PANAMA NATURE FRESH

QUALITY STANDARDS

SPECIFICATIONS FOR BANANA (PNFPL0002)

Banana Production

Around 98% of world production is grown in developing countries. Developed countries are the usual destination for export bananas. In 2000, a total of 123 countries produced bananas. However, production, as well as exports and imports of bananas, are highly concentrated in a few countries. The 10 major banana producing countries accounted for more than 73% of total banana production in 2000. India, Ecuador, Brazil and China alone produced half of total bananas. This concentration of banana production has increased over time although showing a different regional distribution. While the Latin American and Caribbean region dominated up to the eighties, the Asian region took the lead in banana production during the nineties. African production levels have remained relatively stable.

World exports

Bananas also show a high level of concentration, with developing countries accounting for the bulk of exports. Only Latin America and the Caribbean supplied more than 80% of total exports in 2000. The four leading banana exporter countries in 2000 (Ecuador, Costa Rica, Philippines and Colombia) accounted for more than three quarters of world exports. Ecuador alone provided more than 33% of global banana exports. Nevertheless, the participation of Latin American and Caribbean supply has been slightly reduced during the nineties, while participation of Asian exports has increased.

Banana Imports

Bananas are imported mainly by the European Union, the United States of America and Japan, which together accounted for more than 65% of world total imports in 2000, while the first ten banana importing countries represented more than 84% of total imports (considering the EU as a whole). Although geographical concentration of imports remains high, the analysis of import data shows a tendency towards diversification of destination markets for bananas, particularly during the nineties. This is shown by the evolution of imports by the rest of the world group of countries, reflected on the graph on top of this page. It would reflect the increasing importance of emerging markets as the Russian Federation, China or Easter European countries as destinations for banana exports. While during the last decades all importing areas have increased their banana imports, it is possible to appreciate certain stagnation in the volume of imports of the European Union during the nineties.

Physiological development of plantain

Physiological development of plantain and banana fruits includes 4 stages:

- growth
- maturation
- ripening
- senescence

These stages are arbitrary, that is, they are invented for purposes of research. Strict physical or biochemical definitions are difficult to apply to all fruits. Fruits do not have identical types and/or rates of development, but researchers make general assumptions.

Growth. Growth involves cell division and cell expansion, which accounts for the final size of the fruit.

Maturation. Maturation usually starts before growth stops. Immature plantain and banana fruits are angular, with sharp edges and well-pronounced ridges. As plantain and banana mature, the fruits become more rounded. Further changes include coloration from green to yellow and the development of attractive flavors and aromas.

Growth, maturation, and senescence occur in all crops, but for fruits, including plantain and banana, another process termed 'ripening' also plays a part.

Ripening. Ripening is a biochemical process occurring in fruit between late maturation and early senescence. Ripening transforms a physiologically mature but often inedible plant into a visually attractive fruit with characteristic aromas and flavors.

Ripening also makes the fruit more attractive to animals as agents of seed dispersal. Plantain is unusual because it is consumed at all stages of maturity and ripeness.

Major biochemical changes occurring during ripening are:

- seed maturation (in pollinated fruits)
- peel color change
- abscission (detachment of fruits from parent plant)
- a dramatic rise in respiration rate
- increased ethylene production
- increased peel permeability
- softening of pulp tissue
- decrease in starch:sugar ratio
- production of volatiles (flavor and smell)

Senescence. During senescence, catabolic (degenerative/breaking down) biochemical processes replace anabolic (synthetic/building up) processes. This causes aging and finally death. In plantain and banana, the most obvious changes relating to fruit senescence are peel color change, from yellow to black, and softening pulp.

Pineapple illustrates typical changes during fruit ripening and provides a comparison with plantain and banana ripening. Weight increases during growth, stabilizes at the onset of ripening, and falls during senescence. Chlorophyll levels in fruit peel decrease on ripening. Levels of carotenoid (the yellow pigment found in ripe fruits) increase. Sugar levels increase during senescence.

Fruit growth and maturation can only be completed when the fruit is attached to the plant. Ripening and senescence occur whether the fruit is attached or detached from the plant. Fruit is generally harvested either when mature, at full size, or when ripe, having developed full flavor and color.

The most important physiological processes in harvested plantain and banana fruits are:

- transpiration
- respiration

Postharvest improvements aim to slow down these physiological processes. A reduction in the rate of transpiration or respiration extends market life and improves overall fruit quality.

Transpiration. Plants lose water by transpiration through the stomata. Transpiration is related to cooling and photosynthesis. As temperature increases, the rate of transpiration also increases.

Fruits lose water through the peel. Different fruits lose water at different rates, because of varying peel thickness. An orange, for example, has a thick waxy peel which holds in water, whereas a grape has a very thin peel which increases water loss. Plantain and banana are intermediate between these two crops.

Respiration. Respiration involves the uptake of oxygen, the release of carbon dioxide, and the breakdown of stored reserves. Respiration provides energy for metabolism, growth, and maturation. All cells respire, continuously oxidizing starch and sugars to produce carbon dioxide, water, and energy.

Respiration is described by the equation:

$C_6H_{12}O_6$	+ $6O_2$	--›	$6CO_2$	+ $6H_2O$	+ energy
glucose	oxygen		carbon dioxide	water	

Respiration rate indicates metabolic activity in plant tissue. It is also a guide to the potential storage life of fruits. Generally, the higher the respiration rate, the shorter the storage life. Respiration rate is measured by recording carbon dioxide production.

Generally, respiration rate is highest at the early growth stage, and declines with fruit maturity. However, plantain and banana are exceptions because of the climacteric response.

Crops harvested at an early growth stage have a high respiration rate and a short storage life. For example, young, rapidly growing lettuce leaves or banana flowers, which are eaten in Southeast Asia, are harvested at an early growth stage. Such products have a storage life of 1-2 days at ambient tropical temperatures. Plant products harvested at a mature stage, for example, potatoes and watermelons, can be stored for several weeks with little change in quality. For this reason, fruits are usually harvested at a late stage of maturity.

Climacteric response. Initially, plantain and banana show a gradual decrease in respiration with maturity. Then, pulp tissue suddenly produces a large amount of ethylene. The high concentration of ethylene triggers a rapid increase in respiration, which is termed the 'climacteric response'. At this point, all characteristic changes of ripening occur.

Fruits like plantain, banana, tomato, mango, and papaya have a climacteric respiratory pattern and are called climacteric fruits. Table 1 lists examples of climacteric and nonclimacteric fruits.

Climacteric fruits are identified by three major events:

- a rapid burst in ethylene production
- a sharp rise in respiration, indicated by an increase in carbon dioxide production
- a decrease in the oxygen level of internal tissues (pulp)

The climacteric response and full ripening occur whether the fruit is still attached to the parent plant or harvested. Ripening is slower in nonclimacteric fruits than in climacteric fruits. The division of fruits into climacteric and nonclimacteric is important, as it affects handling and storage.

The climacteric respiratory response has been the subject of much research. However, the control mechanism for this process is still unclear. Ethylene is an important agent in ripening and may have a moderating/coordinating role.

<u>Factors affecting banana ripening</u>

Factors affecting plantain and banana ripening can be physiological, physical, or biotic.

Physiological factors relate to fruit maturity or environmental factors, which affect the metabolism of plantain and banana.

Physical factors include mechanical damage, or relate to dimensions of the fruit.

Biotic factors include attack from pests and diseases.

Fruit maturity. The more mature plantain is at harvest, the shorter the ripening period. Studies show that False Horn plantain harvested 100 days after flowering ripened in 11 days. When the same cultivar was harvested 90 days after flowering, the ripening period increased to 15 days, and further increased to 22 days when the fruit was harvested at 80 days. Farmers have to match the date of harvest with the transportation time to the market. However, an early harvest reduces yield.

As fruits mature, the cross-sectional diameter increases. Fruit angularity also changes during growth and maturation. As fruits approach full maturity, fruit angles become less acute. Fruit angularity can be used to predict the optimum harvest date.

Temperature. Physiological studies on bananas show that storage life decreases as external temperature increases over the range 15-35ºC. A 1ºC reduction increases storage period by 1-2 days.

However, at temperatures below 11ºC, fruits suffer chilling injury. Therefore, optimum storage temperature for plantain and banana fruits is 13-14ºC. This temperature will maintain fully mature, ripe and unripe fruits for 1-2 weeks. Storage period can extend to 4 weeks when plantain and banana are harvested up to 4 weeks before full maturity.

The relationship between ripening period and temperature is due to fruit respiration. Fruit respiration depends on many enzymatic reactions, and the rate of these reactions increases exponentially with increase in temperature. Studies show that ripe fruits respire at approximately 4 times the rate of unripe fruits. Consequently, ripe fruits lose sugar resources at a higher rate than unripe fruits. This explains why ripe fruits deteriorate quickly.

The relationship between temperature and respiration is described mathematically by van't Hoff's temperature quotient (Q10). van't Hoff showed that the rate of respiration approximately doubles for each 10ºC rise in temperature.

Water loss and humidity. Where fruit is sold on a weight basis, loss of water means economic loss. Additionally, water loss reduces visual quality. Water loss causes plantain to lose its firmness, the peel becomes soft and shriveled, and ripening period reduces.

Detailed studies on plantain show a curvilinear or power relationship between fruit weight loss and ripening period. For a 2% change from 2% to 4% weight loss per day, ripening period reduced by 9 days or 50%. However, for the same 2% change from 8% to 10% per day, only a 1 day or 5% reduction in the ripening period occurred. Therefore, at a low rate of weight loss, a small increase in weight loss has a critical effect on ripening.

The rate of water loss depends on the ambient relative humidity (RH). RH is the amount of water vapor present in the air, relative to the maximum amount of water vapor that can be held in the air, at a given temperature, saturated air being 100% RH. When a watercontaining material such as fruit is placed in an enclosed space, for example, a sealed container, the water content of the air within the container increases or decreases until it is in equilibrium with the fruit.

The water equilibrium principle applies when fruit is stored. The rate of water loss depends on the ambient RH. At an ambient RH of 95-100%, fruit loses little or no moisture, and ripening period is unaffected. However, as humidity decreases, the rate of water loss increases, and ripening period reduces.

Excessive wetting can also be a problem. When plantain is stored in wet conditions, such as in moist coir (coconut fiber), the uptake of water from the coir to the plantain leads to peel splitting.

Sunlight. Exposure to direct sunlight reduces the ripening period of plantain and banana. Sunlight increases fruit temperature above ambient temperature, which increases respiration, and possibly the rate of water loss. Therefore, in traditional African markets, some traders shade their produce.

Ethylene. Ethylene (C2H4) is a gaseous plant hormone which determines the time between harvest and senescence. The time from harvest to the climacteric respiratory response is called the 'green life' or preclimacteric period. Ethylene shortens the preclimacteric period; at high concentrations, ethylene causes rapid initiation of the climacteric respiratory response and accelerates ripening.

All fruits produce small amounts of ethylene during development and when damaged or stressed. During ripening, climacteric fruits produce larger amounts of ethylene than nonclimacteric fruits.

When ethylene is applied to climacteric fruits, at a concentration as low as 0.1-1.0 ml/l, for 1 day, ripening starts. Once ripening starts, climacteric fruits ripen within 1-2 days.

When nonclimacteric fruits are exposed to ethylene, fruits show an increased rate of respiration. However, respiration rate falls when ethylene is removed. A rise in respiration rate may occur more than once in nonclimacteric fruits. However, for climacteric fruits, the climacteric is autocatalytic, that is, once started, the process cannot be stopped until the fruit is ripe.

Poor storage methods allow a build up of ethylene, stimulate the climacteric response, and reduce the ripening period. For example, plastic sheets placed over stacks of fruit for shade increase the level of ethylene within the plantain stack and increase the rate of ripening. Therefore, store plantain in thatched or ventilated areas to prevent the build up of ethylene. Also, do not store unripe fruits with ripe fruits.

During the preclimacteric period, fruits are less susceptible to physical damage and pathological attack. This is the best time for handling, transportation, and marketing.

Mechanical damage. Mechanical damage is a physical factor affecting ripening. Fruit damage during handling generates ethylene. If ethylene production is sufficient to start the climacteric respiratory response, fruit immediately starts to ripen.

Damage can also reduce ripening period by causing moisture loss. The effect of damage can easily be measured by recording fruit weight loss over time. Cuts and abrasions on the surface membrane cause the most weight loss.

After harvest, fruits lose the ability to repair ruptured peel. Harvesting techniques which damage fruit reduce storability.

Studies on plantain show that an abrasion affecting 5-10% of the peel can reduce the ripening period by 40%. A trader selling abraded fruit has half the normal time to sell an already less attractive product. Damage can also lead to secondary infection, which increases the rate of water loss and further reduces quality.

Surface to volume ratio. The ratio between surface area and volume determines the rate of water loss. The greater the surface to volume ratio, the shorter the postharvest life. A leaf which has two large surfaces with little volume loses moisture faster than a fruit. Large fruits lose less water than small fruits.

Peel thickness. Fruits with thin peel lose more water. A higher peel permeability leads to a higher rate of water loss and a faster ripening rate. Also, fruits with thick peel, for example melons, withstand damage better than fruits with thin peel, such as tomatoes.

Stomatal density. A higher density of stomata may cause a higher rate of water loss, which accelerates ripening. Studies show that the French plantain cultivar Obino l'Ewai has a more dense arrangement of stomata than other cultivars.

Biotic stress. Fungi, bacteria, viruses, and insects also account for a considerable proportion of total postharvest loss. Pests and diseases reduce both ripening period and overall quality. However, attack by pests and diseases is often secondary because a pest exploits a damaged area of the fruit. Careful fruit handling often prevents such attack.

Physiological & Physical Disorders

Chilling injury Symptoms include surface discoloration, dull or smokey anal color, subepidermal tissues reveal dark-brown streaks, failure to ripen, and, in severe cases, flesh browning. Chilling injury results from exposing bananas to temperatures below 13°C (56°F) for a few hours to a few days, depending on cultivar, maturity, and temperature. For example, moderate chilling injury will result from exposing mature-green bananas to one hour at 10°C (50°F), 5 hours at 11.7°C (53°F), 24 hours at 12.2°C (54°F), or 72 hours at 12.8°C (55°F). Chilled fruits are more sensitive to mechanical injury.
Skin abrasions Abrasions result from skin scuffing against other fruits or surfaces of handling equipment or shipping boxes. When exposed to low (<90%) relative humidity

conditions, water loss from scuffed areas is accelerated and their color turns brown to black.
Impact bruising Dropping of bananas may induce browning of the flesh without damage to the skin.

Pathological Disorders
Crown rot This disease is caused by one or more of the following fungi: *Thielaviopsis paradoxa, Lasiodiplodia theobromae, Colletotrichum musae, Deightoniella torulosa*, and *Fusarium roseum*--which attack the cut surface of the hands. From the rotting hand tissue the fungi grow into the finger neck and with time, down into the fruit.
Anthracnose Caused by *Colletrichum musae*, becomes evident as the bananas ripen, especially in wounds and skin splits.
Stem-end rot Caused by Lasiodiplodia theobromae and/or Thielaviopsis paradoxa, which enter through the cut stem or hand. The invaded flesh becomes soft and water-soaked.
Cigar-end rot Caused by *Verticillium theobromae* and/or *Trachysphaera fructigena*. The rotted portion of the banana finger is dry and tends to adhere to fruits (appears similar to the ash of a cigar).
Control strategies. Minimizing bruising; prompt cooling to 14°C (58°F); proper sanitation of handling facilities; hot water treatments [such as 5 minutes in 50°C (120°F) water] and/or fungicide (such as Imazalil) treatment to control crown rot.

POST HARVEST

Plantain harvest maturity and storage conditions are essential in attaining a storage life of up to three weeks. Incorrect maturity or inappropriate post-harvest handling will significantly reduce the green-life of the fruit.

Harvesting

Maiden plantain harvested for the export market and transported by sea, should be cut at the"light-three-quarter" grade. Harvest maturity standards should be rigidly maintained as the stage of ripeness on arrival is affected by the original physiological maturity. Plantain above the light-three-quarter grade are not harvested for exports by sea-shipment. Maturity in maiden plantain can be judged by the angularity of the fingers in much the same way as bananas. Light-three-quarter grade fruit show angular fingers with distinct ridges; as the fruit matures on the plant, the fingers become less angular and more rounded.
After removal of the stem from the plant, the fruit should be dehanded in the field; transport of fruit on the stems to a central packing facility will increase the levels of mechanical damage, particularly on fruit resting against the floor. Dehanding should be carried out with a sharp, clean, "banana" knife, making a smooth cut as close as possible to the stem. Care is required when dehanding to prevent fruit damage by the knife. Hands should not be moved by lifting with one or two central or end fingers; this may cause finger breakage and will cause pedicel bruising which can lead to problems during

ripening. Dirty of blunt knives will increase the levels of crown disease development; trimming the crown close to the fingers will result in crown breakage. After dehanding, the fruit are placed with the crown facing downwards onto a layer of leaves to allow for latex drainage. In order to restrict crown disease development, a crown pad can be applied after two minutes of dehanding or the crown dipped in a solution of 0.05% Thaibendazole.

Field packing of plantain is preferred; after application of the crown pads, the hands should be packed directly into the carton, in an overlapping inter-locking system. If field packing is inappropriate due to weather conditions or location, the dehanded plantain should be transferred to field crates for transport to a centralised packing facility. This process will assist in minimising mechanical damage.

Export Grading and Packing

Procedures for selection of acceptable fruit is identical whether carried out in the field or the packing house. No immature or over-mature fruit are tolerated. A certain level of healed scars or insect damage may be tolerated depending on the market involved, otherwise outgrading is required of fruit with excessive scars (leaf rub, insect and bird damage), discolouration, rust damage, and any form of mechanical damage. No size grading of the individual hands within a carton is required, assuming the minimum finger size is achieved. A minimum of four fingers per hand is allowed. Plantain are packed into cartons the same way as bananas: the hands on the bottom are placed in the center and then overlapped with the next hands with the crowns facing the base of the carton. Cartons are packed to a net weight of 12.3 kg (27 lbs). An additional 5% of fruit is required for sea-shipped plantain to account for weight loss during storage and transport. Overpacking is to be avoided as "box rub" and mechanical damage will occur. Fruit should never be forced into the carton nor overpacked.

Harvesting is required on the day before, or the day of shipment when exported by sea.

Packaging

Full telescopic two-piece fibreboard carton; double walled base is preferable; bursting strength 275 lb/in2. The "banana" type carton is suitable, but should include a central vertical divider to improve carton strength and fruit protection. Where staples are used in carton construction care should be taken to ensure complete staple closure to prevent fruit damage.

Carton internal dimensions

20 by 51 by 34 cm (7.9" by 20" by 13.4")

Storage and Transportation

Plantain can be exported successfully by sea-shipment if the guidelines relating to harvest maturity and handling are followed. Storage conditions of 12° to 13.5°C and 85 to 95% relative humidity are required. Storage room pre-cooling is recommended prior to loading for shipment; where this is not possible, the storage environment should have sufficient cooling capacity to remove field heat and maintain a constant temperature within 24 hours of loading. In commercial practice, with the sea-shipment availability from the East Caribbean (Geest), acceptable storage locations for plantain can be found in the refrigerated holds or in Seacold containers. Standard Email reefer containers on the Geest vessels have been shown to have insufficient cooling capacity and temperature maintenance for reliable successful shipping of plantain.

Potential Post-harvest Losses

Ripening and Spoilage in Plantain

Ship Ripes

Assessments have indicated that in shipments which arrive with ripe fruit, there are several degrees of ripeness. The most advanced plantain are almost invariable the most physiologically mature, as judged by the harvest maturity parameters. Plantain which are less ripe are generally more advanced than the light-three-quarter grade; in the majority of cases, the fully ripe plantain will have initiated some of the other fruit to ripen. This is particularly evident on removal from the storage conditions to higher temperatures. Therefore, it is essential that no plantain is shipped at grades above that specified. Shipment of 5% over grade may result in up to 15 to 20% ripe fruit on arrival as a result of ripening initiation during transport.

Ripening during shipment is particularly apparent from February to April as a result of the environmental conditions during fruit development. Cool conditions limit the development of the physical characteristics of the fruit while the internal characteristics continue as under normal warmer conditions. The overall result is that although the plantain may appear at the light-three-quarter grade, physiologically the fruit is more advanced. Hence, care is required on grade control at all times.

Mechanical Damage

Mechanically damaged plantain will produce blackened areas in green fruit and will eventually will result in soft areas with fungal infections. This is particularly apparent with poor or careless handling which results in bruising or pedicel damage, or overpacking resulting in box rub and damage from crown pressure on adjacent fingers.

Inappropriate Storage

Prolonged storage at temperatures below 12°C will result in chilling injury, the symptoms of which include blackening of the peel, increased rate of decay, abnormal or inhibited ripening and detrimental changes in flavour characteristics. Storage at temperatures above 13.5°C are favourable for ripening and are not recommended as shipping storage temperatures.

Pathological Factors

Infection by micro-organisms is not the primary cause of post-harvest losses in plantain exports as spoilage generally occurs when the fruit are in advanced stages of ripening or have mechanical damage. The main disease problem is found in crown rot, where the crown decays causing pedicel breakage and subsequent finger removal. This can be reduced by ensuring the crown is removed as near to the stem as possible and not near to the fingers and by using crown pads or a Thaibendazole dip.

Storing plantain and banana

Plantain and banana are important staple crops, supplying up to 25% of the carbohydrates for approximately 70 million people in the humid zone of sub-Saharan Africa. Crops are mostly grown on small-scale farms, in backyards, or on farm plots of less than 0.5 hectares. Plantain and banana are also an important source of revenue for smallholders.

A major problem of plantain and banana is that the fruits are highly perishable. At ambient tropical temperatures, plantain and banana have an average market life of 1-10 days, compared with several weeks for yam, for example.

The difficulties associated with the short storage life of plantain are worsened by the marketing system. The marketing system in Africa usually involves several retailers. Buying and selling takes time and leads to increased crop damage. Transport is often delayed, and can fail altogether, because of poor conditions of vehicles and roads.

The environment within the market is also not suited to long-term storage. A combination of high perishability, high ambient temperatures, slow marketing systems, and poor market conditions leads to losses in fruit quality, and ultimately to postharvest losses.

To reduce or avoid physical or economic losses, researchers look for ways to extend storage life. Storage life depends on

- crop type/variety
- fruit maturity at harvest
- time of day at harvest
- desired ripeness at purchase
- desired ripeness for eating
- storage conditions
  - temperature
  - relative humidity
  - ventilation rate
  - atmospheric composition
- mechanical stress/packaging
- pathological stress

Some of these factors can be controlled or manipulated to extend storage life of the fruit. Another way of extending storage life is by processing; for example, a perishable fruit can be changed into a dry product.

Methods to improve the storage life of a crop must make economic sense. For example, a temperature-controlled marketing system would improve plantain quality and market life, but such a system could not be supported in traditional plantain marketing systems. In African markets, only low-cost schemes are viable.

Improved handling and storage methods can be used on farms, at loading sites, during transport, and at the market. Improved storage maintains fruit quality from farmers' fields to consumers.

Improving storage life

The storage life of a crop can be improved by various methods. Some are simple, such as field sanitation. Others require more advanced technologies, such as cool chains.

To maintain product quality throughout the market chain, the whole system, from the farm to the consumer, should be considered. Improvements in one area may be ineffective if other areas of the retail system are not considered.

Several strategies can substantially improve storage life:

- breeding and selection
- improved cultural practices
- appropriate time of harvest
- improved field storage
- control of postharvest environment
- treatment of fruit
- improved postharvest handling

Breeding and selection. Some genotypes have a greater ability to retain market quality than others. For example, the storage life of two tetraploid plantain clones was 30-40% shorter than that of the triploid 'Agbagba'. However, improved storage life must be considered relative to other desired characteristics. For example, plantain clones bred for resistance to the fungal disease, black sigatoka, may have a reduced ripening period, and hence shorter storage life, but resistance may be considered to be the more important characteristic.

Improved cultural practices. Cultural practices affect the postharvest quality of a crop. Timely cultivation, moderate use of nitrogen fertilizer, avoidance of drought, and control of fungal infection all increase storage potential. Crops are prone to pests and diseases in the field. Thus, farmers should be aware of crop protection measures.

Appropriate time of harvest. Fruits harvested at the appropriate time give the highest quality. In commercial production of dessert banana, the date of harvest is based on size rather than maturity, because the fruit can be ripened as required by exposure to ethylene. Market standards dictate the size at harvest.

However, plantains are mainly grown on small-scale farms, where sophisticated management practices are not used. The date of harvest depends on market demand, and the financial needs of the farmer. Farmers may harvest fully mature fruit for their own consumption and local markets, and harvest less mature fruit for sale at distant markets.

Improved field storage. After harvesting, fruit should not be exposed to sun, rain, or wind. Collection points for the harvested fruit should be accessible to vehicles for transportation. Collection points should also be shaded. Researchers have reported up to 10 °C difference in temperature between shaded and exposed fruit. Rudimentary grading at this point can also improve overall fruit quality. Farmers should discard diseased, damaged, or over-ripe fruit.

Control of postharvest environment. Ripening can be delayed by manipulating environmental conditions. These environmental conditions affect the physiology of the crop. The three main methods for extending storage life are control of temperature, ventilation, and humidity (see Section 3). Modifying atmospheric composition also affects crop physiology and delays ripening, but it is currently less used (see Section 4).

Treatment of fruit. Chemical coating of fruit, treatment of fruit with gibberellic acid, and treatment of fruit with radiation all extend storage life (see Section 5).

Improved postharvest handling. Improving postharvest handling is the easiest way to extend storage life (see Section 6).

Temperature, humidity and ventilation

A plant product after harvest is still living. The most important physiological functions affecting product quality during storage are the rates of respiration and transpiration. To extend storage life, respiration and transpiration should be reduced as much as possible. This is often done by controlling, individually or in combination

- temperature
- humidity
- ventilation
- atmospheric composition

Temperature. Reducing the temperature reduces the rate of respiration, which delays ripening and thus extends storage life. Optimum storage temperature for plantain and banana is 13-14 °C. At this temperature, storage life of mature, ripe fruit is 1-2 weeks. Below
11 °C, stored fruit develops chilling injuries, and peel turns gray.

Fruit should be harvested early in the day, when the temperature is low. Immediately after harvest, fruits are cooled to the storage temperature. This stage, called precooling, should be rapid.

Fruit can be cooled using cold air (room cooling, forced air cooling), cold water (hydro-cooling), direct contact with ice, or evaporation of water from the fruit (evaporative cooling, vacuum cooling). Plantain and banana are usually cooled with cold air, to prevent temperatures becoming too low, which can cause chilling injury.

Humidity. High humidity reduces water loss, and increases storage life. However, high humidity also encourages fungal growth. A relative humidity of 90% provides the best compromise for storing plantain and banana.

Humidity can be raised in a container or room by spraying water in a fine mist. Humidity is reduced by venting. Humidity can be controlled with the help of a humidistat.

Traditional methods for increasing the storage humidity include spraying fruit intermittently with water, storing fruit on wet sacking, and storing fruit in boxes filled with moist coir or sawdust. Although effective, these methods can cause excessive wetting, which leads to fruit splitting and reduces market quality.

Ventilation. Air circulation is an effective method used to reduce temperature in storage rooms. However, ventilation also increases water loss from fruit, by removing the saturated layer of air that surrounds the fruit.

If ventilation is used to reduce temperature, water loss can be reduced by

- covering fruit with tarpaulins
- packing fruit into bags, boxes, or cartons
- wrapping fruit in polyethylene bags or heat shrink plastic films

Atmospheric composition

Respiration can be reduced, and hence storage life increased, by modifying atmospheric composition within the storage area. However, this method can be costly, and therefore is less used.

Normal atmospheric composition is approximately 21% oxygen, 78% nitrogen, and 0.03% carbon dioxide. By reducing the proportion of oxygen and raising the carbon dioxide, the rate of respiration is reduced, and plantain and banana ripening is delayed. For example, bananas stored in 5% carbon dioxide and 3% oxygen at 20 °C have been stored for more than 6 months.

Control of atmospheric composition requires a sealed environment. Sealed storage rooms, where levels of atmospheric gases can be monitored and adjusted, are expensive. A cheaper alternative is a plastic tent. Plastic tents are used in Malaysia and the Philippines to extend the storage life of Pisang Mas (Golden banana).

A simple and cheaper method is to seal fruit in polythene (polyethylene) bags. Plantains sealed in polythene bags remain green for a longer period than fruits stored in perforated polythene bags, paper bags, or wet coir. As the fruits respire, the atmosphere within the bag decreases in oxygen and increases in carbon dioxide. Respiration is then inhibited because of the reduced oxygen.

Plantain and banana may be sealed individually, or several fruits may be bagged together. When several plantains or bananas are stored together in a bag, the first fruit that ripens produces ethylene, and this causes other fruit to ripen. Therefore, only bag together fruit of the same maturity.

In one study, storing bananas in polythene bags at 20 °C delayed ripening by up to 6 days. Also, weight loss was reduced and there was less mechanical damage. High humidity develops in polythene bags. This reduces water loss from fruit, and also has a lubricating effect, which protects fruit from physical damage.

Although polythene bags can extend storage life, there are a number of problems associated with their use. High humidity within bags can result in development of crown rots, caused by *Gleosporium musarum.* These rots are controlled with fungicides such as benomyl and TBZ.

'Green soft' or 'boiling' may also occur in fruit stored in polythene bags. The peel remains green, but the pulp becomes soft and develops an off-flavor and odor. This disorder results from storing fruit in high levels of ethylene and carbon dioxide, with low oxygen. 'Green soft' can be avoided by including an ethylene absorber in the bag (see below), or using semipermeable polythene.

Polythene bags are now widely used in Australia to extend storage life of fruit. Studies in Sudan and Ghana confirmed the advantage of using polythene bags to extend storage life, but the technology has not been adopted in these countries. Reasons may be lack of information or unavailability of materials. However, it is more likely that polythene bags were not suited to the current system of handling, or that the extra investment in materials and time was not rewarded by higher profit at the market.

Storing perishable produce in bags to extend storage life has also proven successful with cassava. To avoid high costs, cheap and easily available materials, such as moist jute bags, can also be used.

Ethylene removal. Reducing ethylene levels delays ripening. Using chemical ethylene absorbents or oxidizers, to reduce ethylene inside polythene bags, is a feasible method for extending storage life.

Ethylene can be absorbed by activated carbon, or oxidized by potassium permanganate, ozone, ultraviolet light, or the use of catalysts.

The simplest ethylene absorber consists of an inert carrier, such as vermiculite or rice hulm and ash, impregnated with potassium permanganate. Potassium permanganate absorbs free ethylene. Recently, Japanese researchers have made plastic bags coated with zeolites, which absorb both oxygen and ethylene. Zeolite use is at an early stage, but may eventually result in an appropriate technology for extending storage life of plantain and banana.

Treatment of fruit

Researchers have investigated some chemical and physical treatments of fruit, as a cheaper way of extending storage life. The main methods investigated so far are

- chemical coating of fruits
- treatment with gibberellic acid
- radiation

Chemical coating of fruit. There is commercial interest in the use of chemical fruit coatings, such as Prolong and Semperfresh, to delay ripening. These formulations are based on sucrose esters and carboxymethyl cellulose, and they are water dispersable.

They provide a microfilm coating on the fruit surface. This film has no effect on water movement, but it may restrict the rate of gas movement through the skin of the fruit, slowing down respiration.

Studies have shown that Prolong and Semperfresh delay the ripening of plantains by 8-10 days at 30 °C and low humidity. Hence, chemical coatings have potential use where temperature and humidity cannot be controlled.

However, fruit coating has not been accepted in the banana trade, mainly because of high costs. Also, the subsequent ripening of the coated fruit is unpredictable, and uneven.

Treatment with gibberellic acid. Dipping of fruit into gibberellic acid was shown to delay ripening of bananas at high humidity, but not at low humidity. This method has not been adopted commercially.

Radiation. Studies in the USA and India have reported that storage life can be extended by irradiating bananas after harvest. Doses of 200-400 Gy increased storage life by 4-8 days at 24-28 °C. However, some types of plantain might be damaged by these doses. Also, the technology is not widely available, and is expensive; and despite acceptance by the USA Food Council, radiation is still unacceptable to consumers in many countries because of negative associations.

Improving postharvest handling

The majority of factors that reduce the storage life of plantain and banana occur after harvest. Postharvest handling includes field storage, grading, packing, transport, and marketing.

Improved practices during postharvest handling can greatly increase storage life. This is illustrated by comparing traditional postharvest handling of plantain and banana with the highly organized postharvest handling of dessert bananas for export.

Traditional postharvest handling. In West Africa, production of plantain and banana is mainly small scale, and farmers have no specialized harvesting equipment. Fruits are often moved in bulk from farms to towns for sale, which can be several hundred kilometers away. Vehicles used for transport include trucks, the tops of buses, and bicycles.

Plantains and bananas may be transported as whole bunches, as hands, as clusters, or as individual fingers. They may be stacked up to 2 m deep to fill all available space. In some cases, plantains and bananas are cushioned with leaves or stored in jute sacks, but often there is no protection against damage.

Dehanding (separating bunches into hands) and transporting fruit in sacks reduces damage during transport. However, dehanding and packing are labor- and time-intensive processes. Therefore, there may be a trade-off between the advantages of dehanding and the time and skill available.

Harvesting, dehanding, and loading plantain and banana into vehicles may take 2-3 days. Journey time to town may be a further 3 days. Therefore, plantain and banana may be exposed to ambient conditions, with no protection from physical damage, dehydration, and high temperatures, for up to 6 days. Despite this, most of the produce reaches the market green and without significant damage. It is estimated that losses in traditional West African systems are less than 10%.

Improved postharvest handling. For transport to more distant markets, often thousands of kilometers away, a highly organized postharvest system has been developed for dessert bananas.

The bananas are harvested at a specific maturity, relating to the number of days from flowering, the angularity of the fingers in cross section, the size of fingers, and distance to market. Skilled teams harvest the bananas, using specialized equipment to cut stems and support cut bunches. Where flat land allows, wire and pole systems suspend and transport the bunches from the field to the packing shed.

The bananas are then separated into hands. The hands are washed in a solution (2% alum, 20% chlorine) to sterilize them, and to prevent latex from cut fruit staining the peel, and then treated with fungicide.

The hands are then packed into fiberboard boxes. The boxes may be lined with polythene, or the hands may be sealed in polythene bags. The boxes are stowed at a specific stack height and configuration in refrigerated stores or transport containers. At the destination countries, the unripe bananas are distributed to ripening depots, where the ripening process is initiated with ethylene gas. Bananas are then distributed to retail outlets/markets. The storage life of bananas, using these techniques, is 4-8 weeks.

EC QUALITY STANDARDS FOR BANANAS

The EC quality standards for bananas have come into force on June 1st, 1995. They are technical norms, defining the minimum standards for bananas marketed within the Community. They apply to bananas from all producer countries, that is to say to bananas from EC members and non-members alike. They only apply to the Cavendish and Gros Michel banana fruit, and only to green, unripe fruit.
The EC quality standards for bananas cover the following chapters:

- minimum standards
- quality
- size
- size and quality tolerances
- presentation
- labelling.

The following is a short list of some of the standards.
Whole: Every single finger of a package must be undamaged. This applies to damage which has occurred during the harvesting and processing as well as during the loading and unloading.
Healthy: The single clusters must not bear any sign of disease, physiological defects or rottenness.
Clean: The single fingers must be clean, which means they must be free from earth, soot etc..
Undamaged stems: The stems must neither be torn nor cut, nor may they become cracked during the packaging, transport, loading or unloading. Fresh cracks can be seen as dark green lines and are not considered to be defects. Old cracks ("broken feeder lines") are darkly coloured and are classified as not conforming with the standards.
Healthy and smoothly cut crown: The crown must be healthy. If there are signs of crown rottenness, the respective part is cut off in 3.5 mm thick slices. If there are still signs of rottenness after two slices, all fingers of the cluster are classified as having rotten crowns.
Moreover, all fingers of the cluster must stick tightly in the crown. The sides of the crown must be cut off smoothly, because torn crowns increase the risk of microorganisms entering the fruit, and thus the risk of secondary infections.
Abnormal curvature: Whether the curvature of a fruit is abnormal depends on the curvature of the neighbouring fruits within the cluster. In order to ensure safe packaging, all fruits of one cluster or one hand must have the same curvature.
Bruises: The quality standards only apply to bruises which diminish the quality of the fruit pulp.
Chill damage or Under Peel Discolouration: There are four levels of discolouration: very light, light, medium and grave. Bananas with medium discolouration, which hardly contain any liquid, and grave discolouration may not be marketed within the EC.
Slightly ripened bananas/turnings: Hands or clusters which have ripened during the transport induce the uncontrolled ripening of the entire package. Bananas from packages including ripe or ripening fruits can obtain an appropriate level of ripeness and can thus be consumed. This is why ripe or slightly ripened fruits are tolerated within the 10% tolerance for class 2 bananas, and within the 2% tolerance for class 1 bananas. Although the trade could theoretically sort out ripened clusters, these clusters are usually destroyed for economic reasons.
The EC norms do not apply to bananas that have the same degree of ripeness. These fruits are therefore not controlled. This also goes for ripe bananas which have been transported by plane.
Latex: clear, non-discoloured latex is tolerated in all classes. Brown, dry latex is tolerated to a certain extent in class 1 and 2. Oily, wet latex is not tolerated in any class.
Thrips damage: puncture and suction marks caused by thrips are tolerated to a certain extent in class 1 and 2.
Damaged peel: Damage to the peel occurs when the bananas grow. This includes traces of rubbing, scratches, traces of eating caused by insects and damage caused by thrips. The EC norms tolerate damage that does not exceed a total of 1 cm2 per finger for an Extra class banana, 2 cm2 for a class 1 banana and 4 cm2 for a class 2 banana.

Size: The length of a banana is measured along the length of the curvature from the tip up to the beginning of the stem in the crown. One reference finger is measured. It must be at least 14 cm long. In the context of size tolerances, though, a length of 13 cm is also tolerated.
Labelling: Each package must contain information about the packer (with name and adress), the sort and the type (Cavendish), the producer country, the class, the net weight and the size, which means the minimum size to be found within the package. An indication of the maximum size is not obligatory.
Tolerances: All minimum standards must be fulfilled in the Extra class and in class 1. The exceptions mentioned in the context of quality standards are interpreted in such a way that three or four fingers which do not comply with the minimum standards are tolerated if twenty packages are checked. In other cases, the tolerances only apply to bananas which are not affected in their appearance or durability, and which can be consumed.
The EC standards for bananas are in compliance with the Codex Norm for Bananas which the Codex Alimentarius Commission agreed upon at its 22nd session in Geneva from June 23rd to June 28th, 1997. The Codex Norm also contains further, general requirements concerning heavy metals and hygiene, that is to say standards that go beyond mere trade norms and touch health-related issues.
Control: The EC control regulations, or VO (EC) Nr 2898/95, have come into force on July 1st, 1996. Controls are obligatory regardless of the bananas' origin. Community bananas must be controlled in their producer country before being loaded and sent to a destination within the EC, and also when they are unloaded, which does not free producers and exporters from their duty to check their bananas in the packing stations and/or in their ports.
The control regulations make it possible to free reliable importers from a regular state control in their ports. This possibility is successfully taken advantage of in European ports. The respective importers carry through controls within their own companies and see to it that bananas that do not fulfill EC standards are not marketed within the EC. These importers must record their controls and are monitored by the responsible authorities on a regular basis.
Containers that are not supposed to be opened before they reach their destination must be checked by the responsible authority upon their arrival.
Every controlling body of the member states establishes its control result by evaluating the fingers and not the clusters. This is the only reliable and comprehensive method of controlling if the standards are fulfilled.
Bananas from biological production: An evaluation of bananas from biological production which were imported to Germany showed that they had varying degrees of quality, even when they came from the same producer. In the beginning, some packages did not fulfill the standards. The BLE allowed the importers to sort out some of the bananas when they were ripe, although this does not comply with the control regulations. This project took a lot of time and did not pay off economically, which is why it is no longer practised today.
The control of bananas from biological production has shown that 10 to 15% of the defects could have been avoided in the exporter's country:

- The loading of a container in the exporter's port sometimes takes 10 to 14 days. The containers are not cooled during that time. The bananas in these containers are rotten when they arrive, and are therefore destroyed by the importer.
- It can also pose problems if there are bananas from 30 to 40 different producers in one container. The quality of the fruits may differ from producer to producer. This is why bananas of poorer quality from one producer can mean that the entire carton or the whole package has to be destroyed.
- Some bananas from biological production have damage that does not result from the biological production methods: torn crowns, chains of clusters that are almost torn apart, cuts that are not smooth, long stems remains (when single fingers have been cut out), and traces of rubbing.
- The greatest problems are: rotten crowns, rotten stems and anthracnosis. To reduce the risks, many exporters deliver bananas which are rather small in section but still fulfill the minimum standard of a 27 mm diameter.

By and large, good bananas from biological production are equivalent to class 2 bananas, in some cases even to class 1 bananas.
Summing up, I would like to say that bananas from biological production can easily fulfill the EC standards. Defects that occur during the preparation and packaging should be avoided, because consumers of ecologically produced bananas also have a right to buy products which fulfill the minimum standards.