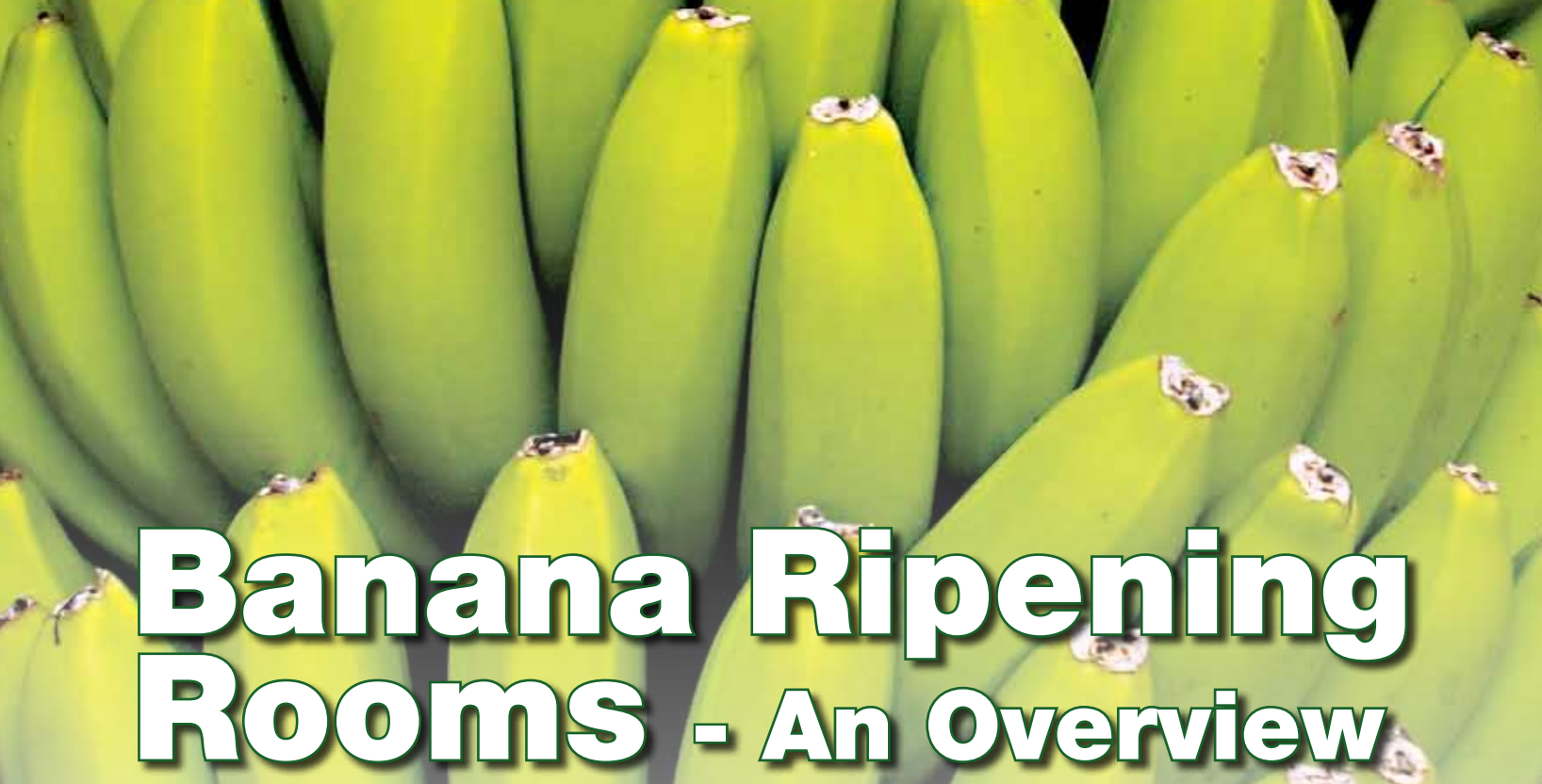

Banana Ripening Rooms - An Overview

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Ripening is a process in the life of a fruit. Some fruits ripen on the tree itself and some are required to be harvested and then ripened for satisfactory taste and appearance. This article outlines the process of controlled ripening of a very common fruit - the banana.

Banana is a tropical fruit found in abundance practically everywhere in India and more importantly round the year. Perhaps this may be a reason for its appearance at all religious functions throughout the country and throughout the year. Bananas are eaten mainly as a dessert fruit because they are sweet when ripe. Plantains, also referred to as 'cooking' bananas, are much starchier and can be eaten either ripe or unripe especially when processed into chips.

It is a known fact that banana does not ripen satisfactorily and evenly on the tree. Hence traditionally the unripe green banana was (and still is) harvested and sold to banana wholesalers. These wholesalers then put the banana bunches into ripening rooms and allow them to ripen using traditional means. These means are varied and differ from one place to another. After ripening the wholesalers sell these to the retailers and thereafter they are sold for the common man's consumption. In this process the yield of ripened bananas invariably is low, and not of uniform ripeness. Also, since dubious means are sometimes used for the ripening process, although the banana gets a color it does not acquire the sweet natural taste.

In the context of booming consumerism and retail trade being an accepted form of buying experience there is a demand for all "ready-to-eat" and "ready-to-drink" items.

Fruits are no different and it is for retailers to ensure that a ripe and tasty bunch of bananas is always there on their shelf, at all times.

The challenge is to be imagined to understand why the country is in need of a technologically advanced banana ripening process which ensures adequate natural ripening in a controlled way to obtain a prefixed quantity of evenly ripened bananas with a great natural taste.

A banana ripening room is the answer to this challenge. The use of such special rooms are expected to ripen the bananas in a natural way, uniformly throughout the lot and ensure that the bananas acquire a natural taste.

So let us first examine the natural process of banana ripening to understand how a banana ripening room does it all.

The natural ripening in bananas is triggered off by a set of optimum environment conditions of

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temperature, relative humidity and presence of ethylene gas. This situation triggers off the ripening and in a period of 3-4 days the bananas if undisturbed from this situation acquire the golden yellow color and the great natural taste. They are ready for consumption. Such conditions need to be artificially created for ripening since such conditions are nearly impossible in a free natural environment.

Hence special banana ripening rooms were designed and produced. These rooms are designed and equipped to create the desired environmental conditions of temperature, relative humidity and the balance of gases to ensure optimum and even ripening of the raw banana. The rooms are constructed with insulation, ventilation, ethylene injection and a host of features to ensure even ripening for a prefixed yield. Accordingly one can have a desired yield per day per room. In fact size is dictated by the logistics of supply and demand.

Harvesting of Bananas

Commercially, bananas and plantains must be harvested while mature green, and transported to destination markets where they are ripened under controlled conditions. Fruits ripened on the plant often split and have poor texture. Harvest time represents a compromise between leaving the fruit on the plant long enough to maximize yield, but harvesting it soon enough so that sufficient green life remains to market fruit with acceptable quality. The stage of maturity for harvesting the fruit depends on the market for which it is intended and is determined in terms of the marketable life required.

A good indicator for maturity for harvesting is the cross sectional area of the green banana which should be rather round than triangular.

Transportation

Transportation from areas of harvest to market places or *Distribution Centers* requires that bananas be shipped in boxes packed as a cluster of fingers (each banana is a finger). Ideally bananas need to be transported under controlled conditions of temperature of about 14°C. This is essential when the ambient temperature goes beyond 20°C.

The Banana Ripening Process

Ripening of bananas is the process of conversion of the starchy pulp to sugar by the exposure of the raw bananas to ethylene gas, which triggers and accelerates the hormonal process of ripening (also called "fruit maturation") under certain favorable conditions of temperature and relative humidity.

Temperature monitoring during the ripening process is critical since optimum ripening to get good taste and color occurs between 13 to 17°C. Higher temperatures may result in over-ripening too early and may soften the pulp but the skin may remain green or sometimes split the fruit. Too low a temperature may result in chilling injury.

It is important to maintain relative air humidity inside the chamber between 85 to 95% and levels lower than 85 % may result in dehydration of the fruit and may produce a ripe fruit with too much of scarring or with a grayish tan.

Photo 1 : Raw bananas are harvested & stored in pallets in the ripening room.

Raw mature fruit is harvested and packed in cardboard cartons or in plastic crates and loaded into palletized formations in the ripening rooms (Refer *Photo 1*)

The banana ripening cycle can be any period between 4 days to 7 days. This is generally dictated by the logistics and ripe fruit supply to markets. Accordingly, to obtain a specific quantity of ripened fruit each day for shipment it is essential to have a specific number of rooms.

For example, to obtain 2 MT of ripened fruit supply each day, suppose we opt for a 5 day ripening cycle, then it is essential to set up 5 rooms, each of 2 MT capacity. Load each room with mature green raw bananas each day with 2 MT and operate the room as per sequence of operation shown below so that the 1st room will deliver the fruit ripened on day 6 and the 2nd room will deliver ripened fruit on day 7 and so on. Remember to load room 1 on day 6 with fresh raw bananas after unloading the ripened bananas This cycle can continue, with the result that from day 6 we get 2 MT of ripened bananas each day ideally.

Day 1: The room is loaded with raw mature green bananas, closed and the refrigeration / heating system is started and run for a day to optimize the banana pulp temperature between 15 to 17°C. (Refer *Figure 1*)

Day 2: The ethylene gas dose is injected into the room on this day, at a concentration of around 100 to 400 ppm and at about 150 ppm this converts to approximately 185 mg/m^3. The ethylene gets mixed into the air distribution system and passes through the banana pallets. It acts as a catalyst initiating the hormonal process of ripening. Handling ethylene gas is a skilled process (refer safety

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Ripening Schedule	Temp Day 1	Temp Day 2	Temp Day 3	Temp Day 4	Temp Day 5	Temp Day 6	Temp Day 7
4 Day Cycle	18	18	17	16			
5 Day Cycle	17	17	17	17	16		
6 Day Cycle	17	17	16	16	16	14	
7 Day Cycle	16	16	16	16	16	14	14

Figure 1 : Temperatures required in a banana ripening cycle.

note in handling ethylene on page 136).

Day 3: The product in the room is getting ripened and in the process exudes a fair amount of heat and CO_2 as a part of the respiration and ripening process. This heat is extracted by the refrigeration system. The refrigeration system also ensures that the RH in the room is maintained between 85 to 90 % by means of a humidifier. The CO_2 gas produced inside the room is extracted using a well-defined extraction system, and fresh air is introduced into the room in a dosed manner via a fresh air damper.

Day 4: The room temp is maintained at 17°C and reduced to about 15°C over a period of 2 days. In this period fruit pulp may reach higher temperatures and CO_2 and heat is generated. This heat and CO_2 is removed by the refrigeration and extraction systems respectively. Fresh air introduction is also equally important.

Day 5: The room is finally evacuated and well ventilated before entry of plant personnel and the ripe fruit is removed and moved to the distribution chain.

The ripening stages can be also observed by the change in color of the banana skin. (Refer *Figure 2*)

Construction of the Ripening Room

The banana ripening rooms are situated near market places, especially in *Distribution Centers* and

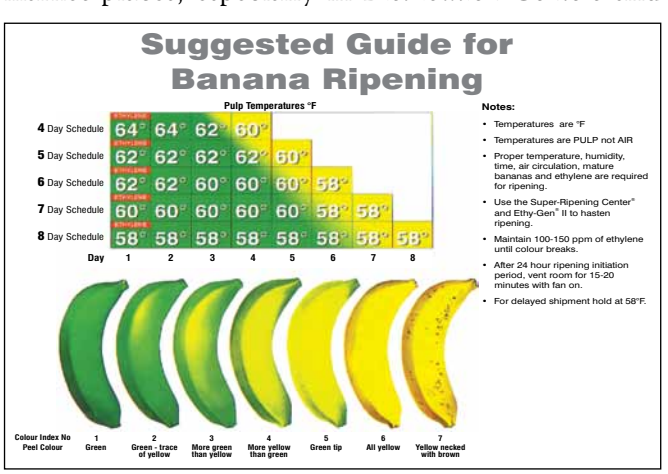

Figure 2 : Suggested guide for banana repening.

Photo 2 : A (4 day cycle) banana ripening room construction.

Photo 3 : Chamber construction - plenum

are constructed with adequate insulation and vapor barrier to maintain a low temperature of about 12 to 15°C and a relative humidity of about 85%. Refer *Photos 2* and *3*.

Good engineering practices advocate the use of the following requirements for building an operational banana ripening room:

1. Prefabricated metal clad insulated panels for construction of the room.
2. Quality doors with an excellent gasket seal to ensure leak proof operation.
3. A refrigeration system designed for the payload of bananas to ensure adequate removal of heat of respiration and to maintain accurate temperature control.
4. A humidity control system with a humidifier for ensuring optimum humidity.
5. An ethylene injection system.
6. A CO_2 extraction system coupled to a fresh air inductor system.
7. Automation program to operate the above systems in tandem to ensure accurate environmental conditions and to obtain good natural ripening of the bananas.

Some Notes on Banana Ripening Rooms

a. The room must be as air tight as possible to prevent ethylene from leaking out.
b. The room must be properly insulated to be able to control the temperature within a few degrees.
c. The room must have adequate refrigeration. Bananas produce large quantities of heat when they are

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ripening. The refrigeration equipment must have the capacity to accurately control the pulp temperature.

d. The room may need heating equipment in order to maintain proper room temperature in cold weather. Electric heating elements have proven the most satisfactory and are often a part of the cooling system. Open flame type heating should never be used.

e. The room must have adequate air circulation. Because uniform pulp temperatures throughout the load are essential for even ripening, the refrigerated air in the room must circulate at all times and uniformly throughout the load. The room should be constructed so that the air-flow path from the cooler, through the load and back to the cooler is unobstructed. Proper airflow patterns are of the utmost importance. See *Figure 3*.

f. The boxes or crates of bananas should be "air stacked". That is, the boxes should be offset to allow the air to circulate among all the boxes.

g. Avoid "chilling" or "cooking" the fruit. Bananas are very sensitive to temperatures. Chilling will occur if the fruit is subject to temperatures below 13°C. for several hours. It causes the peel to have a smoky, dull gray appearance. This may not show up for 18 to 24 hours after chilling occurs. Cooked bananas result from excessively high temperatures. The peel will have a brown to orange appearance. The fruit may be soft and have a short shelf life.

h. Maintain proper humidity levels. For best ripening results, humidity should be 85 to 95%. If the humidity is too low, install a humidifier; wetting the floor of the room with water may increase the humidity but may cause sanitation issues.

i. Apply ethylene for a minimum of 24 hours during the initial phase of the ripening cycle. We recommend 100-150 ppm. To achieve this, the generator setting will depend on the size of the ripening room.

Ethylene Gas Injection System

Ethylene gas required for banana ripening may be produced by any of the three methods given below:

a. ***Ethylene Generators*** which use a catalytic process of producing pure ethylene gas from a solution mainly containing ethyl alcohol (ethanol). The solution is poured into a receptacle in the generator and from there it is gradually fed to a heating chamber, which vaporizes the ethanol and then passes thro' a catalytic convertor. Each litre of ethanol can produce approximately 0.3 to 0.4 m^3 of ethylene gas.

b. ***Ethylene cartridges*** are available containing approx. 50 g of pure ethylene (approx. 0.4 m^3 of gas at 20°C). Ethylene is released into the chamber by piercing the cartridge with an appropriate tool.

c. ***Ethylene/Ethylene+Nitrogen Cylinders.*** Bulk cylinders may be used containing either pure ethylene or a safer mixture of ethylene (5%) and nitrogen. It is of critical importance that whatever method of ethylene production is used care should be taken to ensure proper and effective distribution of the gas throughout the raw banana pallets.

d. ***Safety Note on Ethylene.*** Ethylene gas is flammable and explosive in certain proportions. Hence injection of ethylene gas is should be strictly regulated to a safe proportion. 5% ethylene in a nitrogen cylinder is a safe mixture. Alternatively concentration not exceeding 400 ppm is considered safe. Controls will include good quality ethylene sensors and gas analyzers. No naked lights should be used inside the ripening rooms. All electrical wiring should be cabled and conduited. No open wiring is allowed inside the ripening chamber.

Refrigeration System

Refrigeration systems for ripening rooms are generally based on non-CFC refrigerants. Ammonia is not advised due to its harmful effects on bananas. There is a remote possibility of using ammonia as a primary refrigerant and then the rooms can be cooled thro' a secondary refrigerant compatible to the fruit. The refrigeration system should be capable of extracting the heat of respiration (and ripening) of the fruit in the entire cycle. Heat load calculations are of critical importance to final fruit ripening quality and uniformity. It is most advisable not to assume thumb rules or copy an existing plant.

Room temperatures are maintained typically in the range of 15 to 17°C. In most cases a DX refrigeration system is used. It is advisable to have a dedicated condensing unit and evaporating unit combination for individual rooms instead of a central DX plant, because each room is maintained at different temperatures at any given point of time. Hence balancing refrigerant flows can cause problems of back pressure regulation.

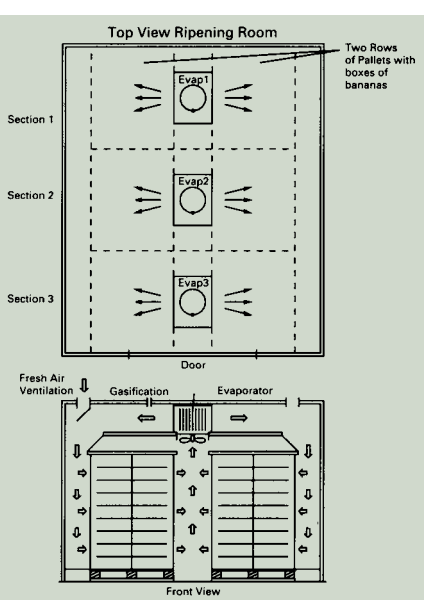

Figure 3 : Raw bananas are harvested & stored in pallets in the ripening room.

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if chilled water is available, then chilled water cooling units are used in individual rooms.

Refrigeration Heat Load Estimates

The heat load estimations for banana ripening are carried out on similar lines as for other fresh fruit. There are basically the following heat inputs for arriving at the refrigeration load:

a. Transmission load is dependent on the size, surface area and the insulation construction of the ripening room.
b. Infiltration load is quite negligible since the room is generally not opened during the ripening process
c. Product load is calculated using a specific heat of bananas as 3.35kJ/kg °K i.e. mass of the bananas in the room × 3.35 × 1000 × Δt / time of pulldown in seconds.
d. A pull down of 0.5°K per hour is desirable.
e. Electrical load inside the room would comprise the wattage of the evaporator fans and the steam type humidifier.
f. Human load is negligible since there is no human movement when the ripening process is in progress.

Typically a crate /box of bananas weighing around 22 kg will contribute a heat load of about 17-18 watts. (a 10 MT ripening chamber will need a refrigeration unit of 3 TR)

Air Circulation

Air temperature uniformity in the ripening room is critical since this affects uniformity of ripening. Also it is essential to remove the heat of respiration from the stacked bananas even when the bananas are held at constant temperature. Hence proper volume and velocity of air is important and needs to be quite large. Use of plenums and baffles is common in ripening rooms.

For large rooms, circulatory fans are rated for 125 to 150 Pa static pressure.

Airflow calculations show an approximate requirement of 7 liters per second air per crate / box of bananas weighing about 19-20 kg. (a 10 MT ripening chamber would need about 3800 lit/sec of airflow)

Humidification System

Humidification is a method of artificially increasing the humidity content of an environment by adding moisture to the enclosed air. Banana ripening rooms generally use a steam type humidifier. Here the moisture is generated by generating controlled steam and then introducing the steam into the room. The location of the humidifier is such that the steam generated gets into the air flow from the unit cooler and mixes thoroughly with the air creating a higher RH level.

Water sent to the humidifier should have a hardness of less than 75 ppm. Other types of humidifiers used are "pan type" or "mister sprays" although in both these types the disadvantage is that they tend to deposit water droplets on the product which is best avoided. The "steam type" humidifier has proved to be the best for banana ripening chambers.

Automation System

The automation system should be capable of integrating the temperature and humidity sensors with the refrigeration system. Also, the automation system should ensure integration of humidification and CO_2 extraction system operation.

Humidistats are used for measuring and setting the humidity levels. These will activate the humidifier as and when the humidity levels go down from the preset levels.

They also shut off the humidifier when the room RH reaches the preset level.

CO_2 sensors are used to detect the CO_2 level and then activate the CO_2 extraction system to extract the gas out of the ripening room. Using a timer, this system will also activate the fresh air damper to bring in fresh air.

CO_2 extraction systems are equipped with a CO_2 scrubber system, as prescribed in statutory norms that prevent venting out CO_2 directly to the atmosphere. For smaller ripening rooms the quantity of CO_2 is insignificant and hence this criteria may get overruled. However for large ripening chambers, a scrubber system is invariably provided and it comprises the following components;

- Calcium hydroxide – about 75 percent
- Water – about 20 percent
- Sodium hydroxide – about 3 percent
- Potassium hydroxide – about 1 percent.

Scrubbing is carried out in a closed circuit between the ripening room and the scrubber itself. PVC mains of 4, 6 or 8 inches are typically used for the main suction and discharge lines and 3 inch PVC lines are used for transition in and out of the rooms. The control valves are usually electric slide valves or occasionally manual ones.

Where ethylene injection is done using a cylinder system, the ethylene sensors are required to detect the levels of ethylene and accordingly shut off the gas supply once the required ppm concentration is achieved.

The automation process can also be mapped on a computer screen as well as a printed record obtained for each batch. This record will aid traceability for each batch. Data loggers are installed to log the data, which can then be retrieved any time, over printed records or over a computer screen.

Conclusion

This article is only an overview of the banana ripening system. Each aspect of the ripening process like, harvesting, ripening process, room construction, refrigeration, automation, humidification, economic operational quantity, power analysis etc, can all be analyzed for taking commercially viable decisions. ❖