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UNDER THE MULTILATERAL FUND FOR THE IMPLEMENTATION
OF THE MONTREAL PROTOCOL

Importance of cold chain

Extending the shelf life of cut flowers and fresh produce

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Under the Montreal Protocol on Substances that Deplete the Ozone Layer, the discussions about the refrigeration cold chain usually focus on the food industry (including supermarkets) and to a lesser degree on the fishing industry (including fishing vessels, fish products distribution and storage). However, the international trade of fresh produce and flowers are often overlooked. Yet, the shelf life of these products critically depends on an adequate cold chain: ideally, uninterrupted storage at the optimum conservation temperature from the time of harvest until delivery. This includes cold rooms at the farm or production point (for storage, packaging), refrigerated ground transport to port of delivery, cold storage before shipping, refrigerated transport to end market by air or sea, and refrigerated storage and transport at point of arrival, until the point of delivery to the end consumer.

In addition, availability of cold storage directly impacts food security by reducing and delaying losses caused by rotting and decay stemming from the attack of bacteria and fungi.

Learning more about the cold chain as it impacts the marketing and consumption of fresh produce and flowers provides a prime opportunity for promoting the Kigali Amendment, identifying areas of work and feasible alternatives and conducting awareness-raising activities in many countries.

INTRODUCTION

Whether selling locally or exporting to long-distance destinations, growers of fruits, vegetables and cut flowers, all face the same challenge: preserving good quality and extending shelf life of their harvested goods as much as possible, to ensure reaching end consumers with the best quality products.

Once harvested, fresh produce spoils rapidly, due to wilting (water loss), attacks from pathogens such as bacteria and fungi or mechanical damage (which in turn can lead to the first two). A correct harvesting stage, proper (and minimal) handling of produce, cleaning and sorting or grading, plus adequate packaging are other factors directly influencing post-harvest life of fresh produce and cut flower.

Temperature and relative humidity management are the most effective means of extending and maintaining quality and safety of fresh horticultural commodities. Even though harvested fresh produce is still alive, at low temperatures physiological change takes place: respiration, ethylene production and enzymatic processes are slowed down and as a result flower ageing and fruit ripening are delayed. Growth of microorganisms (bacteria and fungi) is also retarded.

However, access to cold storage and a cold change is often quite limited. In India for example, it is estimated that only about 4% of the produce is handled with cold and food spoilage or crop losses can reach as much as 40% of the harvest, with huge impacts on food security and availability.[1]

1 FoodTank, June 2019. Opinion: Bringing food cold chains to more people in India. https://foodtank.com/news/2019/06/opinion-bringing-food-cold-chains-to-more-people-in-india/

THE COLD CHAIN

Although cold or refrigerated storage of harvested goods is clearly essential to minimize post-harvest losses, it is only part of the story as losses occur at every step in the post-harvest cycle. Cold storage thus cannot be considered a full or single solution to prevent or avoid post-harvest spoilage; it is one of various components, needing to be integrated into a "cold chain" that spans from the point of harvest up until the moment when the end consumer makes a purchase. Research has shown time and again that maintaining low temperatures which are as stable as possible, during the storage and shipping process, is essential to a long shelf life. In general, the goal is to reach and maintain temperatures at a maximum of 4°C, ideally 2°C. This is no easy feat, considering the series of events that need to take place before flowers and produce reach the end consumer. Ground transportation, airport processes, airfreight, distribution and display all are part of that chain, and need to be considered.

For best results, the cold chain should comprise the following stages:

Pre-cooling
The first step is to remove field heat, which will vary according to production conditions. This includes preferably harvesting early in the day – when temperatures are cooler (especially in warmer regions) – and also establishing a "pre-cooling" process, which is generally done before packing, in a cold room.

Packing and pre-shipment cold storage
Once produce has been pre-cooled, it is best to pack directly inside the cold room (at around 6ºC). Forcing cold air into packed boxes is often used as follow-up and is a good strategy to help preserve temperature inside the boxes during transport. Packed boxes are then moved to a cold storage room, which is maintained at around 2-4ºC according to the goods being processed. Some tropical products (flowers and produce alike) cannot withstand these low temperatures and need much warmer levels (10-13ºC). See table 1. Cold storage may also take place at airports or sea ports and this may be a particularly difficult step in the chain, due to logistics, handling large cargoes and others.

Transportation
This includes shipping goods from the production site to the airport or port, and/or from the arrival point to distribution centers. Depending on the goods traded the distance and other factors, this step may involve refrigerated trucks, air freight and/or sea transport. The number of steps or transfers involved will directly impact the stability of the cold chain

Pre-sale cold storage
At distribution centers, such as wholesale and mass markets (e.g. supermarket chain, garden or produce center storage facilities). Storage time should be as short as possible.

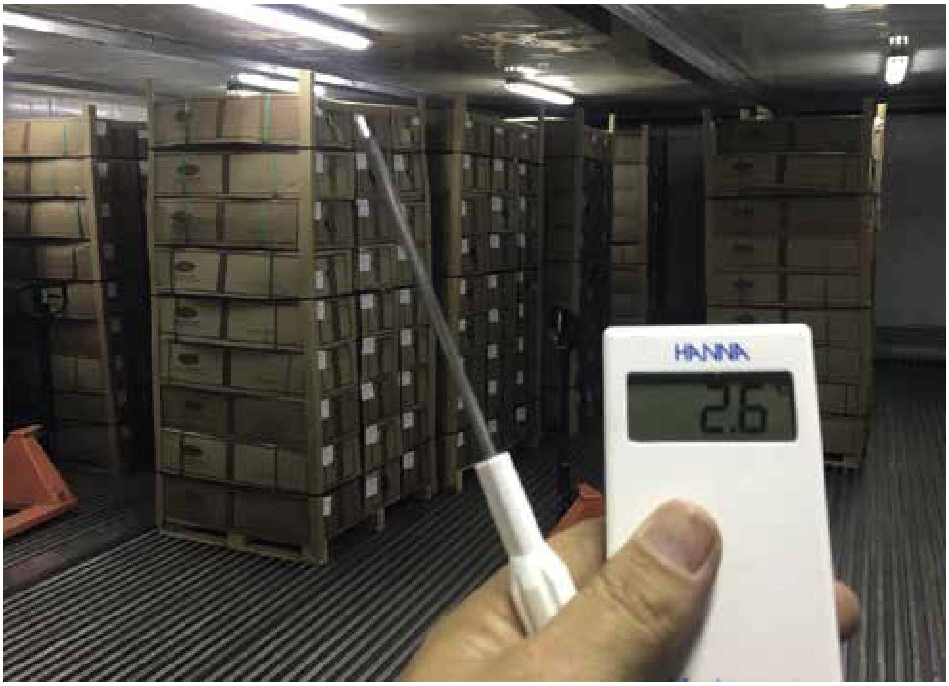
Refrigerated retail display
When fresh flowers, fruits and vegetables are offered to the end consumer. In the case of fresh fruit and vegetables this could be followed by home refrigeration.

Table 1. Recommended cold storage temperatures for fresh fruits, flowers and vegetables

Product	Optimum storage temperature	Relative humidity
Leafy vegetables (spinach, lettuce) Cole crops (broccoli, cauliflower) Temperate fruits (apples, pears, plums) Berries	0-2ºC	90-98%
Citrus fruits (lemon, orange) Tropical fruits (mangoes, papaya, bananas) Many fruit-type vegetables (tomatoes)	7-10ºC	85-95%
Root-type vegetables (potatoes), squash, melons, watermelons	13-18ºC	85-95%
Temperate flowers (roses, carnations, chrysanthemums)	0-2ºC	> 95%
Tropical flowers (anthurium, heliconias, gingers)	10-13ºC	85-95%

COLD STORAGE MANAGEMENT

Cold storage of fresh produce and flowers can lead to huge benefits by extending their useful life, but is costly and energy intensive; good management is essential to ensure efficiency and best results, and to avoid losses resulting from storage errors.



For example, some produce – particularly that of tropical origin – is sensitive to chilling injury and if stored below optimum temperature will become blackened, pitted and generally spoiled. They may also ripen faster or simply wilt, become shriveled and/or rot away. Effects can be cumulative; that is, the effects of storage periods below optimum temperatures will add up even if conditions are correct during periods in between. The level of ripeness and the point of harvest are among the factors that can affect predisposition to chilling injury.

If temperatures fall below 0ºC, freezing will cause cell rupture and the damage to produce will generally only be observed once temperatures go above this level. Damage will translate into symptoms like waterlogging and glassy areas in the flesh or petals.

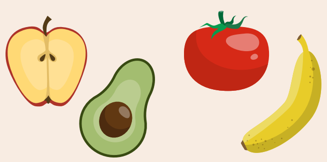
Since different kinds of produce have different requirements, it is important to store them accordingly. Examples are given in the table 1.

In addition, some products should never be stored together. Apples, avocado, tomatoes and bananas for example, produce high amounts of ethylene, a plant hormone promoting flower senescence, and to which carnations are particularly sensitive. Needless to say, these should not be stored (or even displayed) together as shelf life will be impaired. Apples and pears should not be stored together with onions, potatoes or carrots as they tend to adopt their odor and taste; and green peppers can taint pineapples.

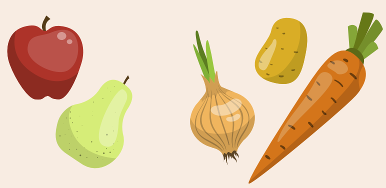
Ensuring good circulation of cold air by avoiding stacking product improperly or overloading trucks, for example, is another way in which the efficiency of cooling can be assured. Forced air cooling (forcing cold air to pass through produce via a pressure gradient across packages) , hydrocooling (where the refrigeration medium is cold water) and vacuum cooling (a rapid process achieved at very low pressure) are some of the systems that can be considered for use. The choice will depend on many factors including the size of the operation, the distance where the goods are to be shipped, the time in storage and transport and others.

SHOULD NOT BE STORED TOGETHER

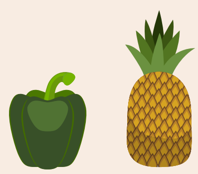
Apples, avocado, tomatoes and bananas



Apples and pears with onions, potatoes or carrots



Green peppers can taint pineapples



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Importance of the Kigali Amendment

The Montreal Protocol's Kigali Amendment focuses on the phase-down of hydrofluorocarbons (HFCs). HFCs are refrigerant replacements for ozone-depleting hydrofluorochlorocarbons (HCFCs) and adopted as such in many applications, but have high or very high Global Warming Potentials (GWP), thus acting as powerful greenhouse gases. By phasing-down HFCs, the Kigali Amendment creates a strong link between ozone and climate protection and sets a clear path in protecting our planet's environment: by eliminating HFCs, up to 0.4 °C of global warming could be avoided by the end of this century, while continued ozone protection is ensured. In addition, the amendment has created very clear opportunities to increase energy efficiency in the cooling sectors.

When thinking of the refrigeration and air conditioning (RAC) sector; however, refrigeration in the fresh produce sector is not often addressed, and thus not included in communication strategies, action plans and other activities related to the implementation of the Kigali Amendment.

Several projects to replace HFCs or bypass them when replacing HCFCs in the cold chain related to fresh produce and flowers have been completed or are underway with support from the Multilateral Fund for the implementation of the Montreal Protocol. These experiences provide useful insights and lessons learned, for example:

▶ In **Colombia**, a demonstration project led by UNDP and the Ministry of Environment was undertaken together with a very large flower grower/ exporter (over 300 Ha in production), to replace the refrigerant HCFC-22 used in the cold rooms with R-290 (propane, a hydrocarbon). Technical requirements to make the conversion and new installation were identified, the required equipment was installed in the cold rooms, and the thermal/ energetic performance of the new system was compared with previous conditions. Safety and energy efficiency standards were monitored. Cooling conditions and results were highly satisfactory and a 20% energy saving was achieved. Some barriers to implementation of the systems were however encountered, including lack of trained professionals (engineers, technicians, maintenance personnel) and, in consequence, lack of in the new refrigerant and system, difficulty in sourcing the required equipment and absence of regulatory standards for this alternative refrigerant.

▶ In **Ecuador** a pilot demonstration project is under way, which is part of their HCFC phase-out management plan (HPMP), currently being implemented by UNIDO. The goal is to replace HCFC-22 refrigeration with HC-290 (propane) in a cold room used for storing cut flowers (specifically sunflowers) for export prior to shipment. The counterpart is the company Hilsea, a well-known, large flower exporter from Ecuador, comprising about 160 ha in production and selling flowers mainly to Europe and the United States since many years. Initial results are successful and should lead to refrigerant replacement in about 20 cold rooms, in this enterprise only. Security standards, training and maintenance, energy efficiency and economic parameters are being considered.

The role of refrigeration in successfully delivering fresh flowers, fruits and vegetables "from farm to table" (or home) is substantive, and has a big impact on their quality, safety and useful shelf life. This of course is important not only to the consumer of the fresh produce, but to the thousands of people around the world whose livelihoods depend on the success of these important agricultural industries.

The value of traded goods is impressive:

▶ According to research from COMTRADE, (the United Nations' international trade database), global exports of cut flowers were worth nearly $10 billion USD in 2018, amounting to (an increase larger than 46% from 1995). Top exporters include the Netherlands, Colombia, Ecuador, Kenya and Ethiopia.

▶ The fresh fruit and vegetables sector is much larger (worth hundreds of billions of dollars) and very complex, given the variety of products grown and traded worldwide. For example, Chile is the top world exporter of grapes, whilst Spain is the largest world exporter of melons and fresh strawberries and Mexico is at the top of the list with fresh tomatoes.

Millions of tons of goods are traded - and cooled! - before they reach the end consumers. Accordingly, refrigerant use and demand in this sector has grown continuously over the past decades and needs attention. This provides a prime opportunity for Article 5 countries to develop enabling activities such as capacity-building, training, institutional training and demonstration projects under the provisions set forth by the Kigali Amendment.

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