

## Introduction

A large range of agricultural produce is stored and transported across an increasingly complex supply chain. Low temperature storage facilities help to avoid products perishing and degrading during transportation. The cold chain encompasses several critical steps that products must undergo in order to maintain quality. Poor temperature management results in deteriorating product quality and produce waste which leads to GHG emissions. The cold chain infrastructure needs to be optimised to avoid this waste and will include aspects of refrigeration, storage, handling and humidity control. Table 1 illustrates actions that can be taken to reduce produce losses

Activity	Action
Harvest	Minimise delays before cooling      Cool product thoroughly
Cooling	Store product at optimum temperature
Storage	Rotate produce in storage      Transport to market quickly
Transportation	Use a refrigerated loading area      Cool truck before loading Load pallets correctly      Avoid delays during transport Monitor product temperature
Handling	Use of refrigerated unloading area      Monitor product temperature Move product quickly to storage area

Table 1 - Activities to maintain in the produce storage and transportation

## Refrigeration and Cold Storage

Most fruits and vegetables will be cooled immediately following harvesting to slow the inevitable ripening and decaying process. Different types of horticultural crops will have different requirements in terms of post-harvest temperatures. Temperate crops will usually require lower storage temperatures (0-2 degrees) than tropical crops (12-15 degrees). As a general guide, storage criteria for produce types are shown in table 2.

Storage 0-2° C	Storage 7-10° C	Storage 13-18° C
Apple	Basil	Potato
Berries and cherries	Green beans	Pumpkin
Celery	Pepper	
Cruciferous vegetables	Pineapple	
Cut vegetables		
Fennel		
Herbs		
Lettuce and salads		
Mushrooms		
Pear		
Peas		
Plum		
Root vegetables		
Spinach and greens		

Table 2- Approximate storage temperatures for fruits and vegetables.

An adequate storage facility will require insulation of the roof and walls to ensure efficiency and minimise GHG emissions. Correct stacking of produce within the room whilst avoiding overloading, will have a great effect on

the efficiency of the storage cooler. The energy efficiency of a cold-storage facility can be improved using the following measures:

- Reduce roof temperatures using light coloured or reflective roofing materials
- Reduce fan and lighting use by maximising efficiency
- Increase insulation in ceilings and walls
- Seal openings around doors
- Install extra heat exchange surfaces for the condenser
- Ensure temperature of refrigerant fluid in condenser is as low as possible

Some produce will require rapid cooling in the summer months. Temperature controlled transport from the field can be effective in achieving this and will maintain the quality of vegetables. Mobile temperature control will however be less efficient than stationary control with insulation not as great due to the need for mobility and efficient transportation

### Cold Chain Methods

Temperature control in storage is a significant cost and this becomes greater if produce travels longer distances. If produce were not refrigerated it would spoil and this would lead to the production of methane from subsequent landfill. More food would then need to be produced and subsequent additional energy inputs would be required. The cold chain therefore performs a vital function. Produce will not degrade as quickly, it maintains vitamin levels and nutritional value. Lowering a storage temperature can therefore slow the rate of produce spoilage despite the energy use involved.

The number of fruits and vegetables grown and transported in the food chain is vast, and will comprise different parts of crop plants e.g. fruits, stems and leaves. The plant variety, maturity at harvest and which part of the plant is to be transported, will all influence the type of storage conditions required. Tubers and bulbs will be less susceptible to fluctuating storage temperatures, leafy parts of plants from temperate plants tend to need temperatures rapidly reduced for transportation. Transportation of temperate crops can involve greater energy inputs and produce GHG emissions due to the lower temperature requirements. Here are some of the methods used:



Cooling method	Process
Room cooling	Cold air from evaporator coils sweeps past the produce containers and cools the product which can then be stored in the same room.
Forced air cooling.	This is faster than room cooling. Cold air moves through rather than around the commodities. Air is in contact with the product and is therefore quite energy efficient.
Forced air evaporative cooling.	Evaporative cooling is more energy efficient. Produce containers must be vented and remain unblocked to increase efficiency.
Hydrocooling	They will either use an immersion or shower system which brings the product in contact with cold water. Water can be pumped to an overhead perforated distribution pan and showers over the produce.
Package icing	Fully packed containers with crushed ice can cool produce rapidly. As the ice melts the cooling rate will slow and a high humidity will be maintained around the produce.
Vacuum cooling.	Moisture loss and cooling is achieved by pumping air out of a chamber which removes heat from the product.

Table 3 - Methods of cooling produce

Effective cooler management is critical to energy efficiency and a lower GHG impact. Container and storage units will operate more optimally when field heat is removed from the products. This pre-cooling is also a potentially important part of the prevention of product losses in storage and transportation. Additionally, rapid

and thorough cooling of products is needed to avoid waste. The energy requirements for each cooling method need to be balanced against produce type and the transportation distance.

Energy efficiency in storage is an important consideration. Areas that contribute to this are store management and control, air leakage, refrigeration system efficiency, insulation type and quantity, air movement efficiency, and temperature uniformity within the store. The storage tonnage and temperature, length of storage period, and ambient temperature will also have an influence. The carbon footprint of storing root vegetables or top fruit, for example, can be greater, as storage times are comparatively longer than for other produce.

## Transportation



Produce will be moved a number of times within the horticultural supply chain from field to pack-house and from cold-storage to port for export or another land location. Controlled atmospheres can be important for preventing degradation of fruits and vegetables. In controlled atmosphere storage, atmospheric composition is maintained as required. There are certain risks associated with altering the composition of this. As fruits and vegetables respire, oxygen is consumed. If oxygen is too low, this will result in high concentrations of carbon dioxide causing suffocation. Limiting access to oxygen correctly makes it possible to slow down the respiration rate and prolong the potential storage life. This prevents breakdown, avoiding further GHG emissions.

Transportation related energy costs can form a significant part of the total carbon footprint of a product. Air-freighted transportation can contribute significantly to total energy and emissions in the supply chain, in some cases the alternative will be intensive glasshouse production, which would make a more significant contribution to GHG emissions.

Air freight is a carbon intensive activity, but is a trade with high value to the marketplace. It has been suggested that air freight is predicted to rise and take account of the majority of emissions. The choice of transportation containers is also important. Nets and bags can be used for some products such as onions and potatoes and although these provide good ventilation, the product will not stack as easily. This could be viewed as non-efficient transportation leading to excessive GHG emissions. Rigid boxes will stack correctly, but ventilation will be poor and this could compromise product quality.

## Conclusions

- Evaluate the cooling method used for transportation e.g. ambient vs. cool chain in order to reduce GHG emissions. Optimise the stacking efficiency for transportation and type of container which will reduce energy costs. Ensure the efficient stacking of produce to optimise temperature maintenance and distribution in storage.
- Consider transportation by rail or water, rather than road or air freight which have higher GHG emissions.
- Determine the potential of local distribution of farm produce to reduce transportation costs and subsequent GHG emissions.
- Choose an efficient cool chain method for your farm operation in order to reduce GHG emissions.
- Maintenance of the system will be key to optimising efficiency.

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