DOI : 10.5958/0974-0112.2020.00077.8

Indian J. Hort. 77(3), September 2020: 532-540

Influence of caliper grade threshold and storage environment on the postharvest behaviour of Red Banana (AAA)

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ABSTRACT

Red Banana is one of the important traditional banana varieties with unique characteristics of reddish-purple skin colour, good flavour, taste, nutrients coupled with higher export value. The study was undertaken to standardize the harvest maturity and storage environment for the Red Banana to different market destinations. Different maturity level of (70%, 80%, 90% and 100%) Red Banana was harvested and then stored at cold temperature (13.5ºC±1ºC) and room temperature (28.5ºC±2ºC). The observations were recorded at 10 days interval during storage. The results revealed that 70% maturity (40-44 mm caliper), recorded shelf life of 72 to 77 days, whereas 80% maturity (44-48 mm caliper) maintained about 65-70 days, 90% maturity (48-52 mm caliper) was 57 to 62 days and 100% maturity (52-56 mm caliper) showed 32 to 40 days shelf life. At room temperature, Red Banana exhibited shelf life upto 18 days, 16 days, 14 days and 10 days at 70, 80, 90 and 100% maturity respectively. The chroma value, pulp to peel ratio, sugar and acidity increased with the maturity whereas the firmness and shelf life decreased. For export market, the fruits with 46-50 mm caliper with 80-90% maturity could be harvested to have the better shelf life without compromising on the bunch weight and quality. Low temperature storage of vacuum packaged banana could maximize the beneficial effects without impeding the sensory quality.

Key words: *Musa* spp., export, green life, ethylene, package, storage.

INTRODUCTION

Banana is an important commercial fruit crop, consumed all over the world for its balanced pack of nutrients and quick release of energy. It is cultivated in more than 120 countries with the production of around 155 million tons, export trade value of US$ 12 billion (Approx. Rs. 80000 crores). Cavendish banana occupies more than 60 % of banana cultivation and is the major variety being exported in the banana market with the catchment of North America, Europe and part of Asia. Columbia, Ecuador and Philippines are the dominant players in the Banana trade (Suresh Kumar *et al.,* 14). India is the largest producer of banana, with a production of 31.75 million tons, from 0.8 million hectares, contributing 2.3% of agricultural GDP (Gross Domestic Product), value of US$8 billion (Approx. Rs. 60000 crores) and occupies 13 per cent of the total area under fruit crops. However, India's total export of fresh banana is very meager with the value of Rs. 415.06 crores, contributing less than 0.4% of world banana trade. Due to weather vagaries, diseases like Tropical race 4 in other major banana exporting countries, India has a greater chance to enhance its export trade to the value of US$ 3 billion over the years (NHB, 8).

With the presence of Indian diaspora, the export of ethnic banana varieties like Red Banana (AAA syn: Lal velchi), Nendran (AAB syn: Aethan) and Ney Poovan (AB syn: Elakki, Kadali) to foreign market offers a greater scope to enhance the foreign exchange. The Red Banana (AAA) is one of the important varieties, highly in demand and fetches premium price due to its unique fruit characteristics like taste, flavour and reddish-purple skin and higher carotenoid content (19.7 µg/g) than the commercial Grand Naine (0.54 µg/g) (Lokesh *et al.,* 10). The maturity stage of the harvested bananas plays an important role in determining quality such as fruit weight, shape, pulp to peel ratio, shelf life and market price. Quality is an important factor in the marketing of banana, especially when intended for fresh consumption. Being a climacteric fruit, banana is generally harvested at unripe full maturity stage. Banana produces high levels of ethylene itself, which triggers the ripening process, characterized by the rapid softening of the internal and external tissues of the banana, which influences its shelf life, physicochemical characteristics and market price considerably (Ahmad *et al.,* 1).

Reduction of postharvest loss of banana from the present 22-25% to less than 10% coupled with better shelf life could be achieved by selecting the right

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maturity stage, scientific handling process (grading, washing, use of disinfectant, fungicides), packaging techniques (active packaging, vacuum sealing) and manipulation of environmental conditions. However, in spite of the commercial potential of Red Banana, unlike Grand Naine, the fruit quality parameters like caliper level, fruit characteristics and postharvest treatments are not standardized which hampers the exploitation of this unique banana for the export market. With this background, considering the importance of standardizing the caliper threshold and other fruit parameters for the export of Red Banana, the present study was designed to evaluate the effect of maturity and storage environment on the shelf life of Red Banana and to define the codex standards for boosting the banana trade.

MATERIALS AND METHODS

Scientifically cultivated, well maintained, fruits orchard was selected in the farmer's field at Theni, Tamil Nadu where commercial cultivation of Red Banana is being followed. Fruit trees were tagged on the day of spike emergence with different coloured ribbons to facilitate the harvesting of bunches with different maturity. With ten trees per replications, 50 trees were tagged for each maturity and thus totally 200 trees were tagged for four different maturities. The maturity of the hands was corroborated with days from flowering *vis a vis* that the fruit were harvested on 70% maturity: 85-90 days (40-44 mm); 80% maturity: 95-100 days (44-48 mm); 90% maturity: 105-110 days (48-52 mm) and 100% maturity: 115-125 days (52-56 mm) were showed in Table 1. Second hand from the top was selected to read the caliper measurement of the fruits using dial reading caliper (QA Supplies, LLC, Norfolk, VA). The banana bunches were harvested according to the maturity and cut into individual banana hands (16 - 18 fruits/ hand) with enough crown, packed in cushioned plastic crates in single layer, covered with foam paper to avoid latex staining on the fruit skin, and then brought to ICAR- National Research Centre for Banana for further studies.

Table 1. Days to maturity and caliper grade of Red Banana at different level of maturity.

Maturity level (%)	Number of Days (Shooting to harvest period)	Caliper (mm)
70	85 – 90	40-44
80	95 – 100	44-48
90	105 – 110	48-52
100	115 – 125	52-56

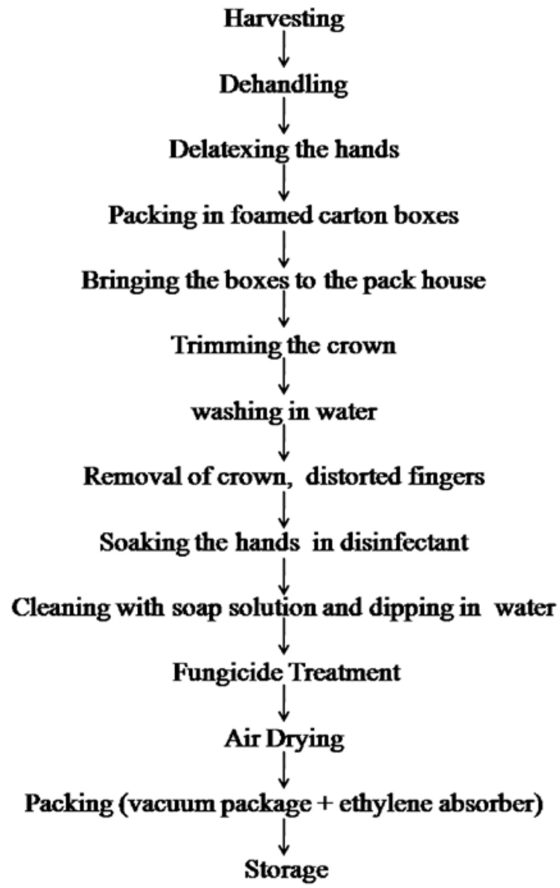


Fig. 1. Postharvest handling protocol for Red Banana.

The schematic illustration of the various postharvest treatments to be followed is presented in the Fig. 1. In brief, the fruits were cleaned, the hands are clustered to smaller units of 7-8 fruits and immersed in the water. Poorly developed, mechanically injured and blemished fruits were discarded to maintain the uniformity according to the treatments.

Later the fruits were treated with tap water containing 0.01% sodium hypochlorite and dipped in Carbendazim (0.2%) for 5 minutes and then drained, air dried to remove the moisture adhered on the skin and vacuum packed after keeping the ethylene absorber in the each box. The packed boxes were kept in two storage environments namely cold storage (13.5±1°C, 88±2% relative humidity) and ambient temperature (28.5±2°C, 65±2% relative humidity). The boxes were withdrawn at 10 days interval for all the treatments and the experiment for the particular treatment was terminated when the fruit pulp becomes firm and soft. The specific gravity of the fruits was determined by using the platform scale method (AOAC, 2). The fruit weight (g), pulp and peel weight (g) was measured by using electronic weight balance. The pulp to peel ratio was determined by dividing the weight of pulp to peel, fruit length (cm) and circumference (cm) were also recorded. Ten fruits from each box were randomly taken for each replication and have been observed over the period of storage. The colour (L, a*, b*) of banana peel was measured using Chromameter (CR – 400, MINOLTA CO., LTD, JAPAN). Chroma and hue values were calculated. Firmness and elasticity was determined by using a texture analyzer (Stable Micro Systems, TA-TX Plus, Surrey, UK.) using a 10-kg load cell and the corresponding application program provided with the apparatus. The working conditions during the measurements were; mode-measure force in compression, pre-test speed 1.5 mm/s, test speed 1.0 mm/s, post-test speed 10mm/s trigger type-auto 5 kg. 2 mm cylinder probe (P/2) was used for the experiment. The fruit was kept in the most stable position on a heavy-duty platform and the readings were taken at the apical, middle and basal part of the fruit. The mean of the three readings was calculated as a measure of firmness (N) for each fruit.

The total soluble solids content was determined by using digital refractometer (JS7, RUDOLPH Research, Hackettstown, NJ). Titratable acidity was estimated by titrating a known amount of pulp against the 0.1N sodium hydroxide solution using phenolphthalein as an indicator and was expressed as citric acid equivalent (AOAC, 2). Homogenized pulp was used for the estimation of total sugar and starch content of fruit (Ranganna, 12) through spectrometric methods (UV-3200 Double beam spectrometer).

The treatments at the end of the green period were withdrawn and kept in the ripening chamber and 100 ppm of ethylene was infused for 24 hrs (18 ± 2°C; RH: 85± 2) and then the fruit kept in 22 ± 2°C for 24 hrs. Sensory attributes specific to banana were defined namely colour, dark spots of banana peel, firmness, pulp spots, after taste, flavour, over-ripe zones, sweetness, astringency and over all acceptability (OAA). The descriptors were judged by giving the samples to untrained participants with age group of 22 – 60, using 9-point hedonic scale.

The data obtained in the present study was subjected to completely randomized block design (CRBD) analysis using an analysis of variance (ANOVA). All the experiments were conducted in triplicate and the values are reported as mean value ± standard deviation. Duncan's multiple range test was used to establish the multiple comparisons of the mean values at 95% confidence level ($p<0.05$). SPSS version 21 for windows (IBM SPSS Inc., Chicago, IL) statistical software was used for all statistical analysis. Origin 8.5 version, (OriginLab) software used for graphical representation and Exponent connect software used for texture analysis.

RESULTS AND DISCUSSION

The physical and chemical characteristics of the fruits of different maturity of the Red Banana are presented in Table 2. There was a significant increase in finger weight between 70- 100 %, maturity after bunch emergence, as 171.59 (35.08%), 199.82 (58.16%) and 210.15g (66.33%) in 80%, 90% and 100% maturity when compared to 70% of maturity of Red Banana. The finger length increased gradually throughout the fruit development. The increase in fruit length was not significant after 90% maturity. The mean finger girth of 13.83 cm, 15.03 cm 15.90 cm and 16.03cm were noticed at 70, 80%, 90% and 100% maturity of Red Banana. A significant increase in finger girth was noticed until 100% of maturity. Pulp weight increased significantly during the entire fruit development period and the highest increase was in 90% and 100% maturity after bunch emergence. Pulp to peel ratio also increased with the increase in maturity. The increase was exponential during the period of 70-90% maturity and it was marginal between 90-100% maturity. The pulp yield is an important parameter for the consumer acceptance and the consumption of banana. Maturity which offers the highest pulp weight could be preferred by the farmers, traders as well as consumers (Aquino *et al.,* 3). The specific gravity of fruit was 0.94 at 70% maturity. After that it increased significantly and recorded 1.14 with at 100% maturity. The specific gravity of above one is generally preferred in the banana trade.

Firmness and elasticity showed the fruit texture characteristics over different maturities. Both decreased with the advancement of maturity. Room temperature stored fruits showed abrupt decrease in firmness than the cold stored fruits. Firmness decreased from 18.08 N at 70% maturity to 14.93 N at 100% maturity. Elasticity was 4.69 mm at 70% maturity after bunch emergence, which decreased to 3.1mm at 100% maturity. These results could be explained by the difference in starch content with varying maturity and storage environment. Presence of starch, enzymatic degradation of pectic components of the cell wall and middle lamella, conversion of starch into sugars influences the firmness of the fruits (Garcıa *et al.,* 6).

Though the visual colour is not the right parameter to judge the maturity in case of Red Banana, it turned from dark red to purple brown over the period of maturity. Based on the maturity stage, the lightness (L) increased from 32.64 to 34.73, whereas, a* value decreased from 5.19 to 2.37. The change of

Table 2. Physicochemical characteristics of unripe Red Banana at different maturity at harvest.

Parameters		Maturity			
		70%	80%	90%	100%
Fruit weight (g)		126.34 ± 6.06	171.59 ± 4.51	199.82 ± 2.20	210.15 ± 2.44
Fruit Length (cm)		16.56 ± 0.40	18.73 ±0.46	20.70 ± 0.82	19.73 ± 0.64
Fruit Girth (cm)		13.83 ±1.04	15.03± 0.04	15.90 ± 0.06	16.03 ±0.50
Caliper (mm)		41.73 ±0.62	44.37 ±1.18	50.15 ±1.20	53.15 ±1.05
Pulp weight (g)		68.33 ± 2.53	97.35 ±3.48	128.68 ±2.62	135.68 ±5.73
Peel weight (g)		57.94 ± 3.73	74.11 ± 1.84	70.94 ± 0.64	70.21 ± 0.66
Pulp peel ratio (PPR)		1.17 ± 0.03	1.31 ± 0.04	1.81 ± 0.05	1.91 ± 0.09
Firmness (N)		18.08 ± 0.38	17.86 ± 0.80	15.67 ± 0.56	14.93 ± 0.92
Elasticity (mm)		4.69 ± 0.18	4.11 ± 0.12	3.2 ± 0.16	3.1 ± 0.16
Specific Gravity		0.94 ±0.01	1.00 ±0.03	1.02 ±0.10	1.14 ± 0.10
Colour value	L	32.64 ± 0.55	34.91 ± 0.78	33.43 ± 0.64	34.73 ± 0.81
	a^*	5.19 ± 0.13	3.65 ± 0.27	2.24 ± 0.20	2.37 ± 0.25
	b^*	17.97 ± 0.55	19.20 ± 0.29	19.31 ± 0.91	18.98 ± 0.44
Chroma		18.70± 0.68	19.54± 0.54	19.43± 0.37	19.12± 0.81
Delta E		37.61± 0.51	40.01± 0.19	38.67± 0.34	39.64± 0.54
Moisture (%)		65.4 ±1.15	66.3 ±0.89	65.89 ±1.02	68.6 ± 0.95
TSS (ºBrix)		4.05 ± 0.01	4.84 ± 0.57	5.29 ± 0.47	5.73 ± 0.25
Acidity (%)		0.14 ±0.03	0.14 ±0.01	0.14 ±0.02	0.15 ± 0.01
Total sugars (%)		1.43 ± 0.04	1.50 ± 0.10	1.68 ± 0.08	1.81 ± 0.12
Total starch (%)		25.29 ± 0.47	25.20 ± 0.88	24.60 ± 0.59	24.53 ± 1.12

banana skin color from reddish purple to light red and green streaks turned to yellowish streaks in Red Banana with varying maturity. The change of green to yellow skin is due to the degradation of chlorophyll (green pigment) and synthesis of carotenoid (yellow) pigments. Typically, in Red Banana, thin layer (0.1mm) of red pigment (lutein, anthocyanin, carotenoids) is present over the top layer of the skin whereas the yellow pigment is presented in the bottom layer like other banana varieties. These colour pigments gets expressed depending upon the maturity and the growing condition of the crops (Wills *et al*., 15). Similar observations were also recorded by Chang *et al.* (5) in banana which was attributed to high tannin content in fruits of lower maturity.

The TSS content of the unripe fruit pulp ranged between 4.05 and 5.73°Brix during fruit development. Acidity content in the raw fruit decreased over the maturity however the change was non-significant. The total sugar content in planta also varied from 1.43 to 1.81% with the different maturity. The starch content of the Red Banana did not change significantly with different maturity. Generally, the fruit growing conditions, cultivation practices followed and disease control systems at field level greatly influences the physic chemical parameters of the Red Banana (Brat *et al*., 4).

Effect of maturity level on changes in physical characteristics during storage is presented in Fig. 2. The pulp to peel ratio (PPR) increased from 1.16 to 1.54 at 70%, 1.32 to 1.63 at 80%, 1.77 to 2.23 at 90% and 1.72 to 2.48 at 100% at the end of 70, 60, 50 and 30th days of storage when stored at cold temperature (13.5ºC). In case of room temperature, the PPR enhanced from 1.52 to 2.23 in 100% followed by 90% (1.77 to 2.08), 80% (1.32 to 1.77). Low pulp peel ratio was observed at 70% (1.16 to 1.81). The PPR increased linearly over the storage period for all the maturities. Increase in the maturity stage of the Red Banana had positively influenced the pulp peel ratio. Increase in PPR of banana is related to the accumulation of more storage material i.e starch, moisture in the pulp derived from carbohydrate breakdown and osmotic transfer of water and other solutes from the peel (Kudachikar *et al.,* 9). In general the change in PPR was more at the end of storage in low temperature than room temperature.

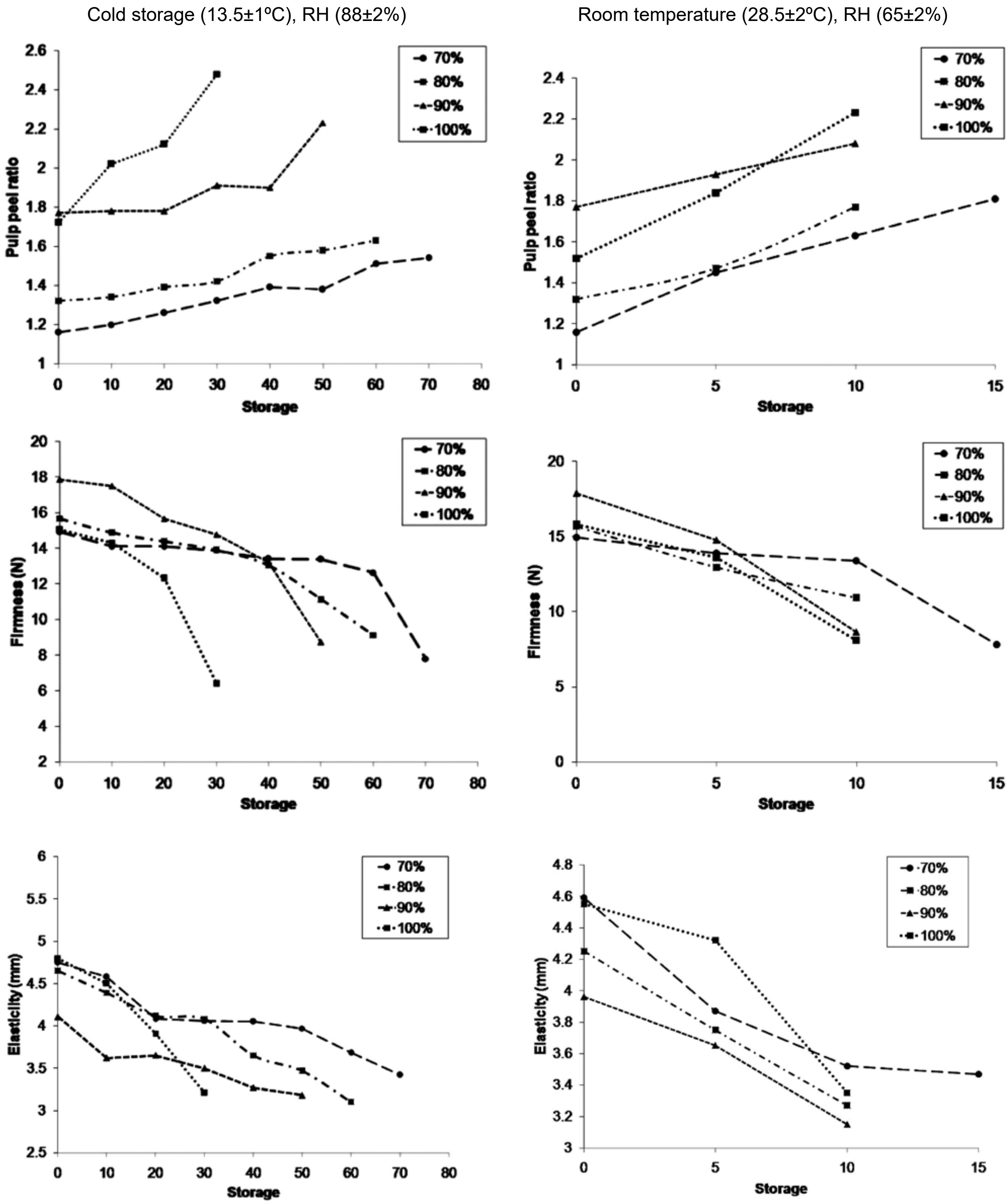
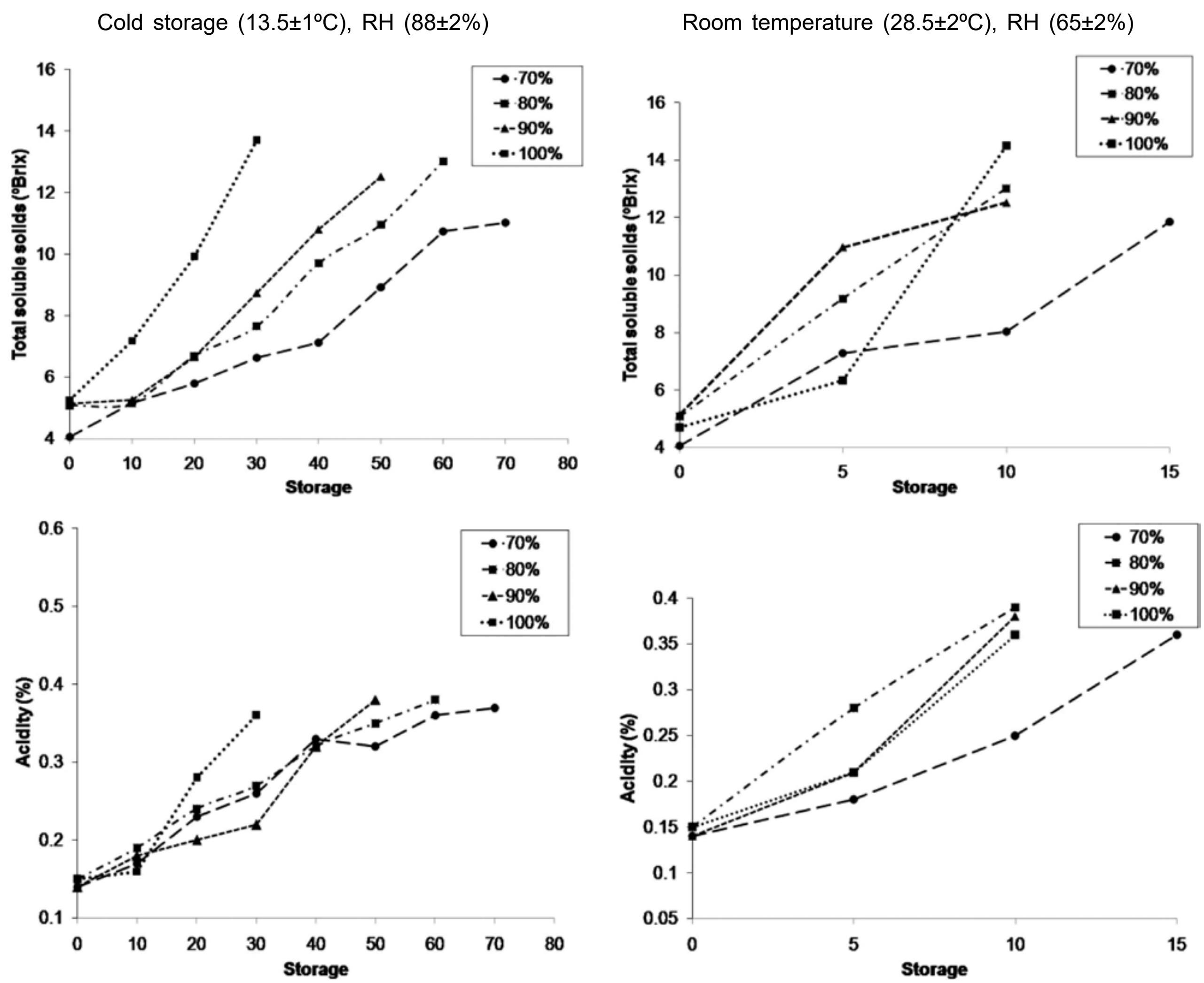


Fig. 2. Effect of different maturity of Red Banana on physical characteristics during storage period.

The firmness of the Red Banana decreased (57.35%) at 30th day in 100% maturity while it was least (47.7%) in 70 maturity at 70 day of cold storage. The room temperature stored fruits lost their firmness by 10-14th day depending upon the maturity. The firmness of the fruits decreased linearly over the storage periods irrespective of the maturity. However, the reduction was more predominant with higher the maturity. Similarly with the texture analyser, it was observed that the highest value of elasticity (4.75, 4.65, 4.11 and 4.70 mm) was recorded for the fruits at 100%, 90, 80 and 70% maturity respectively during the initial period. The fruits lost its elasticity by 30th day in 100% (3.21 mm), 50th day in 90% (3.18 mm), 60th day in 80% (3.20 mm) and 70th day in 70% (3.62 mm). In this study, the elasticity losses were significant between storage, maturity and their interaction. The changes in the physicochemical parameters during fruit maturity have reshuffled the starch into sugar, breakdown the pectin components and the movement of water from the skin to the flesh of the fruit at the time of maturation process (Harker *et al.,* 7; Ahmed *et al.,* 1) are the main reason for altering the textural characteristics.

Effect of maturity level in chemical characteristics during storage presented in Fig. 3. The total soluble solids (TSS) of fruits varied significantly with the maturity and storage environment. It increased from 4.07 to 11.03 °brix at 70th day, 5.08 to 13.02 °brix at 60th day, 5.15 to 12.52 °brix at 50th day and 5.27 to 13.70 °brix in 30th day with 70%, 80%, 90%, and 100% maturity respectively. The highest mean value of the TSS (8.77) was observed at100%maturity whereas it was lower with 70% (7.32°Brix) maturity.Similarly, fruits when stored at room temperature showed increase in TSS (5.12 to 12.52) at 90% maturity, (5.08 to 13.02) at 80% maturity significantly. The change in moisture content significantly influenced the TSS content as it was correlated to increase in sugar content by hydrolysis of starch at different per cent of maturity (Mohapatra *et al.,* 11). The fruits stored at room temperature recorded higher TSS than low temperature stored fruits irrespective of the maturity.

The acidity significantly increased (0.14 to 0.37%) at the end of storage days with different



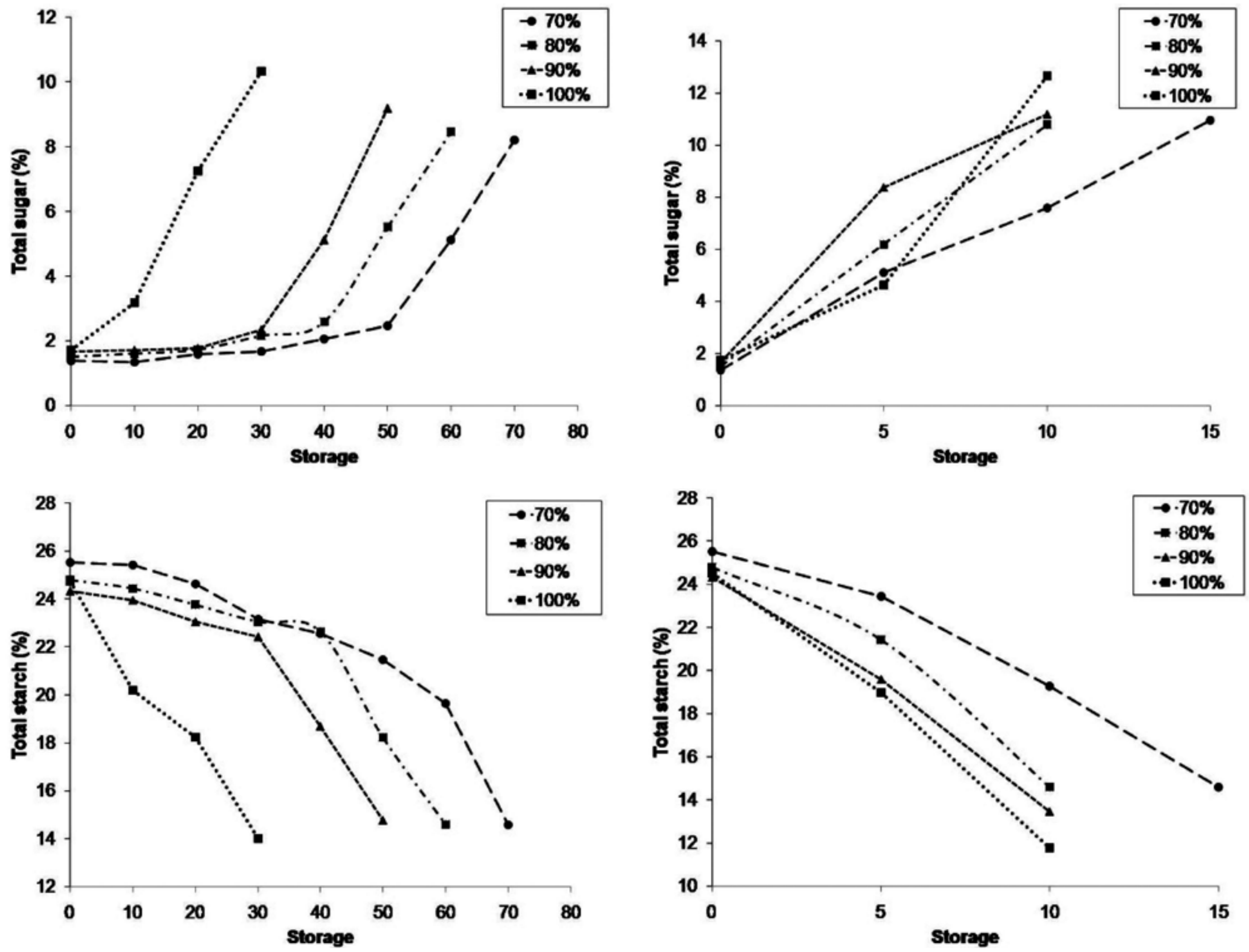


Fig. 3. Effect of different maturity of Red Banana on chemical characteristics during storage period.

maturity. Higher the maturity showed the higher acidity irrespective of the storage periods. An increase in acidity content at the time of ripening was due to the presence of organic acids like malic, citric and oxalic acids. The increase in acidity might be due to excess bio-synthesis of oxalic acid in green bananas and with the advance of maturity, oxalic acid content decreased while malic acid bio-synthesis predominated and also, these acids were reduced, which leads to degradation of starch from hydrolyzed of sugar (Ahmad *et al.,* 1).

Total sugars content in the fruit was inversely correlated with the starch content. The varying maturity namely 70%, 80%, 90%, and 100% recorded the initial total sugar of 1.38, 1.51. 1.68 and 1.72 per cent (Figure 3) respectively when the packs stored at low temperature. At the end of storage period, the fruits with 100% maturity showed higher total sugar content (10.32%) than the fruits with 70% maturity (8.20%). Between the storage environments, total sugar content more with room temperature stored fruits (12.66%) at 100% maturity. Presence of amylase and phosphorylase has highly interacted with starch substrates at different maturity stages which led to increased level of reducing and total sugars during ripening and storage condition. Starch is the primary energy reserve factor for climacteric fruits and is synthesized in amyloplast during growth. At unripe condition, the banana is having a 20-25% starch content, which is quickly degraded into sugars at the time of ripening (Seymour *et al.,* 13).

The shelf life of the Red Banana is presented in Fig. 4. Fruits harvested at 70% maturity showed maximum green life of 74 days compared to 100% maturity (32 days). Fruits with the caliper threshold of 48-52 mm with 90% maturity showed the green life of 59 days whereas the 80% maturity exhibited 65 days of green life. The fruits stored at room temperature showed the green life in the following descending order; 18 days (70%) >16 days (80%) >

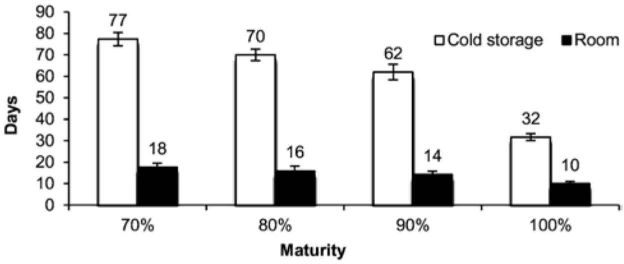


Fig. 4. Effect of different maturity level on shelf life of Red Banana.

14 days (90%) and 10 days (100%) with the different maturity.

Descriptive score for sensory characteristics evaluated at different maturity and storage conditions is presented in Fig. 5. There was a significant difference ($p<0.05$) between sensory characteristics viz., colour, dark spots of banana peel, firmness, pulp spots, after taste, flavour, over-ripe zones, sweetness, astringency and over all acceptability (OAA) of the fruits at the end of storage life in both room temperature and in cold storage with varying maturity. The fruits with 90 and 100% maturity, stored under cold storage condition exhibited higher sensory score over other maturity levels. Dark spot a negative descriptor, was identified more with 70 and 100% maturity. Similarly pulp spot and astringency values were also higher with fruits which were harvested earlier. This may be due to hindrance and arrest of conversion of starch to sugar and improper starch hydrolysis. The positive attributes like colour, firmness, after taste, flavor, sweetness and over all acceptability were more with 90 and 100% maturity. Though the fruits had a longer green life with 70 and 80% maturity, the fruits, did not attain the consumer accepted level of fullness and emitted musky flavour which was not accepted by the panellists. The banana fruits with more intense and bright colour

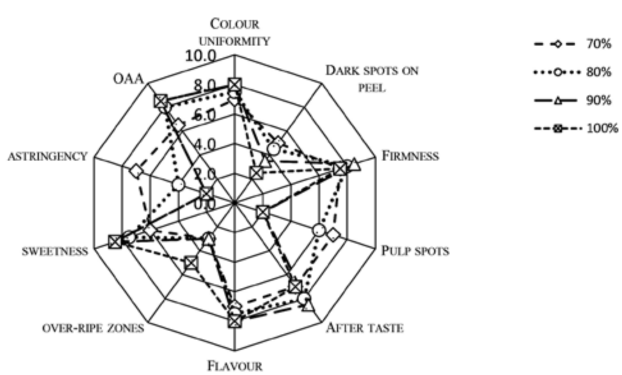


Fig. 5. Effect of different maturity on descriptive score of Red Banana.

(Red yellow peel) coupled with soft texture seems to be more attractive and exhibited higher preference index by the panellists this was exhibited with 90 and 100% maturity.

From the study, in spite of higher green life of fruits harvested earlier (70% maturity), it showed very low PPR with lesser fruit weight which in turn affected the bunch weight and the price realization. The study proved that low-temperature storage of vacuum packaged banana has maximized the beneficial effects without impeding the sensory quality. Therefore, identifying the optimum harvest maturity stage (80 – 90%, 100-105 days) for Red Banana is pre-requisite to tap the export market. We, therefore, summarize that the Red Banana fruit with the following specifications; Fruit weight 185.59±14.00 g, fruit length 16.73± 2.67 cm, fruit girth 15.03±1.04 cm, caliper grade 46-50 mm and PPR 1.71±0.86 could be chosen for the distance market like Europe without compromising on the price realization with better shelf life (50-60 days) when stored under low temperature of 13.5±1°C with the RH of 85-90%.

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(Received : April, 2020; Revised : August, 2020; Accepted : August, 2020)