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RESEARCH ARTICLE

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CASE STUDY AND ANALYSIS OF BANANA RIPENING CHAMBER USING SENSORS TO DETECT THE CAUSE OF IMPROPER RIPENING AT KEVENTER AGRO LTD

GAURAB BHOWMICK*, PARNASHREE MITRA, GUNJAN DE
Mechanical Engineering, Electronics & Telecommunication Engineering, Mechanical Engineering
Dr. Sudhir Ch. Sur Degree Engineering College, Kolkata, India
gaurabh.bhowmick@gmail.com, mitra.parnashree@gmail.com, degunjan@gmail.com

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GAURABBHOWMICK
*Author for Correspondence

ABSTRACT: Banana Ripening Chamber or BRC are used to artificially simulate the natural ripening condition of Banana. The conditions are artificially created by using various equipment like Air Handling Unit (AHU), Freon Cooler, Ethylene generator, etc. The temperature, humidity, ethylene concentration required for natural ripening is maintained within the chamber for particular number of days until the banana are ripe enough for transportation to distributors. But, recently the ripening process was not proper and the consistencies, color of the bananas were not as per the standard of the industry. In this case study the problems and its cause were analyzed and recommendations were made so that proper ripening of bananas take place. The improper ripening caused loss of economy, market share of the distributors due to poor quality of product.

Keywords—BRC, Ethylene, humidity, ripening

INTRODUCTION

Banana Ripening Chambers or BRCs are the artificial enclosure where the bananas are naturally ripened by artificially simulating the natural ripening condition. The process and chain from production to consumption[1] :

1. Country of origin
- Growing
- Harvesting
- Washing / disinfection
- Packing (transport /shipment)

2. Transport (overseas)
- Initiating the cooling process
- Storage
- Ventilation
- Off-loading
- Refrigerated transport

3. Country of consumption
- Ripening (including sorting and labelling)
- Order picking

- Refrigerated transport and storage with retailers refrigerated
- Sale to customers
- Transport to consumer
- Final ripening on fruit basket

1.1 Cooling technology and product quality Critical steps[2]

1. Place of origin

- Timing the harvest
- Handling
- Transport
- Embarkation

2. Transportation (overseas)

- Storage temperature (14°C)
- Low levels of ethylene (ventilation)
- Off-loading
- Refrigerated transport

3. Country of consumption

- Equalization and ripening
- Refrigerated transport
- Storage by the retailer
- Sale to consumer
- Transport to consumer
- Consumption

1.2 The Banana Ripening Process[3]

- On the plant /separated from plant
- Hormone controlled (ethylene)
- Conversion (starch to sugar)
- Temperature dependence of the ripening process:

1. Too high: irregular ripening of the fruit / poor keeping quality (> 18°C)
2. Higher: rapid ripening / difficult to control
3. Lower: slower ripening / possibly slight taste degradation
4. Too low: chilling injury (< 12°C)

- Dependent on gas composition (O_2 / CO_2)

Cooling and air techniques for banana ripening[4]

The ripening process consists of the following steps:

- Equalization
- Gassing
- Stepped or continuous temperature settings
- Regular ventilation

Important aspects of the ripening process:

- Ripening program
- Temperature distribution inside the ripening chamber
- Temperature distribution within the pallets
- Temperature distribution within box / plastic bag

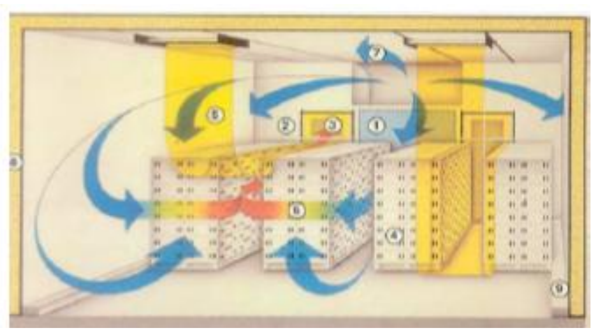
Another important aspect of the ripening process:

- Energy consumption
- Dramatic reduction in the need for cooling
- Point of insertion of ethylene gas (dispersal)
- Sensor placements for measurements of gas concentration

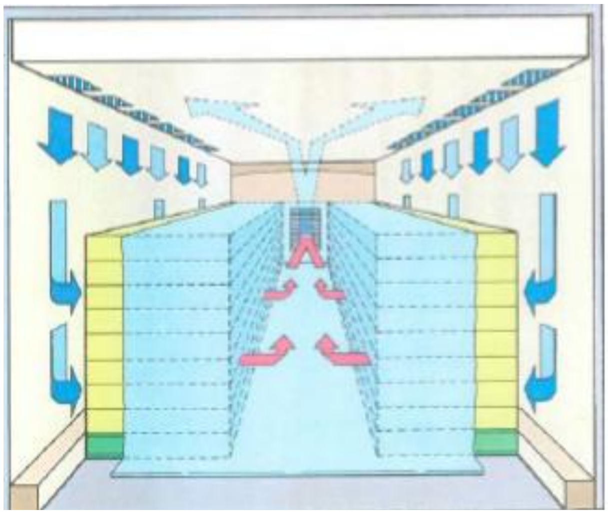
Ripening system[5]

- Primitive
- Traditional (standard cold room with openly stacking of boxes)
- Modern (so-called pressure-ripening)

Tarp[6]



Tarp with improved air circulation[7]



Air bags (vertical air circulation)[8]

Side curtains with reversible airflow[10]

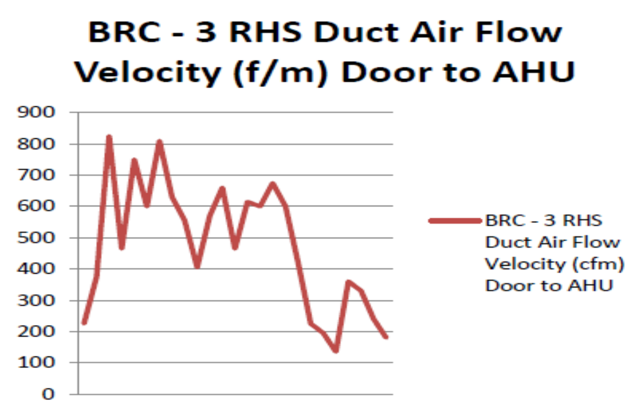
Horizontal air circulation[9]

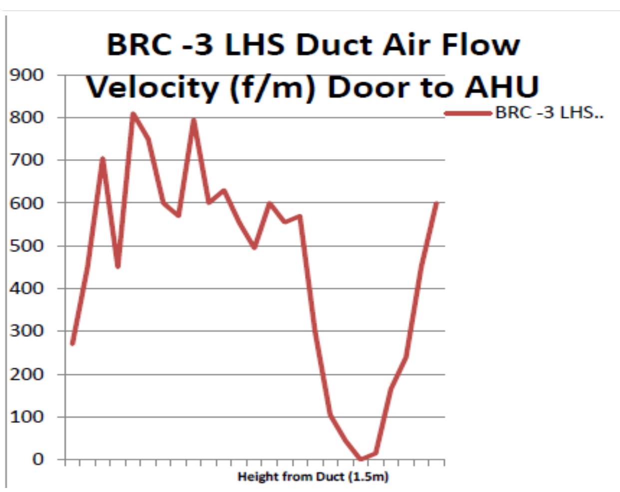
Sock system[11]

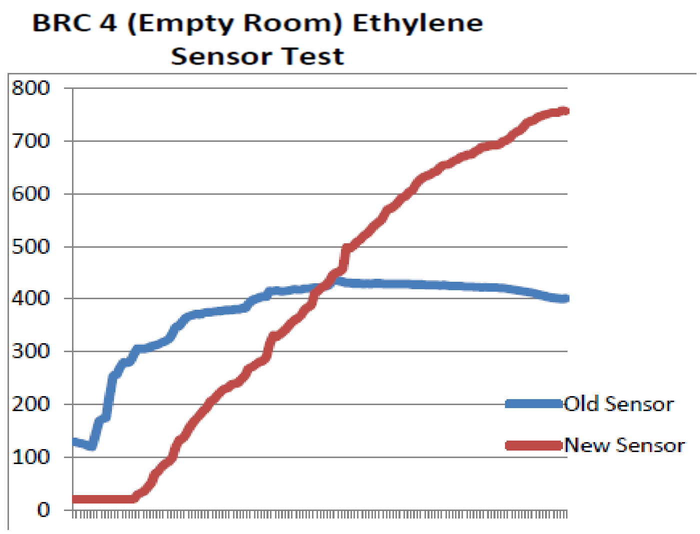
Comparing ripening systems

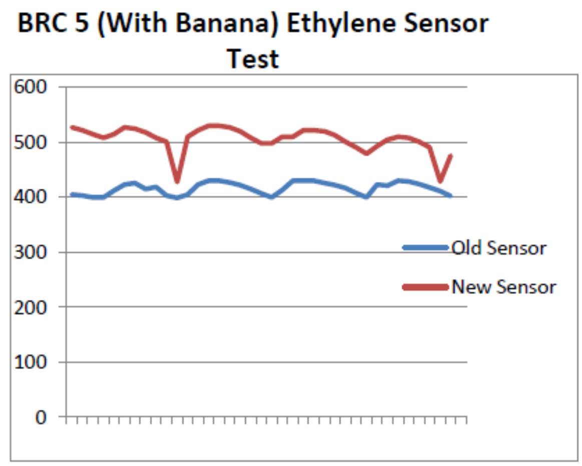
- There are great variations in the quantities of air used (1400-3000 m³ / h per ton)
- The efficiency of the air circulation systems used varies greatly through various types of leakage paths (only 5-20% of the ventilation capacity is actually used to aerate the pallets)
- Some ripening chambers have relatively high pressure losses due to poor design of the circulation channels (up to 1/3 of the total static pressure loss)
- Proper closure of the pallets is influenced by poor stacking of the boxes and similarly poor placement of the pallets in the ripening chamber
- (Almost) all ripening chambers have moveable parts for closing, that require regular maintenance and labour to operate them

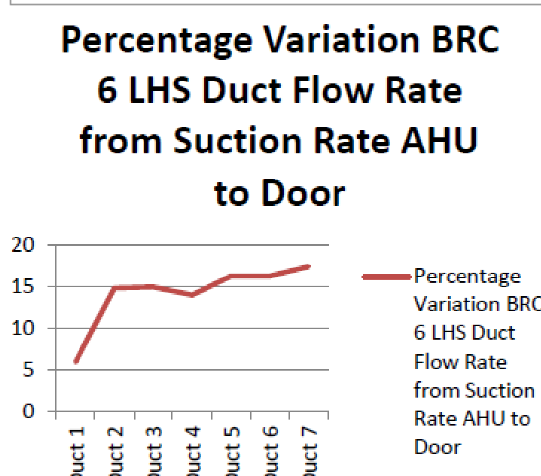
CASE STUDY

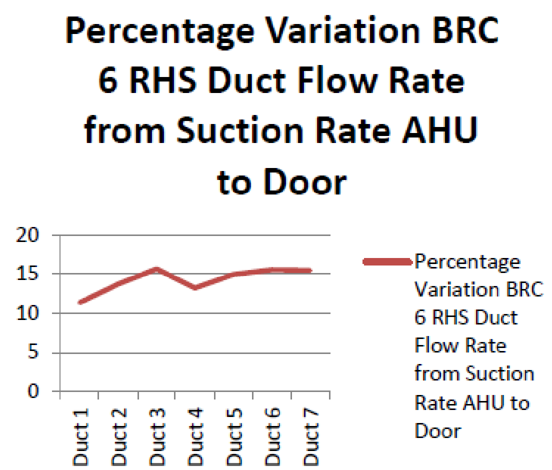












AHU Analysis

BRC – 6

Left Side :

Dimension -> 1076 x 1810 sq.mm

Area = 3.53 x 5.94 = 20.96 sq.ft

So, Average air velocity, V(avg) = 65.75 x factor

Or, V(avg) = 65.75 x 15

Or, V(avg) = 986.25 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 986.25

Or, Q = 20671.8 cfm

Right Side :

Area, A = 20.96 sq.ft

So, Average air velocity, V(avg) = 66.125 x factor

Or, V(avg) = 66.125 x 15

Or, V(avg) = 991.875 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 991.875

Or, Q = 20789.7 cfm

BRC – 7

Left Side :

Dimension -> 1076 x 1810 sq.mm

Area = 3.53 x 5.94 = 20.96 sq.ft

So, Average air velocity, V(avg) = 62.25 x factor

Or, V(avg) = 62.25 x 15

Or, V(avg) = 933.75 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 933.75

Or = 19571.4 cfm

Right Side :

Area, A = 20.96 sq.ft

So, Average air velocity, V(avg) = 69.33 x factor

Or, V(avg) = 69.33 x 15

Or, V(avg) = 1040 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 1040

Or, Q = 21798.4 cfm

BRC – 8

Left Side :

Dimension -> 1076 x 1810 sq.mm

Area = 3.53 x 5.94 = 20.96 sq.ft

So, Average air velocity, V(avg) = 63.29 x factor

Or, V(avg) = 63.29 x 15

Or, V(avg) = 949.35 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 949.35

Or, Q = 19898.37 cfm

Right Side :

Area, A = 20.96 sq.ft

So, Average air velocity, V(avg) = 63.08 x factor

Or, V(avg) = 63.08 x 15

Or, V(avg) = 946.2 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 946.2

Or, Q = 19832.35 cfm

BRC – 9

Left Side :

Dimension -> 1076 x 1810 sq.mm

Area = 3.53 x 5.94 = 20.96 sq.ft

So, Average air velocity, V(avg) = 64.83 x factor

Or, V(avg) = 64.83 x 15

Or, V(avg) = 972.45 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 972.45

Or, Q = 20382.55 cfm

Right Side :

Area, A = 20.96 sq.ft

So, Average air velocity, V(avg) = 66.92 x factor

Or, V(avg) = 66.92 x 15

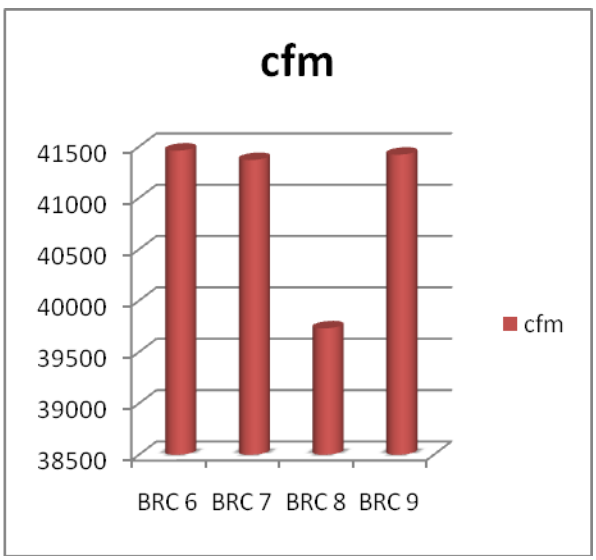
Or, V(avg) = 1003.8 ft/min

Therefore, Actual air flow rate in cfm = A x V(avg)

Or, Q = 20.96 x 1003.8

Or, Q = 21039.65 cfm

BRC	LHS flow rate (cfm)	RHS flow rate (cfm)	Total flow rate (cfm)
BRC 6	20671.8	20789.7	41461.5
BRC 7	19571.4	21798.4	41369.8
BRC 8	19898.37	19832.35	39730.72
BRC 9	20382.55	21039.65	41422.2



Analysis of Duct (LHS)

Outlet(AHU to Door)	Avg. reading of Anemometer	Factor x Avg. reading (x15)	Flow rate Q (cfm) Vel. X Area(1.197sq. ft)
1	51.33	769.95	921.63
2	128.67	1930.05	2310.26
3	129.67	1945.05	2328.22
4	121.33	1819.95	2178.48
5	141.33	2119.95	2537.58
6	141.33	2119.95	2537.58
7	151.33	2269.95	2717.13

Analysis of Duct (RHS)

Outlet(AHU to Door)	Avg. reading of Anemometer	Factor x Avg. reading (x15)	Flow rate Q (cfm) Vel. X Area(1.197sq. ft)
1	107	1605	1921.18
2	130	1950	2334.15
3	147.67	2215.05	2651.41
4	125.33	1879.95	2250.3
5	141	2115	2531.65
6	146.67	2200.05	2633.46
7	146	2190	2621.43

Vent – Out Analysis

BRC – 1

Sweep = 230mm

Area, A = 41526.5 sq.mm = 0.447 sq.ft

Average air velocity, V(avg) = 25.25 x 15

Or, V(avg) = 378.75 ft/min

Flow rate. Q = 0.447 x 378.75 = 169.30 cfm

So, Air change rate = 11282.54/169.30 = 66.64 min

Where, Room volume = 11282.54 cu.ft

BRC – 2

Sweep = 230mm

Area, A = 41526.5 sq.mm = 0.447 sq.ft

Average air velocity, V(avg) = 83.75 x 15

Or, V(avg) = 1256.25 ft/min

Flow rate. Q = 0.447 x 378.75 = 561.54 cfm

So, Air change rate = 11282.54/169.30 = 20.09 min
Where, Room volume = 11282.54 cu.ft

BRC – 3

Sweep = 230mm
Area, A = 41526.5 sq.mm = 0.447 sq.ft
Average air velocity, V(avg) = 24.5 x 15
Or, V(avg) = 367.5 ft/min
Flow rate. Q = 0.447 x 378.75 = 164.27 cfm
So, Air change rate = 11282.54/169.30 = 68.68 min
Where, Room volume = 11282.54 cu.ft

BRC – 4

Sweep = 230mm
Area, A = 41526.5 sq.mm = 0.447 sq.ft
Average air velocity, V(avg) = 49.25 x 15
Or, V(avg) = 738.75 ft/min
Flow rate. Q = 0.447 x 378.75 = 330.22 cfm
So, Air change rate = 11282.54/169.30 = 34.16 min
Where, Room volume = 11282.54 cu.ft

BRC – 5

Sweep = 230mm
Area, A = 41526.5 sq.mm = 0.447 sq.ft
Average air velocity, V(avg) = 30.50 x 15
Or, V(avg) = 457.5 ft/min
Flow rate. Q = 0.447 x 378.75 = 204.5 cfm
So, Air change rate = 11282.54/169.30 = 55.17 min
Where, Room volume = 11282.54 cu.ft

BRC – 6

Sweep = 220mm
Area, A = 37994 sq.mm = 0.409 sq.ft
Average air velocity, V(avg) = 58 x 15
Or, V(avg) = 870 ft/min
Flow rate. Q = 0.447 x 378.75 = 355.83 cfm
So, Air change rate = 11282.54/169.30 = 31.70 min
Where, Room volume = 11282.54 cu.ft

BRC – 7

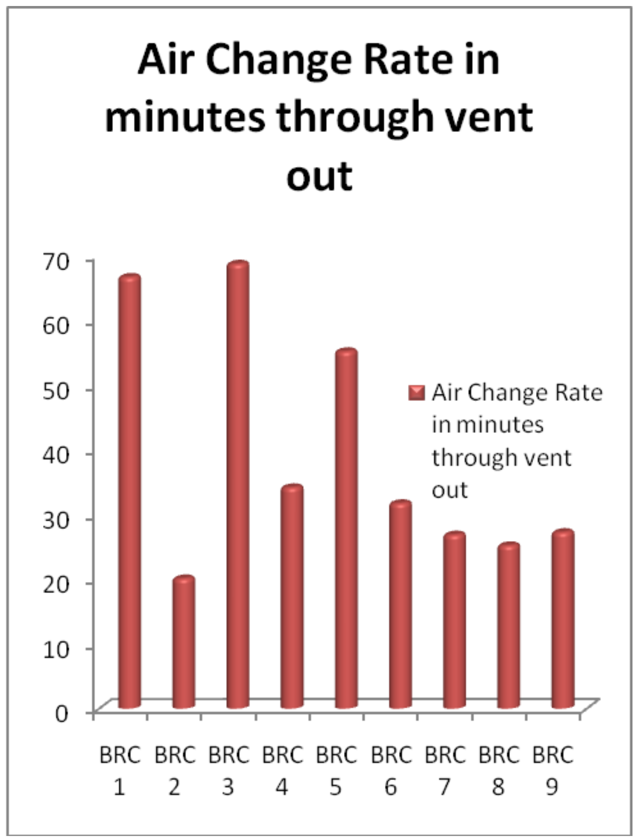
Sweep = 220mm
Area, A = 37994 sq.mm = 0.409 sq.ft
Average air velocity, V(avg) = 68.5 x 15
Or, V(avg) = 1027.5 ft/min
Flow rate. Q = 0.447 x 378.75 = 420.25 cfm
So, Air change rate = 11282.54/169.30 = 26.85 min
Where, Room volume = 11282.54 cu.ft

BRC – 8

Sweep = 220mm
Area, A = 37994 sq.mm = 0.409 sq.ft
Average air velocity, V(avg) = 73 x 15
Or, V(avg) = 1095 ft/min
Flow rate. Q = 0.447 x 378.75 = 447.85 cfm
So, Air change rate = 11282.54/169.30 = 25.20 min
Where, Room volume = 11282.54 cu.ft

BRC – 9

Sweep = 220mm
Area, A = 37994 sq.mm = 0.409 sq.ft
Average air velocity, V(avg) = 67.5 x 15
Or, V(avg) = 1012.5 ft/min
Flow rate. Q = 0.447 x 378.75 = 414.11 cfm
So, Air change rate = 11282.54/169.30 = 27.24 min
Where, Room volume = 11282.54 cu.ft



FINDINGS & PROPOSED MODIFICATION

- From the observations made using sensors and equipment, it is seen that the air flow required for optimum ripening of bananas was not there. The AHU's air circulating capacity was less than the optimum capacity required for the room.

- Air ducting was not properly placed, the direction of the vents in the ducts were such that maximum air was flowing through the free passages not through the crates.
- The ethylene concentration required for stimulating natural ripening within the bananas was not present in the room. The reason being the ethylene generator used was of less capacity than required.
- The CO2 diffuser vents were of different manufacturers for the same type of BRC, so as a result of which the air change rate was different for the BRCs, which in optimum sense has to be uniform for the same specification of BRCs.
- The placement of ethylene sensor was near the AHU, whereas for optimum detection of concentration of ethylene the sensor has to be placed at the middle portion of the chamber.
- The above shortcomings are responsible for improper ripening of bananas.
- For proper ripening of bananas the above mentioned issues has to be taken care of.
- Proper placement of ethylene sensor, uniform air exchanger, uniform CO2 diffuser, proper circulation vents and ducts should be installed; AHU's capacity has to be increased.

CONCLUSION

- The causes of the problems faced were found out by various testing equipments and sensors.
- The installations of the units within the chambers were not according to the proper guidelines for banana ripening.
- Proper protocols have to be followed in order to obtain perfect ripening of bananas.
- The findings of the case study were given to the management for proper rectification of the issues.

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