

of enveloping the fruit in a high humidity atmosphere resulting in fresher arrivals at destination.

In order to minimize the handling of this tender fruit as much as possible, the banana industry is now beginning to cut the hands of fruit from the stems in the tropics. These hands are then packed in boxes at the tropical plantations, thus eliminating many of the sources of handling damage. There is still much to learn concerning refinements in this tropical packaging operation but due to the domestic improvement in fruit appearance, the refrigeration industry should recognize the difference in handling and ripening tropical boxed fruit as well as stem fruit.

The stems are harvested in the usual manner and transported to strategically located receiving stations or to centralized boxing stations. Here the hands are cut from the stalks and are then subjected to various processes for removal of foreign matter, elimination of latex (elastic, sticky, milky white fluid which exudes from green fruit when cut), and treatment with fungicides or fungistats. Some bananas are hydrocooled, boxed, and stored in holding rooms prior to shipment to the tropical seaport, while other boxes are shipped directly to the port where the refrigerating system of the ship is used to remove the field heat from the boxed fruit.

To prevent stems and boxes of bananas from ripening during shipment, the holds of the refrigerated steamships are precooled so that the field heat will be removed as rapidly as possible. The fruit is reduced to a carrying temperature of about 55 F which is maintained throughout the journey to the domestic port. The stems and boxes of fruit are unloaded at the domestic wharf with mechanical unloading equipment. The discharge of a banana cargo must be a continuous operation from the time the ship's hatches are first opened until all the fruit is unloaded and stored in refrigerator cars or trailer trucks for distribution to food warehouses in various cities. The bananas are protected as far as possible from damage by exposure to excessively high or low temperatures. In the winter, where the climate requires, provision is made to heat the discharging areas so that the fruit will not be exposed to temperatures lower than 55 F. The bananas are inspected periodically while enroute to the consignee to insure safe delivery temperatures. Only refrigerated, insulated, fan-type railroad cars and refrigerated trailers are recommended for banana service. Refrigeration is required in the summer, and heat is provided in the winter as necessary.

The total length of time required for shipment and temperature during shipment affect the ripening and handling characteristics of various lots of bananas. The total time elapsed from harvesting to ripening room depends on: (1) the distance from the plantation to the tropical port, (2) the ocean voyage which may vary from 4 to 10 days, and (3) the distance from the domestic port to the ripening room which may be up to 7 additional days.

This time lapse, plus temperature, humidity and ventilation influence the condition of the fruit on arrival at the ripening rooms and the rate of ripening. Usually, bananas subjected to greater lengths of time in transit will have undergone ripening to a further degree than bananas that have been recently harvested.

Another factor responsible for variation in ripening and handling characteristics is the maturity of the bunch at the time of harvesting as indicated by the fullness or plumpness of the individual fingers, which is known as grade.

There are many other factors that influence or cause variations in ripening and handling characteristics such as, climate, rainfall, etc.

Bananas are sold by the importer to wholesale jobbers in carload or truckload lots of whole stems, or tropically packed

Table 7 Approximate Temperatures for Ripening Stem Bananas*

Ripening Schedule	Temperature, F							
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8-10th day
4 days	64	64	62	60				
5 days	62	62	62	62	60			
6 days	62	62	60	60	60	58		
7 days	60	60	60	60	60	58	58	
8-10 days	58	58	58	58	58	58	58	58

* Valid only if ripening is done with ethylene.

boxes weighing 40 lb net. Bananas should be unloaded as soon as possible after arrival at the ripening plant. Prompt unloading and careful handling will minimize damage. The fruit must be brought under control as soon as possible to insure successful ripening on a predetermined schedule which is possible only in properly equipped ripening rooms.

Ripening

During ripening, enzymatic changes take place in the pulp of the fruit. The pulp of the green banana contains about 20 percent starch. As ripening progresses, this starch is converted to sugars, principally sucrose, dextrose and levulose. Color changes in the peel occur simultaneously with the pulp change and are also enzymatic. Rates at which these changes take place depend upon the relative activities of different enzymes, which, in turn, are stimulated or depressed by the physical conditions to which the fruit is exposed. Green bananas contain two classes of pigments, chlorophyll (green) and carotene (yellow). During ripening, the chlorophyll is gradually destroyed by enzymatic action allowing the carotene to become more and more evident.

Within certain limits, the period required for ripening green fruit can be extended or shortened to meet trade requirements. Under average conditions ripening cannot be accomplished in less than 3 or 4 days nor extended much beyond 8 to 10 days without resorting to drastic treatment harmful to the quality and salability of the fruit.

Especially important in controlling ripening is the change in rate of heat generation as the ripening cycle progresses. The rate of respiration and corresponding rate of heat generation varies with the temperature at which the fruit is held and with its stage of ripeness. The rate increases as the temperature rises and is highest when the fruit is in the turning stage.

The controlling factors in banana ripening are generally recognized to be temperature, humidity and ventilation.

Temperature. Ripening characteristics of different lots of bananas vary with the country of origin, botanical variety, season of the year, maturity of the fruit when harvested and other factors. It is impractical to set down precise ripening temperatures that will cover all of the foregoing variables. Suggested ripening temperatures are for bananas with average characteristics. Approximate temperatures for ripening average shipments of bananas are indicated in Tables 7 and 8. These temperatures are approximately correct only if ethylene is administered on the first day, and the room is ventilated 24 hr after the application of ethylene. If, for any reason, ethylene is not used, initial temperatures must be 3 to 4 F deg higher than shown.

The temperatures shown for ripening tropical boxed fruit are reliable only if the boxes are stacked to permit adequate air circulation. The two most common stacking methods are the in-line stack utilizing forced air principles, and the chimney

Storage of Apples, Pears, Grapes, and Bananas

Table 8 Approximate Temperatures for Ripening Tropical Boxed Bananas*

Ripening Schedule	Temperature, F							
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
4 days	64	64	62	58				
5 days	64	62	62	60	57			
6 days	64	60	58	56	56 ^a	56 ^a		
8 days	62	58	58	58	58	57	57	56 ^a

* Valid only if ripening is done with ethylene.

^a Thermotest setting, Gros Michel 55 F, Varieties 57 F.

stack. With the first method the boxes are stacked in rows, about seven boxes high, the longitudinal axis of each box being parallel to the longitudinal axis of the room. The rows of boxes are separated by 4 in. air channels. Air baffles of cardboard, canvas, plywood or other suitable materials are arranged so that the delivery air will be directed to the air channel entrances which are farthest from the unit cooler. These baffles are positioned so that the air must pass through the air channels before returning to the unit cooler. The second method is known as the *chimney stack* which provides a tied load on standard pallets and is commonly used in the produce industry.

Humidity. For green stem fruit, it is recommended that the relative humidity in the rooms be kept as high as possible, 95 to 100 percent. To keep down loss of moisture it is further advisable to avoid excessive air circulation. Circulating fans are connected so that they run continuously only during the initial heating period; and when under refrigeration, only during the periods when the cooling thermostat is calling for refrigeration. The relative humidity must be somewhat lower, about 85 percent, after the fruit has started to color. The effect of refrigeration when reducing the temperature of turning fruit is to automatically lower the relative humidity of the air at a stage of the ripening cycle when lower humidity is desired.

Humidity control is somewhat different when ripening tropical boxed fruit. The transpiration of the bananas will increase the relative humidity of the air surrounding the fruit and the box itself tends to prevent loss of moisture because there is little air movement inside the box. The spray nozzle system for providing moisture when ripening stems is not used when ripening boxed fruit.

Ventilation. Banana rooms should be tightly constructed and not ventilated during the early stages of ripening. Bananas, during ripening, give off small amounts of ethylene, volatile esters, and carbon dioxide, which must be confined to the ripening room, particularly during the early stages of the ripening process. The amount of these gases present has a direct bearing on the rate of ripening at a given temperature. To control the speed of ripening, it is highly desirable to administer ethylene artificially. Only a very small amount of ethylene is required (1 cu ft of ethylene per 1000 cu ft of room volume). Since the bananas themselves produce ethylene, a natural ripening stimulant, the ripening process is normal and no deleterious effects result and no difference in taste of ethylene-ripened fruit can be detected. The effect of ethylene is merely to stimulate or trigger the normal enzymatic changes which occur during ripening. Ethylene is recommended for ripening all varieties of bananas, both stems and tropical boxed shipments. Such treatment will assure uniform coloration on a predetermined schedule and will permit the use of lower than normal ripening temperatures, resulting in increased store life of the fruit.

Effect of Exposure to Excessively High or Low Temperatures

Exposure to temperatures above 70 F or below 55 F adversely affect bananas, with the extent of the injury depending on both the temperature and the time of exposure.

Chilling is mainly a peel injury caused by low but not freezing temperatures. Certain surface cells of the peel are killed as evidenced by discoloration and by examination under a microscope. Dead cell contents darken by oxidation and give chilled fruit its characteristic dull appearance.

Chilling affects both green and ripe bananas. With ripe bananas, the effect of chilling is not immediately apparent. The dull color does not appear until after the fruit is exposed to warmer temperatures. Chilling causes a dullness of the peel and increased sensitiveness to even slight handling.

The exact upper limits of chilling temperatures cannot be sharply defined but vary somewhat with the variety and the condition of the bananas and, of course, with the duration of the exposed period. It is well to avoid temperatures below 58 F for Gros Michel and 58 F for the variety fruits such as Lacatan and Cavendish, especially in moving air. Twelve hours exposure at any temperature below 45 F in still air generally causes chilling injury sufficient to affect the salability of the fruit, regardless of the stage of ripeness when exposed.

Since no method has been found by which the dead cells may be restored, no remedial measures are available. Bananas subjected to low temperatures should be brought to normal ripening temperatures as rapidly as possible to reduce, in a measure, the period of exposure. Although the peel appearance will be affected, slightly chilled bananas will ripen normally.

Exposure of ripe fruit to temperatures greater than 70 F also has a deleterious effect, the damage being proportional to the temperature and time of exposure. In severe cases, the bananas become soft, the peel is weak and easily split or broken. The term *cooked* is normally used to describe this type of injury. Cooked fruit may be the consequence of poor ripening procedures, failure of the refrigerating system, or high temperatures encountered in retail stores during the summer months.

Banana Ripening Rooms

The construction of banana ripening rooms is somewhat similar to that of ordinary cold storage rooms. The rooms require adequate insulation, refrigerating and heating systems, and must be as air tight as construction techniques will permit.

An important consideration in the design of rooms for handling stems of fruit is that the banana load is suspended from joists or racks instead of resting on the floor. This load is transferred through posts or columns to reinforced concrete curbs along the side walls of the rooms. These supports carry a concentrated load, therefore, the curbs and footings must be designed to support the maximum loading conditions of the rooms.

The stems are hung from hooks inserted in the joists, or carrier bars in the case of fork-lift type rooms.

For rooms equipped with banana joists, a clear height of 9 ft is required from the floor to the underside of the banana joists. The joists should be on 14 in. centers and the banana hooks and eyes spaced 8 in. apart along the joists. These hooks and eyes should alternate in both directions, so that no two hooks and no two eyes are adjacent. The stems of bananas are hung in two tiers, the upper tier hanging directly from the hooks and the lower tier suspended on ropes fastened to the eyes.