## 4.7 Respiration

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Respiration is the process by which plants take in oxygen and give out carbon dioxide. As shown in Figure 4.5, oxygen from the air breaks down carbohydrates in the plant into carbon dioxide and water. This reaction produces energy in the form of heat.

Respiration is a basic reaction of all plant material, both in the field and after harvest. It is a continuing process in the growing plant as long as the leaves continue to make carbohydrates, and cannot be stopped without damage to the growing plant or harvested produce.

Fresh produce cannot replace carbohydrates or water after harvest. Respiration uses stored starch or sugar and will stop when reserves of these are exhausted; ageing follows and the produce dies and decays.

4.7.1 **Effect of air supply on respiration**. Respiration depends on a good air supply. Air contains about 20 percent of the oxygen essential to normal plant respiration, during which starch and sugars are converted to carbon dioxide and water vapour. When the air supply is restricted and the amount of available oxygen in the environment falls to about 2 percent or less, fermentation instead of respiration occurs. Fermentation breaks down sugars to alcohol and carbon dioxide, and the alcohol produced causes unpleasant flavours in produce and promotes premature ageing.

4.7.2 **The effect of carbon dioxide on respiration**. Poor ventilation of produce because of restricted air supply leads also to the accumulation of carbon dioxide around the produce. When the concentration of this gas rises to between I and 5 percent in the atmosphere, it will quickly ruin produce by causing bad flavours, internal breakdown, failure of fruit to ripen and other abnormal physiological conditions. Thus, the proper ventilation of produce is essential.

## 4.8 Transpiration, or the loss of water

Most fresh produce contains from 65 to 95 percent water when harvested. Within growing plants there is a constant flow of water. Liquid water is absorbed from the soil by the roots, then passed up through the stems and finally is lost from the aerial parts, especially leaves, as water vapour.

Figure 4.5 Photosynthesis and respiration

The passage of water through the plants is called the transpiration stream. It maintains the high water content of the plant, and the pressure inside the plant helps to support it. A lack of water will cause plants to wilt and perhaps to die.

The surfaces of all plant parts are covered by a waxy or corky layer of skin or bark limiting water loss. Natural water loss from the plant occurs only through tiny pores, which are most numerous on the leaves. The pores on the plant surfaces can open or close with changing atmospheric conditions to give a controlled rate of loss of water and to keep the growing parts in a firm condition.

Fresh produce continues to lose water after harvest, but unlike the growing plant it can no longer replace lost

water from the soil and so must use up its water content remaining at harvest. This loss of water from fresh produce after harvest is a serious problem, causing shrinkage and loss of weight.

When the harvested produce loses 5 or 10 percent of its fresh weight, it begins to wilt and soon becomes unusable. To extend the usable life of produce, its rate of water loss must be as low as possible.

4.8.1 **The effect of moisture content of the air on water loss**. Air spaces are present inside all plants so that water and gases can pass in and out to all their parts. The air in these spaces contains water vapour, a combination of water from the transpiration stream and that produced by respiration. Water vapour inside the plant develops pressure causing it to pass out through the pores of the plant surface. The rate at which water is lost from plant parts depends on the difference between the water vapour pressure inside the plant and the pressure of water vapour in the air. To keep water loss from fresh produce as low as possible, it must be kept in a moist atmosphere.

4.8.2 **The effect of air movement on water loss**. The faster the surrounding air moves over fresh produce the quicker water is lost. Air movement through produce is essential to remove the heat of respiration, but the rate of movement must be kept as low as possible. Well-designed packaging materials and suitable stacking patterns for crates and boxes can contribute to controlled air flow through produce.

4.8.3 **The Influence of the type of produce on water loss**. The rate at which water is lost varies with the type of produce. Leafy green vegetables, especially spinach, lose water quickly because they have a thin waxy skin with many pores. Others, such as potatoes, which have a thick corky skin with few pores, have a much lower rate of water loss.

The significant factor in water loss is the ratio of the surface area of the type of plant part to its volume. The greater the surface area in relation to the volume the more rapid will be the loss of water.

## 4.9 Ripening of fruits

Fleshy fruits undergo a natural stage of development known as ripening. This occurs when the fruit has ceased growing and is said to be mature. Ripeness is followed by ageing (often called senescence) and breakdown of the fruit. The fruit referred to here includes those used as vegetables or salads, such as aubergine, sweet pepper, tomato, breadfruit and avocado.

There are two characteristic types of fruit ripening that show different patterns of respiration:

- Non-climacteric fruit ripening-refers to those fruits which ripen only while still attached to the parent plant. Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase further. Respiration rate slows gradually during growth and after harvest. Maturation and ripening are a gradual process. Examples are: cherry, cucumber, grape, lemon, pineapple.
- Climacteric fruit ripening-refers to fruits that can be harvested when mature but before ripening has begun. These fruits may be ripened naturally or artificially. The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Examples are: apple, banana, melon, papaya, tomato.

In commercial fruit production and marketing, artificial ripening is used to control the rate of ripening, thus enabling transport and distribution to be carefully planned.

4.9.1 **The effect of ethylene on post-harvest fresh produce**. Ethylene gas is produced in most plant tissues and is known to be an important factor in starting off the ripening of fruits. Ethylene is important in fresh produce marketing because:

- it can be used commercially for the artificial ripening of the climacteric fruits. This has made it possible for tropical fruits such as mangoes and bananas to be harvested green and shipped to distant markets, where

they are ripened under controlled conditions;
- natural ethylene production by fruits can cause problems in storage facilities. Flowers, in particular, are easily damaged by very small amounts of the gas. Ethylene destroys the green colour of plants, so lettuce and other vegetables marketed in the mature green but unripe state will be damaged if put into storage with ripening fruit;
- ethylene production is increased when fruits are injured or attacked by moulds causing decay. This can start the ripening process and result in early ripening of climacteric fruit during transport. All produce should be handled with care to avoid injuries leading to decay. Damaged or decaying produce should not be stored;
- citrus fruit grown in tropical areas remains green after becoming fully ripe on the tree. It develops full colour after harvest only if "degreened" by the use of (manufactured) ethylene gas. The gas concentration, temperature, humidity and ventilation have to be carefully controlled in specialized rooms, so degreening is economically viable only for high-value export or domestic markets. In most tropical countries fully ripe green citrus fruit is acceptable to local populations.

## 4.10 Post-harvest damage to fresh produce

Physical damage to fresh produce can come from a variety of causes, the most common being:

4.10.1 **Mechanical injury**. The high moisture content and soft texture of fruit, vegetables and root crops make them susceptible to mechanical injury, which can occur at any stage from production to retail marketing because of:

- poor harvesting practices;
- unsuitable field or marketing containers and crates, which may have splintered wood, sharp edges, poor nailing or stapling;
- overpacking or underpacking of field or marketing containers;
- careless handling, such as dropping or throwing or walking on produce and packed containers during the process of grading, transport or marketing.

Injuries caused can take many forms:

- splitting of fruits or roots and tubers from the impact when they are dropped;
- internal bruising, not visible externally, caused by impact;
- superficial grazing or scratches affecting the skins and outer layer of cells;
- crushing of leafy vegetables and other soft produce.

Injuries cutting through or scraping away the outer skin of produce will:

- provide entry points for moulds and bacteria causing decay;
- increase water loss from the damaged area;
- cause an increase in respiration rate and thus heat production.

Bruising injuries, which leave the skin intact and may not be visible externally cause:

- increased respiration rate and heat production;
- internal discoloration because of damaged tissues;
- off-flavours because of abnormal physiological reactions in damaged parts.

4.10.2 **Injuries from temperature effects**. All fresh produce is subject to damage when exposed to extremes of temperature. Commodities vary considerably in their temperature tolerance. Their levels of tolerance to low temperatures are of great importance where cool storage is concerned:

- Freezing injury-all produce is subject to freezing at temperatures between 0 and -2 degrees Celsius. Frozen

produce has a water-soaked or glassy appearance. Although a few commodities are tolerant of slight freezing, it is advisable to avoid such temperatures because subsequent storage life is short. Produce which has recovered from freezing is highly susceptible to decay.

- Chilling injury- some types of fresh produce are susceptible to injury at low but non-freezing temperatures. Such crops are mostly of tropical or subtropical origin, but a few temperate crops may be affected (Table 2).

| **Effect of chilling injury** | **Symptom** |
|---|---|
| Discoloration | Internal or external or both, usually brown or black |
| Skin piking | Sunken spots, especially under dry conditions |
| Abnormal ripening (fruits) | Ripening is uneven or fails; off-flavours |
| Increase in decay | Activity of micro-organisms |

**TABLE 2. Susceptibillty of fruits and vegetables to chilling injury at low but non-freezing temperatures**

| **Commodity** | **Approximate lowest safe temperature °C** | **Chilling injury symtoms** |
|---|---|---|
| Aubergines | 7 | Surface scald, *Alternaria* rot |
| Avocados | 5-13 | Grey discoloration of flesh |
| Bananas (green/ripe) | 12-14 | Dull, gray-brown skin color |
| Beans (green) | 7 | Pitting, russeting |
| Cucumbers | 7 | Pitting water-soaked spots, decay |
| Grapefruit | 10 | Brown scald, piking, watery breakdown |
| Lemons | 13-15 | Pitting, membrane stain, red blotch |
| Limes | 7-10 | Pitting |
| Mangoes | 10-13 | Grey skin scald, uneven ripening |
| Melons: Honeydew | 7-10 | Pitting failure to ripen, decay |
| Watermelon | 5 | Pitting, biker flavour |
| Okra | 7 | Discoloration, water-soaked areas, piking |
| Oranges | 7 | Pitting brown stain, watery breakdown |
| Papaya | 7 | Pitting failure to ripen, off-flavour, decay |
| Pineapples | 7-10 | Dull green colour, poor flavour |
| Potatoes | 4 | Internal discoloration, sweetening |
| Pumpkins | 10 | Decay |
| Sweet peppers | 7 | Pitting *Alternaria* rot |
| Sweet potato | 13 | Internal discoloration, piking, decay |
| Tomatoes: Mature green | 13 | Water-soaked softening, decay |
| Ripe | 7-10 | Poor colour, abnormal ripening, *Alternaria* rot |

Source Lutz, J.M. and Hardenburg, R.E., 1966, The commercial storage of fruits, vegetables and florist And

nursery storks, Agricultural Handbook No. 66, USDA, Washington

Sensitivity varies with the commodity, but with each there is a temperature below which injury occurs: the lowest safe temperature (LST). Within a single commodity type, the LST may vary between varieties (Table 2). Fruit is generally less sensitive when ripe.

Symptoms of chilling injury may not develop until the produce is removed from cold storage to normal market (i.e. ambient) temperatures. When susceptible produce has to be held for some time in storage, it must be kept at a temperature just above its LST. This means that such crops will have a shorter marketing life than non-sensitive crops because respiration has continued at a relatively fast rate during storage at higher than normal cold-storage temperatures.

- High temperature injury - if fresh produce is exposed to high temperatures caused by solar radiation, it will deteriorate rapidly. Produce left in the sun after harvest may reach temperatures as high as 50 degrees Celsius. It will achieve a high rate of respiration and, if packed and transported without cooling or adequate ventilation, will become unusable. Long exposure to tropical sun will cause severe water loss from thin-skinned root crops such as carrots and turnips and from leafy vegetables.

4.10.3 **Diseases and pests**. Diseases caused by fungi and bacteria commonly result in losses of fresh produce. Virus diseases, which can cause severe losses in growing crops, are not a serious post-harvest problem.

Insect pests that are mainly responsible for wastage in cereals and grain legumes are rarely a cause of post-harvest loss in fresh produce. Where they do appear, they are often locally serious, e.g. the potato tuber moth.

*Diseases*. Losses from post-harvest disease in fresh produce fall into two main categories.

Loss in quantity, the more serious, occurs where deep penetration of decay makes the infected produce unusable. This is often the result of infection of the produce in the field before harvest.

Loss in quality occurs when the disease affects only the surface of produce. It may cause skin blemishes that can lower the value of a commercial crop. In crops grown for local consumption, the result is less serious since the affected skin can often be removed and the undamaged interior can be used.

Fungal and bacterial diseases are spread for the most part by microscopic spores, which are widely distributed in the air and soil and on dead and decaying plant material. Produce can become infected:

- through injuries caused by careless handling, by insect or other animal damage, or through growth cracks (see colour section, Figure 1);
- through natural pores in the above- and below-ground parts of plants, which allow the movement of air, carbon dioxide and water vapour into and out of the plant;
- by direct penetration of the intact skin of the plant (see colour section, Figure 2). The time of infection varies with the crop and with different diseases. It can occur in the field before harvest or at any time afterwards.

Field infections before harvest may not become visible until after harvest. For example, decay of root crops caused by soil moulds will develop during storage. Similarly, tropical fruits infected at any time during their development may show decay only during ripening.

Infection after harvest can occur at any time between the field and the final consumer. It is for the most part the result of invasion of harvesting or handling injuries by moulds or bacteria.

Post-harvest diseases may be spread in the field before harvest by the use of infected seed or other planting material. Many diseases can survive by using weed plants or other crops as alternate or alternative hosts. They are also spread by means of infected soil carried on farm implements, vehicles, boots, etc. and from crop residues or

rejected produce left decaying in the field.

Post-harvest diseases can also be spread by:

- field boxes contaminated by soil or decaying produce or both;
- contaminated water used to wash produce before packing;
- decaying rejected produce left lying around packing houses;
- contaminating healthy produce in packages.

*Pests*. Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious.

- Insect damage is usually caused by insect larvae burrowing through produce, e.g. fruit fly, sweet potato weevil, potato tuber moth. Infestation usually occurs before harvest. Post-harvest spread is a problem where produce is held in store or is exposed to lengthy periods of transport.
- Rats, mice and other animal pests again are sometimes a problem when produce is stored on the farm.

## 4.11 Loss assessment

There are no generally accepted methods for evaluating post-harvest losses of fresh produce. Whatever evaluation method may be used, the result can refer only to the described situation.

In the appraisal of an existing marketing operation, the accurate evaluation of losses occurring is a problem. It may be suspected that losses are too great, but there may be no figures to support this view because:

- records do not exist;
- records if available do not cover a long enough period of time;
- the figures available are only estimates made by several observers;
- records may not truly represent a continuing situation; for example, losses may have been calculated only when unusually high or low;
- loss figures may be deliberately over- or understated for commercial or other reasons in order to gain benefits or to avoid embarrassment.

Consequently, if accurate records of losses at various stages of the marketing operation have not been kept over a period of time, a reliable assessment of the potential cost-effectiveness of ways to improve handling methods is virtually impossible, and the marketing position of the grower is difficult to strengthen. It is evident that the grower who wants to reduce his post-harvest losses must maintain reliable records.

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