocculation, froth flotation, filtration using filter aids.

Filamentous fungi are relatively easily separated from a broth by straining, or filtration, but control of their growth in fermentation is more difficult than that of unicells.

c) Sterilization of Medium

Is asepsis needed? Perhaps the growth activities of the chosen organism will prevent excessive contamination. Perhaps a minimal level of contamination is acceptable in the final product provided no toxicity is introduced.

d) Design of Fermenter

i) As an axiom, aim to use the simplest design of fermenter based on the cheapest available construction materials. Have wood, concrete, plastic holes in the ground (e.g. as for silage) been considered? What is lost in efficiency may be gained in reduced capital costs and the ability to do-it-yourself.

ii) Investigate air lift and aspirator fermenters, surface and 'fixed cultures' (koji/tempe) method. The supply of agitation and air adds to capital and recurrent costs.

e) General

i) ALWAYS look for the lowest technology commensurate with the commercial and technical objectives.

ii) Investigate "Village" industry to find out how they have solved similar problems, e.g., Cassava processing in Amazonas. The best way to develop a fermentation may be by developing a process locally understood.

iii) Investigate the logistics of the problem. Two small plants may be more efficient than one large one if the waste is widely distributed.

It must be emphasized that this particular check list is a pioneer effort. It may be, on the basis of study, that the decision is made to alter the process producing the waste, or embark on a training programme so that the local experts can themselves develop and modify the process. In the sections which follow, consideration will be given to the current state of technology in the microbiological utilization of specific groups of wastes.

A summary and discussion have been added, the contents of which are based on discussion at the symposium.

Section 2: CELLULOSIC RESIDUES

The most important agro-industrial waste in world terms is cellulose, (Humphrey, 1976), usually in the form of ligno-cellulose combined with a variety of secondary compounds. Microbiologically it has proved to be the most difficult material to treat effectively, to provide a useful concentrated food, or other useful product. Conversely, it has been one of the earliest materials to be used by man directly as a food material using microbiological methods. This has been:

via ruminant animals
via mushroom production
via composting

Table 2 below gives data presented by Humphrey (1976) to reinforce the argument on relative abundance of cellulosic residues in comparison with other forms of agro-industrial waste. Developing countries do not have wastes of this magnitude, in general, though their capacity to produce wastes increases as their production increases.

Table 2

Quantities of Wastes Available (USA data, Humphrey 1976)

Waste Type	10^6 Tons/Year
Agricultural and Food Wastes	400
Manure	200
Urban Refuse	150
Logging and other Wood Wastes	60
Industrial Wastes	45
Municipal Sewage Solids	15
Miscellaneous Organic Wastes	70
Total	940

2.1 Cellulose Digesting Animals

2.1.1 Ruminants (Review reference: Cuthbertson, 1969)

The system which develops in the gastro-intestinal tract of ruminant animals is still the most important fermentation method for the conversion of the cellulosic materials and accessory substances into useful food materials. Although this fermentation system can be subjected to abuse in the living animal by providing unusual substrates in varying proportions, it has proved most difficult to create an equivalent in vitro system, as has been shown by the work of Hungate, Hobson and others.

Through natural selection the ruminant stomach has evolved to achieve an efficiency of microbial digestion of plant fibres, in the presence of a contaminant material, which is truly remarkable. At the same time, it achieves a biosynthesis of microbial polysaccharides, proteins and certain vitamins.

2.1.2 Other Animals Which Digest Cellulose

2.1.2.1 Insects

Cellulose digestion, via microorganisms, also occurs in the gut of certain insects. These insect digestion systems have not received as much attention as has been applied to the rumen though it appears to be via intestinal bacteria (Serzedella, 1976). Nevertheless, the use of insects as a source of useful proteinaceous biomass from cellulosic wastes should not be overlooked. The author has, for instance, undertaken preliminary investigation into the utilization of a large weevil larva, Rhyncophorus species, which feeds on the cut stump and residues after the extraction of starch of sago palm and is regarded as a delicacy by the local people of Sarawak, Borneo. Similarly, termites are widely consumed in Africa, though their culture would not appear to be as easy to control as that of the aforementioned Rhyncophorus species.

2.1.2.2 Snails

The giant african snail is also a cellulose digesting animal and the author was surprised in his recent visit to Ghana to see how the economic value had increased since he was resident in West Africa in the 1950s. Farming these snails has been discussed, but never taken up as far as the author is aware. Snail digestion is not strictly microbiological.

2.1.2.3 Cellulose Digestion by Fish

The grass carp and certain other fish species appear capable of digesting cellulose. How far this digestion is directly due to the fishes' enzymes and how far by the intervention of micro-organisms in the alimentary tract of the animal is not always clear. Investigations in our laboratory, by dissection of the gut of carp, tilapia and other species has shown that, whereas in some of the carp species the cell walls of ingested algae are dissolved, this process does not occur in the gut of tilapia, although tilapia are widely recommended as a fish suitable for culture in eutrophic waters, such as algae-containing oxidation ponds.

2.1.3 Recycling cellulosic faeces

Although the rumen is recognized as the most efficient natural form of cellulose digestion, nevertheless it has been demonstrated that its efficiency can be improved by careful balancing of the diet of the animals concerned and also by recycling the excretary products, with additional nutrients to aid in the digestion of the recycled material. In Sweden, for instance, experiments have been conducted on the ensilage of cow-dung with beet molasses for use as a winter feed. Loehr (this Symposium) cites a number of references to similar work in the U.S.A.

2.1.4 Improving rumen function

In the tropics, most of the cellulosic material available in the dry season is extremely low in nitrogenous residues. The utilisation of cellulose present in this material can be substantially improved by the addition of a nitrogen source such as urea to the diet. In areas where it is available, chicken manure is a valuable alternative source of nitrogen, though it has a pathological danger if not pre-treated. This danger can be reduced by pre-fermentation of the chicken manure, aerobically, prior to recycling. This has the advantage of breaking down some of the keratin in the material and pre-digesting part of the cellulose. Rhizopus sp., such as are used in tempe, will grow on moist chicken dung and this fungus has extra-cellular cellulases. Lactic (anaerobic) fermentations have also been employed in breaking the pathogen cycle in recycling animal excreta, but the heat production of these fermentations is lower and elimination is dependent more on acidity and microbial antagonism than thermal inactivation.

2.1.5 Silica content

However, both chicken manure and the other cellulosic wastes, such as the cellulosic grass wastes, suffer from a high silica content. This is frequently the limiting factor in their use. A cellulosic waste of a lower silica content, but having complications in other directions, is that derived from wood. In this type of material, the cellulose content may be as low as 40% though normally nearer 70% (King and Smith, 1975), the remainder being made up of lignin and a variety of fermentation resistant compounds. It is possible to remove the lignin microbiologically. At present this is only a laboratory-scale process.

2.2 Non-Ruminant Microbial Utilization of Cellulose

2.2.1 Fungi

Much work has been done by the Natick Laboratory U.S.A. (Mandels and Sternberg 1975) and in Japan on the use of the fungus Trichoderma viride as a source of cellulolytic enzymes. High efficiency of conversion of pre-treated cellulose to glucose has been achieved by these enzymes. Preparations from this fungus can digest, almost quantitatively to glucose, alkali pre-treated cellulosic materials, Fig. 1 (Rolz, 1975). A typical flow chart for a system employing fungal cellulase is given in Figure 1. However the efficiency of Trichoderma processes depends on expensive chemical pre-treatment by acid and alkali, together with sterilization and the overall economics compare unfavourably with direct chemical digestion to glucose using the Porteus process, for instance.

More recently, Hofsten & Hofsten (1974) and others have been working with the basidiomycete Sporotrichum pulverulentum (syn. Phanerochyte chrysosporium). The preferred method for the production of a microbial biomass, using this fungus, is in liquid culture with a mixed substrate containing both starch and cellulose derived from milling residues with added nutrients. This is a practical outcome of work on white rat fungi originating from Waksman (1944) and followed by extensive work of Eriksson and others in Sweden (reviewed by Wang, 1976).

2.2.2 Bacteria

A high degree of digestion has been achieved, using pre-treated bagasse, by a group of research workers in Louisiana using a bacterial system of two organisms (Srinivasan and Han, 1969). The first of which, a Cellulomonas (ATCC 21399) converts the alkali pre-treated cellulose of the bagasse to cellobiose and the second organism, Alcaligenes faecalis, transforms this polysaccharide into glucose and microbial biomass.

2.2.3 Actinomycetes

Humphrey et al. (1976) have considered the use of actinomycetes as cellulose digesting organisms and information comes from China that these organisms have been used to advantage in composting, but no details are available. This group of organisms has theoretical interest for cellulose digestion particularly the thermotolerant species, Thermoactinomycetes. However, the work is still in the laboratory stage, the problem being conversion efficiency and conversion percentage. A particular difficulty is the maintenance of high growth rate and this requires maintenance of a high dissolved oxygen in the medium.

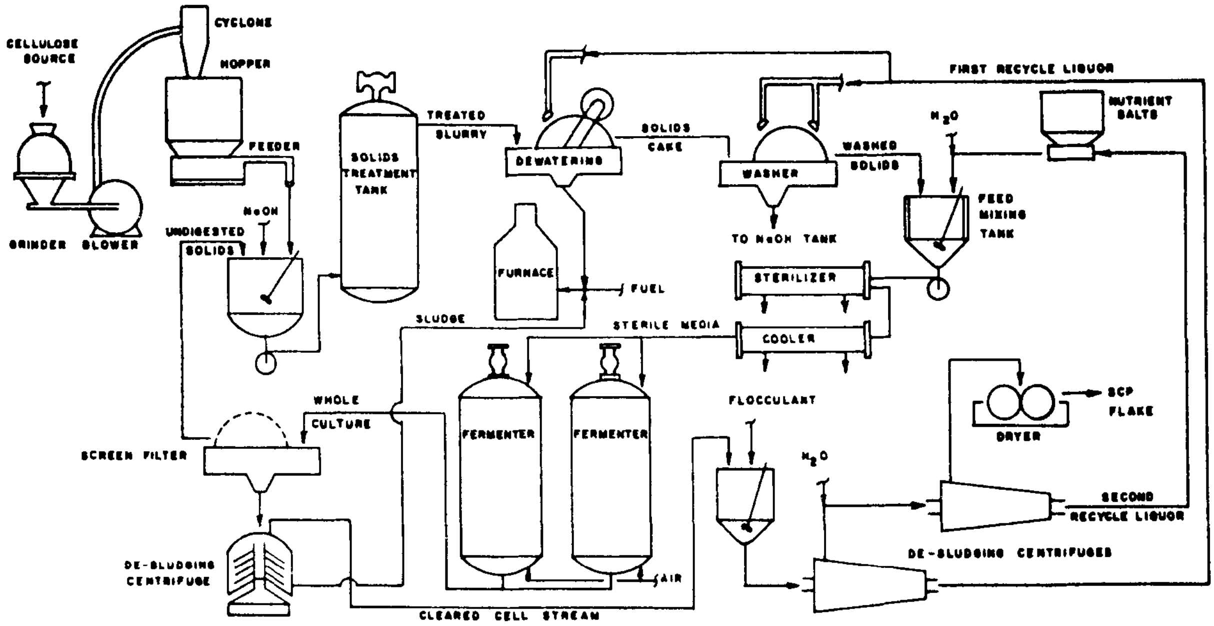
2.2.4 Tropical Basidiomycetes

Wang (1976) has made a search for basidiomycetes, which might be substitutes for the present limited range of useful organisms for degrading ligno-cellulose. In the wild, there are a large number of wood-attacking basidiomycetes and, under equatorial conditions, the growth rate of some of these species is high. For this reason, investigation has been concentrated on equatorial basidiomycetes, amongst which it has been found that the fungus Volvariella has properties which make it useful for the digestion of straw and wood wastes, using a comparatively short fermentation time - as short as four days - for the partial conversion of the raw material.

2.2.4.1 Predigestion by Basidiomycetes

Imre and Petofi (1967) used Agaricus bisprous for the partial digestion of cellulosic material prior to feeding to animals, but this is a comparatively slow-growing organism. A virtue of using these higher basidiomycetes is that they are food organisms in their own right. There has been no evidence of toxic compounds produced in the course of the fermentations in which they have been used. Amongst others which showed promise, amongst the ligno-cellulose digesting equatorial basidiomycetes, were Pleurotus spp and further investigation of their use is recommended.

FIGURE 1



Proposed flow chart for a plant to produce single-cell protein from cellulose residues.

based on Dunlap (1975)

2.3 Mushroom Production: Choice of Species

Of the many thousands of species of basidiomycetes occurring in the wild only some 20 to 30 are actually used for food.

2.3.1 Nutritional Value Versus Economic Value

Conversion of fixed carbon in the substrate to digestible carbon in the product by basidiomycetes is poor, especially in solid substrate culture and, although mushrooms may at times comprise the major component of a diet in the form of bulk, as far as the author is aware no food system exists in which basidiomycete-mycelium is the main component of the diet. Nevertheless, the basidiomycetes provide a product which is, for many of the species cultivated, capable of being processed so that it is easily transportable, with a high value per unit weight.

Consideration of utilization of cellulosic waste via mushrooms should therefore be seriously considered because it augments the cash income of rural people.

2.3.2 Composting (Solid substrate fermentation)

2.3.3 Combined Mushroom and Animal Feed Production

It appears possible to enhance the digestibility and nutritive value of the substrate and produce a separate microbial biomass. It is feasible to use a cellulose base to culture a quick growing mushroom species and, at the end of the mushroom culture, use the residue from the compost for animal feed. For this purpose Agaricus bisporus is relatively unsuitable, though it has been used, and quick growing species, such as Pleurotus (Zadrazil, 1976), are favoured.

The nutritional value of these fungi, although not high, are well known and they are known to be free of toxic components. However, much has to be done at the pilot plant stage before these processes can be considered as commercially practicable.

2.4 Two Stage Fermentations Using Basidiomycetes

2.4.1 Protein Content of Basidiomycetes

It has been mentioned in the previous section that basidiomycetes can use the world's most abundant source of fixed carbon. However, they may not be the most appropriate organisms to convert that fixed carbon finally into microbial biomass, as their protein contents are relatively low in comparison with other groups of filamentous fungi and yeasts. Rarely do the sporophores of basidiomycetes achieve a crude protein content (on the basis of amino-nitrogen) in the mycelium higher than 25% on the basis of dry matter and figures of the order of 15% are common. By contrast other fungi used for single cell protein culture, such as Fusarium spp (Anderson and others, 1975) and even Rhizopus spp (which also has cellulitic activity), have crude protein contents of over 40%. The role of the basidiomycetes therefore is in a two-phase system in which their function is to pre-digest the substrate for use of the products of digestion by a non-cellulolitic organism with a higher protein content and growth rate.

2.4.2 Growth Rate and C:N Ratio in Basidiomycetes

Most basidiomycetes are exacting in their carbon to nitrogen ratio. They favour naturally a high carbon content in the medium. These conditions are however unfavourable to the production of large quantities of mycelium in relation to the substrate. Commonly, in the literature on mushroom, ratios of 1 unit of sporophore mass to 20 units of substrate are to be found, whereas on a theoretical basis, it should be possible to produce 1 unit of microbial biomass per 2 or 3 units of cellulose consumed. A further disadvantage is that most of the basidiomycetes are slow growing, though it has been shown that there are exceptions to this rule to be found in such genera as Volvariella.

2.4.3. Cellulase Substitution Fig. 2 (Rolz, 1975)

As an alternative to the direct use of a culture, it is possible to use the cellulolytic enzymes from cellulase active fungi, such as *Trichoderma viride*, to digest the cellulosic material. This is now a commercial development in the United States and Japan and is useful in special industrial situations. As far as the author is aware this process has not been widely adopted in other territories.

Nevertheless, in view of the combined ligyolitic and cellulolytic properties of many basidiomycetes, it is possible to envisage a fermentation in which the carbon to nitrogen ratio and the organism are both altered after the first stage to give a more effective yield and higher protein on biomass per unit substrate consumed. This type of process, as an alternative to chemical digestion, is still not in commercial production, but research is being conducted on it at a number of centres. This is the equivalent to the SYMBA process (section 3) in which cellulose replaces starch. (Since this paper was presented the author has found reference to a process of wood degradation operated by farmers in a sub-alpine area (evergreen moisture forest) which envelops a natural symbiosis for wood degradation for cattle feed. The yeasts are allied to the flax-retting yeasts and utilize lignin breakdown products.) (Kahlwein, 1963) See Appendix Viable Processes.

In view of the economic value of mushrooms these come within the definition of fermentation methods for the utilization of cellulosic wastes and the production of such rapid growing basidiomycetes as *Pleurotus*, especially with the development of sporeless strains (Eger, 1976) promises a method of utilizing waste straw materials, giving a high conversion efficiency of product to substrate. This organism is easily cultured. It is particularly fast growing and easy to culture (Essex, 1974). It can even fructify in bottles on steriled chopped rice straw. Thus starter cultures are easily maintained.

Because of its rapid growth and intense production of mycelium the cultures are less prone to invasion by other fungi than those of *Agaricus*, or even *Volvariella*.

2.5 Conclusions

It appears that there are a variety of approaches (Torev, 1973; King and Smith, 1975; Powell and Bullock, 1976; Porteous, 1976) to the utilization of cellulosic wastes by micro-organisms. For the immediate future for application to developing countries it appears that improved ruminant nutrition and the 'basidiomycete sporophore + compost-to-stock' methods are the most easily applicable. Neither of these methods require heavy capital investment, technological resources (Powell and Smith, 1976) beyond the capacity of the existing training systems, or expensive pre-treatment of the waste. In the search for micro-organisms which are capable of digesting ligno-cellulose the requisite strategy is different from that of screening for extra-cellular cellulose activity and it is concluded that more emphasis is required on screening for ability to digest *native* ligno-cellulose.

Section 3: STARCHY WASTES

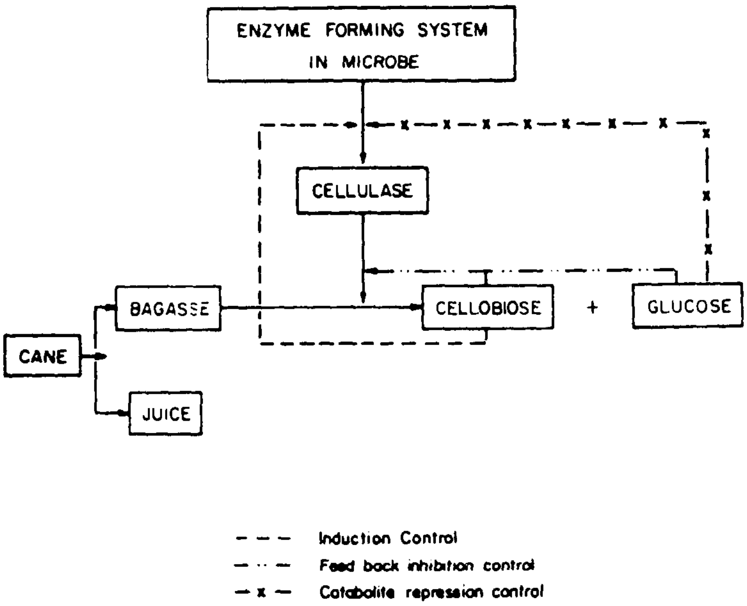
Starch wastes, whether in solid or liquid form, are a far more attractive proposition for microbiological processing than cellulosic wastes. There are, in consequence, a number of processes at the stage of full scale development which utilize the starch as the active component in a waste material. The restriction on full utilization of these processes has been not so much the technical difficulties at the pilot plant scale as food and drug regulations and medical concern about the possible hazards to health of man and animals arising from the compounds which the end-products might contain.

3.1 Food Safety Restrictions

3.1.1 Toxin Producing Fungi

Amongst the organisms preferred for starch degradation and utilization, from a technical point of view, are members of the genera *Aspergillus*, *Penicillium* and *Fusarium*,

FIGURE 2



based on Srinivasan (1969)
Rolz (1975)

strains of all of which fungi can produce highly toxic compounds which subsequently could appear in the ultimate preparation. Food safety becomes, therefore, an important issue when these organisms are used.

3.1.2 Non Toxic Fungi

For this reason, the author has favoured in his own research the use of some of the mucoraceous fungi, which are the natural fermenting agents in a wide variety of fermented foods such as the 'two-stage bantu beer' fermentations of Africa and the TEMPES AND RAGIS of Southeast Asia. In the tempe fermentation in particular the microbial biomass constitutes a significant proportion (10%-15%) of the dry matter of the final product. Although occasional doubts have been raised on the absolute food safety of mucoraceous fungi, there has been a general consensus of opinion amongst the scientists working in this area of study that the Mucoraceae are a particularly innocuous family of fungi as a whole from the point of view of potential hazards due to mycotoxins.

3.2 Relative Growth Rates of Different Fungi

Unfortunately, in liquid culture, members of the genera Aspergillus and Fusarium have been shown to be superior to the genus Rhizopus and other mucoraceous fungi in their rate of growth and in their ability to grow under adverse conditions, such as low pH and high temperature. Under industrial conditions, where the whole of the fermentation can be carefully controlled, they have been the preferred organisms for development of SCP processes. It is admitted that the genera Aspergillus and Penicillium are also widely used in food processes, but wastes in general do not satisfy the criteria of standard composition and regular supply.

3.3 Commercial Processes

3.3.1 Liquid Culture of Fungi

Substantial research has therefore been conducted in recent years into the testing of the food safety of the selected strains of the former genera and the preliminary tests have shown that they are food safe. The genus Aspergillus has been favoured by the IDRC team (University of Guelph, Canada) whereas Rank-Hovis/**Dupont**, U.K. and Tate and Lyle (Righelato et al 1976), have favoured a Fusarium (Anderson and others, 1975). The former now have pilot plant equipment in operation in Latin America using cassava meal (Manihot esculenta) as the substrate. The fermentation liquor is maintained at a low pH by the addition of sulphuric acid (Reade and Gregory, 1976). This presents a hazard when the effluent is subsequently discharged.

3.3.2 Harvesting Microfungi from Carbohydrate Liquors

The filamentous fungi have mechanical advantages over unicellular micro-organisms from the point of view of harvest in that the products of fermentation can be gathered on stainless steel or nylon sieves, or even on 'string' filters, whereas true unicellular cultures require precipitation, filtration or centrifugation. It is therefore possible to operate filamentous-organism cultures at relatively low concentrations of active component of the substrate. For instance, the 'fruit' waters from starch factories containing less than 0.5% of starch can be effectively treated by these means, provided that other features of the process do not intervene to make the cost of preparation of the fermentation liquor too expensive.

3.4 Starchy Effluents

3.4.1 Avoidance of Sterilization

It is desirable, from the viewpoint of process economics, to avoid sterilization of the large quantities of liquor involved in starch effluent processing. Acidification may not be practical as the volume of these liquors would demand excessive quantities of acid to bring their pH to the necessary operational level. An ecological approach is therefore indicated, in which a naturally occurring organism is encouraged to become the dominant one.

3.5 Oxidation Pond Fermentations

As an alternative to utilizing the starch and sugars by a heterotrophic fermentation, our research has been directed to the use of 'septic' aerobic/micro-aerobic fermentation systems, using bacteria in the first stage. In this stage the carbohydrate mixtures are converted, because of the limited air supply, to ethanol and organic acids, which compounds are, in turn, consumed by an appropriate algal flora.

3.5.1 Growth of Chlorella

It so happens that the dominant species in the southern monsoonal and equatorial conditions of Asia which arises in dilute ethanol/organic acid containing effluents, that is oxidation ponds, is the alga *Chlorella* and effort is therefore being currently applied to the most economical method of harvesting this organism. Too high a loading or too highly acidic conditions are not tolerated by the *Chlorella*.

It has been shown that *Chlorella* is nutritionally valuable and has an international market value in excess of its value as a single cell protein source. Where, however, the concentrations of nutrients are too low to give a density of algae (1×10^7 cells/cc) which can be economically harvested, the ultimate stage of such a waste processing procedure is to utilize the eutrophic water for fish farming. This process is in effect the manipulation of a 'facultative' oxidation pond.

3.6 Concentrated Starchy Liquors

For more concentrated starchy effluents (in the range of 0.5% - 2% concentration or higher (Labuza, 1975) there are advantages in using a yeast as the ultimate biomass produced. However, since the common yeasts are not capable of digesting starch directly, it is necessary to employ a primary phase in which the starch is converted to sugars either by chemical, enzymic or biological means.

3.6.1 Chemical Digestion

In the chemical process the starch is hydrolysed by hydrochloric acid, which is subsequently partially neutralized with caustic soda. This is still the most widely used and cheapest method for the production of glucose syrups from starch.

3.6.2 Enzymic Digestion

Strenuous efforts are being made to improve the economy of enzymic conversion by the use of immobilized enzymes.

3.6.2.1 Use of Immobilized Enzymes

A recent report of this application of immobilized enzymes has been given by Heden and others (1975) and enzymes are now being used in effluent treatment. Although the techniques of preparation of the immobilized enzymes requires highly refined technology, nevertheless the products are stable and can be subjected to chemical abuse from the variety of accessory substances in the starchy liquors. Furthermore, it has been demonstrated that an immobilized enzyme system, based on cellulose fibres for instance, can remain stable and active for a period of six months or more.

3.6.2.2 Use of Immobilized Enzymes in Diluted 'Fruit' Waters and Self-Generated Enzymes for Extraction of Wastes

The great advantage of using immobilized enzymes is that the enzyme is not diluted and lost in dilute waste waters. Amongst the fully biological systems of starch digestion, which has been employed for thousands of years, is the Japanese KOJI process. In this process, the starchy substrate - usually grain, but any granular waste may be used - is encouraged to grow a fungus such as an *Aspergillus*, or *Rhizopus* sp. This mixture of fungus mycelium and substrate is subsequently autolysed by immersion in water to give a sugar syrup. The enzymatic activity of the original KOJI mixture is capable of converting several times (>4X) its own weight of starch when immersed in a starchy slurry. At

At present, it is a relatively expensive method of generation of a glucose syrup, but nevertheless has attraction for waste utilization in that the first stage can be replaced by a starchy waste, such as that from the production of tapioca or sago (Metroxylon sagu) starch. The culture grown on this waste, can then be used to digest the residual starch in the fruit water, provided that the latter has been prepared in concentrated form by a suitable counter-current process.

This method may also be used to extract starch, by leaching in the form of sugars from fibrous residues. This is analagous to the malting process. The resulting liquor can then be used for fermentation either to yeast or to alcohol.

As alternatives to chemical digestion, or enzymatic digestion where a yeast is the preferred end-product, there is a commercially viable process called the SYMBA process. In this process two organisms are employed simultaneously, a filamentous yeast Endomycopsis fibuliger, which is capable of digesting starch, and the fast growing food yeast Candida utilis. The pre-sterilized starch slurry is inoculated with a mixture of the two organisms, but because of the faster growth of the Candida the end-product is mainly Candida biomass. However, this process is not so attractive as the KOJI process for extracting the carbohydrate from solid residues and is likely to be superseded by the immobilized enzyme process for liquors.

In the past, low grade alcohol has not had a good market, but one of the benefits of the recent advances in world oil prices, and hence petroleum prices, has been to make fermentation methods involving the production of fuel grade alcohol from sugars and starches an attractive proposition. The trend is for this process to become more attractive in the future, especially in view of the current advances in fermentation engineering. (Hepner, 1976)

The method of recycling flocculating yeast at a high concentration to the digestion of sugary waste, a yeast equivalent of the activated sludge process, has been developed by Meyrath (1975) and will be discussed under the section on sugars (4).

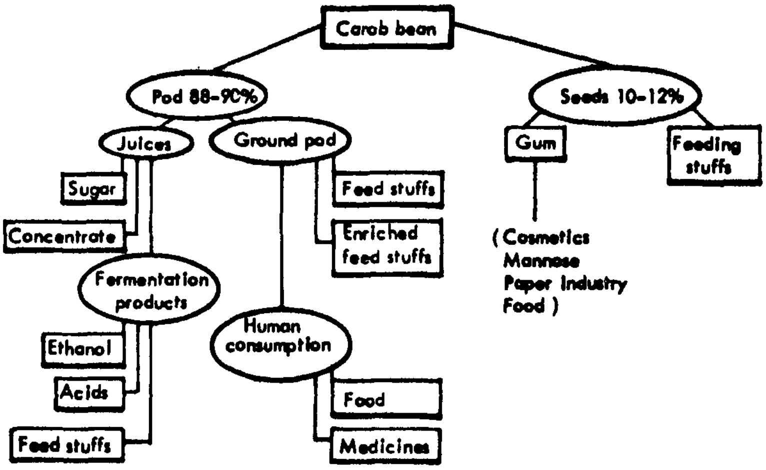
The treatment of starchy effluents by low-grade amylases and Endomycopsis fibuliger to provide a liquor suitable for yeast growth has been reported by Leveau and Bouix (1976). The Meyrath development renders such a treatment potentially economic.

3.7 Conclusions

Solid and liquid starch wastes provide attractive materials for the production of microbial biomass and fermentation metabolites. The biomass may be a yeast, fungus or alga, the choice being dependent on a variety of technical and social considerations.

Many communities already apply classical fermentation methods involving starch or starch waste as the original substrate. The skills required are therefore already within the competence of such communities to apply the principles of fermentation to novel starchy materials. Extreme caution is advocated in the application of small scale starch based fermentations using fungi.

FIGURE 3



utilization of carob beans

Imrie & Vlitos 1975

Section 4: SUGARY AND MIXED EFFLUENTS

4.1 Physical Characteristics of Sugary Wastes

Sugary wastes are usually in the form of liquids, though exceptions occur in that slurry and even solid wastes from natural product processing may also contain sugars, capable of fermentation in situ or after extraction (e.g. Carob. Imrie and Vlitos, 1975) Figure 3 .

4.1.1 Examples of Sugary Wastes

Typical of the semi-solid wastes are brewer's grains and of the slurry type are the liquors which arise from coffee, Rolz, 1975 (Figure 4) and fibre extraction, from sisal processing for instance. The pineapply industry produces both a solid and a liquid waste, the latter is not a slurry, but contains a fibrous matter suspended in the effluent. Many other fruit and vegetable wastes also lie in this range of solidity.

4.1.2 Fruit Processing Wastes

Noteworthy as well documented are those arising from the production of olives, pears, plums, tomatoes and citrus fruit. Some of these wastes contain a sufficiently high percentage of solids to justify drying the whole waste; these are therefore not available for fermentation treatment.

4.1.3 Yeast Containing Wastes

Yet other waste liquors already contain the micro-organism. Typical of these are the brewery yeast wastes. For such wastes it is only a matter of washing, de-watering and finally drying the yeast (Figure 5), or alternatively rupture of the yeast cells, extraction of the protein and a residual non-protein extract (Figure 6). Breweries are a world-wide phenomenon and cause pollution irrespective of their location. The techniques of yeast processing are well known and the products find a ready market.

Two approaches to fermentation are possible. Firstly, that in which the whole waste material is fermented and the fibrous matter harvested along with the microbial biomass. Leaving the fibre in the fermenting mass reduces the cost of preparation of the substrate, but the end-product may be of low value or have too high a fibre content to be useful for the animal-feed market.

4.2 Anaerobic Processing of Sugary Wastes

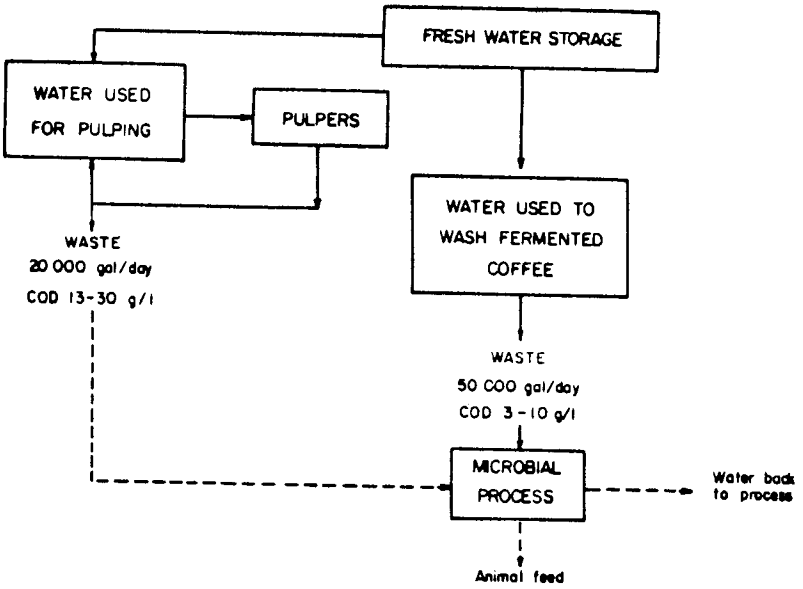
If, however, an anaerobic process is employed, in which the ultimate production of microbial biomass is not important, as with alcohol production from pineapple waste for example, then it is acceptable to leave the suspended solids in the liquor. This use of the total slurry is classically applied for the methane fermentation. However, it is possible to generate an alcoholic fermentation leaving the suspended solids in the liquor provided that, during the subsequent distillation process, components of the suspended solids do not interfere with this second operation. This interference may be physical, through interference with heat transfer, and by the solid matter giving rise to volatile components which make the distillate unacceptable.

4.3 Component Separation Prior to Fermentation

As a choice of approach to processing via fermentation technology, it is eminently preferable to separate the solid component and apply fermentation procedures to the liquid. If the solid material is suitable for fermentation then this may be treated by one of the methods considered in Section 2, in which the fermentation is primarily cellulolytic (see Section 2, Cellulosic fermentation of cattle waste, Humphrey, 1975).

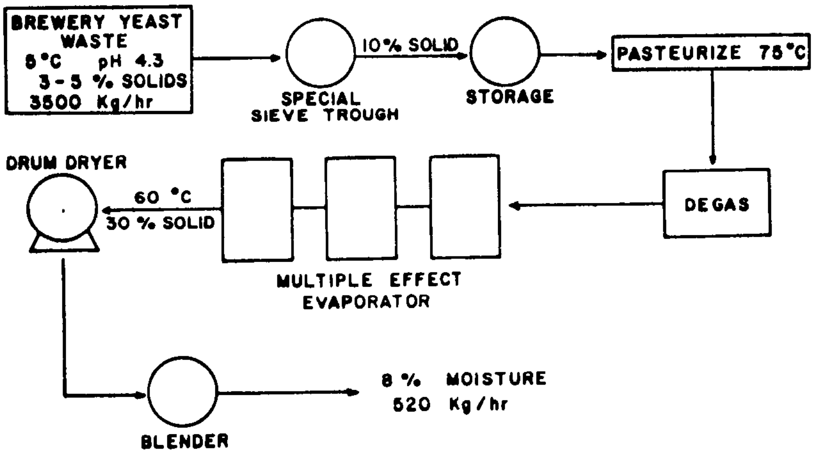
Figure 4

Utilization of waste from production of coffee



Rolz 1975

Figure 5



Production flow chart for dried yeast.

Labuza 1975

Trembois GmbH,Dortmund, Allemagne

4.3.1 Reduction of Pollution by Solids Removal

Separation of the solid fraction often removes the protein and higher polysaccharides concomitantly, thus contributing to the removal of the biological and chemical oxygen demand of the material. This technique is frequently applied to reduce the polluting effect of the original waste. Removal of the solids from such mixed effluents as palm oil processing effluent have been shown to reduce B.O.D. by a half or more. (Stanton, 1974). Removal of the suspended solids may assist in removal of heavy metal contamination as well as inert matter. This is advantageous to subsequent processing.

4.3.2 Critical Level of Carbohydrate

The problem with the resulting liquor is that, as with the starch waste mentioned in the previous chapter, the remaining fermentable carbohydrate is in the range of concentration below that in which it is economical to harvest a unicellular organism centrifugally. That is, the concentrations normally encountered are of the order of 0.5% to 0.2% of carbohydrate, or lower. This concentration is still ten times that of domestic sewage. In view of the quantities of waste liquor available having these intermediate carbohydrate levels the special problems of harvesting are currently the subject of widespread investigation.

4.3.3 Relation of Carbohydrate to Fermenting Organism

Additionally, it is necessary to enquire into the spectrum of carbohydrates available and other features of the medium, in order to select the appropriate organism for use in the fermentation. If these problems can be overcome then the problem remains of maintenance of dominance of the preferred organism in a liquor which is normally septic.

4.4 Use of the Activated Sludge Principle

Particularly pertinent therefore are the recent studies by Meyrath (1975), for example, which have shown that the problems posed above can be overcome by the application of the principles of the activated sludge process for effluent treatment, together with the use of a thermophilic yeast with a high flocculation capacity.

4.4.1 The Meyrath Process

For effective operation of the Meyrath process, it is necessary to use a continuous fermentation with a short residence time and a concentration of yeast near the maximum required for rapid removal of the carbon. Other characters, which may be valuable, are 'ability to grow in an unusual carbohydrate medium' and 'ability to grow at a low pH', as low as pH 3.

This system appears to be particularly attractive for application to sauerkraut, olive, palm oil, fruit, tomato processing and pineapple wastes. Each effluent would require the selection of an appropriate flocculating yeast for successful operation. The flocculation principle could be applied to a modification of the SYMBA process, but as far as the author is aware, this has not been reported to date. It is an effective alternative to the utilization of filamentous fungi and removes the hazard associated with growing fungi or liquid wastes.

4.5 Mixed Effluents

4.5.1 Range of Mixed Effluents

By definition, the range of mixed nitrogenous and carbohydrate effluents is very large and the concentrations of bio-active components varies widely. It is important to distinguish between the moderately-high-level nitrogenous effluents produced by plant-product processes and the nitrogenous effluents produced by animal processing, a typical example of the latter being slaughterhouse drainings which contain blood, hair and gut contents. The latter requires an entirely different form of treatment in that the protein may be recovered first before a fermentation method is applied. (This protein extraction step is now also being applied to plant juices and might, for instance, be incorporated in the sisal juice treatment process.) (Section 4.5.4)

4.5.2 Seasonality of Effluents

With the majority of the biologically active vegetable - derived liquid wastes the problem is not so much one of technical difficulty of microbiological conversion but seasonality of production. The period of production ranges from a few days (as is found with pickles such as olive and sauerkraut) up to six months for crops such as tomato. Though the duration of processing time for the tomato is deceptive in that, although the period of harvesting may be a relatively long one, it reaches a peak in two or three weeks and there is a steady decline after this peak, during which the production is comparatively small. These differences in duration of production were found by the author in his survey of Egypt.

4.5.3 All-Year-Round Vegetable Wastes

Far more attractive, from the fermentation point of view, are those vegetable wastes which occur throughout the year such as from cocoa, pineapple canning wastes, copra waste liquor and others encountered by the author, including sisal and palm oil processing wastes. Rather surprisingly research is being concentrated in the sisal waste on processing the fibrous solid material as the major nutritional component lies in the liquid fraction.

4.5.4 Liquid Fraction of Sisal Waste

Sisal waste is particularly interesting in that, in contrast to most crops, the fibre is retained and the non-fibre rejected. To recover the secondary products economically, in the author's opinion, it will be necessary to re-structure the whole process of fibre extraction to ensure that the final wash water contains a much higher concentration of solids than at present. This can be done by a countercurrent process so that the cleanest water gives the fibre its final rinse and the concentration of waste in the water rises, counter to the movement of the fibres, through the process. A similar processing situation arises with abaca (Musa textilis). Though research is already in progress, as far as the author is aware, on the production of forula yeast from the expressed liquor of the abaca pseudostems. Sisal waste liquor contains a mixture of cell walls and short fibres, plant organelles, proteins, amino acids, and sugars. Little research has been done on this liquid material because the industry has been, until the oil crisis, on the wane and at the time of the author's visit to East Africa, May 1976, the sisal plantations appeared neglected. However, natural fibres are regaining importance and being recognized for their true worth.

4.5.5 Economic Future of Sisal Linked to Waste Usage

Provided that other factors do not intervene, it is envisaged that sisal will be one of the pioneer crops in which the 'total product' of the harvest is processed and used. It is envisaged that, after recovery of the cellulose and the protein, the true liquid waste can then be used either as a fertilizer, or applied to fermentation by the Meyrath process.

4.6 Palm Oil Processing Waste

Palm oil processing waste, with which the author has had some experience, has similar problems to that of sisal in that it is a slurry containing ash/dirt and suspended plant-derived solids. It has a chemical oxygen demand of over 30,000 and biological oxygen demand of over 20,000. Removal of the ash and suspended solids reduces the polluting effect of the liquor fraction to a biological oxygen demand of under 15,000, that is approximately half. This is a relatively difficult concentration at which to operate in that it is not strong enough for an 'intensive' fermentation, but too strong for normal sewage treatment methods. Thus the type of process developed by Meyrath appears ideal for this type of liquor.

4.6.1 Final Treatment (Polishing) of Agro-Industrial Waste Waters

Yeast processes do not 'polish' the liquor from an effluent. It is difficult to do this with any process involving a heterotroph, though the gas oil research workers claim that, by adjustment of the nutrient input, a very high efficiency of recovery of the applied nutrients is achieved. As far as normal effluents are concerned such high efficiencies of recovery are difficult to obtain because of the expense of adjusting the nutrient level to meet the variable imbalance which occurs in effluents.

4.7 Lowering of Residual B.O.D.

For final polishing at the present time algae offer one of the most attractive methods in the tropics in that they can be encouraged to consume organic acids directly and, at the same time, generate their own air supply. This method is already being applied in the oxidation ponds of sewage systems. These can be regarded as mixed culture fermentation systems, although the harvested product is usually fish or other aquatic animals. An interesting new development is the culture in a light-assisted anaerobic system of the so-called 'purple' bacteria (Kobayashi, 1976).

4.8 Other Processes

Space does not permit detailed discussing of other sugary and organic acid wastes, such as those arising in latex processing, or methods being developed for addition (Finn, 1976) and removal (Focht and Chang, 1975) of nitrogen and for the application of 'adhesive fermentation', a type of whole-live-cell immobilized enzyme system (Englebert and Delweg, 1976), for biomass recovery. The latter two of these processes are still in the experimental stage.

4.9 Conclusions

In conclusion, the economic processing of sugary and mixed effluents to provide a useful product depends on a variety of factors, listed in Section 1. The actual fermentation systems are simple and may be operated under septic conditions. The metabolism of the organisms are well understood, particularly the yeasts (Tomlinson, 1975) and some of the algae. Research is continuing on growth optimization, harvesting and processing, though off-the-shelf processes are now available for known food-safe organisms. Fears expressed in the early years of SCP study over toxicity problems, for animals, with nucleic acids have been proved unjustified. For human foods the pre-treatment illustrated in Figure 6 is appropriate.

Section 5: ANIMAL BY-PRODUCTS AND WASTES

5.1 Pig Faeces

The recycling of cattle dung has already been mentioned in Section 2 (2.1.3). Direct re-feeding of pig faeces is also practised and it is reported from Japan that a solid substrate fermentation using pig faeces and aspen (Corylus sp.) leaves, using an Aspergillus species as the fermentation micro-organism, is also used as an animal feed. No details are available to the author.

5.2 Chicken Faeces

Chicken faeces are a valuable source of nitrogen and phosphorus to assist in cellulosic fermentations, or for feeding to cattle along with cellulosic wastes to improve digestion of the cellulose.

5.2.1 Value of Chicken Faeces in Solid Substrate Fermentation

Recently, the author has been experimenting with chicken manure as the nutrient source for solid-substrate fermentation of starchy wastes for non-ruminant animal feed. This material, chicken dung, has the advantage over mineral nitrogen sources, or urea, in that the uric acid nitrogen is only slowly released as required by the fungus. Whereas ammonium salts and urea inhibit growth at concentrations below 2% nitrogen in the dry matter of the substrate, the fermentation using chicken manure is unaffected by higher concentrations of nitrogen. The upper limit for practical purposes is determined by the ash and fibre contents of the manure. This absence of inhibition may be demonstrated in petri-dish culture using pure uric acid. Under these conditions the fungus mycelium, of Rhizopus for example, may be seen to be attracted towards the insoluble particles of the acid.

5.2.2 Effect of Source of Chicken Dung

The utility of this material is greatly affected by the source from whence it is derived and the feeding of the stock, since a high ash or fibre in the diet will be reflected in the faeces. Further ash and fibre is contributed after excretion, though this addition is small with intensively reared animals.

5.2.3 Substitution of Pig for Chicken Faeces

Pig faeces could be used in a similar manner and the fermentation would destroy pathogens in the excreta, but this material would present problems with collection and handling. At present, the principal study on the utilization of pig faeces is for methane production.

5.3 Human Sewage

Humphrey, 1965 has suggested a method of hydro-classification of human sewage/urban refuse which could be applied to mixed faecal animal wastes such as that from piggeries. The method employs comminution followed by hydro-classification. The comminution releases the heavy particles such as sand and these are subsequently separated by the hydrocyclone. From this stage the liquid fraction would be treated by an activated sludge and algal process and the excess of sludge over that required for recycling added back to the fibre fraction for composting.

Chicken manure is amenable to air classification after drying and grinding. This provides a suitable solid for use as a nutrient source in the solid-substrate starch waste fermentation discussed in Section 3.

5.4 Slaughter House Waste

As far as the author is aware no microbial biomass process based on slaughter house liquor has been developed, though this material lends itself to oxidation pond treatment and fish rearing after appropriate pre-treatment. The current method of recovery of protein from slaughter house waste water is not a microbial process.

5.5 Milk Processing Wastes

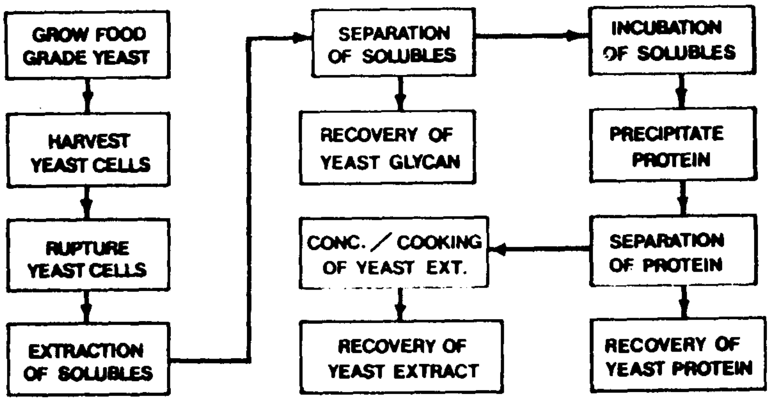
Milk processing yields by-products suitable for yeast, or bacteria (Reddy et al 1976) fermentations based on the lactose as carbon source and the residual proteins and amino acids as nitrogen source. (Figure 7) It is difficult to identify a 'waste' from milk processing as the whey is now frequently utilized and in separated milk the non-fat solids are also used. Alcoholic fermentation based on milk carbohydrates is known and a number of yeasts are capable of producing a biomass on the non-fat solids. Such products as kishk, yoghurt, kefir, all employ the non-fat components of milk and these processes are well documented. The only difficult waste encountered by the author was a high-salt whey, but this is an unusual product which nevertheless would appear to be amenable to fermentation.

5.6 Fermented Fish Products

Fish wastes are not normally considered as a raw material for fermentation and their use for fermentation competes with direct methods for protein recovery (FPC, or fish protein concentrate). However, FPC demands expensive equipment and advanced technology. Further, it is only economical to produce this material if there is a large regular supply of feedstock. Further, if the end-product is to be acceptable then the raw material requires selection.

As an alternative, fish trash may be preserved by chemically or microbiological ensiling. The latter process lies within the domain of this paper.

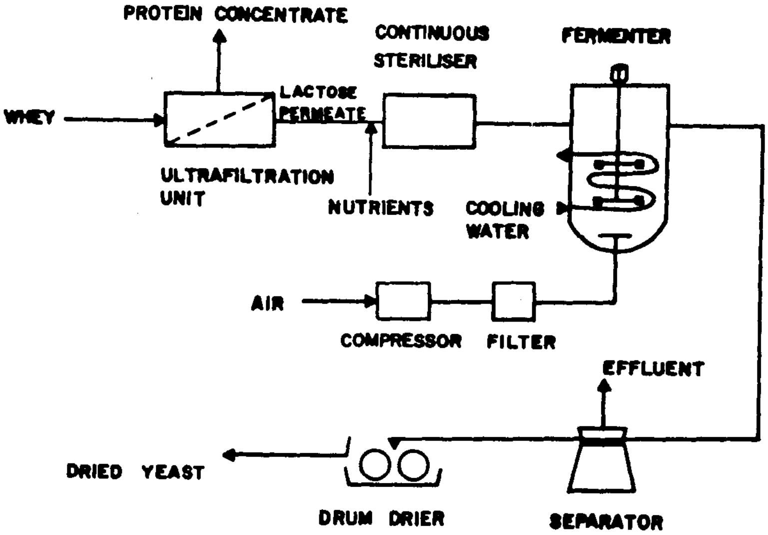
Figure 6



Yeast fractionation process

Sinskey & Tannenbaum, 1975

Figure 7



Flow diagram for an ultrafiltration/fermentation plant for processing cheese whey

5.6.1 Fish Silage

Fermentation ensilage of fish depends on the generation of a lactic fermentation with added sugars, or an autolytic process in the presence of salt (more than 12%). High salt fermentation is not suitable for the preservation of fish to provide a main protein component of a diet. On the contrary, a lactic fermentation not only preserves the protein, but adds a protective element.

The method of lactic fermentation was initially developed in Scandinavia, though there are equivalent oriental processes. More recently a citric preservation has been applied but this depends on pre-formed citric acid. The Scandinavian process depends on the use of active malt as an additive to the minced fish, care being taken that the process is maintained anaerobic. Over 1% lactic acid is generated and the pH drops to below 4.8. On the basis of this the author investigated the possible application under equatorial conditions and found that an effective lactic fermentation could be produced at tropical ambient temperatures (27°C). As a substitute for malt a local fermenting agent, RAGI, was used together with a lactic bacteria starter culture. RAGI is the Indonesian term but equivalent microbial enzyme active cakes are found throughout South East Asia.

This method has the advantage over an FPC process of being applicable on a small scale with little cost of equipment and the use of locally available additives (Stanton and Yeo, 1976).

5.7 Conclusions

In conclusion it may be said that subject to 'loading rate' and aeration, all the above wastes, even the solid wastes of faeces, are amenable to oxidation pond treatment to yield fish as the useful end product. A recent suggestion (bearing in mind the danger of introducing a noxious weed) for treating high nitrogen effluents is by the culture of *Eichornia crassipes* after primary and secondary treatment of the sewage. This plant, the water hyacinth, is easily harvested and is a useful stock food. Through harvesting up to 90% of the nitrogen is removed and the anaerobic conditions underneath the layer of water plants assist in denitrification (Wooten and Dodd, 1976).

Efficiency of oxidation ponds can be increased substantially by attention to loading, geometry and recycling or stirring (even by hand on a small scale). Such ponds may be coupled to other fermentation systems and are, in the author's opinion, one of the most practical methods of processing a wide variety of effluents.

Section 6: TOXIC WASTES

6.1 Degradation of Agirucltural Chemicals

This survey of microbial processing and utilization of agricultural wastes would not be complete without consideration of the application of micro-organisms to the destruction of toxic compounds and thus the rendering safe of potential food materials, or water for re-use.

Fermentation microbiology has developed an armoury of micro-organisms for utilizing unusual organic compounds so that the process of utilization of straight chain hydrocarbons, aromatic ring compounds and organic sulphur is now well documented.

Some of the most formidable compounds arising from agriculture are insecticidal and herbicidal residues and the wastes from cellulosic pulp extraction. Removal of these compounds produces a useful product in the form of clean water. Brief reports on the ability of microorganisms to render some of these compounds innocuous have been given by Munnecke (1976) and Mueller and others (1976). The former discusses insecticides and herbicides and the latter the toxic compounds arising from wood as a consequence of fractionation for paper pulp.

6.2 Production of Toxicants by Waste Fermentation

However, care must be taken in adopting a fermentation process to utilize agricultural waste that a pollutant is not generated at the same time. This subject has been reviewed recently by Alexander (1974). Alexander also points out that incorrect operation of a solid or liquid fermentation system can give rise to hazardous micro-organisms. Potential users of microbial 'waste recovery' processes should also be aware of the capacity of many micro-organisms to selectively concentrate heavy metals such as lead, zinc and mercury. These may already render the original waste unsafe. Chromium for instance can be released from stainless steels and appear in the process effluent. The mechanism of release is uncertain, but the cause of metal contamination may lie in faulty pairing of equipment parts which are individually corrosion resistant, thus giving rise to electrolytic release in acid solutions. Metals arising by such action could inhibit a subsequent microbial treatment process, or be accumulated to render the biomass toxic.

Section 7: GENERAL CONCLUSIONS

7.1 Relevance to developing countries of the processes mentioned in the review.

7.1.1 In the 1960s, there was an unbridled enthusiasm amongst microbiologists and nutritionists for the benefits which the application of SCP techniques and other microbiological processes using agricultural wastes could bring. Now the attitude has changed to one of caution and the approach has also changed from an emphasis on fossil fixed carbon to a return to interest in renewable fixed carbon and autotrophic processes. Respect has been generated for the classical fermentation processes inherent particularly in the Far East and a more favourable attitude has been shown to the idea that it is by grafting onto and evolving these processes that applications of the new microbiology can be made. From this approach and by the application of 'technology transfer between developing countries' will, in the author's opinion, come the most rapid increase in the impact of microbiology in the developing world.

7.1.2 The 'hearths' of the origin of agriculture and food crops are well recognized. Less well identified are the hearths of food technology and food fermentation (Stanton, 1969) Just as changes have occurred in the lives of many communities by the introduction of maize, groundnuts, cassava and oil palm, so one may see in the future equally dramatic changes arising from the spread of techniques such as: the KOJI process; the TEMPE process; the SOYA SAUCE fermentation (which does not have to use soya beans); the family of lacto-bacillic fermentations, the tropical mushroom fermentations based on *Volvariella* and *Pleurotus*; the *Spirulina* process, the mixed fungus-yeast processes common to RAGI and BANTU BEER and the various detoxifying and micro-nutrient-supplying fermentations which are beneficial to diets.

7.1.3 It follows from this consideration of a need for technology transfer that a valuable contribution may be made by training of personnel not in the advanced laboratories of the United States, Western Europe and Japan, but in a region different from that of the technologists' homes. That is, the technology transfer should proceed hand-in-hand with crop plant and animal transfer. One might even take this concept further by suggesting that the microbiologists, biotechnologists and nutritionists of the developed world might themselves be in the role of trainees in that there are many lessons to be learned from studying the previously mentioned processes.

7.2 The New Processes

What has been said does not preclude the pursuit of the application of advanced techniques. The author has identified some of these below:

7.2.1 - The incorporation of N-fixing organisms in low-nitrogen fermentation substrates.

7.2.2 - The application of immobilized enzymes to the technology of substrate preparation and product extraction.

7.2.3 - Membrane filtration and other physico-chemical techniques to fractionate the waste products prior to application of microbial techniques and after fermentation to recover useful products.

7.2.4 - The manipulation of cell flocculation both during and after the fermentation process.

7.2.5 - The use of methane, methanol, ethanol, acetic acid derived from low-grade wastes, microbiologically chemically or pirolytically, as the substrate for the final fermentation.

7.2.6 - Environment manipulation as an alternative to sterilization.

7.2.7 - New designs and new materials for the construction of fermentors to economize on capital cost and unit conversion efficiency.

7.2.8 - Application of the principle of 'fed-batch' culture in the development of chemical as well as new fermentations.

7.2.9 - Application of the principle of 'self optimization of growth' of the preferred micro-organism harvested from liquid wastes fermented under continuous culture, thus avoiding the problems of mycotoxin producing and phage sensitive strains.

7.2.10 - Application of solar energy to the growth of microbial cultures, recognizing that solar energy may be applied to anaerobic as well as aerobic cultures.

7.3 Strategy and Benefits of Adopting Microbial Processes

7.3.1 Microbes can use fertilizers, including nitrogen and phosphorus, far more efficiently than higher plants by agriculture.

7.3.2 Microbes can fix nitrogen and can render non-protein nitrogen available to man and animals as protein economically.

7.3.3 They can detoxify potentially useful material and release the useful ingredient from inert matter.

7.3.4 They can concentrate the useful component.

7.3.5 They can make material attractive as foods.

7.4 Hazards

If improperly used,microbes can be highly dangerous. These have been mentioned in the text. Of particular concern has been the group of agro-industrial waste utilization processes which employ fungi to attain a useful food product for man or animals.

7.5 Rate of Development

7.5.1 Research and Information

Parallel work on many of the topics mentioned in this report is being conducted in different countries. Much of the work is as yet unpublished and the author is grateful for the many helpful discussions he has had on his recent travels. The field is so broad that a review would run into many hundreds of references.

7.5.2 Actual Applications

The points on the development front, at which actual applications are occurring, are relatively few. This is especially when these are assessed in terms of current feasibility for the dispersed economies. Application of microbial processes to wastes is difficult, since there is a lack of control over the organisms, their substrates and the environment which is in great contrast to the equivalent industrial processes. Many processes, applicable to specific biological products, are not applicable when those products are seasonal, contaminated, dispersed residues.

7.5.3 Economic Arguments

Dispersion, small size, irregularity of supply make these products unattractive to the industrial technologist. The U.N. Agencies by definition operate in these difficult and remote situations. Development of extensive collecting systems, increase in the supply of energy (Meyer Abich 1976), transfer of population are not solutions. The report has highlighted solutions to residues as they exist, not as the process engineer would wish them to exist.

7.5.4 Rate of Change

Innovations, especially involving biological processes, impinging on the daily life of communities, are only slowly absorbed. Currently, systems analysts (Bildder Wissenschaft 1976) indicate that a 50-year lag is not uncommon (Marchetti 1976). This figure is one order of magnitude too high for a politician. It is not too high for the social instinct of man. An understanding of the microbiological processes which sustain human habitats is not beyond human capacity. Unconsciously these activities have already been developed. Understanding will aid their application. The role of the offsprings of the U.N., such as the UNEP/UNESCO/ICRO Panel of Applied Microbiology is accepted as developing that understanding. Evolution occurs by trying though progress may be difficult to see and critics many (Harrison, 1976).

Section 8: POINTS FROM THE DISCUSSION

8.1 Mycotoxins in SCP Fermentation

8.1.1 (Mr. Hugill). What information was available on the occurrence of these?

In reply (Prof. Senez) stated that extensive research had been conducted and that there was no danger of the organisms mutating to give rise to toxin-producing or pathogenic strains. He added that it had been demonstrated that in continuous culture there was a self selection by the organism for mutants with optimum growth rate on the substrate and towards a genetic condition of 'improved stability'.

8.1.2 Similarly (Dr. Forage) stated that at maximal growth rates of the fungi used for SCP culture on starch the danger from toxic metabolite producing strains was minimal.

8.1.3 (Dr. Kapsiotis) in commenting stressed that what pertained in large industrial plants was not necessarily true at the village level where sub-optimal conditions and surface contamination could occur. He also stated that the statement of Professor Senez might need modifying in relation to processes utilizing residues of variable composition and subject to seasonal fluctuation, transport and storage hazards. (Prof. Senez) agreed with this.

8.2 Nutrient Supplies for Fermentations

8.2.1 (Dr. Nabney) pointed out that every 100 gm of protein required 19 gm NH_3, 34 gm urea, or 75 gm ammonium sulphate. Attention should be drawn to the problem of distribution of the large quantities of material involved, assuming SCP contains approximately 50% crude protein, to rural areas.

8.2.2 (Prof. Fleischmann) asked what was likely to be the effect of a world shortage of phosphorus on nutrient supplies for SCP production.

8.2.3 In reply (Prof. Stanton) referred to the relative efficiency with which micro-organisms in culture used nitrogen and phosphorus in comparison with field-grown plants.

These fermentations would compete increasingly effectively for nutrients in short supply.

8.2.4 (Prof. Sherif) asked whether it was better to supply the ruminant with urea or ammoniated cellulose in mixed animal feeds.

8.2.5 In reply (Prof. Stanton and Prof. Wilson) stated that it was a matter for case study. Slow release nitrogen, as furnished by coated ureas or ureas incorporated into starch, was used more effectively by the ruminant but these forms of nitrogen were relatively expensive.

8.3 Process optimization.

8.3.1 (Prof. Shuytov) brought to the attention of the meeting the recent results from Russia of successful mathematical modelling of multi-organisms, multi-phase fermentation systems as were found in biodegradable effluents. He considered that application of these results to effluent treatment would be economically valuable.

8.3.2 Dr. Schreier (in a similar comment at the SCP Session) advocated application of the principles of economy in oxygen transfer in aerobic fermentations both in terms of rate per unit volume and rate per unit energy supplied. (This concept also applied to the systems mentioned under 8.3.1).

(In discussion afterwards Dr. Nabney pointed out that SCP was won in heterotrophic fermentations at the expense of the fermentable carbohydrate, a feature often overlooked in SCP processes.)

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Appendix Table

Summary of the Present Position on Viability of Various Agro-Industrial Waste Processes for Producing Microbial Biomass and hence S.C.P.

Organism	Processes	Remarks
Bacteria	On-stream processes for SCP none	One company has announced commitment to large-scale production using methanol.
	On-stream processes for amino-acids/vitamins, etc. several	Some mother liquors are used as food additives after extraction of specific amino-acids.
	Classical processes e.g. the microbial gum and cellulose processes	Primarily for production of the polysaccharide as a food. Have been developed for producing commercial food gums but these no longer contain the micro-organisms.
	Near future Methane utilizing bacteria	Unpublished.
	Photosynthetic bacteria	Reported to be used in Japan harvesting aided by hydrolysed chitin (Kobayashi 1976)
Live bacteria in quantity are already ingested as a regular element of human and animal foods, particularly the lactobacillae.		
Blue green algae	Spiruline processes A classical process with commercial developments.	Viable for special application
Fungi (imperfecti)	On-stream processes none	The wastes mycelium of antibiotic manufacture is widely used as an animal food, though not widely publicized, or recommended.
	Near future Starch-derived mycelium of Fusarium and Aspergillus sp.	As large-scale processes projected viable and passed all food & drug tests in 10 years.
	Classical processes animal and vegetable cheeses and 'bantu beer' type processes. Many soya bean processes	Not pure S.C.P. but regularly applied as small-scale processes
Fungi (Basidiomycetes and some higher **Ascomycetes**).	On-stream processes for S.C.P. for food additive	Cost of culture too high as source of straight S.C.P.
	Near future Sporotrichum on starch base by deep culture fermentation	Construction in progress of full-scale plant. Nutritional testing programme complete.

Organism	Processes	Remarks
	Mushrooms Mushrooms are 'microbial biomass' and a limited number of the possible species are widely grown.	Utilization has been limited by cultural requirements and rate of growth.
Yeasts	On-stream processes Using molasses, milk-processing wastes and paper-making wastes (as well as non-recurrent carbon sources)	Viability depends on special circumstances such as cost offsetting in pollution control.
	Near future/limited at present **Brewing wastes, fruit and vegetable processing wastes**	Convenient to handle in large and small scale fermentations. Applicable to a wide range of substrates.
Algae Fresh water	On-stream processes Chlorella	Economies depend on special markets for the end product.
	Special-case viability **Scenedesmus**	Used as an animal feed, but research on harvesting still needed.
	Used as fish food widespread	Application of principles of fermentation technology still in their infancy. Prospects good.
Algae Marine	On-stream processes	
	Micro-algae, not deliberately cultivated widespread	Controlled enrichment of tropical marine waters is feasible.
	Macro algae - cultivated and gathered	Not primarily S.C.P. but commercially important
Higher plant cells	On-stream processes For special products only	A high value end-use of special agricultural liquid by-products.

Waste and Organic Materials as Fertilizers

by Soil Resources Development and Conservation Service,
Land and Water Development Division, FAO

UNEP/FAO/ISS.4/11

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WASTE AND ORGANIC MATERIALS AS FERTILIZERS

by

Soil Resources Development and Conservation Service
Land and Water Development Division, FAO

Introduction

The interest in a more systematic and intensive use of organic fertilizers regained momentum during the period in 1973/74 when, as a consequence of the energy crisis, mineral fertilizers became very scarce and expensive and, because of this, were out of reach of many farmers particularly in developing countries. In the meantime, fertilizer supply possibilities on the world market have returned to normal and prices have reached more reasonable levels. But the experience gained under such critical circumstances has drawn world attention to the need to exploit more intensively all possibilities of increasing agricultural production with less dependency on purchasing expensive inputs. These possibilities include inter alia the recycling of plant nutrients within agricultural production systems and from various organic wastes outside agriculture and making use of beneficial effects of organic material to improve soils in their physical properties for the betterment of water and nutrient holding capacity, soil aeration and the reduction of losses of plant nutrients.

While all these possibilities have high worldwide importance for agriculture, they need specific attention in countries with developing economies in which millions of small farmers are in serious need of increasing the productivity of their soils. For many of these farmers organic sources of fertilization are the only means available and may remain so for a long time to come.

Emphasis on organic fertilizers does not mean that in agricultural production mineral fertilizers could be fully replaced by organic sources of plant nutrients. But, dependent on the availability of both sources of plant nutrients, on the economic feasibilities and on environmental considerations, the optimal exploitation and combination of both sources must guide all efforts to increase soil productivity, crop yields and soil conservation.

As a consequence of the energy crisis and following a resolution by the World Food Conference in November 1974, FAO has developed a systematic programme for assistance in the better use of organic materials as fertilizers. The programme includes:

- Expert consultations on organic materials as fertilizers with the objective of accumulating the most up to date information on the subject.
- Workshops on a regional basis on organic materials as fertilizers with the main objective of adjusting the information advailable to the requirements of countries and working out guidelines for national follow up action.
- Seminars and training courses on the use of organic and mineral fertilizers for extension staff.
- Preparation of training material to be used by extension staff.

The most recent event in FAO's programme on the use of organic materials as fertilizers was the FAO/SIDA Workshop on Organic Fertilizers in Asia, held in October/November 1976 in Bangkok. It was probably the meeting where, due to the experience available in the region, most of the practical know-how was put together by a considerable number of very competent people from the countries concerned. As far as the use of different types of wastes as fertilizers is concerned, the following highlights from the Workshop should be presented:

Due to the rapid population increase and urbanization, cities in Asian countries are producing large amounts of organic wastes and sewages and will produce more in the coming years. The experiences gained from composting solid waste materials are not always positive but, in general, there is a trend towards increasing the number of compost plants in developing countries.

Night soil is being used for agriculture in China and Korea and some cities in Japan are using diluted sewage on farmland under contract. Due to some reasons, night soil is not used by farmers for instance in India, Bangladesh and Sri Lanka. However, the importance and possibilities of using sewage and night soil is recognized and a more rational use seems to be ahead.

Bio-gas systems are becoming more and more widespread in India, China and increasingly in other countries in Asia. The agricultural interest in this is the utilization of their effluents. Interest in this matter has been expressed in Bangladesh, Nepal, Korea and Thailand.

Following some experiences gained in USA, interest was raised in the problem of sludge use methods. The aerated pile method utilizing woodchips and other bulk agents to stabilize dewatered raw sludge is under discussion. The compost produced by these methods is presently used for gardening. There seem to be several reasons for the relatively poor usage of organic fertilizers, namely:

(i) Relative lack of abundance of organic materials due to the use of the material for fuel and fodder.

(ii) Relatively high cost of its use in terms of labour utilization and transport associated with its movement.

(iii) The long established social custom of neglecting its use, and

(iv) Lack of knowledge concerning the proper methods of processing and utilization of compost and similar materials.

The Working Groups at the Workshop on Organic Fertilizers in Asia proposed the following activities at the national and international level:

1. Rural Wastes and Bio-gas

The better utilization of rural wastes as manure is essentially a problem of information and training. Since the raw materials are available in farms and villages, useful know-how practices and motivation of farmers regarding the collection, processing and utilization of wastes may be transferred from countries where it is available to interested countries. The following proposals are made:

Rural Wastes:

I. National Programmes

1. Assessment of the potential resources of rural wastes/organic materials should be made by different countries and their possible utilization as organic fertilizer, on priority basis.

2. Improvement of rural organic wastes utilization through development and applied research programmes.

3. Training of extension workers to deal with these specific problems.

4. Effective extension and publicity programmes to disseminate knowledge and educate farmers in different techniques of organic fertilizer preparation and utilization.

5. Popularisation of specific green manuring practices which do not interfere with the production of main crops.

II. International assistance for Regional Programmes

A. Development:

- Transfer of know-how on specific practices on recycling of organic wastes from one country to another.
- Training of selected staff in order to acquaint them with technical, socio-economic and organizational aspects of organic recycling in countries where these practices have been well established.
- For the introduction of new practices in organic recycling, assistance may be provided to establish Pilot Projects suitable to their conditions.
- Preparation of comprehensive brochures on the techniques concerning the use of organic matter recycling, such as on preparation of compost and farmyard manure on priority.

B. Research

- Research needed to shorten the period required for composting.
- Improving the quality and nutrient status of composts and farmyard manure by different methods.
- Systematic investigation of the effect of organic and combinations of organic and inorganic fertilizers on the yield and quality of crops including soil properties on long-term basis.

Bio-gas

The concept of bio-gas technology is well recognized but the technical know-how has to be disseminated in countries in this region.

International Assistance:

- Transfer of technology for setting up biogas plants to interested countries.

- Research required to improve the efficiency of bio-gas production by use of chemical and microbiological methods.

- Research required to reduce the cost of production of family size bio-gas plants to make it more economical.

- Financial assistance on long term and soft loans required.

Peat and Muck Soils

International Assistance

Study tour of peat and muck soils of Malaysia, Philippines, Indonesia and Thailand with respect to their utilization and management.

2. Urban and Industrial Wastes

Utilization of urban wastes for organic fertilizer production is important from the standpoint of ensuring an aesthetic urban environment, preventing air and water pollution and increasing agricultural production. There is obviously a vast potential and an urgent need for many countries to move toward a greater utilization of urban and industrial wastes as organic fertilizers for increased crop production and as soil conditioners to maintain soil productivity.

The following action programmes are, therefore, recommended:

I. By Governments and urban authorities

(i) Collection of data on the source, availability and composition of organic wastes including liquid wastes; the present situation and future projections for the next 20 years.

(ii) Collection of data on the cost and efficiency of present methods of collection, treatment, disposal and/or utilization.

(iii) Investigation of health and pollution hazards arising from present methods of collection, treatment, disposal and/or utilization and estimation of future health and pollution problems.

(iv) Investigation of possible outlets for utilization of organic wastes, e.g. marketing of compost for home gardeners, market gardeners, municipal parks and gardens, urban re-afforestation programmes, reclamation of disused quarries and distributed lands, etc., as well as the utilization of certain industrial wastes, e.g. bagasse, food processing wastes, slaughterhouse wastes and wastes from paper mills and wood processing.

(v) Launching a national programme to increase public awareness of the need for sanitary disposal, reclamation and recycling of urban wastes for use in agriculture and for other purposes, and to provide training and orientation for municipal workers as well as agricultural extension personnel.

II. International Assistance

(i) In the form of case studies, collect and disseminate information on the economics of existing waste treatment and/or composting plants in developed and developing countries with a view to analysing the reasons for their success or failure, so as to provide necessary guidance to developing countries.

(ii) Collect information and cost data on the technology, processes and equipment currently available for urban waste treatment and utilization, and evaluate their advantages and disadvantages.

(iii) Investigate the ways by which the technology, processes and equipment may be adopted for fabrication and use in developing countries.

(iv) Collect and disseminate information on special problems, eg. utilization of certain types of wastes requiring specialized treatment and control of toxic and hazardous waste components.

(v) Continue technical assistance programmes for developing countries to improve existing plants, to carry out feasibility studies and to establish pilot plants.

(vi) Impress governments of the urgency for a commitment to the establishment and support of multi-disciplinary research and development centres to deal with the processing and utilization of urban and industrial wastes for agricultural use and for other purposes.

(vii) Establish regional research and development centres at appropriate locations with a view towards supporting national programmes on processing and utilization of organic wastes.

(viii) Continue consultations and exchange of information among interested countries.

Utilization of Waste Products in Animal Feeding

by M. Chenost

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PAPERS READ DURING THE TECHNICAL CONSULTATION ON NEW FEED RESOURCES (22-24 NOVEMBER 1976, FAO, ROME)

UTILIZATION OF WASTE PRODUCTS IN ANIMAL FEEDING

Introduction

In the present economic and demographic situation of the world, any way in which animal production may be increased by making it less expensive on the one hand, and less competitive with human feeding on the other hand,.merits special attention.

Many agro-industrial wastes and by-products, though potentially useable as animal feeds, are poorly utilized and even discarded in millions of tons every year, a practice, however, which creates a menace to the environment.

In keeping with its policy of developing animal production, the Animal Production and Health Division organized, in collaboration with the Industry Cooperative Programme, a Technical Consultation on New Feed Resources.

This consultation was held in Rome from 22 to 24 November 1976. It was divided into 4 parts: 1. Poor quality roughages; 2. Agro-industrial by-products; 3. By-products from the wood and cellulose industry, and 4. Recycling of animal and municipal wastes.

The objectives were to review scientific and technical progress in the utilization of these by-products and wastes in animal feeding, to discuss the economic feasibility of such utilization, to study the possibilities for extending research and extension activities in the developing countries, and to suggest means by which to launch such activities.

The purpose of the present note is to summarize the various subjects discussed during that consultation.

I. Poor quality roughages

Involved here were not only roughages (which, strictly speaking, are not agricultural by-products), but also the straws and other fibrous materials remaining in a field after harvesting, and bagasses. These products are rich in woody material and hence are not easily ingested or digested; ruminants are the only possible feeders. Under this heading only crop residues and bagasses will be discussed.

Their animal feed potential was described by C.C. Balch (1). We may note the world figures of 1 710 million tons of cereal straws, 49.9 million tons of sugar-cane tops, and 66.5 million tons of bagasse. These by-products are thrown away or improperly used in very substantial quantities whereas, if properly supplemented - and even in the untreated state - they could constitute a valuable source of supplementary feed during dry periods or in countries where the agricultural land is so limited as to render unlikely the establishment of new grasslands.

Physical treatments to improve their feed value were reviewed by E. Donefer (2). Crushing is the simplest treatment, and is relatively cheap. It increases the quantities ingested but reduces their digestibility somewhat. Treatment by steam under pressure is useful in the case of bagasse; this treatment can be carried out in sugar-cane mills where, moreover, 75 percent of the bagasse produced is burned as fuel.

The chemical treatments described by T. Homb et al. (3) are promising and are already in practical use in the Scandinavian countries without effects on animal health. We may note in particular that the dry treatment with soda in Denmark and the NH_3-treatment of Norway are practicable on the scale of the small farm and the cooperative. Straws thus treated can have as much feed value as average-quality hay; however, the efficacy of these treatments depends on the botanical family of the straws.

Treatment techniques suitable for dissemination exist, therefore, but their profitability, be they physical or chemical, remains to be studied in the specific conditions of each country or region interested in using them.

The biological treatments described by M. Linko (4) seem promising both for the production of single-cell protein as for the use as animal feed of the products resulting from the slight hydrolysis of the residues of fermentation. However, the economic feasibility of these techniques is even more difficult to gauge than for those previously mentioned.

The use of these products, whether treated or untreated, in animal production systems is generally regarded as vital in developing countries (S.P. Atora, 5) though it is more problematical in intensive-production units where, however, it may be justified at least in the feeding of animals with low requirements (C. Demarquilly and M. Petit, 6).

The Consultation strongly urged FAO and interested countries to promote the establishment in the field of simple pilot farms on which methods already known could be tested.

II. Agro-industrial by-products

Involved here are the by-products of the production and processing of cereals, sugar, starch, fruits and vegetables, oil crops, beverages and animal products (milk, meat, eggs, beverages), which may be divided into four major categories for the various nutrients they supply and the part they can play in diets (as sources of energy, nitrogen, of energy and nitrogen together, and miscellaneous by-products suitable as ration supplements).

Their potential and contribution were described on the world level by M. Chenost and L. Mayer (7), and then on the regional level by C. Devendra (8) for Asia and the Far East, by C. Chicco and T. Schultz (9) for Latin America, by A.A. Adegbola (10) for Africa, and by M. Skouri (11) for the Mediterranean countries and the Middle East. The more specific problems involved in the use of nonprotein nitrogen and the establishment of integrated systems of plant and animal production (on the example of sugar-cane) were treated respectively by J. Kowalczyk (12) and T.R. Preston (13). Finally, H.Forage (14), presented the economic aspects of another way of utilising these by-products: fermenting them for the production of single-cell protein.

The use of these by-products as animal feed can be considerably increased; doing so would, moreover, solve a number of pollution problems. Their potential is highly dependent on when and where they are available.

A better understanding is needed not only of their composition but also of their nutritive value and of the quantities in which they are ingestible by the animal. Hence, the toxicity risks should be determined as often as possible.

The seasonality of their supply and the variations in their characteristics make it necessary that animal production systems be as flexible as possible.

Methods of utilisation suitable for dissemination are already available for some of them, such as molasses, sugar-cane grown as a fodder crop, banana wastes, citrus pulp, cakes and the by-products of the cereal processing industry and of breweries and distilleries. In contrast, further studies are still needed on other by-products such as those of coffee, cocoa, pineapple, fruit and vegetable canneries, etc. These studies will involve, in some cases, either basic or applied research. They will be preferably oriented toward the development of the simplest possible methods of utilisation, suitable for application on the small farm and allowing, to the extent possible, the by-passing of any expensive industrial treatment (dehydration) of these by-products.

Finally, economic feasibility studies will have to be undertaken wherever necessary in the context of the very region in which the use of these by-products is envisaged. It will have to be kept in mind that any given by-product, though of no monetary value to begin with, has a strong likelihood of being given a commercial value when its usefulness as a feed has been demonstrated.

One important recommendation put forward during this session calls the attention of governments and the private sector to the need, when contemplating the establishment of some new agro-industry, to provide also for the appropriate utilization of its by-products.

III. By-products from the wood and cellulose industry

The potential (30 to 60 percent of the wood tonnage cut in the United States is lost as waste) of the by-products of wood processing was discussed by H. Hennecke (15) and the nutritional and economic aspects of their utilization by W.J. Pigden (16). These by-products, whose utilization in animal feeding deserves to be developed, constitute a major long-term resource for developing countries, but the techniques now available are not yet ready for application or economically feasible.

The cost of producing single-cell protein from lignosulfites of the wood-pulp industry is still high.

The complete hydrolysis of wood and the use of the by-products resulting from the various stages of this hydrolysis - with the exception, however, of that of molasses - are still expensive.

The partial hydrolysis of hardwoods and their wastes, however, hold out some hopes for the production of feedstuffs useable by ruminants. The treatment of wood with stream under pressure, with or without acid hydrolysis, which yields a product with a digestibility of 50 to 65 percent at a cost of US$ 10 - 25/ton of dry matter, is already in practice in Canada.

Close collaboration between industrialized and developing countries and feeding trials on larger scales than in the past are recommended.

IV. Recycling of animal and municipal wastes

The feed value potential of animal excreta for the various animal species was depicted by L.W. Smith (17), the technology for the production of animal proteins from these wastes (indirect recycling through protein production by monocellular organisms and others such as larvae, earthworms, etc.) by C.C. Calvert (18), the economic aspects by Z, Müller (19), and the health aspects by A.G. de Moor (20).

These wastes constitute an immense protein reservoir; in the United States, for example, they are estimated to represent more than 5 000 million tons of nitrogen (equivalent to the soyabean crop), half of which is recoverable.

Poultry droppings and litter are already recognised as attractive sources of protein for ruminant feeds. They are mainly used in dehydrated form. They can also be ensiled either alone or in association with by-products rich in fermentable sugars, and on the scale of the large commercial farm (near agro-industrial plants) or on that of the small farm (where sources of supply and users are in reasonable proximity to each other). Integrated agro-industrial projects recycling animal excreta and municipal wastes are already operating in some regions (Malaysia, Müller); they appear to be economical.

It is desirable to set up pilot farms on which to test the economic aspects of a particular context, especially in regard to indirect recycling techniques.

Properly treated, animal and municipal wastes pose no particular health risks for ingesting animals. Ensiling has proved an effective technique for the elimination of pathogens.

Conclusion

The salient conclusions that may be drawn from this Technical Consultation are:

- The by-products and wastes of agricultural industries constitute an enormous but still under-exploited potential reservoir of animal feeds.
- Some techniques and methods for incorporating them into feed rations already exist and can be disseminated when their feasibility has been previously tested in pilot operations in the local context in which it is proposed to apply them.
- The factors limiting a better utilisation of these residues are generally:
  - economic and structural, linked to the nature of the livestock raising systems and to the organization of the food industry in the given country,
  - technical and scientific, linked, for some products, to an as yet imperfect understanding of their composition and feed value, and of the techniques for incorporating them into diets.

Papers read during the Technical Consultation on New Feed Resources (22-24 November 1976, FAO, Rome)

(1) The potential of poor quality roughages from agriculture for animal feeding (C.C. Balch)

(2) Physical treatment at commercial and farm level (E. Donefer)

(3) Chemical treatment at commercial and farm level (T. Homb, F. Sundstol and J. Arnason)

(4) Biological treatment of lignocellulose materials (including by-products of the wood and cellulose industry) (M. Linko)

(5) The role of treated roughages in animal production systems in developing countries (S.P. Arora)

(6) Utilisation des pailles et de divers sous-produits végétaux cellulosiques dans les systèmes d'élevage intensifs; comparaison avec les systèmes classiques (C. Demarquilly and M. Petit)

(7) Potential contribution and use of agro-industrial by-products in animal feeding (M. Chenost and L. Mayer)

(8) Utilization of agro-industrial by-products in Asia and the Far East (C. Devendra)

(9) Utilization of agro-industrial by-products in Latin America (C.F. Chicco and T.A. Schultz)

(10) Utilization of agro-industrial by-products in Africa (A.A. Adegbola)

(11) Utilisation des sous-produits agro-industriels dans les pays de la Méditerranée et du Proche-Orient (M. Skouri)

(12) Maximizing NPN use in feeding systems based on agro-industrial by-products (J. Kowalczyk)

(13) Utilization of agro-industrial by-products in integrated systems of plant and animal production (T.R. Preston)

(14) Economic benefits of agro-industrial by-products utilization in animal feeding systems in developing countries (A.J. Forage)

(15) By-products from industrial wood processing as potential sources of animal feed (H. Hennecke)

(16) Nutritional and economic aspects of utilising by-products from the wood processing industry (W.J. Pigden)

(17) The nutritional potential of recycled wastes (L.W. Smith)

(18) Systems for the indirect recycling by using wastes as a substrate for protein production (C.C. Calvert)

(19) Economic aspects of recycling wastes (Z. Müller)

(20) Potential health hazards and legal implications of waste recycling (A.G. de Moor)

Construction Materials, Paper and Paperboard from Agricultural Residues

by Forest Industries Division, FAO.

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- Straw . . . .
- Cotton linters . . . .
- Flax . . . .

Conclusions . . . .

Construction Materials, Paper and Paperboard from Agricultural Residues

by

Forest Industries Division
FAO, Rome

Abstract

The paper describes the current use of agricultural residues, mainly bagasse, straw and cotton linters as raw material for the paper, paperboard, and construction material industry. It draws the attention to the apparent relative smallness of the use in relation to the total availability of agricultural residues in the world. It describes some of the restrictions in the use of the agricultural residues for paper, paperboard, and panel products. It concludes that the technical problems can be overcome without any major difficulties. The most important restricting factors are related to the economics of harvesting, transportation, storage, chemical consumption, fibre yields in relation to raw material input, and finally, the quality of the products.

Short descriptions of the use of the most important agricultural residues are given individually at the end of the paper.

Introduction

Some types of agricultural residues were used as raw material for paper already before the introduction of wood which, at the moment, dominates the raw material supply together with waste paper. The most important agricultural residues used in the paper industry are straw and bagasse, and for panel products bagasse and flax shives, but there are a number of other residues which are also used. Theoretically, any fibrous plant can be pulped to provide cellulosic fibres for paper manufacture, but technical and, more often, economic constraints limit the use.

The purpose of this paper is to provide information on the current use of agricultural residues for construction materials, which in this connexion mean panel products such as fibreboard and particle board, and for paper and paperboard and to indicate the main restrictions which constrain the extension of the use. The specific features of the most important agricultural residues used in these industries are discussed separately.

Current Use

Before any fibrous raw material, be it wood, straw, bamboo, etc. , can be used for paper manufacture, it has to be converted into pulp by disintegrating the fibres from each other. This is also the case in fibreboard production. Pulp and paper manufacturing are very often integrated operations. This is the case practically always when agricultural residues are used as raw material. Fibreboard production is anyway an integrated operation. The technical suitability of a fibrous raw material for paper is determined by the ease with which it can be converted into pulp and by the properties of the resulting pulp which determine its suitability for the production of various types of paper. Therefore, in the following, the use and the suitability of agricultural residues are considered for the whole integrated operation of pulping and papermaking.

The quantification of the current use can only be done by making rough estimates. The FAO Annual Pulp and Paper Capacity Survey provides an estimate of pulp capacity based on all non-wood fibrous raw materials. Agricultural residues form only a part of it. In 1975, the total world capacity to produce all types of paper pulp was 136.1 million tons, of which the non-wood pulp capacity, to which the agricultural residues belong, was 9.3 million tons or nearly seven percent. The relative share of the non-wood pulp capacity is expected to increase slightly by 1980, when some 2.6 million tons of new capacity is estimated to be available for pulping the non-wood fibrous materials. The data are not complete for estimating the share of all agricultural residues as part of the non-wood pulp capacity for the world as a whole. Table 1 which summarizes the paper pulp capacity by regions provides, however, some indication of the extent to which straw and bagasse are used around the world in the production of paper pulp. The most notable area for which no estimates of capacity by these types of non-wood fibrous raw materials are available is China, where the total pulping capacity for these materials is estimated to be as high as 4.7 million tons, i.e., about half of the world total.

Table 1 - World Capacity of Pulp for Papermaking in 1975

	Total Pulp	Wood Pulp	Other Total	Fibre Straw	Bagasse	Pulp Bamboo	Other
	....		1 000 metric tons, air dry				....
World Total	136 110	126 766	9 344	..	..	..	..
Developed Market Ec.s	110 321	108 529	1 792	1 164*	137*	-	491*
Northern America	64 517	63 875	642	200*	70*	-	372*
Japan	11 896	11 892	4	-	-	-	4
Western Europe	31 293	30 210	1 [illegible]	962	10	-	111
Oceania	1 837	1 831	[illegible]	2	-	-	4
Others	778	721	57	-	57	-	-
Teveloping Market Ec.s	6 832	4 576	2 256	183	902	738	433
Africa	467	292	175	44	20	-	111
Latin America	4 170	3 298	872	41	731	49	51
Asia	2 195	986	1 209	98	151	689	271
Centrally Planned Ec.s	18 957	13 661	5 296	..	..	..	..
Asia	6 740	2 075	4 665	..	..	..	..
Eastern Europe	3 367	3 136	231	129	-	-	102
USSR	8 850	8 450	400	200*	-	-	200*

* Tentative estimates by the Secretariat

The table illustrates the overall importance of non-wood fibrous raw materials in the developing countries, about one-third of the total paper pulp capacity. Bagasse pulping capacity, alone, represents about 40 percent of the total non-wood pulping capacity in these countries. Its importance is most pronounced in Latin America.

In the developed market economies, the quantity of non-wood fibre pulp capacity is about half a million tons less than in the developing market economies but the total non-wood fibre pulping capacity is only less than two percent of the total paper pulp capacity in these countries. Straw, especially in Western Europe, dominates among the non-wood fibrous raw materials.

As the yields of pulp vary considerably depending on the pulping processes and the type of raw materials used, no more than estimates of the orders of magnitude can be made regarding the fibre input in the form of straw and bagasse. The quantities of moisture free straw and bagasse which were used in the world excluding China in 1975 for paper and paperboard are estimated to have been something like 4 million tons and 3 million tons respectively. These estimates are based on the assumptions that about 3 tons of moisture-free straw and 3.5 tons of moisture-free bagasse were needed for the production of one ton of paper pulp and that the average rate of using pulp capacity was around 75 percent.

As regards the panel products the most widely used raw materials are flax shives producing around 600 000 tons/yr of particle board of which 70 percent in Belgium and bagasse producing some 100 000 tons/yr of particle board. The other materials which are used on a limited scale are hemp, maize stalks, cotton stalks, jute sticks and palm fibre.

Table 2 provides the estimated capacity of non-wood based particle board by the types of raw material and by the regions.

Table 2 - World: Non-Wood Based Particle Board, Estimated Annual Production Capacity by Type of Raw Material and by Region in 1973

	Bagasse	Flax	Others	Total	Bagasse	Flax	Others	Total
	..... 1 000 m^3				...........Percentages			
North America	-	-	-	-	-	-	-	-
Europe	-	1 427	15[2]	1 442	-	99	1	100
Japan	-	-	-	-	-	-	-	-
USSR	..	.	..	..	..	..	..	..
Asia [1]	50	-	17[3]	67	75	-	25	100
Latin America	104	12	-	116	90	10	-	100
Africa	58	15	-	73	80	20	-	100
Oceania	-	-	-	-	-	-	-	-
World Total	212	1 454	32	1 698[4]	12.5	85.5	2	100

[1] Excluding Japan

[2] Hemp

[3] Jute sticks, cotton stalks and palmfibre

[4] 4.7 percent of total particle board production capacity.

It would appear that flax accounted for something like 85 percent (in the order of 1.45 million m^3) and bagasse for around 12 percent (some 212 000 m^3) of world non-wood based particle board production capacity which it is estimated totalled nearly 1.7 million m^3 in 1973. Europe, it will be noted, accounted for no less than about 1.42 million m^3 (or 99 percent) of the flax based capacity at that time.

It would also seem that, in 1973, of world estimated production capacity to manufacture particle board somewhere around 5 percent was based on non-wood fibrous raw materials (cf. about 6 percent in the case of pulp and paper).

In some European countries the relative share of flax and hemp shives based panels of the total panel production has been diminishing due to insufficient supply of these raw materials rather than to consumer resistance. A great number of other plant residues has been considered and found capable of forming a satisfactory panel. Among these are kenaf, abaca, rice husles, wheat straw, peanut shells etc.

Based on the data on the total production of cereals and cane sugar, it can be estimated that something like 1 500 million tons of moisture-free straw and close to 60 million tons of moisture-free bagasse became available in 1975.

This comparison of the orders of magnitude of the availability and the current use of agricultural residues for paper and panel products manufacture reveals large theoretical potentials. It should, however, be emphasized that the collectable quantities of bagasse and, especially, straw are considerably smaller due mostly to the economic constraints related to the scattered availability of these materials. Furthermore, there are, of course, other uses such as energy production, soil improvement, cattle fodder, bedding, etc., which reduce the availability considerably; but even if the other uses are taken into account, the remaining quantities could still theoretically support large paper and panel industries. Why the residues have not been used to their obvious theoretical potential in the paper and panel industries can be explained by the limiting technical and economic factors resulting from the specific nature of these industries, as well as of the agricultural residues available.

Restrictions to the Use

Some of the restrictions to the more extensive use of agricultural residues as raw material for paper and panel products are resulting from the specific features of the industry. These industries and particularly the pulp and paper industry are capital intensive in which the economies of scale play an important role. This sets already two requirements for the raw material supply. One is that it has to be relatively large and secondly it has to be even all year round. Furthermore for each type of raw material and final product the manufacturing process has to be 'tailored' individually to which the modifications due to the changes in raw material supply or market requirements are extremely costly. This sets the third requirement for the raw material supply, that is that it should be guaranteed for at least the life time of the mill equipment. Finally, as the industry produces semi-manufactured products in bulk the homogeneity of the quality of which is the main guarantee for the secured markets at the further processing stages, the quality and especially the continued homogeneity of the quality of raw materials is of vital importance to the success of the industry.

The raw material supply for each individual mill has to meet all of these four requirements within certain technical and particularly economic limits. It is the specific nature of the agricultural residues that makes it frequently difficult for them to meet all of these requirements. The group of agricultural residues is comprised of a number of different kinds of plant residues which are produced in differing climatic conditions, therefore their individual ability to meet the set requirements naturally varies greatly.

It is typical for the agricultural residues that their sources of supply are often widely dispersed which results in increased collection and transportation costs. This is true especially as regards the residues like straw, becoming available after harvesting the main crop. Even if the residue is available in a more concentrated form like bagasse and flax shives after an industrial processing the quantities becoming available from one place need to be often supplemented with supplies from other processing plants which can mean considerably increased transportation costs. Another factor affecting the collection and transportation costs is the low density of the residues. Sometimes it also becomes necessary to transport unwanted material which cannot be separated economically but at the pulp or panel plant. Examples of this are the high moisture and pith content of some residues.

Agricultural residues are resulting exclusively from annual plants, the harvesting period of which is limited to a few months at most. As the mill operations cannot be interrupted due to the high fixed costs and employment problems, the mills using agricultural residues have to store their raw material. This affects not only the capital and operating costs but sometimes also the quality of the raw material.

Being residues from agricultural production, the main interest naturally lies elsewhere than in residue production. The demand for and the specifications set to the main crop determine the availability of the residues. For example the development of new cereal varieties might result in a considerably reduced straw production. A change in agricultural policy also might cause a sudden reduction in the wanted residue supply as has been the case with flax shives . These would be economically disastrous to the mills due to the long term nature of the investment; therefore the guaranteed long-term supply of standard quality raw material is one of the most vital points when planning this type of an industry.

The suitability of pulp for making various types of paper is determined by the characteristics of raw material and the pulping processes used. One of the main characteristics of the raw material in determining its suitability for various papers is the fibre length. Most of the agricultural residues contain short fibres comparable to those obtained from hardwoods, although notable exceptions exist. High short fibre content restricts their use for paper grades in which the strength is less important i.e. mainly for cultural papers and low grade packaging papers and paperboards. The pulping process used depends on the final use of the pulp and on the properties of the raw material. In general several quite different well-known processes are used for pulping agricultural residues, most of which have been adapted from the wood pulping processes. This also means that the technical problems related to pulping of agricultural residues do not as a rule set any limitations for extension of their use.

Specific features of a few most important Agricultural Residues

In the following, short descriptions are given of the current use, specific features and the technology applied when using bagasse, straw, cotton linters and flax tow as raw materials in the construction material and paper and paperboard industries.

Bagasse

Bagasse is the fibrous residue remaining after the juice is pressed from the sugar cane in a sugar mill. Green bagasse contains about 50 percent moisture, 2-3 percent residual sugar and close to 50 percent fibre. Out of the dry volume of the bagasse fibre, pith constitutes some 35 percent. Although chemically similar to cellulose, pith does not have the fibrous structure required from raw materials for pulping and panel production and must, therefore, be removed. Only the remaining depithed bagasse is suitable for pulping or panel manufacture. It has a fibre length averaging 1.7 mm (maximum 2.8, minimum 0.8 mm), which is shorter than fibre from coniferous trees but somewhat longer than average broadleaved wood fibres. Its chemical composition resembles that of hardwoods especially as regards the lignin content.

Based on the quantity of world raw cane sugar production of some 50 million tons during the 1975-76 harvesting period and by assuming a dry bagasse quantity of 1.15 tons per each sugar tonne, the estimated total dry bagasse quantity is 57.5 million tons.

The amount of bagasse available as raw material for paper and panel mills is, however, limited to a great extent since sugar mills utilize bagasse as fuel in their boilers.

Even without changing to alternative fuels, improved thermal efficiency in sugar mills can result in 20 percent of bagasse production being in excess of fuel requirements. This would mean a surplus of some 11 million tons of dry bagasse corresponding to over 3 million tons of paper pulp. Bagasse pulping capacity in 1975 was only around one million tons. The capacity to produce particle boards was estimated to be 212 000 tons in 1973.

One of the limiting factors to increase the use of bagasse as raw material is, besides the difficulties of using substitute fuels at sugar mills, that sugar mills quite often are small and widely scattered. Bagasse is bulky and, therefore, its transportation for long distances is a significant economic disadvantage. The new sugar mills are however larger and their fuel requirements are better planned so that larger and more concentrated quantities of bagasse become available.

The seasonal nature of the cane processing operation in most places means that extensive storage of bagasse has to be arranged in order to guarantee uninterrupted supply of raw material to the paper or panel mill, the operation of which cannot be interrupted or changed to use other raw materials.

Therefore, economic operations in handling, baling, transport and storage of bagasse are essential for a successful paper or panel mill.

Several different processes are used for the pulping of bagasse, depending on the end product desired. Chemical pulps made from bagasse are used for making almost all grades of paper and paperboard; however, due to the short fibre length of bagasse pulp, additional long-fibre chemical pulp is often required to improve the strength of the panel produced. Semi-chemical and chemi-mechanical processes are used in pulping bagasse for corrugating medium, which is the medium layer of the corrugated board. Mechanical pulp has not yet been made commercially from bagasse, although this is an area of active investigation. The success in developing a commercially viable mechanical pulping process for bagasse could be considerable breakthrough in the production of newsprint from bagasse which has so far not been economically possible.

Straw

Unlike bagasse, straw is not a uniform group of raw material but it consists of a number of cereal straws, rice straw and corn stalks which all have somewhat differing pulping and papermaking properties. Rye straw and wheat straw are considered to be the best of the cereal straws while oat straw and barley straw, due to a higher proportion of leafy material and other extraneous materials are considered to be less suitable. Rice straw, which is perhaps the most difficult of all straws to use, has, besides the extremely slow drainage characteristics which are common of all straws also very high silica content, which makes chemical recovery more difficult. Cereal straws and corn stalks have a fibre length averaging about 1.5 mm with a significant content of long fibres. In this respect they resemble bagasse. Chemically, they have a low lignin content; cereal straws contain about 17 - 19 percent, and rice straw about 12 percent ligning, resulting in easy pulping. The cellulose content of European and North American cereal straws ranges from 36 to 42 percent, rice straw has a cellulose content of about 34 to 38 percent. All straws have a high hemi-cellulose content, which makes them particularly suitable for the production of grease proof and glassine papers.

Straw has also been used in the production of special type of panel by compressing the shredded straw which results in an extruded panel use in building constructions.

It can be estimated that on an average about 3 tons of moisture-free straw are required per one ton of paper.

The yields of straw per ton of grain vary according to the location and type of the plant. In calculating the amount of straw actually available to a paper mill, it is unlikely that more than 50 percent would be considered surplus to agricultural requirements, and draught, storms, disease and crop failures have to be taken also into acccount. The following yields of straw per ton of grain estimated in the USA give an indication of the orders of magnitude by plants:

Wheat Straw	–	2.3 tons/ton of grain
Rye Straw	–	3.1 tons/ton of grain
Oat straw	–	1.6 tons/ton of grain
Barley Straw	–	1.5 tons/ton of grain
Rice Straw	–	1.5 tons/ton of grain

In one calculation, a southern European farming area with a radius of 80 km and an annual wheat production of 320 000 tons was considered to be a reliable supply of only 125 000 tons of straw per year for a pulp and paper mill. This is about 0.4 ton of straw per ton of grain.

The harvest season for cereal straws is brief, which means that nearly a year's supply of these bulky materials must be stored at the pulp and paper mill. There is always deterioration in storage although in mild, dry climatic conditions it is tolerable to store straw in the open. In humid or tropical regions storage under cover is mandatory. In some areas harvesting of rice straw is carried out twice a year or three times every two years, in which cases storage of a six months' supply at least must be provided. The problems associated with the supply of corn stalks are in general similar to those of cereal straws.

The processes used to pulp straw are generally similar to those used for pulping bagasse. The high bulk of straw leads to relatively low yields per cubic metre of digester capacity. Straw pulps are slow-draining, and paper machine sheet-forming sections are unusually long compared with those forming wood fibre papers. Washers in the pulp mill must also be over-sized.

Straw pulps may be used in almost all grades of paper and paperboard, from the coarsest to the finest. Paperboards and corrugating medium are usually made of 100 percent straw pulp furnish, although some long fibre supplementation may be required for the best grades. As with hardwood pulps, a small amount of straw pulp is beneficial to the printing quality of the paper. Some has been used in this way in newsprint manufacture.

Cotton Linters

Cotton linters are the short fibres remaining on the cotton seed after the staple (long) fibres have been removed by ginning. Machines cut the linters from the seed. While linters are too short to be used in textile manufacture, they serve many related purposes, including felting, batting, etc. There are several grades, such as first-cut, second-cut and mill-run. The first-cut fibres are longest and of the best quality. Linters fibre length is 2 to 7 mm.

Cotton linters are purified in non-integrated pulp mills and sold for papermaking, dissolving pulp, or other uses. For some years it was the principal material for making the highest grades of dissolving pulp, for cellulose esters or for tire cord. The position of cotton as a fibrous raw material for dissolving pulp has deteriorated almost to the vanishing point. From 1945 to 1955, more than 100 000 tons of cotton linters were used annually in the United States for the production of dissolving pulp, but by 1965 the figure was less than 1 000 tons. These were for specialties such as transparent moulding grade cellulose esters and for X-ray film. It is, however, a source of cotton fibre for high-quality papers. Total United States production of purified linters is about 250 000 tons; but paper makers may buy raw fibres and purify them themselves. Also, the purified linters have many other uses, in the highest quality protective and writing papers, saturating papers and in filtre papers.

For use in paper pulp or dissolving pulp, linters are purified by relatively simple, conventional soda processes. The cotton fibre is over 90 percent cellulose as received, so the purification processes involve removing waxes and foreign matter. There are three large linters purification plants in the United States, at Hopewell, Virginia, and at Memphis and Chattanooga in Tennessee. There is also a linters purification plant at Reynosa, Mexico. In these plants the baled linters are first cleaned and then subjected to a caustic soda cook under pressure in vertical or in rotating cyclindrical, horizontal digesters. The resulting pulp is washed, bleached and may be sheeted, dried, cut and baled for shipment, or the bulk pulp may be dried, compressed and baled. There is a significant difference in fibre length, since the sheeted pulp is mechanically refined (fibrillated). The average fibre length of bulk purified linters pulp is 2.2 to 3.0 mm, and that of sheeted pulp 1.1 to 2.7 mm. The alpha cellulose content is 98 percent or better. Sheeted pulp is also sold in rolls.

The proportion of cotton in the papermaking furnish may vary from 25 (or less) to 100 percent. Only about 15 percent of cotton content paper contains 100 percent cotton fibres and about 70 percent has 25 percent or less. Banknote papers are usually 75 percent linen fibres and 25 percent cotton fibres.

Flax

Flax is grown extensively for making linen and linen-seed oil. The residual material after removal of the long fibres is known as flax shives . The shives contain about 45 percent cellulose (pure linen is more than 80 percent cellulose) and 13 percent lignin. The yield of flax seed straw per area of cultivation is low. Furthermore, the yield of decorticated fibre and acceptable shives per ton of straw are low. The average pulping yield, varying between 25 and 60 percent depending on the cleanliness of the straw, is also considered to be on the low side. All these result in an extremely expensive pulp which can be used only in very high-priced end products. Such are cigarette paper, for which flax pulp is extensively used and other thin papers requiring high strength, such as banknote and airmail papers. It is estimated that something less than 100 000 tons of flax pulp ar produced in the world. The use is expected to continue to increase although the very high price of the pulp will keep the quantities at a modest level. Flax shives on the other hand, as has been mentioned earlier, constitute an important raw material in the manufacture of particle board.

Conclusions

The use of agricultural residues in the panel products and paper industries is restricted mainly by the economic factors while the technical problems can mostly be overcome. The numerous economic restrictions arise from the specific features of the industries and of the agricultural residues themselves and are related specifically to the economics of harvesting, transportation, storage, chemical consumption, fibre yields and quality of products.

Despite the numerous restrictions to the use of agricultural residues, the economic limitations have been overcome in many individual cases. The proof of this are the numerous mills producing products of satisfactory quality for the local markets. However, when determining the feasibility of the use of agricultural residues for such highly capital intensive industry as paper and paperboard manufacture, it is essential to make a careful study to ascertain the continuous long-term economic availability of the raw materials. This, together with the correct selection of the products to be produced, is the best guarantee of success of such a mill.

The use of bagasse for these industries, due to its more concentrated availability, will increase faster than that of other agricultural waste materials. The increase in the use of straw will be restricted by competitive uses and its scattered availability. The importance of other agricultural residues will remain restricted to products of high price and limited demand.

In the case of panel products, the consumption of non-wood fibrous raw materials has increased over the last ten years but at a slower rate than the total panel production. It remains a very small component of the total raw materials used amounting to 2-3 percent of the total.

Animal Feedstuffs from Waste and Surplus Fish

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Introduction

The objective of all fishery development programmes is to make the best possible use of marine resources as food. The most effective means is obviously by making increased quantities of fish available as human food. However, in most cases there is always part of the fish (intestines, head, bones etc.) which is not consumed. In addition the seasonal nature of many fisheries means that from time to time peak landings glut the market. It would not be cost-effective to install the processing capacity to deal with them if it was to stand idle for the rest of the year. There are also other resources which for one reason or another are not at present used as human food.

Although this is a rather oversimplified view it does indicate that there are substantial quantities of waste and surplus fish which could be made available as animal feed. At present the waste material is a disposal problem, both in developed and developing countries, often being allowed to spoil on beaches or rubbish dumps. Apart from the obvious economic losses of protein and oil there are the more visible problems of pollution and danger to public health. Differences between species make it impossible to assess accurately the quantities involved on a world wide scale. As examples filleting yields rarely exceed 50% of live weight and even the head and intestines can represent 30% of the fish weight. If a conservative figure of 20% of the 47 million tons per year of fish used for direct human consumption is wasted, this represents a considerable disposal problem. However, the overall protein content is probably not high and some of the waste is converted to fish meal. Another more serious cause of waste is inadequate handling and transport facilities which often results in large quantities of fish being caught but becoming unfit for human consumption before they reach the market. Sumner (1976) estimated that more than 800.000 tons of fish per year fall into this category in South East Asia and at least a similar quantity is dumped at sea in this area.

There are also innumerable situations where accessible stocks of fish exist but are not caught because there is no market for the products. A process to convert these resources to animal feed would encourage the development of the fishing industry and also make a significant contribution to the animal protein needs of many countries.

Choice of process

The most obvious process for converting waste fish to animal feed is the production of fish meal; at present some 20 million tons of fish per year are used for this purpose. The meal is mostly fed to poultry and pigs, predominantly in the developed countries, although many developing countries are substantial producers. The disadvantage to installing fish meal equipment to process the waste and surplus catches mentioned earlier, is that modern fish meal production is capital intensive and technologically complex (FAO 1975). An economic operation can only be envisaged if large volumes of fish are available on a regular basis. As a rule of thumb it has been suggested that for profitable operation a small fish meal plant is required to operate at designed capacity for 200 days per year. There is no doubt that fish meal production will continue, and even expand, in areas where these conditions can be met, but in situations characterized by scattered and irregular landings, an alternative and cheaper technology must be applied.

Fish silage

There is a great deal of interest in the production of fish silage as a simple and cheap means of preserving waste fish for animal feed. Fish silage is best described as a liquid product made from fish or parts of fish and acid. Liquefaction results from the action of catheptic enzymes present in the fish and is accelerated by the acid which provides optimum conditions for the enzymes as well as helping to break down bone and prevent the growth of spoilage bacteria. Inorganic or organic acids can be used; alternatively the production of lactic acid can be encouraged by mixing a carbohydrate source with the fish and inducing fermentation by inocculation with lactic acid producing microorganisms.

The preservation of animal feed by acid ensilage dates back to the 1920's when A.I. Virtanen, a Finn, showed that green fodder could be preserved with a mixture of sulphuric and hydrochloric acid. Edin (1940) was the first to apply the process to fish and fish waste in Sweden. Although the strong inorganic acids are cheap they are highly corrosive and the silage must be neutralized with chalk before feeding. Olsson (1942) used formic acid which limits bacterial growth at a higher pH and does not need neutralization, although it is more expensive. The manufacturing process will not be considered here as it has been extensively reviewed by such authors as Petersen (1953), Sikorski et al (1969) and Tatterson and Windsor (1974).

Current production and interest

Fish silage production on an industrial scale is restricted to Denmark and Poland. Danish production in 1974 was about 30.000 tons using a mixture of formic and sulphuric acids. Much of this production takes place at sea from fish that would otherwise be discarded. Poland produces about 10.000 tons per year using mineral acids and sometimes sodium bisulphate. In both cases the silage is used to supplement pig feed. A liquid product is ideally suited to feeding in modern "river" pig feeding systems. Hester (pers.comm.1976) indicates that production has started in Southern California and there is great interest in other parts of the world. Nicholson (1976) reported to a symposium on fish silage held in the UK that fish silage production could be competitive to fish meal up to a radius of 80 miles from the point of landing and manufacture. Beyond this distance the extra transport cost involved in carrying a product with about 15% protein as opposed to fish meal with 60% removed the advantage. However, pig producers in Denmark incorporate fish silage in their diets because of an emotive feeling that it gives better weight gains than fish meal. There is no experimental evidence to confirm this.

Disney et al (1976) and Disney and Hoffman (1976) have reported on a dried silage product produced in the tropics. A sulphuric and formic acid silage was mixed with cassava, readily available in many tropical countries, and sun dried. The resulting product could be crumbled up and stored in bags until used. There was no evidence of insect infestation during drying. This product has obvious advantages for incorporation in poultry diets where a dry feed is required. Other work in the tropics has been carried out by Stanton and Yeoh (1976) in Malaysia on microbiological silage. As the rate of liquefaction during ensiling is dependent on temperature, the process is ideally suited to the ambient conditions in the tropics. It is similar to the production of fish sauces in South East Asia where liquefaction is effected by natural enzymes in the presence of salt to prevent bacterial growth. It is unfortunate that consumption of these products is limited by the high salt content.

The FAO Fish Production and Marketing Service has a programme of cooperative research in fish technology between institutes in the Indo Pacific Fisheries Council Region. Sumner (1976) carried out a feasibility study on fish silage production in the region which has evinced great interest. Plans are being made for experimental production and animal feeding trials in Indonesia, Malaysia, Singapore and Thailand. The results will be spread to other countries. This area appears ideally suited to fish silage production as considerable quantities of waste and trash fish are available. However, landings are scattered and irregular, so fish meal production is unlikely to be economic. All the countries presently import fish meal and demand is expected to increase substantially as living standards improve, resulting in higher demand for animal protein. Fish silage produced on a village or industrial scale, could help to satisfy this demand; at the same time it would reduce imports, remove a pollution problem and make fuller use of available marine resources.

The cooperative research programme for fish silage production in these countries will start with feeding trials in animal research institutes. If these are successful attempts will be made to scale the process up to commercial operation.

Problems and constraints

It cannot be expected that the production and use of fish silage in developing tropical countries can be started without considerable investigation and extension effort. It will probably be more difficult under these conditions than in a developed country. Experience in the UK, which is a major importer of protein for animal feeding and where surplus fish is available, shows that although experimental work has been going on for several years commercialization is still not a reality. A major problem is that an integrated approach between the fishing industry and the livestock industry is required. The livestock industries in developing countries are generally not well developed and pigs and poultry are often left to forage for themselves. However, in South East Asia the business of feed compounding is growing; for instance Malaysia and Singapore each have 30 feedmills and there are 35 in Indonesia.

Very few feeding trials have been carried out with silage in the tropics, although Disney et al (1976) fed silage produced in Africa to chickens in the UK. There have been sporadic attempts to experiment with silage but no real indication of its successful use. Feeding trials in other parts of the world with properly compounded diets seem to indicate weight gains equal to control diets. (Arneson and Einarson 1967, Olley and James 1972, Jensen 1973 and Luscombe 1976). Other workers have shown increased weight gains (Hillyer et al 1976) while others (Smith and Adamson 1976) found reduced weight gains. It is clear that more work is required, but all indications are that silage is an acceptable source of protein and can be produced more cheaply than fish meal. Under these circumstances, and particularly where fish meal has to be imported, reduced weight gains, if they are confirmed, may not be significant.

A more serious potential problem is the possibility of inducing fishy taints in the meat and eggs by the feeding of too high levels of unsaturated fish oils. It is well known that, if the level of marine fat in the total diet exceeds 0.8 to 1% then there is a risk of taints developing. Smith and Adamson (1976) found tainting of pig meat with high levels of oily herring silage but not with de-oiled silage. Olley and James (1972) found an absence of characteristic meat flavour in pigs fed up to bacon weight with silage produced from abalone offal. Dreosti of South Africa has commented previously, that this lack of flavour is an indication of incipient tainting. How serious the tainting problem would be in developing countries is not known but there is good evidence that it can be avoided if marine oils are withdrawn from the diet a short time before slaughter. It is unfortunate that much of the waste and surplus fish in the tropics is small oily species. If it is necessary to de-oil the silage then costs will rise and the recovered oil would have to pay for the extra process if silage is to remain competitive with fish meal. It is unclear what effect spoilage before ensiling has on growth but Olley et al (1968) have reported growth retardation in chickens fed spoiled fish hydrolysates. It is suggested that these may be due to the breakdown of histidine to histamine and other toxic imidazole compounds. More work is evidently required in this field as at high tropical temperatures some spoilage is inevitable.

The problem of high transport costs involved in carrying a 15% protein solution rather than a dry meal have been referred to earlier. In the small fishing and farming communities in the tropics this may not be so severe, as feeding can take place close to the site of production. In an industrialized operation it would be necessary to take this factor into account, although it should be possible to co-dry silage with cereal in most tropical areas.

The corrosive nature of silages made from mineral acids is another difficult problem which has to be faced. Training unskilled and relatively uneducated people in the safety procedures and correct use of strong acids will be difficult. It is easier to use formic acid alone but this is ruled out because of the high cost. The alternative of making microbiological silage in the tropics is attractive, particularly because of the local experience with fermented fish sauces in many places. However, this requires more complex processing and if the surpluses are seasonal it means that a starter culture of the microorganisms must be retained.

Conclusion

Despite the apparent problems there are good prospects for establishing silage production industries both in developed and developing countries. Many advantages can be seen in developing tropical countries where livestock production is rising, causing an increased demand for imports or production of fish meal. Although silage production and use may not be more economic than fish meal production in all cases, but where scattered and irregular landings occur it would solve a potential pollution problem as well as contributing to the animal protein needs of the population. Silage production would also increase small-scale fishermen's and farmers' incomes and reduce the wastage of a valuable resource.

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H.R. Koenig (UNIDO)
E.L. Littmann (FAO/ECA)

Group No. 8 - Animal By-Products

Chairman: D. Strauch Rapporteur: M. Traylor
C. Groom

R.L. Halstead (Canada)
M.J. Riddle (Canada)
E. Parrakova (Czechoslovakia)
A. Møller (Denmark)
A. Bonnin (France)
W. Baader (Germany Fed. Rep.)
E. Offori (Ghana)
H.R. Srinivasan (India)
J.J. Patel (India)
P. Dini (Italy)
B. Boxchi (Italy)
L. Conte (Italy)
R. Lehmann (Italy)
F. Martillotti (Italy)
D. Sinischalchi (Italy)
F. Napolitano (Italy)
P. Van der Wal (Netherlands)

E.I. Tønseth (Norway)
A. Zelechowska (Poland)
M. Winiarczyk (Poland)
O. Johansson (Sweden)
J. Schmekel (Sweden)
J.C. Hawkins (UK)
A.P. Hopwood (UK)
S. Smith (UK)
P. Wix (UK)
F. Fisher (UK)
A. Cwin (USA)
L. Prishchep (USSR)
J. Baicor (USSR)
J. Shvytov (EEC)
L. Pavan (EEC)
G.B. Ward (WHO)

Participants of the Working Groups (contd.)

Group No. 9 - Fish Waste

Chairman: D. James
Rapporteur: J. Nabney

E. Glaser (Israel)
B. Sivik (Sweden)
J. Nabney (UK)
N.B. de Jel (USA)

Group No. 10 - Single Cell Protein

Chairman: J. Senez
Rapporteur: G.D. Kapsiotis
P. Van der Wal

A. Bencharif (Algeria)
A. Hamrour (Algeria)
M.T. Sellal (Algeria)
K. Schreier (Austria)
H. Ashmawi (Egypt)
M.S. El Herrawi (Egypt)
A.G. Abdel Samie (Egypt)
L. Bobichon (France)
A. Bonnin (France)
J.G. Echard (France)
P. Dupuy (France)
M. Raimbault (France)
P. Pichat (France)
A.A. Laryea (Ghana)
E.D. Offori (Ghana)
S. de Cabrera (Guatemala)
M. Sharma (India)
E. Glaser (Israel)
R. Costanzo (Italy)
L. Degen (Italy)
S. Firrisi (Italy)
F. Napolitano (Italy)
S. Giovenco (Italy)
L. Vincenzotti (Italy)
J. Wells (Italy)
P. Stefan (Ivory Coast)
E. Ford (Netherlands)
E.J. Mesu (Netherlands)
O.A. Koleoso (Nigeria)
A. Garandang (Philippines)
I. Cruz (Philippines)
A.S. de Oliveira (Spain)
B. LaFuente-**Ferriols** (Spain)
B.O. Hofsten (Sweden)
B.L. Baret (Switzerland)
N. Chomchalow (Thailand)
A.J. Forage (UK)
J.A.C. Hugill (UK)
J. Nabney (UK)
F. Smith (UK)
R.J. Woolcock (UK)
S.M. Barnett (USA)
M. Fleischman (USA)
T. Gibian (USA)
D.L. Miller (USA)
R.W. Pachaly (USA)
L.G. Prishchep (USSR)
I. Shvytov (USSR)
W.R. Stanton (UNEP/UNESCO/ICRO Panel)
E. DaSilva (UNESCO)
H.R. Koenig (UNIDO)
G. Vasta (OECD)
L. de Rosen (UNEP)
J. Haines (UNEP)
Nay Htun (UNEP)
D. Phantumvanit (UNEP)
J.C. Abbott (FAO)
M. Chenost (FAO)
J.M. Hutchinson (FAO)
E.F. Szczepanik (FAO)