Weights and measures were amongst the earliest tools invented by man. The early system developed with man using his hand, palm, foot, step, etc. as units of measure. The Saxon yard is traditionally reported to have been based on the distance from the tip of King Edgar’s nose to the end of his finger with his arm outstretched. In 1394, the inch was defined as 3 barley corns round and dry.

Out of such confusion there developed a need for a simple standards system of measurement with the base unit of length being the metre. In 1840, its use was made compulsory in France. In 1875, the “Treaty of the Metre” was signed to establish the General Conference of Weights and Measures, which meets to determine the official definitions for the units used in metric countries. In 1960, the Systeme International (SI) unit was adopted world-wide. At present, 150 out of the world’s 152 countries have gone or are committed to the adoption of metric units (SI) of measurement. In January 1992, Jamaica amended the weights and measures act, making the metric system the only legal units in the nation. However, the United States of America, from where Jamaica imports much of its equipment, has not adopted the SI system.

**Every Day Metric Units**

---

**A Guide For Small Farmers and Businesses**

by

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March 2003.
when the consistency of jam is reached. The process takes approximately four hours of cooking. The cinnamon bark has to be removed before the jam is bottled.

### 12.4. Banana Jelly

The ingredients for jelly are the same as that of banana jam. The process is also identical to the point of macerating the banana slices that were cooked for half an hour. Then add two pints of water and mix thoroughly. Pour through a cloth sieve of medium mesh that will permit straining and enable the juice to be extracted by repeated squeezing. The juice resulting is then processed as for jam.
may be packed in butter and stored in closed containers. Figs keep well for to four months.

<table>
<thead>
<tr>
<th>(lb/in²)</th>
<th>(Pa)</th>
<th>(lb/in²)</th>
<th>(Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0205</td>
<td>1</td>
<td>0.0418</td>
<td>95.761</td>
</tr>
<tr>
<td>0.0823</td>
<td>3</td>
<td>0.0363</td>
<td>191.521</td>
</tr>
<tr>
<td>0.1045</td>
<td>5</td>
<td>0.1254</td>
<td>297.582</td>
</tr>
<tr>
<td>0.1463</td>
<td>7</td>
<td>0.1672</td>
<td>383.043</td>
</tr>
<tr>
<td>0.1881</td>
<td>9</td>
<td>0.2090</td>
<td>478.803</td>
</tr>
</tbody>
</table>

Banana flour is rich in carbohydrates and minerals, but poor in protein. However, the starch of banana is more easily digested than that of cereals. For this reason banana flour is used in infant foods. It is cheap, wholesome and has a high nutritive value. It can be made in a few minutes by mixing a heaping tablespoonful (20 grams or one ounce) of banana flour with a pint of water and then boiling for five minutes. A gruel made in this way has excellent colloidal properties when added to milk in equal quantity; it thickens the milk and prevents formation of a leathery coagulum of casein and satisfies the appetite of infants more effectively than diluted milk.

Banana flour is made from fully mature unripe bananas. That is, before the starch is converted into sugar by ripening. The unripe fruits are peeled, cut into thin slices and sun-dried. It is difficult to peel green bananas, but with some experience it can be done easily (Conie and Young, 2003). Also, when the green bananas are placed into scalding water 100° C (176° F) for four to five minutes the peel is easily removed. Ordinary steel knives should not be used as they turn the cut surfaces of bananas black; nickel blades or stainless steel knives are more appropriate. The slices are dried in the sun for about four days to reduce the percentage of water contained in them from 70 to 15%. The chips are then milled and sifted through sieves (48 mesh per square centimetre). The flour is packed in boxes or barrels lined with butter paper, or can be vacuum packed.

**12.3. Banana jam**

Ingredients are: one hundred ripe fruits (when under-ripe fruits are used, they impart a kind of tangy taste), six pounds of white sugar, three pieces of cinnamon bark, and juice extracted from six limes.

The fully ripe bananas are peeled and cut into thin slices, which are boiled for half-an-hour in water (just to cover them), and stirred all the time. Remove from the fire and macerate (mash) the pulp well. Add sugar, boil again over slow steady fire and the add lime juice and cinnamon bark when the mixture thickens. Remove from the fire and

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ACKNOWLEDGEMENTS

This manual was produced as part of the collaboration between the Research Department of the Banana Export Company (on behalf of the Government of Jamaica) and the European Union Banana Support Programme (EUBSP).

The manual was produced in an effort to provide relevant and appropriate information on diversification technologies for producers and entrepreneurs of the Jamaican Banana Industry.

The information was compiled from research and experiences of the staff of the Research Department of the Banana Export Company and Banana Board, as well as from other international organizations, local institutions and ripeners. Special thanks to Mr. Reg Burgess of Antilles Chemical Company, Mr. Roger Turner of Tulloch Estates Limited, Mr. Nicholas Cousins of Jamaica Producers, Mr. Kedrick Randall of the Banana Export Company and St Mary Banana Estates Limited. The Banana Export Company and the European Union Banana Support Programme also acknowledges the information provided by the United Fruit Sales Corporation.

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Funding which was provided by the European Union is appreciated greatly.
The Jamaican Banana Industry, which was traditionally centred on exports, is approaching a cross road in its history, when new strategies must be employed in the changing and highly competitive global market. The impending of non-preferential arrangements for African Caribbean and Pacific bananas being imported in the European Union (EU); the EU single market regime; decreasing prices in the export market; increasing costs of production; decreasing Jamaican banana exports and increasing domestic market, are some of the reasons that have dictated new emphasis on the domestic market; as a complement to export production.

The assistance of European Union Banana Support Programme had provided much needed and timely support to the Jamaican Banana Industry, to the extent that the domestic market had grown significantly. The availability of fresh dessert bananas locally had visibly increased. However, the poor quality of some ripe fruits evidenced the need for dissemination of reliable information on ripening technology. Also, the numerous requests for ripening instructions emphasized the lack of available information.

The manual provides information on: the content and nutritive value of ripened and green bananas and plantains; suitable grades of bananas for harvesting; storage conditions and factors that control the ripening process and instructions to produce good quality ripe fruits. It also provides information on the physical and budgetary requirements for a small ripening business and by-products that can be developed from bananas. The Banana Export Company and the Banana Board is confident that appropriate use of this manual will enhance the Jamaican value-added Banana Industry and be useful to growers and small business enterprises.

Vincent Evans, JP.
Managing Director, Banana Export Company.
Chairman, Banana Board.
1. **INTRODUCTION**

Humans have been obtaining nutrients from bananas for several thousand years. For the last hundred years, the banana has been one of the new food crops to be enjoyed on a truly worldwide scale, by families with the highest income to the lowest paid in all parts of the world. Its texture, taste, convenience, ease to eat, as well as nutritional value, have all contributed to this success. Whether sweet or savoury, the banana has a considerable, if frequently undervalued, role to play in global human nutrition. In Jamaica, bananas and plantains are considered to be one of the most important food crops. They provide a staple food for many people, while export banana generates foreign currency and provides employment for many Jamaicans.

Although export banana farming in the world is dominated by large trans-national companies, there are also many small producers (independent or organized) such as those found in the Caribbean. The small farmers face many disadvantages in a field that is becoming more and more costly, competitive and difficult to manage, due to ever-increasing demands of the export market for quality, complicated further by the struggles between technology and environmental protection, while coping with the pressures of pests and diseases. Consequently, many farmers in Jamaica can no longer produce dessert bananas exclusively for export to the United Kingdom, but rather endeavour to find financially sound alternative local and regional markets for cooking (green) and ripe fruits and value-added products such as banana chips, or peeled green bananas.

This manual aims to assist interested persons with the essential requirements for the ripening trade and provides recommendations for treatments and operations to secure the best fruit quality, as well as scientific information on the nutritive value of banana, so more people can recognize and appreciate the wholesomeness of this fruit.
2. NUTRITIVE VALUE OF BANANA AND PLANTAIN

This section of the manual examines the nutritive value of the popular, multi-purpose crops and provides information on the comparative chemical composition of specific fruits (banana, plantain, apples, oranges, peaches, pears and grapes) and other starchy staples (sweet potato, Irish potato and cassava).

2.1. Chemical Composition

The pulp of the ripe banana is essentially a sugar-rich, easily digested food. The cooked banana is nutritionally similar to the potato. It contains about 70% water; solid material is mostly carbohydrate (27%) and fat (0.3%) and protein (1.2%). In energy terms, each gram provides one calorie. Eleven vitamins have been recorded. Table 1 shows that the banana provides significant amounts of the more important vitamins and minerals (protective factors), especially Vitamin A, ascorbic acid (Vitamin C), B₁ and B₂. These compounds make bananas very favourable for infant food (Figure 1).

The main differences between a banana and a plantain are moisture content and hydrolysis. The plantain averages about 65% moisture and the banana about 83%. Hydrolysis is the process by which starches are converted to sugars. Hydrolysis is faster in bananas than in plantains.

### Table 1. Banana’s Contribution to Daily Nutritional Allowance

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Recommended Daily Allowance</th>
<th>Contribution from One 100 g Banana</th>
<th>Percentage of Recommended Allowance (%) Contributed by One Banana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>3200</td>
<td>88</td>
<td>2.8</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>65</td>
<td>1.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Vitamin A (IU)</td>
<td>5000</td>
<td>430</td>
<td>8.6</td>
</tr>
<tr>
<td>Thiamine (B₁) (mg)</td>
<td>1.6</td>
<td>0.04</td>
<td>2.5</td>
</tr>
<tr>
<td>Riboflavin (B₂) (mg)</td>
<td>1.6</td>
<td>0.05</td>
<td>3.1</td>
</tr>
<tr>
<td>Niacin</td>
<td>16</td>
<td>0.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Ascorbic Acid (C) (mg)</td>
<td>75</td>
<td>10</td>
<td>11.3</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>800</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>12</td>
<td>0.6</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Figures used are from U.S.D.A. handbook No. 8, June, 1950 (Rev. 1957), for a banana 6 inches long.

11. CAUSES OF IMPROPER RIPENING

Improperly ripened fruits are unsightly and readily recognized. In many cases, the difficulties result from efforts to hasten or delay ripening outside of normal limits, or failure to control temperature or moisture.

**Figure 10.** Gros Michel bananas ripened naturally with no ethylene controlled atmosphere. The low humidity caused the crowns to be dried and wrinkled. The high temperatures caused the fruit to ripen unevenly and anthracnose disease (black areas) to grow easily. One finger is “green ripe” while others have dull yellow or brown colour and fingers drop easily.

**Figure 11.** Cavendish bananas ripened or stored in very low temperatures (below 13°C) showing
Table 7. Amount of Ethrel® Required for the Preparation of Spray or Dip Mixture for Banana Ripening

<table>
<thead>
<tr>
<th>Amount of Ethrel® (ml) Required for the Preparation of Spray or Dip Mixture for Banana Ripening</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
</tr>
</tbody>
</table>

Figure 1. Approximate Composition of Fully Ripe Banana

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Sodium</th>
<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
<th>Manganese</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.006 - 0.415</td>
<td>300 - 40</td>
<td>8.0</td>
<td>31.0 - 42.0</td>
<td>0.64 - 0.82</td>
<td>0.14 - 0.21</td>
</tr>
<tr>
<td>Iron</td>
<td>0.6</td>
<td>28.0</td>
<td>13.0</td>
<td>78 - 125</td>
<td>0.02</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*Yields alkaline mineral residues in the body

VITAMINS per 100 grams

- A: 430 International Units
- Thiamine (B₁): 0.04 Milligrams
- Riboflavin (B₂): 0.05 Milligrams
- Niacin (Nicotinic Acid): 0.7 Milligrams
- Ascorbic Acid (C): 10 Milligrams
- Pyridoxine (B₆): 0.52 Milligrams

*Figures from U.S.D.A Handbook No. 8, June 1950 (Rev. 1957), and "Banana - Versatile in Health or illness", U.F. Co. 1959
Carbohydrates
The energy value of a food is derived from the sum of its carbohydrate, fat and protein content. In the case of banana and plantain, the carbohydrate fraction is by far the most important. The sugars and starches that make up this fraction are present in varying concentrations according to the stage of ripeness. The major change during the ripening process in both banana and plantains is the conversion of starch to sugar.

In unripe plantains, starch comprises over 80% of the dry weight of the pulp. The two main components of this starch are amylase and amyllopectin, present in a ratio of approximately 1:5. Sugars comprise only about 1.3% of total dry matter in unripe plantains, but this rises to about 17% in the ripe fruit (Tables 2a & 2b). In bananas, starch level in the unripe fruit is about 20%, and this declines to 1-2% in the fully ripe fruit, while at the same time the soluble sugar increases from less than 1% to 20%. During ripening, the sugars are in the approximate ratio of 20:15:65 of glucose, fructose and sucrose respectively. A banana finger supplies almost one and a half times the energy of an apple and twice that of a citrus fruit (Table 2a).

Fibre
Non-starch fibres include crude fibre, cellulose, pectic substances, hemicellulose and other polysaccharides. Unripe plantain has a total of 3.5% dry matter as cellulose and hemicellulose and therefore constitutes a good source of dietary fibre.

Protein
In relation to the dry weight, total protein value of plantains is approximately 3.5% in ripe pulp, with slightly less in the unripe fruits and in bananas. The amino acids with the highest concentrations in plantains are argenine, aspartate and glutamine. The lowest occurring amino acid is methionine. As starchy staple food, plantains supply about 1 g protein per 100g edible portion (Table 2b). As a healthy adult requires about 0.75 g protein per Kg body weight per day, plantains alone cannot meet adult protein needs.

Fats
The fat content of plantains and bananas is very low, less than 0.5%, and so fats do not contribute much to the energy content. Although the total lipid content remains essentially unchanged during the ripening, the composition of fatty acids, especially within the phospholipid fractions, decrease in saturation.

Vitamins
Bananas and plantains are good sources of vitamins A (carotene), B (thiamine, niacin and riboflavin and B6) and C (ascorbic acid), (Table 2a & 2b). Processing and cooking will decrease the vitamin content, thus banana eaten ripe is a better source of vitamins. In their raw state, plantains are richer in vitamin C than bananas. In comparison with other starchy staples, vitamin C content is similar to sweet potato, cassava and potato. Plantains provide a better source of vitamin A than most other staples. The potato, cassava and cereals provide virtually no vitamin A at all.

10.1. Procedure For Ethrel Ripening

1) Carefully read the product label, and ensure that proper protective clothing is used when mixing and applying Ethrel®

2) Determine the quantity of Ethrel® product required for the desired amount of solution (Table 7).

3) Prepare the mixture by:

i. adding ½ to ¾ of required amount of water to the mixing tank.

ii. Add pH adjuster (alum or PH-PLUS) to lower pH. Remember, that ethephon remains stable at low pH (pH= 4). If the solution is prepared without pH adjuster from the previous day, the product will be reduced. Alum can be used at the rate of ½ lb per 45 litres of water. It is advisable to pre-soak alum overnight, or take time to mix in water until it is dissolved.

iii. Measure the required amount of Ethrel® (Table 6), and mix in a small amount of water.

iv. Add diluted Ethrel® to the tank and mix well.

v. Add the remaining amount of water and mix again.

4) Dip fruits for 30 seconds (treating fruits for longer will not give better results). If spray application is used, ensure even coverage of fruits and avoid drift.

5) Pack the fruits immediately after treatment and place them in the cool room at 22°C and 60-70% relative humidity. Ensure that correct temperature is maintained. Humidity can be maintained by placing a container with water in the cool room.

6) Check fruits daily. Ripening to colour stage 3 or 4 is achieved in two-three days.

7) Remember that ripe banana is sold to consumers at colour stage 4 in order to ensure a reasonable shelf life.

8) Ethephon (Ethrel®) treated bananas must not be treated with ethylene gas!
Very common symptoms of Improperly ripened bananas

Table 6. General Information on the Use of Ethrel (Ethephon)

- Ripening in very high temperatures (e.g., above 30°C) can also cause ethylene production, resulting in premature ripening and discoloration.
- Fruits have soft texture and weak skin, delayed colouring sometimes under peel discolouration (UPD) and short shelf life.
- There are no differences in texture, appearance and taste between fruits ripened with Ethrel (ethephon) (left) and ethylene gas (right).

Figure 8. General Information on the Use of Ethrel (Ethephon)

- Considerable knowledge is required to recognize chilling of green fruit. Clear, glossy, golden-yellow fruit is characteristic of chilling injury.
- Chilling affects both green and ripe bananas. Green fruit is less seriously damaged than ripe or turning fruit after exposure to similar temperatures.
- The characteristic dull color does not appear until after the fruit is exposed to warmer temperatures.
- The extent of chilling increases sensitivity to handling. Even slight handling shows finger marks and discoloured markings where fruit has come into contact with the package material.
- Twelve hours exposure to any temperature below 8°C (45°F) cause chilling injury sufficient to prevent saleable. The extent of chilling depends on the temperature and the length of exposure. Twelve hours exposure to any temperature below 8°C (45°F) will cause chilling injury sufficient to prevent saleable.
- Avoid temperatures below 13°C (56°F), especially in moving air.

Figure 9. General Information on the Use of Ethrel (Ethephon)

- Ripening in insufficient humidity which will vary in severity with the extent of drying out.
- Fruits may be tender and have higher incidence of mould and rots.

Table 2b. Nutritional Values of Bananas compared with other fruits (per 100 grams edible portion)

<table>
<thead>
<tr>
<th>Food Items</th>
<th>Water % (g)</th>
<th>Calories</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Carbohydrate (g)</th>
<th>Fiber (g)</th>
<th>Vitamin A (IU)</th>
<th>Thiamine (mg)</th>
<th>Riboflavin (mg)</th>
<th>Niacin (mg)</th>
<th>Ascorbic Acid (mg)</th>
<th>Calcium (mg)</th>
<th>Phosphorus (mg)</th>
<th>Potassium (mg)</th>
<th>Total Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Water (% or g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>74.1</td>
<td>84.1</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.089</td>
<td>830</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantain</td>
<td>74.1</td>
<td>84.1</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.089</td>
<td>830</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet potato</td>
<td>74.1</td>
<td>84.1</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.089</td>
<td>830</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>74.1</td>
<td>84.1</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.089</td>
<td>830</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>74.1</td>
<td>84.1</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.089</td>
<td>830</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figures used are from U.S.D.A. Handbook No. 8, June 1950. (Rev.1957)

Table 2a. Nutritional Values of Banana and Plantain Compared with Other Starchy Staples (per 100 grams Raw Edible Portion)

<table>
<thead>
<tr>
<th>Food Items</th>
<th>Water (g)</th>
<th>Energy (kcal)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Carbohydrate (g)</th>
<th>Thiamine (mg)</th>
<th>Riboflavin (mg)</th>
<th>Niacin (mg)</th>
<th>Ascorbic Acid (mg)</th>
<th>Calcium (mg)</th>
<th>Phosphorus (mg)</th>
<th>Potassium (mg)</th>
<th>Total Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Water (% or g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>74.1</td>
<td>190</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantain</td>
<td>74.1</td>
<td>190</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet potato</td>
<td>74.1</td>
<td>190</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>74.1</td>
<td>190</td>
<td>0.9</td>
<td>0.1</td>
<td>23.43</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
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<tr>
<td>Cassava</td>
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<td>0.1</td>
<td>23.43</td>
<td>0.07</td>
<td>0.05</td>
<td>0.043</td>
<td>0.132</td>
<td>0.5</td>
<td>0.064</td>
<td>396</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figures used are from U.S.D.A. Nutrient Database (2005) (http://www.nal.usda.gov)
2.2. Other Nutritive Benefits

Ripe bananas are one of the most rapidly digested foods (Table 3). Eating several ripe bananas provides a readily available supply of hundreds of calories. For this reason, bananas are recommended to people who need large amounts of glucose in their blood to maintain adequate levels of muscle action, particularly, athletes and manual labourers.

The energy density of banana and plantains is, in fact, fairly typical of other starchy staples, with the exception of cereals. In their dry state, rice, wheat flour and maize all have nearly triple the energy value of plantains. However, the amount of water absorbed during preparation has a major impact on energy density. Plantains are considered more palatable at a lower water content than corn, thus boiled and mashed banana or plantain may provide higher energy than cornmeal (maize) porridge. Similarly the caloric value of rice decreases by almost two thirds when boiled. If plantain is prepared by frying, the oil used will considerable boost its energy value (Table 4.)

<table>
<thead>
<tr>
<th>Table 3. The Duration in Minutes for Digestion of Various Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripe banana</td>
</tr>
<tr>
<td>105</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4. Energy Value of Plantain (per 100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw green fruit</td>
</tr>
<tr>
<td>Boiled fruit</td>
</tr>
<tr>
<td>Ripe fried fruit</td>
</tr>
</tbody>
</table>

2.3. Therapeutic Value of Eating Bananas

Because of the low lipid and high-energy values, bananas are recommended for obese and elderly (geriatric) patients. Bananas are useful for the treatment of peptic ulcers, infant diarrhoea, celiac disease and colitis. The high carbohydrate and low fat content of the banana makes it suitable for low fat diet.

Certain compounds in banana behave like angiotensin-converting enzyme (ACE) inhibitors. ACE governs release of angiotensin-2, a substance, which has the effect of causing a rise of blood pressure through the constriction of blood vessels. Therefore, potassium-rich foods such as banana help reduce blood pressure.

Many starchy staples contain small amounts of potentially toxic substances and anti-nutritional factors such as trypsin inhibitors. For example, cassava contains toxic cyanogenic glucosides and the potato has glycoalkaloids. In contrast, banana and plantains do not contain significant levels of any toxic compounds.
Ripening bananas to achieve good quality with bright yellow peel is not confined to triggering with ethylene gas only. Stimulating the ripening process of banana and plantain with ethephon plant regulator is another reliable method, which can be recommended for small-scale domestic ripening operations. This method requires post-harvest treatment of fruits by dipping or spraying (Figure 7) with Ethrel® liquid. Ripening to stage 4 can be achieved within 2½ - 3 days.

The Plant Regulator Ethephon (Ethrel®) has the active ingredient ethephon [(2-chloroethyl)phosphoric acid]. When it is applied to plants, the product decomposes within the plant tissue to release ethylene, a naturally occurring plant hormone, which triggers the ripening process in many fruits, including banana. The product is commercially manufactured by the French company Rhone-Poulenc®, and sold under the brand name Ethrel®.

Fruits at the bottom row of box usually ripen faster, and therefore must be checked daily. Slight variations in colour within each box may be seen during the early stages of ripening. Occasionally, slight green spots over otherwise yellow peel (Figure 8) may appear in the initial stages but does not affect the taste or texture of the pulp. Eventually all fruits will develop a uniform bright, yellow colour. There are no major differences in the appearance of the end product of fruits treated with ethylene gas or Ethrel® (Figure 9).

Figure 7. Fruits dipped (left) and sprayed (right) with Ethrel®.

3. COMMERCIAL GRADES OF BANANAS

The ripening characteristics of bananas vary. Scientific studies and commercial ripening have established three definite factors as especially important in predicting the readiness or speed with which the fruit ripen under given conditions.

1) The age of the fruit as determined from flowering to harvest;
2) The maturity of the fruit at reaping, which is indicated mainly by fullness (filling out) or grade (Figure 2) and diameter (calliper) of the finger.
3) The extent to which ripening has progressed since harvest, during transportation and storage.

3.1. Practical Suggestions For Judging Maturity of Fruit

The filling out of the fingers is an indication of the maturity of the fruit. The fullest bananas will usually show signs of turning (colour change) first (Figure 2).

Early indications of ripening are:
1) A slight softening of the peel and pulp.
2) A decreasing tendency of peel to ooze latex when cut.
3) Greater ease of separation of peel from pulp.
4) A gradual increase in the aroma of the banana.

As the fruit begins to “turn” (stages 2 and above) (Figure 3), it gives off increasing heat. A gradual change or “break” in colour from green to yellow appears next.

3.2. Chemical and Physiological Changes During Ripening

All living tissue, plant or animal, contains small amounts of chemical substances, known as enzymes, which bring about many of the vital processes of growth and development. Practically every change in appearance, texture and chemical composition of the ripening banana is due to the action of certain enzymes. In turn, enzymes are stimulated or depressed by physical conditions to which fruit is exposed.

Bananas are harvested while still green, after they have reached a sufficient degree of maturity. Ripening consists of progressive physical and chemical changes starting from the green state in which the fruit is hard and starchy. As ripening proceeds the fruit pulp becomes gradually sweeter and softer in texture. At the same time the peel turns from green to yellow in colour. The starch present in the pulp is nearly all converted into sugar. During this process the characteristic pleasant aroma develops and numerous other subtle changes take place.
Figure 2. Fitness Grades for Harvesting Commercial Bananas

Conventionalized Drawing: showing development of an outside whorl middle finger of a, middle hand of a top quality stem of bananas.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cross-section</th>
<th>Surface View</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Thin</td>
<td>flattened sides, extremely prominent ridges</td>
<td></td>
</tr>
<tr>
<td>(b) ¼</td>
<td>slightly rounded sides, prominent ridges</td>
<td></td>
</tr>
<tr>
<td>(c) Light-full (LF) ½</td>
<td>medium rounded sides, less pronounced ridges, slender finger tips</td>
<td></td>
</tr>
<tr>
<td>(d) Full (F) ½</td>
<td>well rounded sides, slight ridges, well filled finger tips</td>
<td></td>
</tr>
<tr>
<td>(e) Full</td>
<td>rounded or nearly round fingers, practically no ridges, plump fingers</td>
<td></td>
</tr>
</tbody>
</table>

10. RIPENING BANANAS WITH ETHREL (ETHEPHON)

<table>
<thead>
<tr>
<th>Volume Rate (Total Quantity) (litres)</th>
<th>Amount of Ethrel® 480 required to prepare 1000 ppm mixture (millilitres)</th>
<th>Volume Rate (Total Quantity) (litres)</th>
<th>Amount of Ethrel® 480 required to prepare 1000 ppm mixture (millilitres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>26</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>25</td>
<td>52</td>
<td>50</td>
<td>105</td>
</tr>
</tbody>
</table>
2nd through 5th day:
5) Set the thermostat to 14°C (58°F).

6th and 7th day:
6) Set the thermostat to 14°C (57°F).

8th day:
7) Set thermostat to 13°C (55°F) for Gros Michel and 14°C (57°F) for Cavendish varieties.

Figure 3. Colour Stages of Ripened Bananas

1. Green
2. Green with trace of yellow
3. More green than yellow
4. More yellow than green
5. Yellow with trace of green
6. All yellow
Texture
The pulp of the banana is made up of many very small cells. In the green banana, each cell has rigid walls composed mainly of an insoluble substances known as protopectin. Inside of the walls are numerous starch grains. In ripening, the protopectin is partially broken down by enzymes to form soluble pectin, with the result of softening the cell walls. At the same time, starch is converted by enzymes to soluble sugars, which become dispersed in the solid matter within the cell, forming a semi-solid mass. Thus, the green, hard banana is changed to a soft, palatable food.

Flavour and Aroma
These two characteristics of bananas are so interdependent that they may be considered together. Sweetness develops with the formation of sugars. Certain variable amounts of highly volatile esters and perhaps alcohols also develop, and add to the pleasant taste of the banana. Green bananas have an astringency, which is due to considerable amounts of free tannins present in the pulp. During ripening the tannin compounds are combined or bound up in such a way as to completely to nullify their astringency.

5th and 6th day:
1) Set thermostat at 17°C (62°F) and switch to continuous fan.
2) Apply the recommended dose of ethylene gas. Keep door tightly closed for 24 hours.
3) At the end of the first day (24 hours) ventilate the room by opening the door for 15 to 20 minutes (turning the fan off during ventilation).

Product information:
Ethephon is a colourless liquid. Ethrel® 480 is sold locally in one US Gallon containers, at approximate cost of $US 108.00 each. One Gallon of product can make approximately 1480 litres of mixture.

Method of application:
Ethrel® can be used as post-harvest fruit dip or spray treatment.

Recommended dose rate:
Ethephon is used at a concentration 1000 ppm (not exceeding 1200 ppm).

Dipping time:
30 to 60 seconds

Ripening time:
2 ½ to three days (at the recommended temperature) to reach colour 3 - 4 (Figure 3)

Precaution:
The product is corrosive when undiluted. Causes irreversible eye damage and skin irritation. Harmful if swallowed or absorbed through the skin. Use of the product requires personal protective equipment (long-sleeved shirts and long pants, chemical resistant gloves, shoes plus socks and protective eyewear). For detailed information read the product label carefully!

Where to purchase Ethrel®:
Ethrel is distributed locally by Antilles Chemicals Co (96 Marcus Garvey Drive, Tel. 923 - 7015), as well as by several garden supply stores.

4) Turn fan on and close door.
temperature and variety of the fruit. If the fruit is Gros Michel the pulp temperature may be held at 13°C (56°F) but Cavendish cannot be held below 14°C (58°F). The thermostat must be set approximately 1°C - 2°C lower than the desired holding pulp temperature if the peel has not advanced beyond stage 4. Below stage 4 the fruit is still generating heat.

## Operation for Moderate Rate of Ripening (average of 6 days to color stage 4)

The procedure is similar to that of fast ripening:

**Operation for Moderate Rate of Ripening (average of 6 days to color stage 4)**

**1st day:**
1. Set thermostat to 18°C (64°F) and switch to continuous fan. Keep the door tightly closed for 24 hours.
2. Apply the recommended amount of ethylene gas.
3. At the end of the first day (24 hours) ventilate the room by opening the door for 15 to 20 minutes (turning the fan off during ventilation). Turn fans on and close door.

**2nd day:**
4. At the end of the second day (48 hours) inspect the fruit (turning the fan off only during inspection). Set the thermostat at 16°C (60°F).

**3rd day:**
5. At the end of the third day (72 hours) lower the thermostat setting to 14°C (58°F).

**4th day:**
6. At the end of the fourth day adjust thermostat setting at 13°C (56°F).

---

## 4. BANANA RIPENING ROOMS

### 4.1. General Requirements for Banana Ripening Rooms

The majority of the small scale ripening operations in Jamaica consists of one room. This may later expand based on operating experience gained and increased market share. However, an efficient ripening facility generally has at least three rooms. With less than three rooms, ripening in batches of fruit becomes inefficient and there is no storage for green fruit. With three rooms one will always be available to store new green fruits. The other two rooms can be organized so that one carry out fast ripening; the other used for slow ripening; or efficient batch ripening in both, will guarantee that fruits do not ripen at the same time.

### 4.2. Facilities and Equipment

In order to provide the conditions necessary for properly controlled ripening of bananas, the room should have the following:

1. Adequate size
2. Sufficient insulation
3. Be of airtight construction
4. Cooling equipment
5. Thermostat for room temperature control
6. Thermometer for monitoring or checking room temperature
7. Thermometer for pulp temperature

### Room Size

Room size is determined by the daily out-turn of fruits in the peak season of the year and the frequency with which green fruit is received. The size of the room is calculated in cubic meters or cubic feet, and calculated by measuring the length, width and height of the room and by multiplying those parameters. (For example: 10 feet x 10 feet x 10 feet = 1000 cubic feet, or 3 meters x 3 meters x 3 meters = 27 cubic meters.) A room of this size holds approximately 200 boxes. The room is constructed from concrete with no windows and one entrance. A “20 ft” container can be substituted. However, room or container must be airtight, illuminated (well lit), insulated and cooled.

### Insulation

It is important to provide good insulation of walls and ceilings, as well as seals for air-tightness of doors and other spaces where leaks are possible.
Poor insulation of ripening room will result in the following:

1) rapid depletion (loss) of ethylene gas, which is essential for ripening of bananas;
2) contribute to the higher electricity usage, due to loss of cool air and
3) increased pressure on the cooling unit itself (especially during the hottest time of the day).

Use of specially designed insulation materials is advisable for long term cost benefits. Commercial insulation materials are costly but available locally. More appropriate materials can be used, which could be left to the creativity of the entrepreneur. For example, recycled foam and bamboo strips have been used for insulation. Pre-fabricated metal doors with the frame with fitted seals are readily available from local hardware suppliers at a high cost. However, linoleum cut in strips or plastic irrigation hoses cut lengthwise and nailed around the perimeter of doors can serve to make doors air tight.

The majority of small-scale banana ripening rooms in Jamaica are quite simple in design and consist of a concrete structure (without any additional insulation) and equipped with domestic or office air-conditioning unit.

Cooling Requirements

Refrigeration is necessary for the following reasons:

1) Removal of heat generated by the respiration of the fruit itself.
2) Rapid reduction of room temperature after the fruit starts to ripen.
3) Removal of heat inflow through the walls and ceiling.

The cooling unit must have sufficient capacity to meet the peak requirement of the ripening room in which it is mounted. An inadequate cooling system will experience down time during peak periods and fruits will deteriorate after only a few hours.

In order to determine the correct capacity of cooling unit, the following must be considered:

1) The maximum capacity of the room in terms of number boxes to be ripened.
2) The outdoor temperatures (for example during hot summer days cooling unit will use more energy to cool the same amount of fruits than in cooler times of the year).
3) Fruit condition (older fruits or previously improperly stored fruits will accumulate more heat).

Purchase of the cooling unit is one of the major capital costs. The unit selected must work efficiently for an extended period of time. Although technical advise on the correct capacity of cooling unit will be provided by the distributor, it is essential to have basic knowledge of certain critical parameters.
9. INSTRUCTIONS FOR RIPENING WITH ETHYLENE GAS

9.1. Ripening Instructions for All Bananas (Boxed and Stems)

1) Pre-cool the room to the starting temperature recommended for the desired ripening schedule, as shown in the Table 5. Remember that pulp temperatures are 1-2 degrees higher than room temperature.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Commercial Cooling Unit</th>
<th>Air-Conditioning Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit cost</td>
<td>More expensive to buy</td>
<td>Less expensive to purchase</td>
</tr>
<tr>
<td>Consumption of electricity</td>
<td>Low consumer of electricity</td>
<td>Higher usage of electricity</td>
</tr>
<tr>
<td>Temperature control in the ripening room</td>
<td>Better temperature control and faster recovery of after power outages or other emergencies.</td>
<td>Limited temperature control</td>
</tr>
<tr>
<td>Overall operational cost</td>
<td>More economical in the long term</td>
<td>Less efficient</td>
</tr>
</tbody>
</table>

Table 5. Approximate Pulp Temperatures °C (°F) For Ripening Banana

* The most critical period in the ripening cycle is during the third and fourth days.

2) Stack the boxes in the ripening room so that the delivery air can circulate around the sides of the boxes before returning to the AC unit (Figure 5).

3) Apply ethylene gas as soon as possible (within 12 hours) after boxes are properly stacked and the room is acclimatised (maintains desired temperature). Use the recommended amount of ethylene for the specific size ripening room (Section VIII.3)

4) Set the switch for the fan on the AC unit to continuous operation throughout the entire ripening process (except during ventilation). Do not use intermittent fan.

5) Do not ventilate (air out) the room or open the door for the next 24 hours. At the end of the first day, ventilate the room by opening the door for 15 – 20 minutes. Close the door and adjust the thermostat if necessary, after checking and comparing the pulp temperature (Table 5).

6) After the first 24 hours, inspect the fruit twice daily and adjust thermostat to obtain the pulp temperature recommended for the desired ripening schedule.

9.2. Ripening Instructions for Boxed Fruit

Fast Ripening (average of 4 days to colour stage 4)

1) Pre-cool room to ambient (room) temperature of 16-17 °C for at least one hour.

There are major differences between commercial cooling and air-conditioning (AC) units. The evaporator and the condenser of the cooling units are separated and designed to operate consistently in both low and high-pressure periods. Therefore, the commercial cooling unit provides more consistent temperature control, especially during critical physiological periods of ripening, than AC units.

Figure 4. The Evaporator of a Commercial Cooling Unit

Although, the domestic AC units are not the ideal choice for ripening of bananas, they are widely used in Jamaica and therefore remain an option. This is mostly due to the lower price when compared to commercial units. However, the temperature control of AC units is quite limited. The “minimum setting” only of the thermostat (temperature regulator) has to be used throughout the ripening of bananas. In cases of excessive rise in fruit or outdoor temperatures it is very difficult to maintain the recommended temperature. This can lead to accelerated ripening, poor market quality, and sometimes a total loss of fruits.
4.3. Ripening Rooms for Boxed Fruits

Air circulation is extremely important. For small scale ripening operations air circulation by the air-conditioning unit should be sufficient to provide free flow of air in the room. For large capacity ripening rooms, cooling units should be equipped with centrifugal blower, rather than propeller fans (disk type). The blower should have a capacity of approximately 3800 cubic feet per minute (C.F.M.) in a room designed to hold 500 boxes of fruit. Ideally, the boxes should be stacked in rows leaving a 10 cm (4 inches) air channel between adjacent rows and between the first row of boxes and the wall (Figure 5).

Boxes should never be placed directly on the floor, but stacked pallets. Pallets should be positioned to allow easy airflow. It is difficult to recommend one specific stacking arrangement that will suite all types of ripening rooms. However, the chosen stacking arrangement of boxes should guarantee sufficient air flow, so that air leaving the cooling unit is directed over the tops of the boxes to the opposite the wall at the end of the room and then returned through the air channels between the boxes to the intake vents cooling unit.

The method shown in Figure 5 has been found to produce the best ripening results under any given set of conditions due to the fact that the stacked boxes are arranged to make most efficient use of the circulating fan and refrigeration capacity available. This arrangement provides for the boxes to be stacked so that the sides and ends of the boxes carry the weight of the stack, thus taking the weight off the fruit. Unless boxes are stacked in vertical alignment there is danger of bruising the fruit, particularly after it ripens.

An alternative method of stalking known as the "chimney stalk" (Figure 5a) can be successfully employed when sufficient fan power and refrigeration capacity are provided. In most cases, the chimney stack arrangement requires more room space than the vertical stack. The ripeners in Jamaica commonly use this method. However, if the chimney stacked load is inadvertently exposed to high temperatures, it becomes far more difficult to regain control.

- In the event that a rapid reduction in pulp temperature is necessary (for example after electrical outage), the cooling thermostat must be set between 4 to 10 degrees lower than the desired pulp temperature*. It may be necessary to maintain this temperature for several hours. Hourly inspections are advisable during such emergencies and the thermostat adjusted upward if fruits in the boxes nearest the delivery air are in danger of being chilled. When inspection indicates that fruits are approaching the desired pulp temperature, then the thermostat can be raised and maintained at the recommended temperature setting.

- Cavendish fruit may be slightly slower to change from stage 3 to 4 than Gros Michel. The rate of colour change equalize after stage 4.

8.2. Holding Temperatures For Ripened Fruits

1. Fruits should be sold at the minimum pulp temperature after it has reached colour stage 4 (Figure 3). Safe holding pulp temperature is 13°C (56°F) for Gros Michel fruit and 14°C (58°F) for Cavendish fruit.

2. Set thermostat at one to two degrees lower than the recommended pulp temperature if the fruit is not beyond stage 4 because the fruit is still generating heat. If the fruit is fully yellow (stage 5 and above), the thermostat setting and room temperature should be the same as the pulp temperature.

3. Fruits with no yellow colour should not be sold as they are not suitable for immediate sale and will not ripen properly under store or home conditions.

4. Fruits that are harvested and being stored to remain green must be stored separately and held at about 13°C (55°F).
8. TEMPERATURE

8.1. What You Should Know About Ripening Temperatures

- Generally, ripening temperatures for boxed fruit should be kept within the 14 to 18°C (58°F to 64°F) range of pulp temperature.

- Do not try to force or speed up ripening by raising the pulp temperature or allowing room air temperatures to exceed 18°C (64°F). If the pulp temperature is not kept under control when the fruit is generating heat, it will be difficult to reduce the temperature later, and the shelf life of fruit may be severely affected.

- It might be necessary periodically to lower the thermostat setting below that recommended because of high room temperatures due to weather and heat of respiration of the fruit.

- In general, the thermostat should modify the temperature of delivery air (at the entrance of the space between the boxes. If the monitoring thermometer is located near the return air (after passing through boxes) the thermostat setting should be set one degree (even 2 degrees) above the thermostat setting suggested for the desired ripening regime, in order to avoid chilling the fruits in the boxes nearest to the delivery air. The thermostat setting can be determined by calibrating the thermostat against room and pulp temperatures.

- The pulp temperature will almost always be higher than the room temperature (this is due to the fact that bananas generate heat during the ripening process). The box also provides insulation that affects the transfer of heat from the pulp to the circulating air.

- Without separate pulp and air thermometers, it is difficult to provide specific instructions for determining the difference between pulp and room temperatures, because of the wide variations in ripening room characteristics and equipment. During the period of maximum heat generation the pulp temperature may be 2 to 4 degrees higher than the air temperature. The pulp and room temperatures can be checked during routine inspection and ventilation periods, every 24 hours.

<table>
<thead>
<tr>
<th>Ripening Time (days)</th>
<th>Temperature °C (°F) for Each Day of Ripening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
</tr>
<tr>
<td>4</td>
<td>18 (64)</td>
</tr>
<tr>
<td>5</td>
<td>17 (62)</td>
</tr>
<tr>
<td>6</td>
<td>17 (62)</td>
</tr>
<tr>
<td>7</td>
<td>16 (60)</td>
</tr>
<tr>
<td>8-10</td>
<td>14 (58)</td>
</tr>
</tbody>
</table>
6) Purchase balloons that can be blown up to the total circumference desired (Figure 6). If balloons are small then more than can be used. The circumference of the balloons must add up to that required. For example when 111 cm balloon is required, one balloon may be 75 cm and another other 36 cm; two balloons 55 and 56 cm; or three balloons measuring 37 cm in circumference can be used. Balloons with holes must not be used.

**Figure 6. Using a Balloon to Measure the Ethylene**

**Application of Ethylene Using a Regulator**

To fumigate a 27 m$^3$ room using a gas regulator:

1) The valve on the cylinder should be turned to open.
2) The gauge of the regulator should be adjusted to deliver 10 pounds per square inch (psi).
3) Ensure that flow has begun. The metal of the outlet on the regulator gets very cold when felt with the fingers.
4) The gas should be allowed to flow for one minute, through a fitted tube into the closed room.
5) To stop gassing, adjust the regulator to read zero.
6) Turn the cylinder gauge to off.
7) If the tube is flexible and placed through the closed, rubber sealed door, pull the tube through the closed door. To eliminate any need to open the door during fumigation, the gas should be piped through a hole in the wall. However, the opening around the pipe must carefully sealed.
8) The cylinder should remain outside of the ripening room at all times.

Where $C =$ circumference in inches; $X =$ volume of ethylene in cubic feet.
C = 75 x \frac{4}{27} = 111 \text{ cm.}

Two balloons of circumference 55 and 56 cm or three balloons measuring 37 cm would be suitable.

Formula b (imperial): \[ C = \frac{30 \times X}{1} \]

*Note: If pulp thermometer is not available, a convenient way to determine the average pulp temperature (within one or two degrees) is to run the fan on continuous operation (without refrigeration) for an hour or more after the boxes have been stacked in the room, and then check the air temperature in the room. The air temperature would be equal to the pulp temperature.
4.4. Ripening Rooms for Stem Fruits (Bunches)

Ripening rooms for fruits on stems or bunches are similar to those designed for handling boxed fruits. The major differences being that the load is suspended from the joists or racks instead of resting on pallets. The stems should be hung from hooks inserted in joists. The stems should never be lying on the floor as excessive bruising and scarring will result. The room should have a clear height of not less than 270 centimetres (9 feet) from floor to the underside of joists. The joists should be on 35 cm (14") centres and the hook spacing should be 20 (8") x 35 (14") centimetres. The total floor space required is approximately 900 cm² (one square foot) per hook (an average ripening room designed for bunches will accommodate 25% more fruit than boxes). Maintaining high humidity during the ripening of stem fruits is important. In the past, ripening rooms were equipped with water misting nozzles, installed near the ceiling on either side of the aisle. Misting must not be used for ripening boxed fruits.

4.5. Banana Ripening Room Sanitation

Ripening rooms should be regularly cleaned and disinfected in order to reduce growth of mould and decay of banana fruit. Bruises or abrasions occurring during transit and unloading can readily become infected in unsanitary rooms. The result will be increased decay and shrinkage, particularly when the fruit must be held for a prolonged period in the ripening room.

Regular cleaning will also increase the life of the rooms and reduce maintenance cost. A solution of sodium hypochlorite or calcium hypochlorite, commonly known as bleach, has been used with excellent results. Mix one part of household bleach with 20 parts of water and scrub walls, woodwork, etc. with a long handled brush. It is not necessary to rinse the walls unless the surfaces are extremely dirty. When washing becoming necessary allow the solution to remain on the walls for 10-15 minutes and then rinse with a hose. Washing twice per month is adequate for the rooms that are in continuous use.

If walls and woodwork are heavily stained, extremely dirty and mouldy, clean the surfaces with tri-sodium phosphate. This can be accomplished with a long handled brush. Allow the solution to remain on the surface for 10 to 15 minutes and then rinse with a hose. To prepare washing solution, use 58g (two ounces) of tri-sodium phosphate per 4 litres (one gallon) of water. This cleaning agent must be used infrequently and with caution because if used too often or permitted to remain on painted surfaces too long, it will remove some of the paint. Use this deep treatment only once and follow it up with regular treatments of household bleach solution as recommended above.

2) A 27 cubic meter room requires 2.7 litres of ethylene. Equally, a room of 1000 cubic feet need 1 cubic foot of gas

3) To calculate the amount of ethylene gas required for the measured room size use the following formula:

\[ X = \frac{S \text{ m}^3 \times 2.7 \text{ Litres}}{27 \text{ m}^3} \]

Where \( X \) = the amount of ethylene in litres; \( S \) = the room size in cubic meters

For example, if \( S = 40 \text{ m}^3 \)

\[ X = \frac{40 \times 2.7}{27} = 4 \text{ litres} \]

4) A balloon blown up to a circumference of 75 centimetres (30 inches) contains approximately 2.7 litres (1 cubic feet) of ethylene.

5) To determine the circumference of the balloon for the required volume \( X \) use the following formula:

\[ C = \frac{75 \times X}{2.7} \]

Where \( C \) = circumference in centimetres; \( X \) = volume of ethylene required in litres.

For example, if \( X = 4 \text{ litres} \)

\[ C = \frac{75 \times 4}{2.7} \]

\[ C = 85.19 \]
4.6. Unloading and Handling of Fruits

Properly ripened bananas should not only have a good color, fresh appearance, firm pulp texture and good strength of peel, but must show minimal bruising and scars. As bananas begin to ripen, they become softer and more easily bruised. Much of the damage to the pulp is not apparent until the fruit is peeled. This may result in a loss to the consumer and may lead to future reluctance to purchase.

Scarring and bruising from rough handling deface the appearance of the fruit, increase shrinkage and cause concealed damage to the pulp. Skin abrasions result in loss of moisture and black sunken scars on the peel. Broken and crushed fingers are totally unsaleable. It cannot be overstated that careful handling to prevent bruising is extremely important in handling fruit at all stages of ripeness.

The boxed fruit should not be thrown or dropped. They should not be inverted (upside down) or stacked in an inverted position, especially while being transported. It is particularly important to unload the vehicle with boxed fruits on the same day after transportation. In cases where fruits remain in the refrigerated trucks, pulp temperature will vary widely, due to the lack of air circulation.
5. MAJOR COSTS OF ESTABLISHING AND OPERATING THE RIPENING ROOM

Very few ripening rooms are identical to each other in every respect. However, there are basic requirements that must be considered for all facilities. Monetary costs that are presented in the tables below represent the major requirements for a banana ripening business. Reduction of the major costs, namely green fruit raw material and transportation, will make the business more profitable. If farmers produce their own fruit and own transportation, the costs can be lowered. Other costs can be maintained at efficient levels if the correct ripening strategies are used, such as: ripening of fruit with recommended harvest qualities; precise measurement and application of ethylene; good choice of cooling unit and proper insulation of room.

5.1. Various Costs of Establishment of a Ripening Room with Monthly Output of 1600 Boxes of Ripe Fruit

<table>
<thead>
<tr>
<th>Ripening room design</th>
<th>Capital Cost</th>
<th>$ US per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 foot container + insulation (will require commercial insulation)</td>
<td>1,200.00 - 1,400.00</td>
<td></td>
</tr>
<tr>
<td>Room construction 10' x 10' x 10' (including labour and materials)</td>
<td>4,482.00</td>
<td></td>
</tr>
<tr>
<td>Cooling equipment 1st option</td>
<td>(1) 1 HP* Commercial cooling unit (consisting of condenser and evaporator)</td>
<td>1,350.00</td>
</tr>
<tr>
<td>Labour cost for installation</td>
<td>517.00</td>
<td></td>
</tr>
<tr>
<td>Cost of miscellaneous materials (filter dryer, liquid indicator, valves, pipe insulation etc.)</td>
<td>154.00</td>
<td></td>
</tr>
<tr>
<td>2nd option</td>
<td>- Air-conditioning unit (24,000 BTU rating)</td>
<td>1,035.00</td>
</tr>
<tr>
<td>- Installation cost (including labour and miscellaneous materials)</td>
<td>259.00</td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td>- Commercial insulating material ($ US 4.00 / square foot)</td>
<td>4,000.00</td>
</tr>
<tr>
<td>- Labour cost for installation</td>
<td>517.00</td>
<td></td>
</tr>
<tr>
<td>Wooden pallets ($ US 3.10 each x 4)</td>
<td>12.40</td>
<td></td>
</tr>
<tr>
<td>Total major capital cost for various options:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) 20 foot container + commercial cooling unit</td>
<td>7,994.40</td>
<td></td>
</tr>
<tr>
<td>(b) 20 foot container + AC Unit</td>
<td>7,221.60</td>
<td></td>
</tr>
<tr>
<td>(c) Concrete structure + Commercial cooling unit</td>
<td>11,032.40</td>
<td></td>
</tr>
<tr>
<td>(d) Concrete structure + AC Unit</td>
<td>10,305.40</td>
<td></td>
</tr>
</tbody>
</table>

Approximately one cubic foot of ethylene is required to treat the fruits contained in 27 cubic meter (1000 cubic feet) of ripening space (1 part to 1000 parts of air). However, the room must be airtight to maintain this concentration. Approximately 180 balloons (of average size) can be filled from one cylinder. This is equivalent to nine months when ripening is carried out once per week in a 27m$^3$ room.

Ethylene can be applied as soon as bananas are placed in the pre-cooled ripening room. Extreme care should be taken to measure and administer the correct amount. Overdosing with ethylene in excess of recommended amounts will not hasten ripening.

7.3. Application of Ethylene

Applying Ethylene Gas with Balloons

For safety reasons, it is not wise to apply the gas directly from the cylinder. Without the expensive regulator, the method of balloon application, which was developed locally, can be used. Collect the required amount of gas in a balloon. Twist the top without tying and drop the inflated balloon in the ripening room. Close the door immediately and allow the ethylene to escape from the balloon. Measurement of ethylene gas using balloon, as detailed below, will facilitate: the storage of the cylinder in secure place; easy and safe delivery of precise volumes of gas to the ripening room; and reduction of unnecessary movement of the cylinder.

**PRECAUTIONS**

- Ethylene is a flammable gas, which burns in air when the content of ethylene is between 2.75% and 28.6%. When mixed with air in these proportions an ignition by electric spark, flame or heated surface will result in an explosion.

- Cylinders, which contain the gas under high pressure, should not be handled carelessly. It is recommended that one trained person be designated to administer the gas.

- Never apply ethylene directly from large cylinders. Use the balloons or regulators for safety and precision.

1) Calculate the size of the ripening room by multiplying its length, width and height. For example: 3
7. **ETHYLENE GAS**

The use of ethylene gas for ripening of banana has several advantages:

1. Fruits ripen evenly and develop the characteristic bright yellow color;
2. It is possible to ripen boxed fruits at comparatively low temperatures, thus permitting positive control of pulp temperature at all times, even during the early or turning stage when the fruit generates the most heat;
3. Ripening at low temperatures has the added advantage of increasing the shelf life of the fruit.

Ethylene is sold in steel cylinders in the form of compressed, non-liquefied gas. The gas is slightly lighter than air, having a specific gravity of 0.0976. Being so nearly the same density as air, ethylene diffuses very rapidly. It does not settle to the floor or stay in one place in the room but quickly distributes itself throughout the whole room.

In very dilute quantities, ethylene gas has been used successfully as a natural ripening stimulant for bananas. The bananas themselves produce ethylene normally, so it causes no deleterious effects and no difference in the taste. The nature of ethylene ripening is such that it is permitted in organic farming. Ethylene ripened fruit that do not have a persistent green tip. However, when higher than the recommended of temperatures are used to hasten ripening of ethylene triggered fruits, they deteriorate badly.

7.1. **Where to Purchase the Gas**

Currently, Industrial Gases Limited (IGL), Industrial Division, in Ferry, St. Catherine, supplies ethylene gas locally. The telephone number is 705-8391. There are no other domestic suppliers. However, special importation can be arranged.

7.2. **How to use Ethylene Gas**

Purchase of ethylene gas is one of the major recurrent expenses. If the amount of gas required for each ripening operation is measured correctly and according to the recommended dose rate, one cylinder can last for an extended period of time. In order to monitor the amount of gas in the cylinder a gauge or meter is necessary. The gauges that are designed particularly for ethylene are costly, but with minor alterations the ones used for acetylene can be adapted. To monitor the amount of ethylene gas remaining in the cylinder (even without a gauge), it is necessary to keep log. When the cylinder is delivered, record the gauge reading, and do so each time gas is used. Without the gauge, a log of the number of balloons filled, will give an indication of the amount of gas remaining.
6. FACTORS THAT CONTROL RIPENING

Control of the speed of ripening is the first requirement for a successful business. When the rate of ripening is controlled at all times, retailers can be kept supplied constantly with good quality fruits and losses from an over-supply are avoided. The controlling factors in banana ripening are: temperature, humidity and ventilation.

During ripening, bananas release small amounts of ethylene, volatile esters and carbon dioxide. It is important that these gases be confined to the ripening room particularly during the early stages of the process. The amount of gases present has a direct bearing on the rate of ripening at a given temperature. To best control the speed of ripening, it is essential to apply ethylene artificially.

Green bananas for storage must not be placed in the same room with ripe ones, as different conditions are required for green and ripe fruit. Green fruit must not be exposed to ethylene and require lower temperature than ripe fruits. Boxed fruit should never be stacked in the same room with stem fruit as humidity requirements differ, and the temperature for ripening stems may cause excessively high temperatures inside the boxes. Conversely, thermostat setting best suited for holding boxed fruit may chill the stem fruit.

All these factors emphasize the need for the appropriate type and number of rooms to meet market requirements.

6.1. Temperature

In the past, temperature in Jamaica was measured in degrees Fahrenheit (°F). However, all new equipment will display temperature in Celsius (°C). For quick reference, a conversion table is appended.

The temperature range for ripening bananas with ethylene is between 14°C (58°F) and 18°C (64°F), and about 22°C (72°F) without ethylene. With ethylene, the lower temperature ripens the fruit slower than the upper range. For ripening of boxed fruits it is recommended that the air circulating fans be operated continuously, in order to ensure uniform pulp temperatures throughout the room.

6.2. Humidity

Low humidity can cause delayed and irregular ripening. Transpiration (water loss) is regulated by tiny microscopic openings in the peel known as stomata. These openings tend to close in dry atmosphere, retarding respiration and ripening. Bananas, ripened in a dry atmosphere, show darkened blemishes on the peel due to drying out of even slight scars and abrasions.

The moisture needed for good ripening will accumulate in the box (and polyethylene bags when used) due to natural processes, and prevent some loss of moisture. There is little air movement inside the box. The circulating air will remove some moisture from the box rather than from the fruit. In order to maintain the required humidity level inside the room (especially if fruits were boxed without plastic bags), the condensate from the air conditioning unit can be directed to collect on the floor. Otherwise, a bucket of water must be placed in the ripening room.

For storage of green stem fruit it is recommended that the humidity in the room be kept as high as possible (approximately 95%). To reduce loss of moisture it is important to avoid excessive air circulation. An efficient and inexpensive method of humidifying banana rooms for stems (only) is by misting. Spray nozzles should be turned on when stems are first put into the room.

6.3. Ventilation

It is important that banana ripening rooms be airtight and no ventilation be given during the early stages of ripening. At this stage, too much ventilation retards ripening and keeping. Generally, tightly closed rooms encourage ripening. Care must be taken, however, particularly in very airtight rooms, to provide some ventilation for short intervals to prevent the build-up of a high concentration of carbon dioxide. Accumulation of carbon dioxide and shortage of oxygen may cause suffocation of the fruit and retard ripening. When ethylene is used as a triggering agent, ventilation is required early in the ripening cycle. Approximately 24 hours after the application of ethylene, opening the door for 15 to 20 minutes should ventilate the ripening room.