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Influence of temperature on natural ripening of mango

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ABSTRACT

The aim of the study was to investigate the effect of different temperature regimes on natural ripening quality of mango cv. *Arka Aruna*. Fruits of optimum maturity were subjected to ripening at three different temperatures (18, 25 and 40°C) and controlled RH (92 to 93%). The stored fruits were analysed for its physico-chemical attributes on 1st, 3rd, 5th, 7th, 9th and 11th day of storage. Results indicated progressive decrease in firmness, titrable acidity (TA) and ascorbic acid with the advent of ripening whereas physiological loss in weight (PLW), β-carotene, total soluble solids (TSS), total sugar, reducing sugars and hue angle increased with the progression of ripening. Fruits stored at 18°C retained good quality and was acceptable till the 11th day of storage. However, those stored at 25°C and 40°C lasted only for 7 days and 4-5 days respectively. Pearson correlation analysis exhibited a relationship of increasing trend of β-carotene, total soluble solids (TSS), total sugar, reducing sugars and hue angle with the advancement of ripening. However, firmness, titrable acidity (TA) and ascorbic acid followed relationship of decreasing trend with the advancement of ripening. Besides, principal component analysis (PCA) was conducted for overall variability of the quality attributes and found that ascorbic acid contributed to maximum variation in the ripening parameters of fruit.

Key words: *Mangifera indica* L., ripening, temperature, storage

INTRODUCTION

Mango (*Mangifera indica*, L) stands as one of the most important fruit crops of India owing to its unique flavour, soothing aroma, pleasant taste and high nutritional value. It is grown in 2.26 million ha across India with an annual production of 21.82 million tonnes (Agricultural Research Data Book 2020 of ICAR). It is the most important fruit of India because of special characteristic flavour, pleasant aroma, taste, and nutritional value. In India, mango is consumed both as ripe and raw and used for preparation of various products such as chutney, pickles, juice, RTS (Ready to Serve) etc. apart from being delicious, mango is a good source of prebiotic dietary fiber, vitamins, minerals and polyphenolic flavonoid antioxidant compounds along with less amount of protein, fats and other nutrients. (Ara *et al*., 1).

Harvesting of mango is usually done at physiological maturity which has low soluble solids content as well as high acidity that results in poor eating quality. Once the fruits get harvested, the fruits can undergo artificial ripening using various chemicals or may be allowed to ripen naturally during storage. When allowed to ripe naturally, the temperature has a greater impact on the several biochemical pathways associated with ripening. It involves a series of metabolic changes that induces faster respiration, chlorophyll degradation, synthesis of carotenoids, conversion of starch to sugars causing softening of fruit. (Gill *et al*., 4). Under natural ripening, fruits get exposed to a wide range of temperature depending on the stage and type of cultivars with the optimum being considered as 18-24°C (Singh and Mathur, 18). However, optima above and below this range is also possible. Vietanamese mango cv. Cat Hoa Loc reported optimum ripening temperature to be 21-24°C (Thinh *et al.*, 19), Australian mango cv. Kensington was found to be more acidic when stored below 18°C and reduced color and sugar development when stored at >24°C (Hare, 6).

Many research studies have been conducted on the use of ripening aids for artificial ripening of mango (Rathore *et al*.,16, Islam *et al*., 8, Doreyappy *et al*., 4). However due to climate change, temperature during mango harvesting season have been shown an unusual increase. Information on the influence of temperature on natural ripening of mango are either scanty or not available. Temperature during ripening is very important for biosynthesis of carotenoid pigments leading to development of both external and internal colour (Palafox-carlos *et al*., 14, Khilladi *et al*., 10). Thus, optimum temperature is a crucial factor determining the quality as well as shelf life of fruits which also depends on the cultivar type as

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well as the agro climatic zone where it is grown. Therefore, this study mainly focused on the effect of different storage temperatures on physico-chemical characteristics of Cv. Arka Aruna with progress in ripening.

MATERIALS AND METHODS

The experiment was conducted at Division of Food Science & Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi in the year 2022. Physiologically mature, uniform sized mango fruits cv. Arka Aruna were hand harvested in early morning from CHES, Bhubneswar, regional station of ICAR-IIHR and immediately transported to the lab in 24 hrs. Fruits were sorted to remove any externally defective fruits or over ripe ones. Sorted fruits were washed with chlorinated water (sodium hypochlorite 4% @2.5 ml/l) to remove surface borne infections and air dried. Fruits were then divided into three experimental lots and packed in ventilated (5%) corrugated fibre board boxes for temperature treatments.

Three lots of fruits were placed in Temperature and RH (95%) controlled chambers. The first one was placed at 18°C, second at 25°C, third at 40°C. The physico-chemical analysis of the fruits from each lot was taken at an interval of 2 days for a storage period till the fruits obtained optimum ripening acceptable by consumers.

The post-harvest ripening indices are a measure of change in physiological loss in weight (PLW), pulp firmness, total soluble solids (TSS), titratable acidity, β-carotene, ascorbic acid, total and reducing sugars of pulp which were recorded in the study.

PLW of fruit was determined on the basis of initial fresh weight and the final weight of fruits and expressed as percentage loss.

$$PLW = \frac{W_i - W_f}{W_i} \times 100$$

PLW is the physiological loss in weight (%), W_i (g) and W_f (g) are the initial and final weights, respectively.

Firmness was measured by Texture Analyzer (Stable Micro Systems, UK) using P/2–2 mm diameter stainless steel cylinder probe in compression mode with pre-test, test and post-test speed of 2, 1 and 2 mm/s, respectively, as per method referred by Jha *et al.*, 6. A 500kg load cell was used for determining force during compression and the measured force acquisition rate was set at 400 points per second.

TSS was determined with help of hand held digital refractometer (ATAGO, PAL-1, Japan). Fruits pulp was meshed and juice obtained was filtered through cheese cloth, with one to two drops placed on prism of refractometer to note the reading and expressed in °Brix. For determination of TA, two ml of strained juice was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator and expressed in percentage. β-carotene content of fruit pulp was extracted with acetone and petroleum ether by following the method described by Ranganna,13. The colour intensity of b-carotene eluent was measured at 452 nm using petroleum ether as blank. b-carotene content was expressed as mg/100 g of pulp. The common chemical parameters such as Vitamin C, titratable acidity, reducing sugar, total sugar were also estimated by the methods indicated in the Manual of Analysis of Fruit and Vegetable Products (Ranganna,15).

The data recorded from the experimental investigation were put to statistical analysis using statistical package SAS 9.3 (The SAS system for Windows, Version 9.3, SAS Institute, Cary, NC). For this study, two factors such as temperature and storage days was laid out in completely randomized block design (Factorial) with seven replications with 20 fruits per replication and data were analyzed for analysis of variance (ANOVA) using Tukey's HSD ($p<0.05$) for significant difference test. Results were expressed as mean ± standard deviation. Further, data was also used for Pearson correlation analysis to find out the correlation between variables and principal component analysis (PCA) to predict the variability.

RESULTS AND DISCUSSION

With progress in ripening, the weight loss of the fruits increased and reached maximum towards the end of storage days where the fruit obtained optimum ripening. (Fig. 1a). It was observed that PLW of the fruits was different for the fruits stored at different temperatures. The PLW values significantly ($p < 0.05$) increased from 0 to 8.54, 10.56 and 13.28% for fruits ripened at 18, 25 and 40°C during 11 days of storage. This physiological loss may be due to respiration, transpiration and other metabolic changes that releases heat by the evaporation of water from the fruit matrix and resulting in weight loss. Gill *et al*. (5) has also reported that PLW of the mangoes stored at room temperature of 29-33°C was higher as compared to lower temperature of 20 and 25°C. The higher weight loss at accelerated temperature causes shrivelling of fruits and shorter shelf life (Rathore *et al*., 16). However, the minimum loss was found in low temperature of 18°C at the end of 11 days and was at optimum ripening fit for consumption.

Firmness is one of the important key factors that influences the post-harvest quality of the climacteric

fruits. With respect to fresh fruits, various biochemical changes occur which results in loss of turgidity of cell wall during ripening. The firmness of the fruits decreased with increase in ripening days at all the temperature regimes. A significant decrease up to 5 days and 7 days were observed in samples stored at 40°C and 25°C although the values decreased till 5.96N and 8.02N at the end of 11 days. The firmness of the fruits decreased from 23.24 to 8.75N when stored at lower temperature of 18°C. This is because the insoluble proto pectin broke down to soluble pectin with increase in ripening that reduced the cohesive force of the middle lamella leading to permeability of the membrane and movement of water from skin to flesh of the fruit.(Zewter *et al*., 20).

TSS of the mango fruits increased with an increase in ripening till the end of 11 days at 18 and 25°C, however, the TSS values increased but were not significant after 5 days of storage when the fruits were kept at 40°C. Increase in TSS may be due to the enzymatic activities associated with conversion of starch to sugars on the onset of ripening. Results indicated that the TSS increased at a slower rate and increased up to 15.40° Brix over the ripening period when fruits were stored at a lower temperature of 18°C. Highest TSS of 17.50°Brix was obtained on 11th day of storage at 40°C but the fruit was acceptable till 5th day of storage (16.28°Brix). The fruits kept at 25°C exhibited significant increase in TSS from 10.24 to 15.99°Brix till 7 day of storage respectively. Barua and Mondal (3) also found that the mango cultivars *Fazli* and *Amrapali* also showed greater TSS with increase in storage days.

The change in acidity of the fruits with advancement in ripening at the three different temperature have been presented in Fig.1(d). Highest juice TA of 0.71% was recorded at lowest temperature of 18°C till the end of ripening period indicating minimum loss of TA as compared to the other two. Highest TA loss was obtained in fruits stored at accelerated storage temperature of 40°C (2.57 -0.41%) followed by storage at 25°C (2.54 -0.45%) and least by 18°C. The decline in acidity may be due to utilisation of the organic acids for respiration and other metabolic changes associated with ripening. It is well known that the TA declines and the TSS increases with maturity and progress of ripening stages of the fruit. (Padda *et al*.,13; Sajib *et al*., 17, Kim *et al*., 11).

The increasing trend of β-carotene with advance in ripening at different storage temperature is presented in Fig. 1e. A significant increase in β-carotene was obtained in mangoes stored at 18°C and the values were in the range of 0.11 to 2.10 mg/100g pulp. However maximum β-carotene content (0.12 – 2.18 mg/100g) was observed in samples stored at 40°C till 5th day of storage and then values were not significant. Storing at 25°C increased the values from 0.12 to 2.13 mg/100 g pulp till 9th day of storage. With the nearness to the ripening period, the β-carotene content increased at higher temperature compared to lower temperatures of 20 and 25°C. This might be due to increased mevalonic acid as well as synthesis of geraniol synthesis that led to the increased amount of carotenoids (Gill *et al*., 4). The development of yellow colour of the fruits on approaching ripening is an indication of loss of chlorophyll and increase in the carotenoids content (Liu *et al*., 12). The change in colour occurs as a result of the unmasking of the pigments present in the mature fruit (Kjilladi *et al*., 10).

The effect of different storage temperature on the Vit. C content of the fruits is shown in Fig.1(f). The results depicted that the Vit. C content decreased significantly with increase in storage days at all the three temperatures. For the fruits stored at 18^{o}C, the values significantly decreased from 29.62 to 19.45mg/100g fresh weight till 9th day and non-significant thereafter. The values decreased from 29.60 to 16.89 when storing at 25°C but was significant only till 7th day of storage. The least Vit.C. values of 16.14 was noticed in samples stored at 40^{o}C but significant values were obtained till 5th day of storage. This declining trend of Vit.C was also noticed in mangoes cv. Langra, Fazli, Khirsapat and Gopalbhog when harvested at different maturity stages and stored at storage temperature of 29-36°C (Azad *et al*., 2).

The variation of total sugars with respect to storage days is presented in Fig.1(g). Significant variation was observed in fruits stored at the three temperature regimes till reaching the optimum ripening. The results indicated that the total sugar content accumulated successively with an increase in storage duration. For the fruits stored at 18°C, the trend was sharp from initial to 11th day whereas for 25°C, the increase was sharp till 7th day and 5th day for fruits stored at 40°C. Maximum sugar content of 17.96%,17.30% and 14.75% was found on 11th day of storage at temperature of 40, 25 and 18°C. Similar results were also obtained by Islam *et al*. (2013) when storing mangoes for 12 days at room temperature. The increase in sugar content with ripening might be due to the conversion of complex starch or polysaccharides chains into simple compounds such as fructose, sucrose, galactose etc. (Hossain *et al*., 7).

The effect of different ripening temperatures on the reducing sugar content is summarized in Fig.1(h). The reducing sugar increased from 3th day

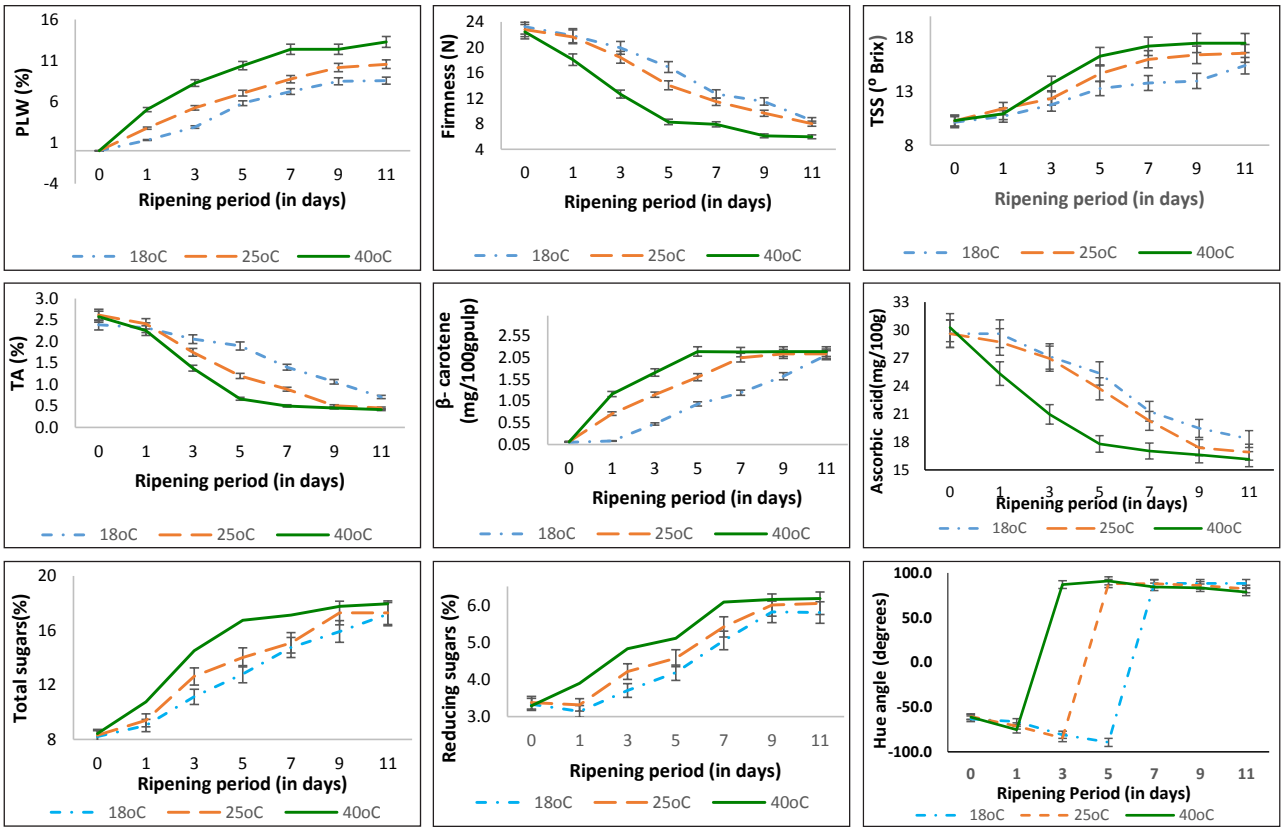

Fig. 1. Changes in Physio chemical attributes i.e. PLW (a), firmness (b), TSS (c), TA (d), β-carotene (e), Ascorbic acid (f), Total sugars (g), Reducing sugars (h),hue angle (i) of mango fruit with onset of ripening stored at different temperatures of 18, 25 and 40°C. Vertical bar represents mean ±SD of mean.

(3.70%) till end of storage on 11th day (5.80 %) when the fruits were stored at 18°C. Storage temperature of 25°C increased the values from 3.37 to 6.05 % whereas highest was achieved by 40°C where the reducing sugar content ranged from 3.29 to 6.18% over the entire storage period. These results are in agreement with Islam *et al*. (8) where reducing sugar of the mangoes increased with storage days. Thus, fruits ripened at 18°C maintained better fruit quality as compared to the fruits stored at 25°C and 40°C considering longer shelf life of 11 days of storage.

Apart from these, color is also an important parameter that determines the stage of ripening of fruit. The effect of ripening temperatures on hue angle (which is a measure of greenness of the fruit) is presented in Fig.1(i). All the storage temperatures showed a shift from negative to positive values indicating yellowing of the fruits over increase in ripening period. Fruits stored at 18°C had a shift in hue angle from -63.16 to 88.29° over a span of 11 days whereas storage at 25°C had the yellowing in 7 days and least was achieved at 5 days when stored at 40°C.

The Pearson's (Table 1) correlation was used to study the relationship among the various quality parameters of the fruits. Among all the parameters, highest positive correlation (r = 0.990) was found for Ascorbic acid and fruit firmness indicating the direct relationship between these two parameters during the ripening process whereas highest negative correlation (r= -0.994) was indicated by total sugar and firmness which shows negative relationship between the two parameters at a significant level of $p < 0.01$ (Fig. 2). Considering the other parameters, PLW had a good correlation with TSS, β-carotene, total and reducing sugars and high negative correlation with firmness, TA and Ascorbic acid. β-carotene had a high positive correlation (r > 0.901) with TSS, total and reducing sugars indicating that these values increase with the onset of ripening, moreover, had a negative relationship (r > -0.892) with firmness, TA and ascorbic acid respectively.

PCA (Principal Component Analysis) was conducted to have an overview of the changes in quality attributes with progress in ripening and also their corresponding contribution towards overall

Table 1. Pearson correlation coefficient of different quality parameters.

	PLW (%)	Firmness	TSS	Acidity	b-carotene	AA	TS
PLW (%)	1.000						
Firmness	-0.986	1.000					
TSS	0.948	-0.981	1.000				
Acidity	-0.978	0.988	-0.952	1.000			
b-carotene	0.975	-0.988	0.982	-0.987	1.000		
AA	-0.986	0.990	-0.980	0.973	-0.987	1.000	
TS	0.990	-0.994	0.985	-0.978	0.985	-0.988	1.000
RS	0.975	-0.977	0.935	-0.981	0.972	-0.984	0.969

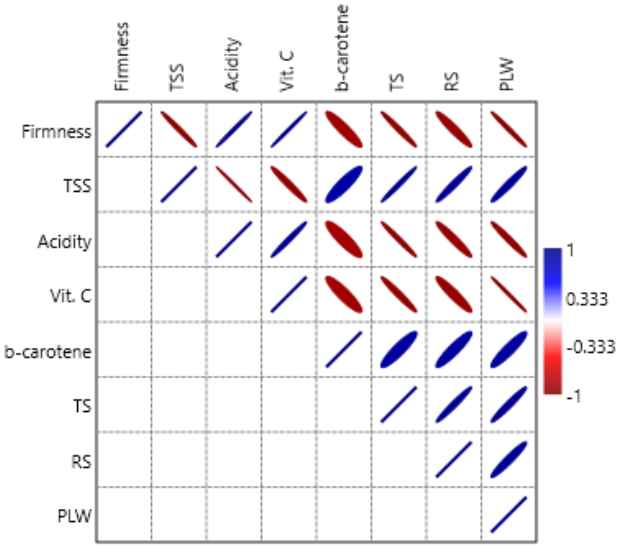

Fig. 2. Scatter plot matrix of different quality attributes of mango.

variability. The overall variability is interpreted by seven factors (F1-F6) as indicated in Table 2. It was observed that 90.8 % variance of total variation was contributed by factor one (F1) and the second factor (F2) was responsible for 9.11% of total variation. From the component pattern plot (Fig. 3), it clearly seen that the component 1 provided positive values for TSS, b-carotene, total and reducing sugars and negative values for Firmness, ascorbic acid, and titrable acidity. The positive values indicated that these quality attributes increased with progress in ripening whereas the negative values showed that the values decreased as the ripening approached. The presence of Firmness and Ascorbic acid in the same quadrant depicted the positive correlation between the two parameters. The scree plots (Fig. 4) also showed the maximum percentage of variability of Component 1 and Component 2 whereas F3, F4, F5 and F6 showed minimum variation with

Table 2. Principal component analysis of quality different quality factors.

PC	Eigen value	% of variance	cumulative %
1	6.357	90.808	90.808
2	0.638	9.118	99.926
3	0.003	0.039	99.965
4	0.002	0.027	99.993
5	0	0.005	99.9998
6	0	0.002	100

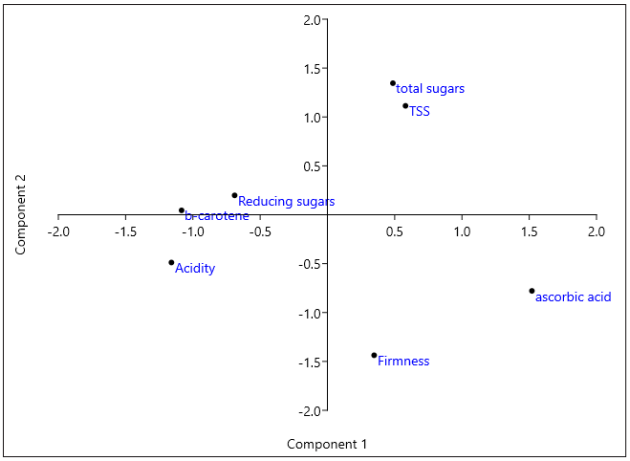

Fig. 3. Component pattern obtained from PCA of first two important factors (F1 and F2).

respect to the various quality parameters with onset of ripening.

This study gave a clear picture of the trend in quality parameters of the fruits with natural ripening at three different temperature regimes. The natural ripening could be an effective way for ripening of fruits as compared to the chemical treatments. Mangoes kept at 18°C required 11 days to attain optimum ripening whereas 25°C took 7-8 days and least of 5 days by 40°C. The mangoes could be safely ripened

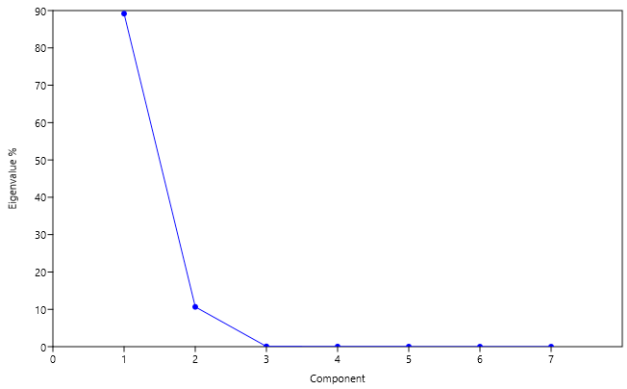

Fig. 4. Scree plot representing the percentage variation of the different components.

at the three mentioned temperatures based on the consumers need in the market.

AUTHORS' CONTRIBUTION

Collection of data, conducing experiment and statistical analysis (SP, AK), Planning & execution of experiment, data interpretation, manuscript finalization (AK)

DECLARATION

The authors declare that they have no conflict of interest

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