

# 3. Basics of Quality Management



## 3. BASICS OF QUALITY MANAGEMENT

In this section basic harvest and postharvest management practices to help keep produce from spoiling before it reaches the market will be discussed.

### 3.1 Harvest management practices

The main issues in harvest management are to make sure crops are harvested at the right stage of maturity, and to use the correct harvesting techniques.

#### 3.1.1 Indicators of maturity

Before harvesting make sure crops are at the right level of maturity. Neither immature nor overmature produce are acceptable since their quality deteriorates sooner, especially during storage and transit, with the development of poor flavour and texture.

Some farmers may want to harvest their produce before it reaches the right level of maturity because of high market demand. Or they may want to leave it to go beyond normal maturity to gain extra weight, since weight is used as the basis for price. However, both practices are unacceptable in the quality market because they contribute to the production of poor-quality produce and consequent damage to the image of the market in the minds of consumers.

But what is the right level of maturity for the market? Generally, there are two levels of maturity: physiological and commercial.

#### Physiological maturity

Physiological maturity is where the plant (or plant organ) has become fully developed, such as ripening in tomatoes or flowering in lettuce. This is the stage just before senescence begins.

#### Commercial maturity

Commercial maturity is where the plant (or plant organ) is at the particular level of development *needed for the market*. It typically occurs before physiological maturity. For example, tomatoes will be harvested at an early stage in the ripening process so that by the time they reach the market they are at the optimum level of ripeness. In some cases the market only wants physiologically immature produce, for example lettuce before it has started flowering.

The right level of maturity for the market is **commercial maturity**. This can be measured using **indicators**, which can be *objective* (where measuring instruments are used) or *subjective* (where someone makes a judgment based on the appearance of the produce). In PNG the most widely used indicators of maturity are subjective. Indeed, because harvesting is generally carried out manually, the person responsible for harvest is also responsible for deciding whether or not the product is mature. This ability depends heavily on experience. Subjective indicators may include size, shape, firmness, taste, dryness and surface characteristics such as colour. In Section 4 subjective indicators for many of the more popular types of produce grown in the highlands of PNG are listed according to produce type. The main advantage of subjective assessment is that it is relatively cheap and someone with experience can measure attributes not easily measured objectively. But the main weakness is that subjective assessments will be variable from individual to individual and hence more subject to error.

### 3.1.2 Harvesting techniques

Using the correct harvesting technique has an important influence on the storage life of the produce. The basic rules are:

- Harvest during the coolest part of the day—early morning or late afternoon. For local markets it is best to harvest in the early morning, while for more distant markets it may be better to harvest in the late afternoon and transport during the night or early the next morning, according to when transport can be arranged.
- Avoid harvesting produce that is wet from dew or rain. Wet produce will overheat if not well ventilated, and is more likely to decay. Some produce will be more subject to damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits.
- Separate out crops that appear unfit for human consumption during harvesting.
- Clean harvesting equipment and containers thoroughly before use, especially if they have been previously used for toxic materials, so as not to contaminate produce.
- Protect harvested produce in the field by putting it under open-sided shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot and deteriorate rapidly. For example, potatoes left exposed to tropical sunlight for 4 hours can reach temperatures of almost 50 °C.

Apart from these basic rules, there are important differences in harvesting techniques between different types of crops. Some crops (e.g. taro, kaukau, green onion and garlic) can be harvested over a long period of time, so the quantity harvested at any one time should be limited to what can be marketed that day. However, other crops (e.g. watermelon, honeydew melon, eggplant, asparagus, pepper, tomatoes, sweet corn, peas, some berries, cassava and soybeans) pass quickly through the stage of harvest maturity and therefore should be harvested daily or every other day. Frequent and timely harvest of these types of produce is necessary if the grower wishes to supply their market with high-quality produce.

To more clearly see the differences between various types of crops, harvesting techniques for three different types of produce—roots and tubers, vegetables, fruit—are discussed below.

### Root and tubers

Most staple roots and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools such as wooden sticks, machetes, spades, hoes and forks.

Harvesting of these crops is easier if they are grown on raised beds or mounds or earthed up, as is common in kaukau growing (Figure 3.1). This enables the digging tool to be pushed into the soil under the roots or tubers (see action 1 in Figure 3.1), which then can be levered upwards (action 2), loosening the soil and reducing the possibility of damage to the crop.

Other root crops such as taro, carrots, turnips and radishes can be loosened from the soil in a similar manner by inserting the tool into the soil at an angle and levering the roots upwards. This method can also be used for celery that has been earthed up or buried to blanch the stem.



Figure 3.1: Harvesting root and tuber crops with a digging fork. The digging tool is pushed into the soil under the roots or tubers (action 1), which can then be levered upwards (action 2).

### Vegetables

Either the whole or part of the vegetative growth can be harvested by hand or using a sharp knife. Knives must be kept sharp and clean at all times to prevent viral diseases spreading from plant to plant. Harvesting methods vary with the plant parts harvested:

- Leaves only (e.g. spinach, rape)—the stem is snapped off by hand.
- Lateral buds (e.g. brussels sprouts)—the stem is snapped off by hand.
- Stem crops (e.g. asparagus)—the stem is cut cleanly with secateurs or a sharp knife.

- Leafy and flower heads (e.g. lettuce, broccoli, cauliflower, cabbage)—the head is pushed slightly to one side and the main stem is cut through with a sharp knife (Figure 3.2.) Trimming is done in the field, taking care not to place the cut stem on the soil.
- Bulbs (e.g. green onions, leeks, matured bulb onions)—immature green onions can usually be pulled from the soil by hand. Leek, garlic and mature bulb onions are loosened by using a digging fork as for root crops such as carrots, and lifted by hand. In addition, simple tractor implements are available for undermining bulbs and bringing them to the surface.
- Seed-bearing structures (e.g. peas, beans, squash, pumpkin)—these are plucked individually by hand at the natural breakpoint of the stalk, which can be easily broken at harvest.



Figure 3.2: Harvesting broccoli with a sharp knife.

## Fruits

Many ripe fruits have a natural breakpoint of the stalk that can be easily broken at harvest. However, fruits that are to be harvested in the unripe green state are difficult to pick without causing damage to either the produce or the plant. In this case it is best to harvest by cutting the fruit from the plant using clippers, secateurs or sharp knives. The clippers may be mounted on long poles for tree fruits, with a bag attached to the pole to catch the fruit (Figure 3.3).

Plucking methods vary according to the kind of produce being harvested:

- Ripe fruit with a natural breakpoint, which leaves the stalk attached to the fruit (e.g. passionfruit, sugar fruit, tomato), is best removed by a 'lift, twist and pull' technique, as in Figure 3.4.
- Mature green or ripe fruits with woody stalks that break at the fruit–stalk junction are best clipped from the tree, leaving up to a centimetre of fruit stalk attached. If the stem is broken off at the point where it joins the fruit (e.g. in mango, citrus, avocado), disease may enter the stem scar and give rise to stem end rot.
- Immature fruit with fleshy stems (e.g. zucchini, okra, papaya, capsicum) can be cut with a sharp knife. These can also be harvested by breaking the stem by hand, but this method may damage the plant or fruit and the rough breakage will be more susceptible to decay than would a clean cut.



Figure 3.3: Bag used for catching tree fruits.

With highly perishable produce, damp cloths can be used to give protection against the sun's heat. Field containers should be removed to a shaded area as soon as possible. Some leafy vegetables may be sprinkled with water at intervals to maintain leaf turgidity. Field assembly points, such as a shade house made out of natural materials or a canvas tent, should be used to keep the produce cool and allow ventilation.

## FACT

The quality of fruit and vegetables cannot be improved after harvest. All that can be done is slow the rate of deterioration through more careful management practices.

Almost all harvesting of fresh produce in PNG is done manually. Since most farms are small scale, this is appropriate. With careful hand harvesting using the techniques described here, damage to produce should be low, and this means higher incomes. Normally, when it is just the immediate family involved in harvesting the produce, it is not difficult to ensure careful hand harvesting. However, when extra workers are hired for harvesting they must be trained and properly supervised.

After harvesting there are a number of activities required before the crop in the field ends up as a sale in the market. The three main types of activities are handling (Section 3.2), storage (Section 3.3) and transportation (Section 3.4).



Figure 3.4: Harvesting tomato using the 'lift, twist and pull' series of movements.

## 3.2 Postharvest handling

The main postharvest handling activities include trimming and washing, sorting, grading, packing, weighing, precooling and curing.

### 3.2.1 Trimming and washing

Trimming involves removing leaves, stems and other plant parts from the harvested produce that are not required by the market. For some crops (e.g. lettuce, cabbage, cauliflower and broccoli) outer leaves may be left to improve the appearance and offer protection to the produce.

Washing removes dirt and other residues (e.g. from sprays and dust) and also improves the appearance of the produce, making it more attractive to the consumer. This is particularly the case for produce with edible parts that come in direct contact with the soil (e.g. lettuce, cabbages, onions, leeks, carrots) (Figure 3.5). However, tubers such as kaukau and potato do not need washing and can be dry brushed after curing to remove dust.

### HINT

To minimise disease damage during storage or shipment, rinse vegetables with a chlorinated solution after washing with clean running water.



Figure 3.5: Produce such as carrots that come in direct contact with the soil benefit from washing.

Fruits like citrus and mango, and fruit vegetables like tomatoes, capsicum and zucchini, may be wiped with a soft clean cloth to remove dust and residues.

After the produce is cleaned it should be kept cool to prevent the development of rot organisms.

### 3.2.2 Sorting

Before packing the produce for market, damaged, bruised, severed, sick, pest-damaged and deformed produce must be sorted out. Figure 3.6 shows two examples of produce that would be removed during sorting. Further examples are shown in Figure 1.1.

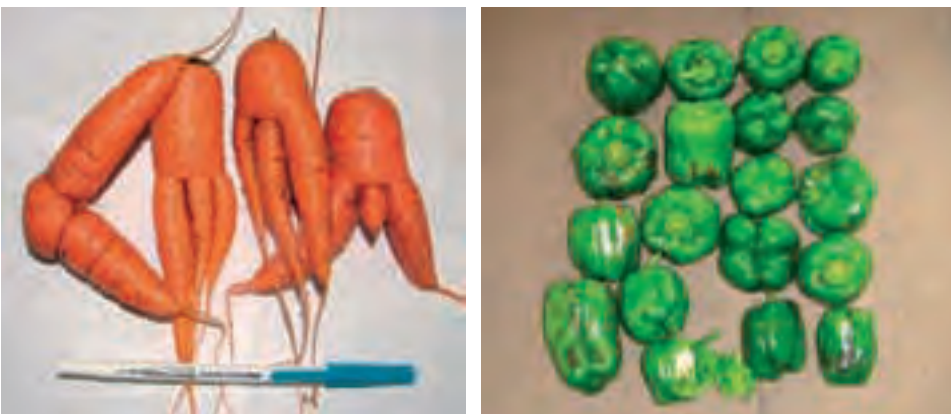


Figure 3.6: Deformed carrots (left) and damaged capsicums (right). These need to be removed during sorting.



### 3.2.3 Grading

Grading involves separating a particular fruit or vegetable into different lots on the basis of specific characteristics such as size, length, colour, firmness—whatever is relevant to the market. Grading ensures that crops are uniform. When produce is graded it looks more attractive to the customers and makes their shopping easier. Even crops of secondary quality when well-graded can be sold faster than poorly graded high-quality crops. Grading may take place before or after sorting (Figure 3.7).

Sorting and grading means that time isn't wasted transporting produce that the buyer will not want or will only take at a discount. It also means that rotten items that may contaminate good produce at later handling stages can be eliminated. Sorting and grading can help build a good long-term relationship with the buyer.



Figure 3.7: Well-graded carrots (top) and capsicum (bottom).



Figure 3.8: Examples of incorrect ways of packing produce and using packing materials. Can you see why?

## PUT YOURSELF IN THE PLACE OF YOUR BUYER

What would you say to someone who wanted to sell you produce that was bruised or damaged? And what would you think if they tried to trick you by putting good-quality produce on top of the pack and poor-quality at the bottom?

### 3.2.4 Packing

The two main functions of packing are to:

- prevent mechanical damage
- sort the produce into an acceptable size for handling and marketing.

Good packing can also enhance the attractiveness of the produce.

Many farmers in PNG pack their produce in whatever cheap packaging materials are available. This is not a bad idea so long as the produce is well protected from physical damage and arrives in good condition. PNG farmers generally do not have to worry about fancy and attractive (and therefore expensive) packaging because when the produce is received by buyers it is typically transferred to the buyer's own packaging materials or directly onto retail shelves for display.

A variety of packaging materials may be used to pack fresh produce including bags, net-bags, cartons, trays, boxes and bilums. Berries are packed into trays while net-bags are used to pack cabbages, bulb onions, carrots and potatoes. Copra bags and flour bags (with holes in the sides) are used to pack potatoes and kaukau. Shade cloth for the plant nursery may be made into bags for packing spring (bunching) onions. Boxes, crates, cartons and string bags (bilums) are used for general purposes.

Fresh produce should be packed properly and neither overpacked nor underpacked. When underpacked, produce tends to move around in the packaging material and can be damaged. When overpacked, damage can result from produce pressing against other produce. Further damage may occur when the packaging materials are incorrectly stacked. See Figure 3.8 for some examples of incorrect packing practices and Figure 3.9 for correct packing practices.

Packing is also a means to sort produce into an acceptable size for handling and marketing. The package needs to be a suitable size for storage and transfer of the produce from the point of production to the point of final sale or consumption. A common problem with overpacking is that it may lead to overheavy and difficult-to-handle packages, which can cause damage by being dropped or handled roughly.

Some growers try to trick their buyers by placing good produce at the top of the pack and poor-quality produce at the bottom. This is not a good idea because the buyer will find out and, in the long run, the grower will lose their buyer.



Figure 3.9: Examples of correct ways of packing fresh produce and the correct packaging materials used.

Various padding materials (e.g. paper, wood strips or dried banana leaves) may be used as bottom cushion pads or between layers of fruit and vegetables to reduce bruising (Figure 3.10).

### 3.2.5 Weighing

In the marketing of fresh produce the prices of crops are set according to weight. The weights of both the produce and the packaging material (especially cartons) are taken (Figure 3.11).



Figure 3.10: Paper strips may be used as effective cushioning material for fresh produce.

### 3.2.6 Precooling

Following harvest the most important factor affecting storage life is pulp temperature, which is the temperature inside the produce. High pulp temperature typically results in a shorter storage life. One way to keep the



Figure 3.11: Weighing produce in the field (top) and at the buyer's warehouse (right).

pulp temperature as low as possible is to harvest in the early mornings when the air temperature is cool. If possible it is also a good idea to ‘precool’ the produce.

In the precooling process, field heat is removed from the produce through quick cooling right after harvest and before it goes into storage. This quickly lowers pulp temperature and so helps to lengthen the storage life of the produce. Some different approaches to precooling involve cool rooms, cool moving water, ice or iced water, and fans.

### Room cooling

Room cooling involves placing produce in a cool room in small containers so that the cool air in the room can completely surround the containers and remove field heat from the produce. A recent example of an ideal cool room is that developed on an experimental basis jointly by the Department of Agriculture, University of Technology, Lae, and the Fresh Produce Development Agency (Figure 3.12). This cool room is double-walled with the two layers separated by a 3-centimetre gap filled with river sand. Cool water is trickled over the sand, providing a cooling effect and helping to maintain humidity. It ensures that the temperature is kept constant, at about 5–10 °C below the outside air temperature.

Because the temperature reduction is not great, produce intended for room cooling must be tolerant of slow heat removal. To maximise the cooling potential, ensure that the containers (boxes or trays) are small and well vented. Room cooling is commonly used on products that have a longer storage life, e.g. potatoes, kaukau and citrus.



Figure 3.12: Evaporative cooling storage room—a low-cost method of cool storage that doesn't require electricity.

## Hydro-cooling

Produce can be cooled more rapidly by contact with moving cool water. Most hydro-cooling involves cold water showering down over produce at 7–10 litres per second per square metre. If there is a cool running creek nearby, this may be used by immersing produce in a wire basket. The use of cold water is an old and effective way of cooling many fruits and vegetables, especially those not sensitive to water. Hydro-cooling may also help in the cleaning of the produce. It is important to ensure that the cold water comes into contact with as much of the surface of the produce as possible to maximise the cooling effect. Also, if the water is to be re-used, soil and debris must be removed to enhance the cleaning and reduce the risk of contamination.

## Package-icing and iced water cooling

If ice is available, some produce (e.g. carrots, brussels sprouts, leaks, parsley and broccoli) can be precooled by placing it on crushed ice in packages, or by placing the produce in a bucket, dish or drum containing iced water (Figure 3.13).



Figure 3.13: Iced water is used to precool broccoli.

**Table 3.1: Appropriate methods of precooling**

Type of commodity	Room	Hydro	Ice/iced water	Forced-air
<b>Tree fruits</b>				
citrus	✓			
tropical	✓			
<b>Leafy vegetables</b>				
(cabbage, lettuce, spinach, Chinese cabbage, bok choy)		✓		✓
<b>Root vegetables</b>				
with tops		✓		✓
topped		✓	✓	✓
potatoes, kaukau	✓			
<b>Stem and flower vegetables</b>				
asparagus		✓		
broccoli, brussels sprouts		✓	✓	✓
cauliflower				✓
celery, rhubarb		✓		✓
green onions, leeks		✓	✓	
Mushrooms				✓
<b>Pod vegetables</b>				
beans		✓		✓
peas			✓	✓
<b>Bulb vegetables</b>				
(dry onions, garlic)	✓			✓
<b>Fruit-type vegetables</b>				
(cucumbers, eggplant)	✓			✓
<b>Melons</b>				
honeydew		✓	✓	✓
watermelon		✓		✓
Peppers	✓		✓	✓
Sweet corn		✓	✓	✓
Tomatoes	✓			✓
Fresh herbs	✓			✓
Strawberries				✓



## Forced-air cooling

If electricity is available, forced-air cooling may be used for many varieties of fruits and vegetables. It is similar to room cooling except that fans are installed to blow air through and around the containers. It is important that containers are well vented and stacked to allow good airflow. The system creates a slight pressure gradient to force air through vents/slots, achieving rapid cooling through the close contact between cold air and warm product.

The most suitable precooling method should be selected depending on the type of produce. For example, strawberries, which cannot tolerate free moisture because of diseases and injury problems, cannot be pre-cooled by hydro-cooling or package-icing. They require fast cooling after harvest so room cooling is not suitable. Thus forced-air cooling is the only effective method for strawberries. Table 3.1 shows which type of precooling is most suitable for a variety of types of produce.

### 3.2.7 Curing

Curing is a simple technology to enhance the storage life of:

- tubers (e.g. kaukau, potatoes)
- bulbs (e.g. bulb onions, garlic)
- corms (e.g. taro).

Curing helps heal harvesting injuries, reduces water loss and prevents entry of decay-causing organisms during storage. Curing may be done in the field or in curing rooms. It takes place after harvest and before storage or marketing. The conditions of temperature, humidity and time required for curing vary with different commodities (Table 3.2).

In curing of tubers and corms an outer skin (periderm) is developed over cut, broken or skinned surfaces to provide protection. After harvest the tubers and corms are put into rooms/sheds that do not have direct sunlight coming in. Direct sunlight can cause the development of green pigment on potatoes and shrivelling of kaukau, both of which are undesirable. Potatoes and kaukau are spread out on the floor or platform as, for example, in Figure 3.14. Kaukau can be cured for up to a week, while potatoes will take about 2 weeks. See Table 3.2 for details of optimum temperature, humidity and duration of curing.

Table 3.2: Optimum conditions for curing

Produce	Temperature (°C)	Humidity (%)	Duration (days)
Potatoes	15–20	85–90	5–15
Kaukau	30–32	85–90	4–7
Bulb onion, garlic	30–45	60–75	14–21



Figure 3.14: Potatoes being cured on the floor of a curing room.

In curing of bulbs the necks and outer scales are dried to provide protection. After harvest, bulb onions and garlic may be cured by drying in direct sunlight for about 2 hours daily for 2–3 weeks, depending on the available sunlight. The bulbs are spread out to allow them to cure (Figure 3.15). Alternatively, they may be cured on platforms in sheds or by putting them in wire baskets in the fireplace and allowing smoke to cure them. While high humidity is required for curing potatoes and kaukau, low humidity is required for curing onions and garlic (Table 3.2). During wet and cloudy weather it is a good idea to dry bulb onions and garlic in heated rooms with temperatures in the range of 30–45 °C.

### 3.3 Storage

Storage tends to stabilise prices by carrying over produce from periods of high production to periods of low production. Without storage the producer would be forced to put produce on the market soon after harvest, regardless of the demand. If all growers market their crops at the same time this could result in a glut (excessive supply), and hence low prices and consequent loss to the producer. For most produce, especially vegetables, the main need of storage is for short periods, in many cases for a few weeks only.

Successful storage requires a good product that is harvested at the right stage of maturity for storage and free of diseases and other injury. A diseased or injured product usually deteriorates rapidly in storage,

## THE COOL CHAIN

Between harvest and market, fresh produce typically goes through a chain of operations—handling (trimming and washing, sorting, grading, packing, weighing, precooling, curing), storing and transporting. At all times the temperature of the produce should be kept cool and constant.

High temperatures, even for a short time, can quickly damage the produce and make it less attractive to buyers.

especially under conditions favourable for the development of storage rot. Apart from these conditions the most important factors affecting storage life are temperature and relative humidity.

### 3.3.1 Temperature

Temperature is by far the most critical environmental factor that influences the deterioration rate of harvested vegetables. Lowering the temperature decreases respiration, transpiration, and microbial and insect growth. Precooling serves to remove field heat from the produce, but (apart from curing) it is then important during storage to lower the pulp temperature and keep it constant. The optimum temperature is the most favourable temperature for extending storage life—the further the storage temperature is from the optimum, the more the vegetables will deteriorate. A rough rule of thumb is that for every increase of 10 °C above the optimum temperature the storage life can be expected to halve. However, this is not true for all produce. Table 3.3 shows the storage lives of different types of produce, first at the optimum temperature (column 4) and then at average atmospheric temperature (column 5).



Figure 3.15: Onions being cured on the floor of a curing room.

**Table 3.3: Ideal storage temperature and relative humidity for various types of fresh produce found in the PNG highlands**

Fruit/vegetable	Temperature °C	Relative humidity* (RH)	Storage life	
			At ideal conditions (weeks)	At normal conditions** (days)
Asparagus	0–4	Very high	2–3	2
Beans, French	5–9	High	1–2	1–2
Broccoli	0–4	Very high	2–3	1–2
Cabbage, Chinese	0–4	Very high	4–6	2–4
Cabbage, English	0–4	Very high	4–16	7
Capsicum	7–13	Very high	2–3	7
Carrots	0–4	Very high	16–24	8
Cauliflower	0–4	Very high	2–3	2–3
Celery	0–4	Very high	4–8	2–3
Cucumber	10–13	Very high	1–2	8
Garlic	0–4	Low	24–28	21–28
Leek	0–4	Very high	8	3
Lettuce	0–4	Very high	2–3	1–2
Onion, bulb (refrigerated)	0–4	Low	4–32	7
Onion, bulb (unrefrigerated)	25–30	Medium	4–8	7
Onions, spring	0–4	Very high	3–4	2–3
Pea, green and snowpea	0–4	Very high	1–2	1–2
Pineapple	7–13	High	2–4	7
Potato	5–13	Very high	20–40	21–28
Silver beet	0–4	Very high	1–2	1–2
Strawberries	0–4	Very high	Up to 1	1
Sweet potato (Kaukau)	13–15	High	16–28	21–28
Tomatoes (mature green)	13–15	Very high	2–3	7
Tomatoes (ripe red)	8–10	Very high	1–1.5	1–2
Zucchini	0–9	Very high	2	2

\*Relative humidity: low = 60–70%; medium = 70–80%; high = 80–90%; very high = 90–100%

\*\*Normal conditions for PNG highlands: 25 °C, 60–70% relative humidity

### 3.3.2 Relative humidity

The air normally contains moisture as water vapour. Sometimes it contains all the water vapour it can hold, in which case it is saturated. Most of the time, though, the air contains less moisture than the maximum, and the ratio of the amount it actually contains and the amount it can hold when it is saturated is called relative humidity. If the air is saturated its relative humidity is 100%. The lower the relative humidity, the drier the air.

Since a vegetable contains 80–90% water, it will lose its water (transpire) if the relative humidity of the air is below this level. The lower the relative humidity of the air below this level, the greater the amount of water lost from the vegetable. As a result, the vegetable will eventually become dry or shrivelled and lose its freshness.

### 3.3.3 Optimum storage temperature and relative humidity

Different types of produce have different ideal temperatures and relative humidities for storage. In columns 2 and 3 of Table 3.3 these ideal values are shown for the various types of produce discussed in detail in Section 4. If, instead of ideal conditions, the produce is stored at normal atmospheric conditions for the highlands of PNG, storage life can be expected to decline to something like the values in column 5 of this table. Higher temperature and lower relative humidity can greatly reduce the storage life of fresh produce. Thus, it is important to keep produce out of the sun and, preferably, in a cool store. Produce left in the sun will quickly deteriorate and the marketer will lose valuable income as a result.

When produce is stored in a cool room or refrigerated container it is important to check temperature and relative humidity on a regular basis (Figure 3.16).



Figure 3.16: When placing produce in a chiller, regular checks on the temperature and humidity are necessary.

## 3.4 Transportation

Harvested produce destined for the commercial market must be transported from the point of production to the point of consumption. These points may be within walking distance or thousands of kilometres apart. In general, the farther away the market is from the farm, the more complicated the system of transport required to maintain quality.

Several modes of transportation are used to move fresh produce from shipping points to destination markets, including road, sea and air. In PNG most of the produce is transported by road for at least part of the journey, although some is transported by road from the highlands to the nearest seaport (e.g. Lae and Madang) and then by sea to other centres like Port Moresby and Rabaul. Only a small proportion of produce (perhaps 5–10%) is air freighted. This tends to be the more valuable, more perishable types of produce going from the highlands to coastal markets.

Losses directly attributed to transport conditions can be high. The goal of every person concerned with the transportation of fresh produce should be to keep the produce in their care in the best possible condition during transit, and for the transportation to be as quick and efficient as possible. To this end, produce should be properly packaged and properly loaded on a suitable vehicle.

### 3.4.1 Road transport

Most fresh produce destined for the market is now moved by road, with lesser amounts going by sea, air or inland waterways. Factors to consider in road transportation are type of road vehicle, handling and stowage practices, and driving practices.

#### **Type of road vehicle**

The most commonly used vehicles are open pick-ups and bigger trucks, either open or enclosed. In choosing the type of road vehicle, users may wish to consider the following:

- Open-sided or half-boarded trucks can be fitted with a roof on a frame. The open sides can be fitted with canvas curtains, which can be rolled up or moved aside in sections to allow loading or unloading at any point around the vehicle. Such curtains protect the produce from the elements but still allow ventilation. Where stealing in small quantities is a problem, the sides and rear of the truck must be enclosed in wire mesh. A white-painted roof can also be fixed as a radiation shield 8–10 cm above the main roof. This will reflect the sun's heat and help to keep the produce cool.
- Refrigerated trucks or road or sea containers may be used for long journeys, but the cost of such transport makes it uneconomical for small-scale operations.
- Closed vehicles without refrigeration should not be used to carry fresh produce except on very short journeys, such as local deliveries from farmers or wholesalers to nearby retailers.

## Handling and stowage practices

The main aim in transportation is to ensure that the load is stable, well protected against damage and well ventilated. Factors to consider are:

- Avoid overloading, which greatly increases the risk of damage to fresh produce (Figure 3.17).
- Cover produce to protect it from rain and sun during transportation, loading and unloading (Figure 3.18).
- Choose the size and design of packages to give adequate levels of ventilation of the contents with the minimum of wasted space, and ensure the packages are strong enough to protect the contents. Stow carefully to avoid collapse during transport. Packages should not be stacked higher than the maximum recommended by the maker, otherwise the bottom layers may collapse under the weight of those above (Figure 3.19). Load packages on pieces of lumber or slatted racks on the beds of vehicles, or on pallets, in order to allow air circulation around the stacks during transport. Distribute the load evenly on the vehicle.
- Avoid careless handling of packed produce during loading and unloading.
- If the packages are to be distributed to several locations, load them in reverse order to that in which they will be unloaded (i.e. last on, first off).



Figure 3.17: Overloading greatly increases the risk of damage to fresh produce.



Figure 3.18: Cover produce from rain and sun during transportation.



Figure 3.19: Collapsed cartons can lead to damaged produce.



## Driving practices

Vibration (shaking) of the vehicle, especially on bad roads, can damage produce. In many cases drivers are induced to speed in order to make more money for themselves or their employers. Remember these tips:

- Whenever possible, only experienced and responsible drivers should be used.
- Restrict transport speeds to a level that will avoid free movement of produce.
- Driving carefully on bad roads is essential. Fast driving should be avoided (Figure 3.20).



Figure 3.20: Bad road conditions can greatly damage produce during transit.

### 3.4.2 Sea transport

This is used for the transportation of produce around the coast (e.g. from Lae to Port Moresby) or from the mainland to the islands. A significant amount of highland produce is transported by road to a coastal port (e.g. Lae or Madang) and then loaded into a shipping container for sea transport on a container ship to another mainland port or to the islands (Figure 3.21). The shipping containers are either dry (for less perishable crops) or refrigerated (for more perishable crops).



Figure 3.21: Container ship used to transport fresh produce in dry or refrigerated containers.

Highland grower–marketers who want to ship their produce by sea transport need to have good communications with the ship owners to know which day the ship will be loading. For example, if a grower–marketer from Goroka in the highlands brings produce down to Lae on Thursday but the container ship is not loading until the following Wednesday, the produce will be sitting in the port for nearly a week, often without adequate storage facilities. This will be a particular problem for perishable produce as it will markedly deteriorate in the warm humid climate.

### 3.4.3 Air transport

Air shipment is restricted to high-value, highly perishable types of fresh produce because of the high cost of freight involved (Figure 3.22). But freight cost is not all that needs to be considered when deciding whether to transport fresh produce by air. There is a significant risk of deterioration in the quality of the produce at airports due to careless handling or exposure to the elements.



Figure 3.22: Loading fresh produce into an airplane.

The situation is often made worse by:

- consignments being left behind in favour of passengers
- flight delays owing to bad weather or breakdowns.

It is important to try to minimise this risk by:

- ensuring good packaging
- staying with the produce until it is loaded onto the plane, and arranging for the buyer or someone trustworthy to pick it up at the end of the flight
- arranging refrigeration where necessary.

## 3.5 Marketing and postharvest losses

When selling produce, whether it is in the local village market or in a distant city market, good quality management can be the difference between making a profit or a loss. In the case study outlined in Box 2, the farmer–trader ended up not even covering his out-of-pocket expenses let alone getting a return for his efforts (or the efforts of his contact in Port Moresby). The lesson to be learned is that it is not sufficient to just look at the buying and selling prices of fresh produce. Although the expected selling prices for the produce were substantially higher than the buying prices, they were outweighed by the costs of shipment. One of the biggest costs, and one that is often forgotten, is the cost of losses in transit due to damage and

## Box 2

This is an actual account of a business arrangement undertaken by a farmer–trader from near Goroka. He buys fresh produce from his neighbours and sells through a contact in Port Moresby. Recently, he found he could buy English potatoes for K100/bag (with each bag weighing 50 kg), kaukau for K50/bag (with each bag weighing 85–90 kg) and English cabbage at K42/bag (with each bag weighing 60–65 kg). At the time his contact in Port Moresby told him that English potatoes were selling there for 50% more than the buying price, while kaukau and English cabbage were selling for double the buying price. This looked like a good business proposition and so he bought 40 bags of potatoes, 20 bags of kaukau and 10 bags of English cabbage for shipment to Port Moresby. The out-of-pocket expenses for undertaking this shipment included:

- a vehicle to pick up the produce and deliver it to a trucking company for shipment to Lae—K280
- shipment by the trucking company to Lae (K6.00/bag)—K420
- labour for loading and unloading—K200 (includes bus fare and travel allowance)
- shipment by container ship from Lae to Port Moresby (K0.50/kg)—K2150.

When the produce arrived in Port Moresby, his contact picked it up at the wharf. However, there was some damage and spoilage to the produce in transit.

- Of the 40 bags of potatoes, 7 were sold for K150 each. A further 30 bags were sold for K140 each, and the remaining 3 bags were completely lost.
- Of the 20 bags of kaukau, 10 were sold for K100 each. A further 8 bags were sold for K80 each and the remaining 2 bags were lost.
- Of the 10 bags of cabbage, 5 were sold for K80 each. A further 3 bags were sold for K70 each and the remaining 2 were lost.

### Income

Potatoes— 7 bags @ K150/each	K1,050
30 bags @ K140/each	K4,200
Kaukau— 10 bags @ K100/each	K1,000
8 bags @ K80/each	K 640
Cabbage— 5 bags @ K80/each	K 400
3 bags @ K70/each	K 210
<b>Total sales income</b>	<b>K7,500</b>

### Out-of-pocket costs

Cost of goods sold	
Potatoes—40 bags @ K100/each	K4,000
Kaukau—20 bags @ K50/each	K1,000
Cabbage—10 bags @ K42/each	K 420
<b>Transportation</b>	
Farm to trucking company	K 280
Road transport to Lae (70 bags @ K6/bag)	K 420
Sea transport to Port Moresby (4,300 kg @ K0.5/kg)	K2,150
Labour (wages, busfare, travel allowance)	K 200

<b>Total out-of-pocket costs</b>	<b>K8,470</b>
<b>Profit</b>	<b>-K 970</b>

spoilage. When produce is lost at the destination point, the cost of the loss includes not just how much was paid for the produce but also the cost of handling, storage and transportation of the produce that was ultimately thrown away.

### 3.6 Summary

What all commercial growers and traders want is a keen buyer and a good price. This is not easy to achieve, but one way to help is to make sure that the fresh produce being supplied to the buyer is of good quality. When fresh produce is to be sold, a supply chain is set up between the grower and the buyer and, as with any chain, it is only as good as its weakest link. Suppose produce is being shipped from the highlands to Lae by truck and then by ship to Port Moresby. It can be kept cool and dry all the way down the Highlands Highway to Lae and then put in a refrigerated container from Lae to Port Moresby. But if it sits in the sun for 2 days at the port in Lae waiting for a ship to arrive then it will be damaged. This is the weakest link.

Every point in the supply chain needs to be looked at and queried as to whether there is anything else that could be done better to maintain the quality of the produce. In this section a number of basic quality management practices have been considered that can be carried out at harvest and post-harvest that will help to ensure the quality is at the highest level when it reaches the buyer. Remember, the more carefully produce is handled at every point in the chain, the less the deterioration as it moves through the rest of the chain.

## GENERAL RULES FOR TRANSPORTING FRESH PRODUCE

Keep it as cool as possible.

Keep it dry.

Move it to market as quickly as possible.



