2. Quality in Fresh Produce

2. QUALITY IN FRESH PRODUCE

This section discusses what is meant by quality in fresh produce and what causes quality to deteriorate. It provides background information for Section 3, which deals with the basic management of quality in fresh produce.

2.1 What is meant by 'quality'?

Quality can mean different things to different people. For the grower it could mean produce with high yields and high returns. For a wholesaler it could mean produce with no bruising and a long storage life. For a retailer it could mean produce with no blemishes and a good appearance. And for a consumer it could mean produce with a good appearance, taste and nutrition. Producing a quality product means finding out what quality means to the potential buyer—what exactly the buyer needs. For example, the quality needs of a wholesaler in Mount Hagen may not match those of a supermarket customer in Port Moresby.

The case study in Box 1 shows an example of a grower–marketer of tomatoes who has different types of buyers for his produce, and is successful because he can meet the particular needs of each of his different buyers. One buyer is a tomato sauce processor who only buys red ripe tomatoes, while the other is a supermarket owner who only buys half-ripe firm tomatoes. The supermarket owner sees less quality in red ripe tomatoes than half-ripe firm tomatoes. On the other hand, the processor sees that red ripe tomatoes are what he needs to make tomato sauce and, for him, half-ripe firm tomatoes would not be satisfactory. Quality depends on the customer's needs and is therefore best defined as 'fitness for purpose'.

Because different markets have different quality requirements, suppliers should match the quality requirements of their customers.

2.2 Quality criteria

Judgment of quality can be divided into two types of factors: external and internal.

External factors are those that can be seen, and include:

- appearance, including size, colour and shape
- condition and absence of defects.

Box 1

A farmer–marketer in the Eastern Highlands province grows tomatoes and is able to supply about 2 tonnes of tomatoes. He has been growing tomatoes for about 15 years supplying different markets in Lae—supermarkets, a hotel, a university and the open market. He harvests his own tomatoes and also purchases from other farmers on Thursdays and Fridays.

On Saturdays and Sunday afternoons he grades and packs the tomatoes according to market requirements, as in the table below.

Grade	Characteristics	Markets	Price
A	Half-ripe, medium size No blemishes and no bruises	Supermarkets	High
B	Red ripe, medium size Minor blemishes and bruises	Hotel	Medium
C	Mixture of half-ripe and red ripe, all sizes Blemishes and bruises	University, mass and open markets	Low

The tomatoes are packed into non-collapsible hard plastic 50-kg crates. On Sunday afternoons at about 5 pm he loads them on his truck and travels to Lae. He travels in the afternoon when it is cool so that his tomatoes do not overheat. By 7 am the next morning, he is already at the door of his first customer, usually one of the supermarkets, leaving that buyer's consignment of tomatoes with one of his boys while transporting the remaining tomatoes to other buyers. By Monday afternoon or Tuesday morning he has sold all his tomatoes and returns home on Tuesday afternoon, sometimes with a back load.

This cycle is repeated every week, so he has now built up a good reputation with his buyers. Although there are no contracts signed, the business is done on trust and confidence. He has a very good relationship with his buyers and there is a good flow of information both to the buyers (on what the future supply looks like) and from the buyers (on what are their future needs).

He is able to meet the quality needs of his different buyers and is able to supply them at the right time with the required volume consistently.

Internal factors cannot be seen, and include:

- flavour and texture
- nutritional value and mouth feel.

In PNG external factors are far more widely used as a means of assessing quality. They are easy to use, fast and, to some extent, reliable; and they cost less. Judgment based on external factors relies heavily on experience or learned criteria. External and internal factors are discussed separately.

2.2.1 External factors

Appearance is very important. Most people buy with their eyes and learn from experience to associate desirable qualities with a certain appearance. A rapid visual assessment can be made on the size, shape, colour, freshness (condition) and presence of blemishes and defects (Figure 2.1). It is important to know or find out the particular needs of your buyer concerning appearance and try to supply what he/she requires.

The condition of the produce includes the freshness, stage of ripeness (senescence), extent of mechanical damage, and presence of pests or diseases.

Examples of produce in poor condition include:

- wilted leafy vegetables
- shrivelled fruits due to loss of moisture
- skin blemishes such as bruises, scratches and cuts.

These all give a bad appearance to the produce and are likely to lower the price or be unacceptable to the buyer, even though they may still be good and safe to eat. Thus, during harvesting and handling of the produce after harvest, great care should be taken to avoid or at least minimise deterioration.

Figure 2.1: Good-quality produce in an open market (left) and a supermarket (right).

2.2.2 Internal factors

Flavour is made up of taste and aroma, while texture is the feel of a product especially when gnawed with the teeth. Nutritional value is probably the most difficult internal factor to assess. Generally, people think that the fresher the produce the higher the nutritional value. Therefore, it is important to take into consideration measures that will help in reducing the fast deterioration of the quality of the produce.

2.3 Why does produce deteriorate in quality?

The basic reasons why produce deteriorates in quality are:

- respiration
- transpiration (water loss)
- disease infection
- growth and development
- handling damage.

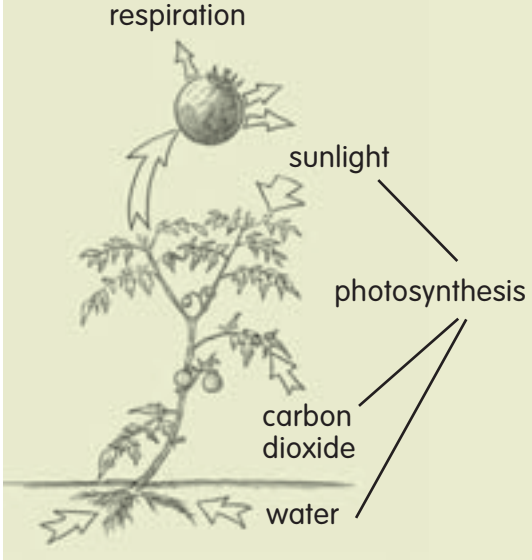
2.3.1 Respiration

Fresh fruits and vegetables are living things. This means they are still respiring and creating energy by 'burning up' carbohydrates, even after harvest. However, the fruits and vegetables are severed from their source of carbohydrates, water and minerals after harvest, and therefore have to rely on their own resources for survival. Through respiration the organic matter in the produce is depleted as the carbohydrates break down into carbon dioxide and water and are 'used up' (Figure 2.2).

Different types of fresh produce have different rates of respiration. Broadly speaking, fresh produce with low overall rates of respiration can be stored for longer periods without loss of acceptability.

Fresh produce can be classified into two basic types:

- **dormant tissue**, e.g. kaukau, carrot, taro and beetroot. These tend to have a *low metabolic rate* and a *long storage life*
- **non-dormant tissue,** e.g. flowers and fruit, stems, leaves. These tend to have a *high metabolic rate* and *deteriorate quickly* unless the rate is slowed down.



During the growing phase of fresh produce the major process taking place in the plant is **photosynthesis**. In this process, carbon dioxide and water are combined with the help of sunlight to create carbohydrates. After harvest the major process taking place in the fresh produce is **respiration**. Fresh produce is still a living organism after harvest, taking in oxygen to break down stored carbohydrate and releasing carbon dioxide and water as by-products.

Figure 2.2: Photosynthesis and respiration in fresh produce.

Apart from the type of tissue involved, respiration is affected by three environmental factors:

- temperature
- the mix of gases (oxygen and carbon dioxide) in the atmosphere
- the presence of ethylene.

These factors are all amenable to control, and knowledge of their effects can therefore be usefully applied to the practical problems of fruit and vegetable storage.

Temperature

Respiration takes place in fruits and vegetables within a certain temperature range. Within this range the rate of respiration normally increases with a rise in temperature, resulting in a faster 'burning up' of carbohydrates and hence a faster loss of quality. Outside this temperature range (i.e. if the temperature is too high or too low), physiological injury occurs. It is therefore advisable to store fresh produce at the lowest temperature within the temperature range in which respiration occurs.

The mix of gases (oxygen and carbon dioxide) in the atmosphere

The normal atmosphere contains 21% oxygen and 0.3% carbon dioxide. In aerobic respiration, oxygen in the atmosphere combines with carbohydrates in the fruits and vegetables to produce carbon dioxide and water. Therefore, one way to restrict respiration is to restrict the level of oxygen in the storage atmosphere. This principle is used in modified atmosphere packaging (MAP), a method whereby the storage life of fresh produce is increased by reducing the level of oxygen available for respiration. This requires considerable expertise as total elimination of oxygen may result in anaerobic respiration, producing alcohol, tissue damage and unpleasant flavours.

The presence of ethylene

Ethylene is a gas formed in small quantities during the ripening of some fruits that can increase the respiration of other fresh produce stored nearby. For example, ripe tomatoes produce ethylene while beans are sensitive to it. Thus, storing ripe tomatoes next to beans will increase the rate of respiration of beans and reduce their storage life. Although ethylene has some good uses, such as in the uniform ripening of bananas, its effects are undesirable from the point of view of maintaining the storage life of fresh produce. It causes sprouting of potatoes and yellowing of broccoli, as shown in Figure 2.3.

Ethylene also causes tomatoes to ripen faster, carrots to become bitter, leafy vegetables like lettuce to become dark and asparagus to become tough. It is thus a good idea to keep ethylene-producing produce apart from ethylene-sensitive produce. Table 2.1 shows a list of the more common ethylene-producing and ethylene-sensitive produce. With low storage temperatures of 4°C and below, the effect of ethylene can be greatly reduced or eliminated entirely.

Figure 2.3: Undesirable effects of ethylene include sprouting in potatoes (top) and yellowing in broccoli (bottom).

Ethylene is also produced by petrochemical reactions, so it is advisable to keep ethylene-sensitive produce away from machine engines that produce heat and light, ripening rooms, rotting produce, gases from aircraft engines, cigarette smoke and rubber material exposed to heat or strong light.

Table 2.1: Ethylene production and sensitivity levels of selected fresh produce			
Fresh produce type	Ethylene-producing	Ethylene-sensitive	Principal reaction to ethylene
Apple	• • •	• • •	Loss of crunch
Artichoke	o	•	
Asparagus	o	• •	Toughening of stems, yellowing of tips
Avocado	• • •	• • •	Decay
Banana	• •	• • •	Decay
Beans	•	• • •	Yellowing
Broccoli	o	• • •	Yellowing
Brussels sprouts	o	• • •	Yellowing
Cabbage, English	o	• • •	Shedding of leaves
Cabbage, Chinese	o	• • •	Shedding of leaves
Capsicum	•	•	
Carrot	o	•	Bitterness
Cauliflower	o	• • •	Discolouration
Celery	o	• •	
Cucumber	•	• • •	Yellowing
Eggplant	•	•	Brown spotting
Garlic	o	•	Odour, sprouting
Ginger	o	•	
Grapefruit	o	• •	Mould
Kohlrabi	o	•	
Leafy greens	o	• • •	Brown spotting
Lemon, lime	o	• •	Mould
Leek	o	• •	
Lettuce	o	• • •	Brown spotting
Mango	• •	• • •	Decay
Melons (excl. watermelon)	• •	• • •	Decay
Mushroom	•	• •	
Okra	•	• •	
Onion, bulb	o	•	Odour, sprouting
Onion, green	o	• •	Decay
Orange, Mandarin	-	• •	Mould

Table 2.1 continued

Fresh produce type	Ethylene-producing	Ethylene-sensitive	Principal reaction to ethylene
Papaya	● ● ●	● ● ●	Decay
Parsnip	○	●	
Peas, green and snowpea	○	● ●	Yellowing
Pineapple	●	●	
Potato	○	● ●	Sprouting
Pumpkin	●	●	
Radish	○	●	
Rambutan	● ● ●	● ● ●	
Spinach	○	● ● ●	Yellowing
Stone fruit (peaches, pears, nectarines)	● ● ●	● ● ●	Decay
Strawberries	●	●	Mould
Sweet corn	○	●	
Kaukau	○	●	Off-flavour, discolouration
Taro	○	○	
Tomato (mature green)	○	● ● ●	Ripening, softening
Tomato (ripe)	● ●	● ● ●	Softening, shrinking
Turnip (root)	○	●	
Turnip (greens)	○	● ● ●	
Watermelon	●	● ● ●	Loss of firmness
Yam	○	●	
Zucchini	○	○	

● ● ● = high or very high; ● ● = medium; ● = low; ○ = very low or none

Sources: http://www.ethylenecontrol.com/about.html, http://www.ethylenecontrol.com/about.html and http://www.mindfully.org/Plastic/Ethylene-Gas.htm

2.3.2 Transpiration (water loss)

Water loss in fresh produce leads to a direct loss in saleable weight, which usually means a direct loss in monetary value. It also leads to a loss of quality through its effect on appearance (e.g. wilting and shrivelling) and texture (e.g. a loss of crispness of leafy vegetables like lettuce). Severe wilting of leafy vegetables and other fresh produce can occur in a matter of hours under hot, dry conditions. Water loss can also adversely affect the nutritional value of fresh produce; e.g. the vitamin C level is reduced in water-stressed leafy vegetables.

For those types of produce susceptible to water loss, it is therefore important to ensure that the humidity level is maintained and the produce kept at a cool temperature, from harvest through to the end user. The appropriate humidity levels for different types of fresh produce are listed in Table 3.3. Precooling (fast cooling right after harvest) reduces the total amount of water loss. In addition, it is important to avoid bruising or otherwise damaging produce during postharvest operations as the surface areas can become sites for excessive water loss.

2.3.3 Disease infection

Many bacteria and fungi can cause spoilage of fresh produce. However, most are weak pathogens in that they usually only spread and grow when the produce is wounded. Wounding may occur due to cuts from fingernails, rough handling and overchilling. The wound site releases sugars and food that allow micro-organisms to grow. Healthy fresh produce will resist microbial attack much more readily than stressed or ripe/overripe produce.

Disease infection is also encouraged by higher temperatures and high humidity, which provide a good environment for the growth of disease-causing micro-organisms. Such pathogens grow best in temperatures of 20–25 °C. By contrast, low temperatures slow down not only the chemical processes of the produce, maximising storage life, but also the growth of these micro-organisms. At storage temperatures around 0 °C very few pathogens will pose a problem.

Disease-causing micro-organisms pass through a number of growth phases. Following initial infection it will take some time for them to adapt to the growth conditions surrounding them. It is only after this phase that they start to multiply at an increasingly faster (exponential) rate, and the damage they cause becomes apparent. Because of this time lag, it is quite possible for damage to be caused at harvest or in the early stages of post-harvest. However, it may not show up until some time later, perhaps after the produce has been transported and just when it is to be offered to the buyer.

There have been many stories of grower–marketers who have taken their produce from the highlands to Lae, loaded it onto refrigerated containers and sent it on a 3-day journey to Port Moresby. When they leave their produce in Lae it looks fine, but when it arrives in Port Moresby it is so badly damaged it is not fit for sale. The grower–marketers claim compensation against the shipowner because of damage due to poor storage practices on the ship. However, in some cases it may also be poor handling and storage practices prior to loading on the vessel that may have led to attack by micro-organisms that only shows up days later.

Development of disease during the postharvest period is a problem that requires careful attention. Deterioration resulting from microbial action can be rapid and severe, often incurring major losses and resulting in the need for re-sorting and repacking. Disease prevention during this period can save a lot of money. This is particularly the case for produce that is to be transported over long distances, which may take considerable time. It is important that this produce be carefully handled and packed, preferably using precooling and cool storage to prevent microbial spoilage.

2.3.4 Growth and development

Underground vegetables such as bulbs, roots, rhizomes and tubers may start to sprout when stored in conditions favourable to growth. For instance, sprouting will occur rapidly if bulbs are held for any period at 5–20 °C. This is undesirable since it is both unattractive to consumers and also contributes to deterioration of the produce. During both short- and long-term storage of underground vegetables, try to keep the produce in the most favourable conditions. See Table 3.3 for details of the ideal storage conditions for such vegetables.

2.3.5 Handling damage

Poor handling can damage fresh produce by means of impact, pressure or vibration. Practices to avoid include:

- dropping bags of produce onto the ground
- throwing boxes around
- sitting on top of bags during transportation
- stacking boxes too high
- underfilling or overfilling containers for transport: underfilling can lead to damage from vibration or rolling around, while overfilling can lead to damage from pressure.

Another source of handling damage is temperatures that are too high or too low. High temperatures, especially when produce is left unprotected in the sun, can cause sunburn and boiling of produce. Temperatures that are too low can cause freezing and chilling injury. At all times throughout the supply chain, produce should be protected from temperature extremes. See Table 3.3 for further details on the optimum temperatures for the various types of produce.

PRINCIPLES OF DISEASE PREVENTION

- Begin with healthy non-stressed produce.
- Provide an environment that will maintain the freshness, e.g. low temperature.
- Prevent any mechanical damage during harvesting, grading, packing and transport.
- Use postharvest applications of fungicides/pesticides if produce is destined for long-term transport or storage.
- Follow instructions strictly.