**Study on ripening behaviour of banana (*Musa acuminata*) at ambient condition**

**ABSTRACT**

Indian is the leading producer of banana with a production of 37.47 million metric tonnes. Banana comes under climacteric fruit category that ripens naturally, showing a respiratory peak after harvest but required long duration. In the present investigation the ripening behaviour of banana at natural condition was studied. The banana covering with paddy straw and kept in plastic container and after 2 days of interval the physico-chemical properties *i.e.* pH, total soluble solid (°B), firmness (N), weight loss (%) and colour value (L\*, a\* and b\*) was determined. It was observed that with the increased in the storage duration (2 to 12 days) the value of pH (5.57 to 5.26) and firmness (28.00 to 7.96 N) gradually decreased and value of total soluble solid (4.65 to 18.07 °B) and weight loss (0.16 to 28.10) gradually increased. In colour values, L\* (82.61 to 79.02) gradually decreased. It was also observed that after 12 days of storage banana does not received desired colour and total soluble solid values required for marketing.

**1. INTRODUCTION**

India is the second-largest producer of fruits in the world, after China, with an annual production of 96.75 million tons across 6.5 million hectares (Horticultural Statistics at a Glance, 2019). In many tropical countries around the world, bananas serve as a vital food crop and are integral to daily diets. As per the FAO Stat (2019), the world's annual production of bananas reached over 114 million tons in 2017, with over 5.6 million hectares devoted to banana cultivation worldwide. India and Brazil are the leading countries in the world that produce sweet bananas. Banana is rich in easily digestible carbohydrates with 67–137 calories per 100 g of fruit, it has a high content of readily absorbed carbohydrates. Other key components of banana fruit include oligosaccharides and different antioxidants, which have been linked to improved blood pressure regulation, weight loss, and the treatment of intestinal disorders as well as the prevention of diabetes, colon cancer, and other diseases (Higgins, 2014; Obrenovich *et al*., 2011, 2010; Wang *et al*., 2014).

The banana is a climacteric fruit that ripens naturally, showing a respiratory peak after harvest but required long duration. The majority of banana bunches are picked while fully mature, still green and unripe, and then left to ripen in natural environments. Green banana bunches are artificially ripened in order to meet the usual household requirement. One of the most popular techniques used to promote ripening is smoke treatment (Ram *et al*. 1979).

Bananas must be stored and ripened properly to preserve their quality and enhance their shelf life. Careful supervision is necessary when using traditional ripening methods, which frequently involve the use of ethylene or controlled climatic conditions, in order to achieve consistent ripening and prevent spoiling. To study the natural ripening process of banana this study was planned which will help to understand the ripening behaviour and need of artificial ripening agent.

**2. MATERIAL AND METHODS**

**2.1. Raw material**

The banana fruits purchased from M/s Mahesh Krishi Farm, Village-Datrenga, Post – Sejbahar, District Raipur (Chhattisgarh) (Fig. 1). In the study, physiologically mature banana (Cv. G-9) fruits were harvested during morning hours (from 8.30 a.m. to 10.00 a.m.) from the field. Then the harvested fruits were washed and cleaned for further investigation. The experiment was conducted in the winter season with the average temperature of 26-30°C with relative humidity ranges from 53-57%.

**2.2. Ripening process**

For the ripening process, banana kept in the 20 litre of plastic container by covering with paddy straw (layer by layer) *i.e.* one layer of straw and one layer of banana and fill the box. The plastic container has top plastic lid to cover the box as and when required (Fig. 2).

**2.4. Physico-chemical characteristics**

The physico-chemical characteristics during ripening of banana fruits like pH, total soluble solids (ºBrix), firmness (N), weight loss (%) and colour value (L\*, a\* and b\*) were recorded by standard methods. These values were measured and recorded for every two days until ripening was completed.

**2.4.1 pH**

The pH estimation was measured by using digital pH-meter according to AOAC, 2005.

**2.4.2 Total soluble solids (TSS)**

Total soluble solids in fruit juice was measured by using digital refractometer following the method given by AOAC, 2005.

**2.4.3 Firmness**

Firmness was measured with the help of digital fruit penetrometer. The fruit firmness was measured after removing about 1 cm2 of the skin of the fruit in the middle of the fruit and with the help of 8 mm stainless steel plunger force required to penetrate was measured. The value indicated by the device represents the maximum force expressed in Newton (Tano *et al.,* 2007).

**2.4.4 Weight loss**

The fruit mass was determined by weighing the fruits in each box at two days interval from three replicates. The weight loss was calculated by the following formula suggested by Srivastava and Tandon (1968) and expressed in percentage.

**2.4.5 Colour**

The colour of fruit was measured by using Hunter lab colour analyser. The color of fruit sample was expressed as L\* (whiteness or darkness), a\* (redness or greenness), b\* (yellowness or blueness) as per the standard procedure. Small quantity of sample was filled in the 10 mm optical glass chamber and placed into the chamber channel. The colour reading was recorded in L\*a\*b\*/RYB scale.

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| Fig. 1. Fresh banana sample |

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| Fig. 2. Storage of banana fruits covered with paddy straw in plastic container |

**3. RESULT AND DISCUSSION**

**3.1. Physico-chemical properties of banana fruits at harvest stage**

The data presented in Table 1 shows the experimental result of certain physico-chemical properties of banana Cv. G9 fruits at harvest stage. The maturity of banana was determined with the help of instrument called ‘banana caliper’ in which finger diameter more than 1.2 inches were selected for harvesting also other marker was angularity of the fruit. In matured fruits angularity was reduced (sides rounder, not sharply ridged).

Table. 1 Physico-chemical properties of banana fruits Cv. G9 at harvest stage

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| --- | --- | --- | --- |
| **S. No.** | **Parameters** | **Value** | **Method of measurement** |
| 1 | pH | 5.87 | Digital pH-meter |
| 2 | Total soluble solid, °Brix | 4.12 | Digital refractometer |
| 3 | Firmness, N | 29.03 | Digital fruit penetrometer |
| 4 | Colour |  | Hunter lab colour analyser |
| L\* value | 82.11 |
| a\* value | -0.19 |
| b\* value | 16.21 |

**3.2 Effect of storage period on physico-chemical changes during ripening of banana fruits.**

As per the set objective, the variation in physico-chemical properties of banana with respect to duration of storage is summarized in Table 2. The pH is one of the important quality parameters which predict the ripening stages of banana fruit. It was observed that, the pH value gradually decreased from (5.57 to 4.83 ) up to 8 days and then increased (5.11 to 5.26) on 10th and 12th day. This pattern reflects the initial accumulation of organic acids during the early stages of ripening, followed by the breakdown of acids and accumulation of sugars as ripening progresses.

Total Soluble Solids (TSS) refer to the concentration of dissolved substances in a fruit’s juice, primarily composed of **sugars (glucose, fructose, sucrose), organic acids, vitamins, minerals, and other soluble compounds**. In general, the unripe green bananas have low TSS (4-6 °Brix) due to high starch content and as ripening progresses, TSS increases to 18-22 °Brix in fully ripe bananas making the fruit sweeter. It was observed that, the value of TSS increased rapidly up to first 8 days of storage and 8 day onwards, TSS values became relatively stable, indicating the transition from active ripening to full ripeness (Table 2.).

Firmness is a crucial indicator of the ripening and textural quality of bananas. As bananas ripen, their firmness decreases due to enzymatic breakdown of cell walls, starch degradation, and moisture loss. During ripening of banana, the value of firmness (N) gradually decreased from 28.00 to 25.34 N up to 8 days and then dropped significantly to 7.96 N (day 8 to 12).

Weight loss in banana fruits is a crucial parameter that affects postharvest quality, shelf life, and marketability. It is mainly caused by **moisture loss due to respiration and transpiration** during storage. During experiment it was observed that, there was continuous increased in weight loss percentage, but rate of weight loss was very less during initial days *i.e.* from 0.16 to 7.36 % and then increased up to 28.10 % from day 8 to day 12, leading to maximum weight loss (%). Similar trend was observed during the ripening of banana by (Ahmad and Thompson, 2007).

Table 2. Physico-chemical characteristics of banana fruits during ripening in a control condition.

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Storage period, Days | pH | TSS,  °B | Firmness (N) | Wt. loss, % | L\* | a\* | b\* |
| 2 | 5.57 | 4.65 | 28.00 | 0.16 | 82.61 | 0.39 | 17.42 |
| 4 | 5.50 | 4.60 | 27.12 | 0.35 | 79.98 | 0.58 | 18.00 |
| 6 | 4.87 | 11.07 | 26.20 | 7.36 | 74.12 | 2.14 | 18.87 |
| 8 | 4.83 | 17.00 | 25.34 | 13.53 | 65.00 | 2.73 | 17.41 |
| 10 | 5.11 | 17.73 | 17.35 | 19.90 | 69.53 | 1.95 | 19.24 |
| 12 | 5.26 | 18.07 | 7.96 | 28.10 | 79.02 | 0.43 | 20.80 |

Fig. 3 Variation in colour values with respect to storage days.

The L\* value (lightness) is an essential indicator of the color changes during banana ripening, reflecting the transition from green to yellow and eventually to brown as the fruit ripens. A higher L\* value indicates a brighter color, while a lower L\* value suggests darkening or senescence. During ripening of banana, the L\* value continuously decreased from 82.61 to 65.00 with respect to storage period of 2 to 8 days and then slightly increased to 79.02 at 12 days. Similar results were observed by Salvador *et. al.* (2007) on ripening the banana fruits. The a\* value represents the red-green color balance in bananas during ripening. Negative a\* values indicate greenness, while positive values indicate yellowing and eventual browning. During banana ripening, the a\* value continuously increased from 0.39 to 2.73 with respect to storage period of 2 to 6 days and then start decreasing from 1.95 to 0.43 for 8 to 12 days. The b\* value is a key indicator of banana pulp color development and ripening progression. In the control sample of banana, the b\* value gradual increased from 17.42 to 20.80 with respect to storage period of 2 to 12 days and in between on 8th day b\* value slightly reduced to 17.41 and then again increased (Fig. 3.).

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| 2nd day of storage | 4th day of storage |
|  |  |
| 6th day of storage | 8th day of storage |
|  |  |
| 10th day of storage | 12th day of storage |
| Fig. 4. Physical appearance of banana at different days of storage | |

**4. CONCLUSION**

In the study of ripening behaviour of banana (Cv. G-9) the fruits were ripened by natural methods *i.e.* without application of any artificial ripening agent. It was observed that natural ripening takes up to 12 days of ripening period. It was also observed that after 12 days of storage firmness of fruit reached to 7.96 N and pH reached to 5.26 which indicate the desired ripening but the value of TSS (18.07 °B) and colour value (L\* - 79.02, a\* - 0.43 and b\* - 20.80) does not indicate the complete ripening.

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