

2.2.3 Packaging

According to Wills et al. (1989), modern packaging must comply with the following requirements:

- a) The package must have sufficient mechanical strength to protect the contents during handling, transport, and stacking.
- b) The packaging material must be free of chemical substances that could transfer to the produce and become toxic to man.
- c) The package must meet handling and marketing requirements in terms of weight, size, and shape.
- d) The package should allow rapid cooling of the contents. Furthermore, the permeability of plastic films to respiratory gases could also be important.
- e) Mechanical strength of the package should be largely unaffected by moisture content (when wet) or high humidity conditions.
- f) The security of the package or ease of opening and closing might be important in some marketing situations.
- g) The package must either exclude light or be transparent.
- h) The package should be appropriate for retail presentations.
- i) The package should be designed for ease of disposal, re-use, or recycling.
- j) Cost of the package in relation to value and the extent of contents protection required should be as low as possible.

Classification of packaging:

Packages can be classified as follows:

- Flexible sacks; made of plastic jute, such as bags (small sacks) and nets (made of open mesh)
- Wooden crates
- Cartons (fibreboard boxes)
- Plastic crates

- Pallet boxes and shipping containers
- Baskets made of woven strips of leaves, bamboo, plastic, etc.

Uses for above packages:

Nets are only suitable for hard produce such as coconuts and root crops (potatoes, onions, yams).

Wooden crates are typically wire bound crates used for citrus fruits and potatoes, or wooden field crates used for softer produce like tomatoes. Wooden crates are resistant to weather and more efficient for large fruits, such as watermelons and other melons, and generally have good ventilation. Disadvantages are that rough surfaces and splinters can cause damage to the produce, they can retain undesirable odours when painted, and raw wood can easily become contaminated with moulds.

Fibreboard boxes are used for tomato, cucumber, and ginger transport. They are easy to handle, light weight, come in different sizes, and come in a variety of colours that can make produce more attractive to consumers. They have some disadvantages, such as the effect of high humidity, which can weaken the box; neither are they waterproof, so wet products would need to be dried before packaging. These boxes are often of lower strength compared to wooden or plastic crates, although multiple thickness trays are very widely used. They can come flat packed with ventilation holes and grab handles, making a cheap attractive alternative that is very popular. Care should be taken that holes on the surface (top and sides) of the box allow adequate ventilation for the produce and prevent heat generation, which can cause rapid product deterioration.

Plastic crates are expensive but last longer than wooden or carton crates.

They are easy to clean due to their smooth surface and are hard in strength, giving protection to products. Plastic crates (Figure 2.8) can be used many times, reducing the cost of transport. They are available in different sizes and colours and are resistant to adverse weather conditions. However, plastic crates can damage some soft produce due to their hard surfaces, thus liners are recommended when using such crates.

Pallet boxes are very efficient for transporting produce from the field to the packinghouse or for handling produce in the packinghouse. Pallet boxes have a standard floor size (1200 × 1000 mm) and depending on the commodity have standard heights. Advantages of the pallet box are that it

reduces the labour and cost of loading, filling, and unloading; reduces space for storage; and increases speed of mechanical harvest. The major disadvantage is that the return volume of most pallet boxes is the same as the full load. Higher investment is also required for the forklift truck, trailer, and handling systems to empty the boxes. They are not affordable to small producers because of high, initial capital investment.

Figure 2.8 Typical plastic crate holding fresh oranges.



2.2.4 Cooling methods and temperatures

Several methods of cooling are applied to produce after harvesting to extend shelf life and maintain a fresh-like quality. Some of the low temperature treatments are unsuitable for simple rural or village treatment but are included for consideration as follows:

2.2.4.1 Precooling

Fruit is precooled when its temperature is reduced from 3 to 6°C (5 to 10°F) and is cool enough for safe transport. Precooling may be done with cold air, cold water (hydrocooling), direct contact with ice, or by evaporation of water from the product under a partial vacuum (vacuum cooling). A combination of cooled air and water in the form of a mist called hyaircooling is an innovation in cooling of vegetables.

2.2.4.2 Air precooling

Precooling of fruits with cold air is the most common practice. It can be done in refrigerator cars, storage rooms, tunnels, or forced air-coolers (air is forced to pass through the container via baffles and pressure differences).

2.2.4.3 Icing

Ice is commonly added to boxes of produce by placing a layer of crushed ice directly on the top of the crop. An ice slurry can be applied in the following proportion: 60% finely crushed ice, 40% water, and 0.1% sodium chloride to lower the melting point. The water to ice ratio may vary from 1:1 to 1:4.

2.2.4.4 Room cooling

This method involves placing the crop in cold storage. The type of room used may vary, but generally consists of a refrigeration unit in which cold air is passed through a fan. The circulation may be such that air is blown across the top of the room and falls through the crop by convection. The main advantage is cost because no specific facility is required.

2.2.4.5 Forced air-cooling

The principle behind this type of precooling is to place the crop into a room where cold air is directed through the crop after flowing over various refrigerated metal coils or pipes. Forced air-cooling systems blow air at a high velocity leading to desiccation of the crop. To minimize this effect, various methods of humidifying the cooling air have been designed such as blowing the air through cold water sprays.

2.2.4.6 Hydrocooling

The transmission of heat from a solid to a liquid is faster than the transmission of heat from a solid to a gas. Therefore, cooling of crops with cooled water can occur quickly and results in zero loss of weight. To achieve high performance, the crop is submerged in cold water, which is constantly circulated through a heat exchanger. When crops are transported around the packhouse in water, the transport can incorporate a hydrocooler. This system has the advantage wherein the speed of the conveyer can be adjusted to the time required to cool the produce. Hydrocooling has a further advantage over other precooling methods in that it can help clean the produce. Chlorinated water can be used to avoid spoilage of the crop. Hydrocooling is commonly

used for vegetables, such as asparagus, celery, sweet corn, radishes, and carrots, but it is seldom used for fruits.

2.2.4.7 Vacuum cooling

Cooling in this case is achieved with the latent heat of vaporization rather than conduction. At normal air pressure (760 mmHg) water will boil at 100°C. As air pressure is reduced so is the boiling point of water, and at 4.6 mmHg water boils at 0°C. For every 5 or 6°C reduction in temperature, under these conditions, the crop loses about 1% of its weight (Barger, 1961). This weight loss may be minimized by spraying the produce with water either before enclosing it in the vacuum chamber or towards the end of the vacuum cooling operation (hydrovacuum cooling). The speed and effectiveness of cooling is related to the ratio between the mass of the crop and its surface area. This method is particularly suitable for leaf crops such as lettuce. Crops like tomatoes having a relatively thick wax cuticle are not suitable for vacuum cooling.

2.2.4.8 Recommended minimum temperature to increase storage time

There is no ideal storage for all fruits and vegetables, because their response to reduced temperatures varies widely. The importance of factors such as mould growth and chilling injuries must be taken into account, as well as the required length of storage (Wills et al., 1989). Storage temperature for fruits and vegetables can range from -1 to 13°C, depending on their perishability. Extremely perishable fruits such as apricots, berries, cherries, figs, watermelons can be stored at -1 to 4°C for 1-5 weeks; less perishable fruits such as mandarin, nectarine, ripe or green pineapple can be stored at 5-9°C for 2-5 weeks; bananas at 10°C for 1-2 weeks and green bananas at 13°C for 1-2 weeks. Highly perishable vegetables can be stored up to 4 weeks such as asparagus, beans, broccoli, and Brussels sprouts at -1-4°C for 1-4 weeks; cauliflower at 5-9°C for 2-4 weeks. Green tomato is less perishable and can be stored at 10°C for 3-6 weeks and non-perishable vegetables such as carrots, onions, potatoes and parsnips can be stored at 5-9°C for 12-28 weeks. Similarly, sweet potatoes can be stored at 10°C for 16-24 weeks. The storage life of produce is highly variable and related to the respiration rate; there is an inverse relation between respiration rate and storage life in that produce with low respiration generally keeps longer.

For example, the respiration rate of a very perishable fruit like ripe banana is $200 \text{ mL CO}_2.\text{kg}^{-1}\text{h}^{-1}$ at 15°C , compared to a non-perishable fruit such as apple, which has a respiration rate of $25 \text{ mL CO}_2.\text{kg}^{-1} \text{ h}^{-1}$ at 15°C .

2.2.4.9 High temperatures

Exposure of fruits and vegetables to high temperatures during post-harvest reduces their storage or marketable life. This is because as living material, their metabolic rate is normally higher with higher temperatures. High temperature treatments are beneficial in curing root crops, drying bulb crops, and controlling diseases and pests in some fruits. Many fruits are exposed to high temperatures in combination with ethylene (or another suitable gas) to initiate or improve ripening or skin colour.

2.2.5 Storage

The marketable life of most fresh vegetables can be extended by prompt storage in an environment that maintains product quality. The desired environment can be obtained in facilities where temperature, air circulation, relative humidity, and sometimes atmosphere composition can be controlled. Storage rooms can be grouped accordingly as those requiring refrigeration and those that do not. Storage rooms and methods not requiring refrigeration include: *in situ*, sand, coir, pits, clamps, windbreaks, cellars, barns, evaporative cooling, and night ventilation:

In situ. This method of storing fruits and vegetables involves delaying the harvest until the crop is required. It can be used in some cases with root crops, such as cassava, but means that the land on which the crop was grown will remain occupied and a new crop cannot be planted. In colder climates, the crop may be exposed to freezing and chilling injury.

Sand or coir: This storage technique is used in countries like India to store potatoes for longer periods of time, which involves covering the commodity under ground with sand.

Pits or trenches are dug at the edges of the field where the crop has been grown. Usually pits are placed at the highest point in the field, especially in regions of high rainfall. The pit or trench is lined with straw or other organic material and filled with the crop being stored, then covered with a layer of organic material followed by a layer of soil. Holes are created with straw at the

top to allow for air ventilation, as lack of ventilation may cause problems with rotting of the crop.

Clamps. This has been a traditional method for storing potatoes in some parts of the world, such as Great Britain. A common design uses an area of land at the side of the field. The width of the clamp is about 1 to 2.5 m. The dimensions are marked out and the potatoes piled on the ground in an elongated conical heap. Sometimes straw is laid on the soil before the potatoes. The central height of the heap depends on its angle of repose, which is about one third the width of the clump. At the top, straw is bent over the ridge so that rain will tend to run off the structure. Straw thickness should be from 15-25 cm when compressed. After two weeks, the clamp is covered with soil to a depth of 15-20 cm, but this may vary depending on the climate.

Windbreaks are constructed by driving wooden stakes into the ground in two parallel rows about 1 m apart. A wooden platform is built between the stakes about 30 cm from the ground, often made from wooden boxes. Chicken wire is affixed between the stakes and across both ends of the windbreak. This method is used in Britain to store onions (Thompson, 1996).

Cellars. These underground or partly underground rooms are often beneath a house. This location has good insulation, providing cooling in warm ambient conditions and protection from excessively low temperatures in cold climates. Cellars have traditionally been used at domestic scale in Britain to store apples, cabbages, onions, and potatoes during winter.

Barns. A barn is a farm building for sheltering, processing, and storing agricultural products, animals, and implements. Although there is no precise scale or measure for the type or size of the building, the term barn is usually reserved for the largest or most important structure on any particular farm. Smaller or minor agricultural buildings are often labelled sheds or outbuildings and are normally used to house smaller implements or activities.

Evaporative cooling. When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage.

Night ventilation. In hot climates, the variation between day and night temperatures can be used to keep stores cool. The storage room should be well insulated when the crop is placed inside. A fan is built into the store room, which is switched on when the outside temperature at night becomes lower than the temperature within. The fan switches off when the temperatures equalize. The fan is controlled by a differential thermostat, which constantly compares the outside air temperature with the internal storage temperature. This method is used to store bulk onions.

Controlled atmospheres are made of gastight chambers with insulated walls, ceiling, and floor. They are increasingly common for fruit storage at larger scale. Depending on the species and variety, various blends of O₂, CO₂, and N₂ are required. Low content O₂ atmospheres (0.8 to 1.5%), called ULO (Ultra -Low Oxygen) atmospheres, are used for fruits with long storage lives (e.g., apples).

2.2.6 Pest control and decay

Crops may be immersed in hot water before storage or marketing to control disease. A common disease of fruits known as anthracnose, caused by the infection of fungus *Colletotrychum spp.* can be successfully controlled in this way. Combining appropriate doses of fungicides with hot water is often effective in controlling disease in fruits after harvesting. Recommended conditions for hot water treatment for controlling diseases in fruits are shown in Table 2.7:

Table 2.7. Recommended conditions for hot water and fungicide treatments.

Water Temperature (°C)	Dipping time (min)	Fungicide (ppm)	Fungus	Fruit	Decay
		benomyl			Controlled
55-53	5	500	Colletotrychum)	Mango	
		flusilazole			
		100			

					90% reduced
46-55	3	0	None	Blueberry	
90	0.03	0	None	Sweet potato	Delay
		benomyl 500			
39	0.5	dichloran 400	Rizopus rot	Stone fruit	Controlled
-	Few seconds	250-500 thiophanate	Botryodiplodia theobromate	Banana	Controlled

Source: Thompson (1998)

Fruit and vegetable decay is also caused by storage conditions. Too low temperatures can cause injury during refrigeration of fruits and vegetables. High temperatures can cause softening of tissues and promote bacterial diseases. The damage that microorganisms inflict on fresh fruits and vegetables is mainly in the physical loss of edible matter, which may be partial or total.