



Technical Guide on Post-harvest of Banana (*Musa paradisiaca* var. *sapientum*)

Use of Refrigeration and Ethylene Generator Equipment

TCP/ERI/3002

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A. Introduction

Eritrea was in the past an exporter of fruit and vegetables to the Middle East and Europe, with bananas being a significant component of its exports. However, banana exports ceased after 1974 as banana plantations decreased due to problems associated with war. Current banana production is based on a total area of about 1 500 ha., mostly in Akordet and Tesseney, areas of the Gash-Barka region, where FAO through its technical cooperation programme implemented, in several phases, a project initially titled: "Preliminary Assistance for Launching Banana Production, Quality and Export Improvement Programme" and later as "Horticultural Marketing Development". The main objectives of these projects have been addressed to strengthen the most relevant post-harvest technologies associated to the improvement of quality and safety of national crop production and its commercialization with emphasis for banana and onion. Therefore, the Agriculture Support System Division of FAO through its technical units AGST and AGSF as lead technical units, along with the Ministry of Agriculture of Eritrea have carried out different activities in order to achieve the objectives approached in these projects. This brochure is a partial result of different activities undertaken in Eritrea to reinforce the post-harvest sector. It is more focused on those technical activities related to the handling, packaging, ripening and storage of banana.

B. Banana Growing and Pre-harvest Considerations

Banana can grow in many types of soil and it is specially productive in deep soil with loam or clay loam textures; it can thrive at an elevation of 1.5 to 1 000 m above sea level and produces sweeter fruits at 600 m and above. The density of planting can be from 1 500-2 000 plants/hectare and it is harvested 11 to 13 months after planting and then, every 9 months can produce bunches in good growing condition. It tolerates wide soil pH, but 6.5 should be ideal. It requires organic matter to be not less than 2.5 percent (300-600 kg/h/year of ammonium

sulphate or ammonium nitrate), 24 ppm of phosphorus, 400-600 ppm of potassium and calcium, magnesium and sulphur to grow well, as well as, some micronutrients, mainly boron, manganese and zinc. Banana also grows well in areas with a rainfall of 7 mm/day or 25-50 mm per week and needs well drained soils. It does not grow well in wet or flooded areas. Banana can tolerate a wind speed of 10 to 14 km/hr but above 35 km/hr may reduce production due to leaf shredding.

The harvest maturity of banana fruits may be based on the following indices: a) the angularity or shape of the fingers. It is recommended that banana should be harvested when the fruit shape is full $\frac{3}{4}$ or full stage depending on the selected market. b) the physiological age of the fruit based on the number of weeks from shooting (when the flower bud appears) to maturity. Harvesting the bunches is preferable in the morning. Cut the trunk slowly about one third from the top for the bunch to fall slowly. Hold the tail end of the bunch before it touches the ground. Then cut the peduncle, leaving about 30 cm of the stalk for easy handling.

C. Quality Standards

Quality Standards (EU Standards). These standards refer to genus *Musa* (AAA) Spp, subgroup Cavendish e Gross Michel.

Quality characteristics

1. The minimum characteristics of bananas requested before ripening for all the categories must be:

- green but with an adequate development stage, and not ripened; whole firm; sound; clean; free from parasites; free from decay symptoms; with intact, sound, clean stem; free of flowers residues; free of deformation and normally curved; free of any external leakage; no off-odors and off-flavors

2. Classification.

Bananas are classified in three categories:

- i) Extra. Bananas must not have any defects, except slight peel defects (less than 1 cm² over all surface) which do not affect the appearance of the whole hand, or finger.
- ii) First. As before but bananas can present: slight shape defects; slight peel alterations (less than 2 cm²) which have not touched the pulp
- iii) Second. Banana must respect the minimum requirements but can present: shape defects; peel defects due to abrasions (less than 4 cm²) which have not touched the pulp.

Calibration (see Figure 1)

To take the following measurements (calliper grade or calibration) we must consider the middle finger (banana) on outer whorls of the second hand on the stem before running fruit through packing plant processes.

- banana length: measured (cm) from the base of the banana stem to the apex
- banana width (calliper grade): cross section in the middle of banana (mm)

Calliper grade: ≥ 27 mm. Length: ≥ 14 cm.

Dole Company considers acceptable to good bananas (Dole Class one, Giant Cavendish) with: calliper grade: 31-39.5 mm (North Europe Markets); 32-38 mm (Mediterranean Markets) and length: ≥ 19 cm

Tolerances

In each packing case are admitted tolerances in quality and size.

1. Quality tolerances

- i) **Category Extra:** 5 percent of weight or number of bananas of first category
- ii) **First category:** 10 percent of weight or number of bananas not matching neither the category requirements nor the minimum requirements, but not admitted fruits with decay or other consume intolerable defects.

2. Calibration tolerances

For all the categories, 10 percent of number of bananas with length less than 1 cm of the minimum requested (14 cm)

Packing and display

1. Uniformity

Each packing must have only bananas with the same origin, quality, and variety. The visible part of the bananas inside the box must represent the whole bunch of bananas of the box.

2. Handling

The bananas must be handled in such way to guarantee the product protection. The materials which are used for packing must be new, clean, and not toxic or physically dangerous for the product as well as for the consumer. The use of paper or printed materials in contact with the fruits must be approved for food use. The package must not have any foreign bodies.

3. Display

The bananas must be inside the package in hands or cluster which is minimum 4 fingers

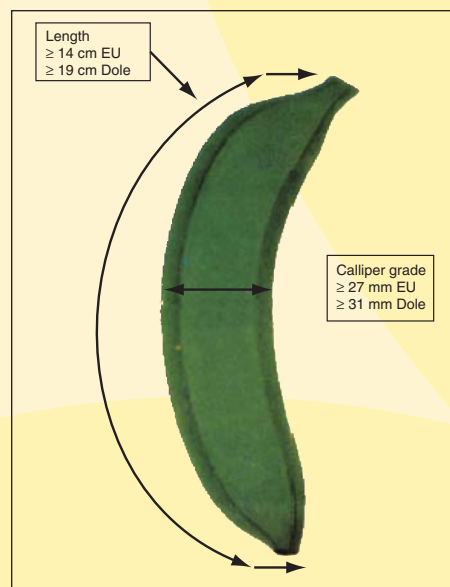


Figure 1. How to measure bananas.

(bananas) together. In each package, one cluster is tolerated without 2 fruits if they are removed in a correct way, which means with sharp knife cut of the stem. In each layer of the package, it is admitted only one cluster with 3 bananas with the same characteristics of the other fruits. Dole Company tolerates clusters with 4-8 bananas but only one cluster with 3 bananas for each box. 14-18 clusters per package are admitted for bananas long more than 19 cm.

External notes in the package

Each package must be shown on the same side clear, readable, and not erasable following information:

- identification; product type (“banana”, variety name); product origin; commercial characteristics (category, net weight, min and max calliper grade and length)

D. Harvest Index

One very useful criteria for harvesting fruit that is used commercially is age of the bunch after emergence from the pseudo stem (emergence can be defined as the day on which the first complete hand of fruit is visible).

Important: a) mark with colour straps the banana stems (bunches) according to weeks of age; b) protect each hand from the other by using plastic film, paper, or other soft, not abrasive, materials such as leaves (Figure 2) (At a given age, the maturity of hands in a stem varies, those hands at the proximal end of the stem being more mature than those at the distal end); c) estimate maturity of the entire stem using the second hand from the proximal end and measuring length and calliper grade.

E. Harvest Care

- Before cutting the stem **PROTECT** the whole bunch with plastic bag to avoid the latex dropping
 - One worker must push up the bunch and another worker cut the stem with the knife (machete)
 - The third worker carries the whole bunch on the shoulder having care to use a soft blanket, not abrasive
 - **AVOID** the contact of the latex with bananas peel; aluminium sulphate (Alum) is the best to flocculate latex but if it is not available you can just dry with paper or other fabric tissue
 - **DO NOT USE** blanket stained with latex since it becomes rough and abrasive.
- Important: use gloves for all these operations



Figure 2. Banana hands protection with plastic film and paper.

F. Transport to the Packing Shed

- AVOID contacts among the banana hands; protects each other with soft materials
 - DO NOT unload heavily the bunch on tough surface (trailer)
 - PLACE soft materials on unloading surface for banana (trailer)
 - Try to AVOID rough road with big holes
- Methods for transport to the packing house: a) cableway; b) on the man shoulder or back; c) with dry leaves on the back of a donkey; d) carrying a bunch of banana hanging on a pole (Figure 3).

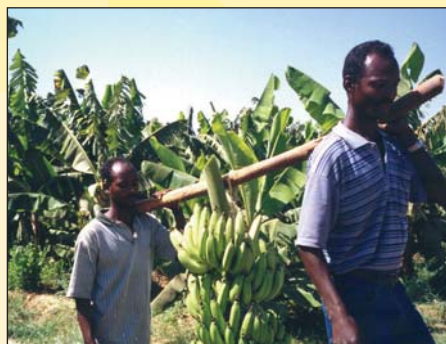


Figure 3. A bunch of banana hanging on a pole and carried by two men.

G. Packing Shed Operation

1. Unloading and washing

Upon arrival to the packing house, the fruit should be inspected for finger fullness and length, blemishes, scars, insect attacks and decay. Only fruit which meet quality requirements should be packed and lower quality can be sent for processing.

- IF WATER IS AVAILABLE: there are two options.
 - a) Upon arrival the bunch is hung on a metallic hook for de-handing. Then the hands are unloaded in the first tank.
 - b) Unloaded the bananas bunch into the first water tank. In both cases de-handing of banana bunch should be with a knife into 8-14 hands from up to down (16-18 fingers per hand). Remove the stem from the water. Water is useful to protect the bunch during unloading and to wash the bunch. Important: water can be added in the first tank with a latex suspender agent such as Bacterol 100 (optional). In the second tank a fungicide like Thiabendazole and a healing-bleach substance as Aluminium sulphate (alum) is required. Likewise, 75-125 ppm of sodium hypochlorite is commonly added to water to reduce decay organisms. Also important is to fill the tanks to 75 percent of the total volume to avoid water spill.

- IF WATER IS NOT AVAILABLE: unload the bunches gently over a flat surface covered with spongy, soft, materials (cardboard, fabric, leaves) and de-handed with a knife into 8-14 hands (16-18 fingers per hand) remove the stem and all the foreign bodies (leaves, dirt, stains) clean the cut surface to remove latex. Important: the materials covering the table must be changed very often.

2. Sorting

- CUT the hands into smaller clusters (clusters are typically 3-8 fingers), cluster's crowns are shaped sharply to reduce latex flow and rot incidence, and for aesthetics

- If water and latex suspender like Bacterol 100 agent are available, immerse the cluster in a second tank for 20 min.
- The recommended fungicide (Thiabendazole) concentrations can be 400 ppm (for EU) or 200 ppm (for USA), and the bleaching substance (Alum) 1 percent, both in the second tank. Water should be changed and monitored the chemical solution concentrations used.
- BRUSH the crowns with bleach solution or fungicide solution (if water tank is not available)
- PACKED the clusters in the boxes having care to separate with paper or plastic film one layer from the others and if possible one cluster from the others (see Figures 4, 5 and 6 below)
- USE similar age cluster or bananas in each box to avoid uneven ripening after the ethylene treatment.



Figure 4. Cluster of bananas ready to be packed.



Figure 5. Single cluster packed in plastic perforated bag and coded.

H. Storage and Stacking

- It is important to take reasonable precautions to ensure optimum shelf life. Bananas should be stored away from doors, windows, exterior walls and cold or hot drafts.
- Carton lids should be removed and plastic liners turned back. This prevents the generation of heat in closed cartons. Cartons should be cross-stacked to ensure adequate ventilation.
- The banana ripening process relies upon creating high humidity conditions in the ripening room. As a consequence banana cartons absorb water and carton walls can weaken and collapse. Therefore it is important to ensure that cartons are not stacked too high. To prevent product damage due to the sagging of the sides of the cartons or their collapse while at the retailer, no more than 5 cartons should be stacked.



Figure 6. Clusters of bananas packed for shipping overseas.

- Stock rotation must be practiced to ensure that the customer receives the best and freshest product. However, on occasion it may be necessary to fast track the sale of an arriving consignment due to its state of ripeness.

As a general rule bananas should be segregated to ensure that the ripest bananas are selected for sale first and greener bananas are held in storage

Main steps

- Stack the boxes in a way to permit the air to flow through and inside the box (Figures 7 and 8); OPEN the boxes and fold back the plastic bag
- DO NOT PLACE the boxes attached to the walls and in front of the evaporator (Figures 9)
- COVER the first boxes close to the evaporators during the storage room at 13 °C because the air temperature coming out from the evaporator is lower
- CHECK the temperature in different corner of the room and at different heights
- CHECK the ventilation in different corner of the room and at different heights by using light strip of paper or straw; the strip must move even in front of the door
- If you don't use plastic bags for bananas, CHECK the RELATIVE HUMIDITY; if it is too low, WET the floor
- If you don't use pallet, KEEP the boxes uplifted from the floor
- KEEP CLEAN the storage room: floor, walls, ceiling, evaporators

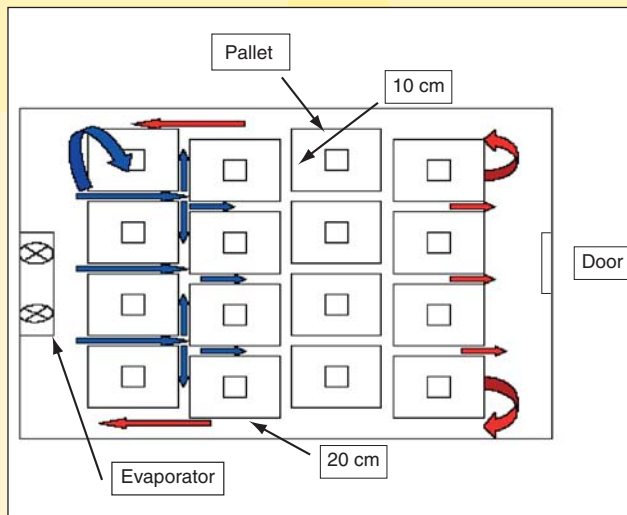


Figure 7. Flow of the cold and the warm air inside a storage room with a special stacking system useful for ripening bananas (overview).

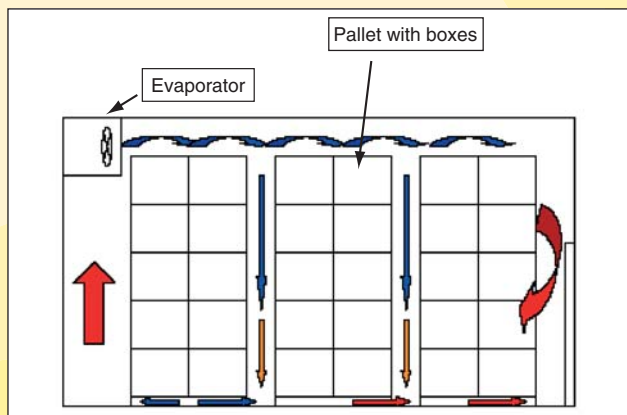


Figure 8. Air flow in the storage room as above.

(cross section)
cold air: bleu
warm air: red
warm-cold air: orange
evaporator
Pallet with boxes

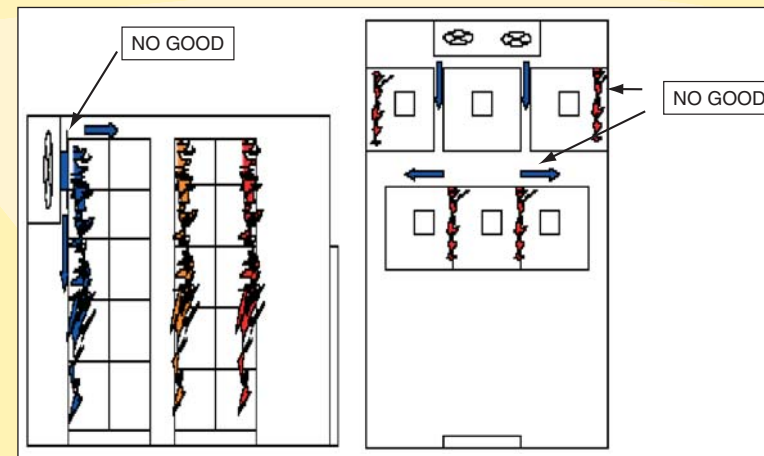


Figure 9. These systems of stacking are not good for storage and ethylene diffusion.

I. Cold Room Instructions

Parameter to set:

- Storage temperature: PRESS “set” AND “up” OR “down”

How to vary other parameter: main parameters

- HOLD DOWN “set” BUTTOM AND “up” BUTTOM FOR MORE THAN 5 SEC
- APPEAR THE FIRST PARAMETER
- TO SET THE OTHER PARAMETERS PRESS “up” OR “down” BUTTOMS
- TO SEE THE VALUE OF THE PARAMETER PRESS “set”

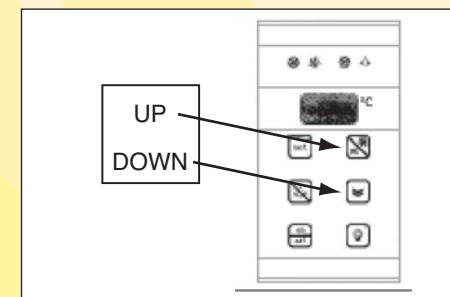


Figure 10. Panel display for control of parameters of cold storage room for banana in Tesseney and Akurdet, Eritrea.

Parameters to change eventually

- n. 2 and 3 of the manual: Minimum and maximum value of setting (LSE and HSE)
PRESS “up” TO REACH the symbols LSE and HSE
To see the temperature PRESS SET; to change: PRESS “up” OR “down” UNTIL THE DESIRED VALUE IS REACHED. These values are the range of temperature in which the equipment can work

- n.17 and 18 of the manual: max and min alarm (HAL and LAL)
PRESS “up” TO REACH HAL and LAL
To see the temperature PRESS SET; to change: PRESS “up” OR “down” UNTIL THE

DESIRED VALUE IS REACHED. These values are the temperature above or below them the equipment must not go.

- n.24 : block evaporator fans when compression is OFF (Fco)

PRESS “set” AND “up” TO REACH Fco

A symbol “of” or “on” will be shown; to change PRESS “up” OR “down” TO SHOW THE DESIRED SYMBOL

For ripening is better to set this parameter on “of”, this permits to the maintain continuously the uniformity of atmosphere inside the room

- n. 25: block evaporator fans when door is open PRESS “set” AND “up” TO REACH Fod

A symbol “of” or “on” will be shown; to change PRESS “up” OR “down” TO SHOW THE DESIRED SYMBOL

During the ripening this parameter MUST BE “on”: during the storage, it MUST BE “of”, in order to prevent the entrance of warm air from outside.

EACH TIME YOU CHANGE THE PARAMETERS, SWITCH OFF AND THEN ON THE EQUIPMENT PRESSING THE BUTTOM ON/OFF

J. Maintenance (Main steps)

- EVERY WEEK: clean the evaporator with bleach solution
- EVERY WEEK: clean the condenser with bleach solution, remove the dust from the fins and the fans
- EVERY FEW MONTHS: checks the electric connections and the refrigerant circuits; check the refrigerant flow indicator (no bubble should be seen)
- EVERY FEW MONTHS: check the colour of the element sensitive to humidity through the indicator of the liquid line: GREEN: OK; YELLOW: NO. If YELLOW call the technician.
- CHECK regularly the noise of the compressor: if it is beating something is wrong. STOP the equipment

K. Trouble Shootings (Main)

• **Symptom: gas bubbles in the refrigerant flow indicator.**

Causes are:

1. lack of refrigerant
2. expansion valve failure
3. condenser does not work properly

• **Symptom: the compressor work continuously.**

Causes are:

1. unsealed discharge valves
2. lack of refrigerant
3. excessive cooling requested

• **Symptom: the compressor does not start.**

Causes are:

1. lack of refrigerant
2. refrigerant unit incorrectly set
3. current interrupted: fuse blown, thermo magnetic switch damaged
4. closed solenoid valve on the liquid line

• **Symptom: unusual noise in the compressor**

Causes are:

1. suction of liquid or foreign materials
2. loosening of the connections

• **Symptom: suction temperature is too low**

Causes are:

1. expansion valve capacity is too high or too low
2. imprecise thermometer
3. excess of refrigerant
4. expansion valve failure

• **Symptom: suction temperature is too high**

Causes are:

1. suction valve or piston unsealed
2. suction pipes uninsulated correctly
3. imprecise thermometer
4. lack of refrigerant
5. clogged expansion valve filter
6. ice formation in the expansion valve
7. expansion valve failure

• **Symptom: discharge temperature too high**

Causes are:

1. suction valve or piston unsealed
2. unsealed discharge valve
3. expansion valve capacity too low
4. by-pass shut off valve opened
5. imprecise thermometer
6. presence of air in the refrigerant
7. lack of refrigerant
8. temperature of the condenser is too high
9. expansion valve failure

• **Symptom: discharge temperature too low**

Causes are:

1. expansion valve capacity too high
2. imprecise thermometer
3. expansion valve failure

L. Banana Ripening Requirements

1. Banana consignment for ripening

- Consignments should be unpacked in an undercover area if possible.
- Prior to loading pallets into the ripening rooms, pallets must be placed in an area where they will not be subject to heating or cooling.
- On arrival each banana consignment should be inspected to ensure that the produce meets the set quality specifications. Cartons throughout the consignment must be selected to ensure a sample of cartons from each grower is inspected.
- Random pulp temperatures should be taken throughout the consignment to ensure that no adverse temperature fluctuations occurred during transit. If adverse fluctuations have occurred the ripening period for the produce may not be constant and it may be necessary to split the consignment to various ripening rooms. The pulping temperature of the bananas should be in the range of 13-17 °C.
- To some extent it is possible to control when bananas should be matured for sale, based on Figure 11. The needs of the market and price will have some influence on the desired ripening time. The manager of the ripener must determine a ripening regime based on the needs of the market, the quality of bananas, the condition in which they arrived and the general behaviour of bananas from particular growers during ripening.
- Banana cartons will absorb water in high humidity ripening rooms. This causes carton walls to weaken and product damage on the bottom two rows of the pallet. Thus pallets should be broken down prior to ripening room placement and no more than seven cartons should be stacked.

2. Ripening requirements

Banana colour: 1-2

Treatment Temperature: 20-25 °C; Treatment Relative Humidity: 90-95 percent (high-very high).

Treatment Ethylene concentration: 500-1 000 ppm; Ventilation (use fans to move the air inside the room).

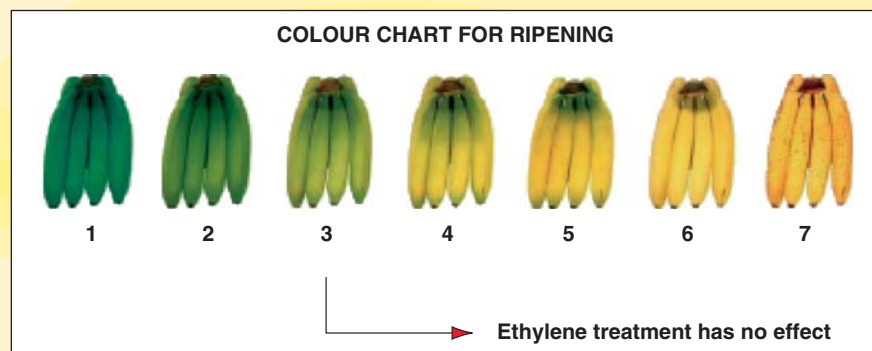


Figure 11. Colour guideline for ripening.

1: **dark-dark green**: no light yellow colour should appear on bananas; good for long distance shipping (ship); good for ripening; 24-48 h of ethylene treatment at 20 °C (Table 1).

→ **24-48 h of ethylene treatment at 20 °C**

2: **light green**: light yellow appears on banana which is still green; good for short distance transport; good for ripening; 12-24 h of ethylene treatment at 20 °C (Table 1).

→ **12-48 h of ethylene treatment at 20 °C**

3: **light yellow**, green and yellow are covering equally the banana; good for rapid distribution

4, 5, 6: **yellow**; preference for the consumer at colour 4 should be in the retail (as shown also in Figure 12)

7: **overripe**; diffuse brown spots

Table 1. Colour stage, temperature, and ethylene treatment time for banana

Colour	Temperature of treatment and maintenance (°C)	Time of treatment (h)	Days to reach colour 4
1	14	48-96	7-10
1	20	24-48	3-5
2	14	24-48	5-8
2	20	12-24	2-4

If after the treatment at 14 °C the temperature is rise up to 20 °C the days to reach colour 4 are halved. The values are indicative and can vary depending on the variety, pulp temperature, agronomic condition

IMPORTANT

- Temperature must not go below 13.5 °C
- Adequate pallets stacking and ventilation to uniform temperature and ethylene distribution

3. Inspection

Before starting the ripening:

- CHECK the temperature of bananas
- CHECK the firmness (Table 2)

After ripening treatment:

- CHECK the firmness
- CHECK the sugar content (Table 2)



Figure 12. Banana ready for the retail shop (color 4).

Table 2. Values of firmness (Penetrometer) and sugar content (Refractometer) for Giant cavendish.

Ripening stage (Colour)	Firmness (Kg)	Sugar (%)
Light green (2)	3-4	2-5
Light yellow (3)	2-3	7-9
Yellow (4-5)	1-1.5	10-14
Brown spots (6-7)	0.5	≥ 14

4. Sugar content and firmness determination

a) Sugar content determination (Refractometer)

- TAKE 10 bananas from one box in each corner of the ripening/storage room: total 40 bananas (this is the minimum)
- REMOVE the peel
- SLICE 50 g of the banana pulp (from the middle area) or an amount you like; if you have an homogeniser weight a right amount for the homogeniser
- PLACE the amount in a glass and add the same amount of water
- MIX together very carefully to obtain an uniform mixture
- LEAVE for half an hour and every ten minutes, with a spoon, MIX the solution
- After half an hour, TAKE one drop or two drops of the solution (clear it is possible; if not filter with fabric tissue) and place in the refractometer
- The value obtained must be multiplied by 2

b) Firmness determination (Penetrometer with 8 mm diameter tip)

- Same samples of the sugar content determination or other samples
- PEEL the banana
- PLACE the banana over the tough, flat table
- PRESS the penetrometer vertically in the banana flesh in 3 points: two extremes and in the middle
- When the tip of penetrometer has perforated the pulp STOP the pressure
- READ the value on the penetrometer

M. Ethylene generator operation steps (ETHYLFAST Figures 13 and 14)

1. Wear the gloves
2. Open the lid
3. Pour the ZETA powder in the internal free cylindrical container
4. Add water up to the 5 cm from the top, and stirring with a metal stick
5. Fill the main container EthylFast with water up to half height
6. Collect in a glass the measured amount (from the Table 3) of DAMELENE and pour in the internal cylindrical container

7. Close immediately the lid of EthylFast

The gas is naturally released in the room.

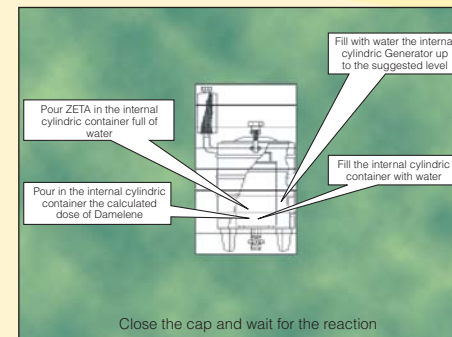


Figure 13. Ethylene generator.

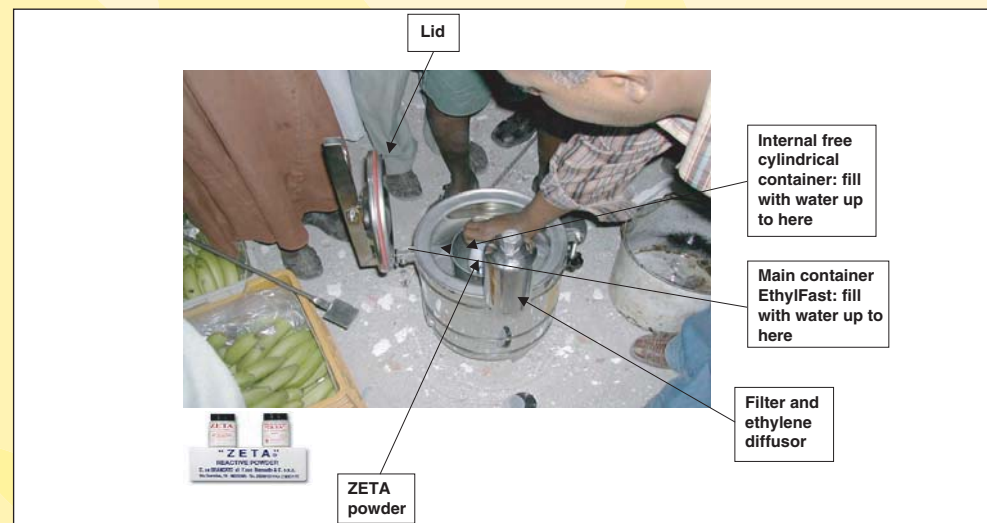


Figure 14. Ethylene generator use.

Table 3. Relation between room volume and DameleNE (ml) required for ethylene concentration.

Free volume of the room m ³ (without bananas)	ml of DAMELENE to obtain 500 ppm of ethylene	ml of DAMELENE to obtain 1 000 ppm of ethylene
10	10	20
20	20	40
30	30	60
40	40	80
50	50	100
100	100	200

