Physico-chemical changes during progressive ripening of mango (*Mangifera indica* L.) cv. Dashehari under different temperature regimes

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Abstract The effect of different temperature regimes on ripening quality of mango cv. Dashehari was investigated. Fruits were kept at 20, 25 °C in temperature controlled chambers and at room temperature. Fruits were analyzed periodically for physico-chemical characteristics after every 24 h interval up to 168 h of ripening period. Development of soluble solid contents (SSC), flesh softening and physiological loss of weight of fruits occurred progressively during ripening. Progression of ripening changes in fruit were found to be less at 20 and 25 °C than at room temperature. β -carotene content of pulp improved with ripening but declined after 144 h. Sensory quality (SQ) of mangoes ripened at lower temperature maintained for longer duration and were more acceptable than fruits ripened at room temperature. Pearson's correlation matrix studies showed the inverse relationship of quality parameters SSC, β -carotene and SQ with firmness and titratable acidity during progressive ripening of fruits. Further, principal component analysis for extensive view of changes in quality parameters and their contribution to overall variability revealed that sensory quality (F1) contributed to maximum variation in ripening indices of fruit.

Keywords Mango · Ripening · Temperature · Quality

Introduction

Dashehari, a mid-season mango is amongst one of the most popular variety of northern India due to its high yield potential and good fruit quality. Under prevailing conditions, it is harvested in the month of July when weather is hot and humid. Ripening of fruits on tree results in heterogeneous quality fruits in terms of its size as well as in sensory attributes. Hence, the fruit of mango is picked at mature green but unripe stage. Mango fruits at mature green harvest stage are hard in texture, possess low soluble solids contents, high acidity resulting poor edible quality. The ripening process of mango fruit involves a series of metabolic activities that cause chemical changes, increased respiration, change in structural polysaccharides causing softening of fruits, degradation of chlorophyll and carotenoids biosynthesis, hydrolysis of starch into sugars, thus leading to ripening of fruit with softening of texture to acceptable quality (Herianus et al. 2003). Excessive textural softening during ripening leads to spoilage of the fruits. At ambient temperatures, fruits exhibit a sharp rise in respiration and ethylene production after 3rd to 4th day of harvesting (Narayana et al. 1996), thereby restricting its consumer acceptance and post harvest life. Thus, primary aim of post harvest intervention is to contrive a method to induce homogenous ripening of mangoes and to reduce the loss along with maintaining the quality of produce. Various methods have been developed to induce post-harvest ripening of mangoes. Common method used in India is the use of calcium carbide salt due to its faster fruit ripening properties and its low cost. Calcium carbide releases acetylene which results in poor flavour and fruit quality (Siddiqui and Dhua 2010). But use of carbide to ripen fruits is associated with many health hazards and is now banned under Prevention of Food Adulteration (PFA) act. Another

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widely acceptable method involves the use of ethylene gas, however, lack of infrastructural facilities limited its use. Ripening of fruits through ethephon treatments and under controlled temperature regimes is also gaining acceptance (Singh et al. 2012; Jawandha et al. 2015). Temperature is an important factor affecting fruit quality and its shelf life (Nunes et al. 2007). Optimum temperature for ripening of Vietnamese mango cv. Cat Hoa Loc was reported to be 21–24 °C (Thinh et al. 2013). For Alphonso mango, temperatures below 25 °C adversely affected the development of aroma, flavour and carotenoid formation during the ripening (Thomas 1975). On the other hand, mango is highly sensitive to lower temperature storage below 10–13 °C due to chilling injury (Nair and Singh 2009). Thus, optimum temperature required for ripening of mango varied from cultivar type and agro-climatic conditions during growth and development of the fruit. Therefore, aim of this study was to evaluate the effect of different temperature regimes on physico-chemical characteristics of ‘Dashehari’ mango fruits during progression of ripening.

Materials and methods

Collection of samples and ripening conditions

The experiment was conducted at Department of Fruit Science, Punjab Agricultural University, Ludhiana, India during the year 2015. Physiologically mature, uniform sized ‘Dashehari’ mango fruits were hand harvested in morning hours from College Orchard, (30°89’N, 75°80’E, 247 amsl) and immediately transported to the Post Harvest laboratory. Fruits were sorted to discard any over-ripened, externally defected fruits. 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 fiber board boxes for temperature treatments.

Ripening conditions

Two experimental lots of fruits were placed in temperature controlled chambers, with first lot placed at 20 °C and the second one at 25 °C. The third lot of fruits was kept at room temperature (29.6–33.1 °C). Physico-chemical analysis of fruits from each lot was done at the time of harvesting and after 48, 72, 96, 120, 144 and 168 h of ripening period.

Physico-chemical analysis

Post harvest physico-chemical changes indicative of the quality of fruits were studied by recording

physiological loss in weight, pulp firmness, soluble solids content, titratable acidity, sensory quality and β -carotene of pulp.

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

$$W_L = (W_i - W_f/W_i) * 100$$

where W_L is the weight loss (%), W_i (g) and W_f (g) are the initial and final weights, respectively.

Firmness Flesh firmness was measured with stand mounted penetrometer (model FT-327, USA) fitted with spherical tip with 8 mm plunger diameter after removal of piece of peel 2 mm in diameter. The maximum force required to plunge a spherical tip into peeled skin of fruit was recorded and expressed in kgf.

Soluble solids content, titratable acidity, sensory quality SSC 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. SQ of fruits was observed on basis of colour, appearance, texture and taste and were sensory rated by panel a of five judges using nine point hedonic scale (1–9) as described by Amerine et al. (1965).

β -carotene β -carotene content of fruit pulp was extracted with acetone and petroleum ether by following the method described by Ranganna (1977). The colour intensity of β -carotene eluent was measured at 452 nm using petroleum ether as blank. β -carotene content was expressed as mg/100 g of pulp.

Statistical analysis

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). The two factor experiment (factors; temperature and ripening period) was laid out in completely randomized block design (Factorial) with seven replications 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 $\pm$ standard deviation. Further, data was subjected to Pearson correlation analysis to find out the correlation between variables and principal component analysis (PCA) to predict the variability.

Results and discussion

Physiological loss in weight

Loss in weight of fruits increased with the advancement of ripening and the maximum weight loss recorded at the end of ripening period (Fig. 1a). Similarly, PLW of fruits varied in response to different ripening temperatures. A significant ($p < 0.05$) increment in weight loss of 7.32, 11.88 and 14.70% was observed from 0 to 168 h for fruits ripened at 20, 25 °C and room temperature, respectively. This physiological loss in weight of fruits was possibly due to respiration, transpiration and other biochemical changes occurring in mango fruits (Thinh et al. 2013). Fruits ripened at room temperature, showed significantly greater weight loss throughout the ripening period as compared to fruits ripened in temperature controlled chambers. Waskar

and Masalkar (1997) reported that increase in PLW of mango fruits was at faster rate during storage at room temperature than that of cool chambers. The higher temperatures results in greater weight loss of fruits causing the fruits to shrivel (Rathore et al. 2007). The minimum PLW was recorded in fruits ripened at 20 °C by delaying the ripening process in contrast to ripening at room temperature.

Fruit firmness

The softening of fruit pulp occurred with progression of ripening period regardless of ripening temperatures (Fig. 1b). Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes that finally leads to the development of a soft

Fig. 1 Changes in fruit quality parameters i.e. PLW (a), firmness (b), SSC (c), TA (d), SQ (e), β-carotene (f) of mango cv. Dashehari during progression of ripening under different temperature treatments. Vertical bar represents ±SD of mean

edible ripe fruit (Kaur et al. 2014). A significant decrease in fruit firmness up to 96 h of ripening period was recorded for fruits kept at 20 °C and till 120 h of ripening period for fruits at 25 °C and room temperature. Maximum loss in fruit firmness (9.85–0.40 kgf) during ripening study was recorded in fruits kept at room temperature. After 144 h of ripening the fruit firmness was not detectable as pulp become very soft to be measured by penetrometer used in present study. A decrease in firmness might be due to an increase in activity of polygalacturonase and cellulase during ripening (Zoghbi 1994). Higher pulp firmness after 144 h of ripening was retained by fruits kept at 20 °C which registered a value of 1.56 kgf. Hence the fruits that were allowed to ripen in temperature controlled chambers retained more firmness as compared to fruits at room temperature.

Soluble solids content

SSC of mango fruits increased with the ripening process and reached to its peak value at the end of ripening period for fruits kept at 20 and 25 °C (Fig. 1c) whereas, for fruits at room temperature this increase was recorded upto 144 h of ripening followed by a slight decline. Changes in TSS content were natural phenomenon is correlated with hydrolytic changes in carbohydrates during storage (Kishore et al. 2011). The increase in TSS during fruit ripening might be attributed to an increase in activity of enzymes responsible for hydrolysis of starch to soluble sugars (Zhong et al. 2006). At room temperature the rate of increase in SSC was rapid from 0 to 96 h suggesting early onset of ripening process as compared to fruits kept at lower temperatures. Highest SSC of 17.80% was recorded after 144 h and at 168 h of ripening period for fruits at room temperature and 25 °C, respectively, while lower SSC was recorded for fruits kept at 20 °C all over the ripening period. Results were supported by findings of Baloch and Bibi (2012) who observed high TSS at high storage temperature and it increased with the ripening process. Ahmad et al. (2001) also observed the greater TSS in banana kept at higher temperatures than those at lower temperatures.

Titrateable acidity

The changes in TA of Dashehari mango fruit with progress of ripening at different temperatures regimes is presented in Fig. 1d. TA declined linearly with advancement in ripening period irrespective of ripening temperatures. A decline in acidity might be due to their utilization as substrates for respiration (Medlicott and Thompson 1985). Lowest juice TA of 0.14% was recorded at the end of ripening for fruits ripened at room temperature followed by

0.17% for the fruits kept at 25 °C. Overall, the rate of reduction in juice acids content was highest in fruits ripened at room temperature with TA of juice recorded at the end of ripening period was reduced by about 15 times as compared to TA recorded at 0 h. Loss in TA content was minimum in fruits kept at 20 °C. These results correspond with observations of Gill et al. (2015), who reported constant decrease in acid content of mango fruits during ripening.

Sensory quality

Effect of different ripening temperatures on SQ of mango is represented in Fig. 1e. At the time of harvest, fruits were firm in texture, highly acidic and had poor edible quality. SQ of fruits kept at 20 °C improved continuously with the advancement of ripening period while for the fruits kept at 25 °C, SQ improved till 144 h of ripening period and thereafter, a significant ($p < 0.05$) decline in SQ was recorded. The concentration of volatile compounds increases with ripening of fruit and is responsible for improving flavor of fruit making it more delicious and valuable (Malundo et al. 1996). During ripening process SQ for fruits at room temperatures improved with onset of ripening up to 72 h and afterwards a decline in SQ of fruits was recorded, however fruits kept at 25 and 20 °C developed superior quality during the ripening process. The maximum sensory score of 8.40 was recorded for fruits kept at 25 °C at 144 h of ripening period. Thus fruits ripened at 25 °C, maintained better sensory quality attributes as compared to fruits ripened at 20 °C or room temperature.

β -carotene

The effect of different ripening temperatures on β -carotene content of mango fruit pulp is summarized in Fig. 1f. A significant increase in β -carotene content of fruits ripened at 25 °C and room temperature was recorded up to 120 h of ripening period where it ranged from 0.23 mg/100 g (0 h) to 2.41, 2.69(mg/100 g), respectively and thereafter a decline was recorded till the end of ripening studies. The maximum β -carotene content throughout the ripening period was recorded for fruits ripened at room temperature whereas, the minimum was observed for fruits kept at 20 °C till 144 h of ripening period. With the progression of ripening period an increase in β -carotene content was more prominent at room temperature might be due to an increase in mevalonic acid and geraniol synthesis, which lead to higher levels of carotenoids (Mitra and Baldwin 1997). Disappearance of green colour is the first visible result of degradation of chlorophyll as a consequence of maturation and ripening of fruits. An increase in carotenoids is marked

by loss of green colour and the development of yellow coloration with an almost complete loss of chlorophyll (Medlicott et al. 1986). After 120 h of ripening period, β -carotene content observed amongst fruits was non-significant irrespective of the temperature treatments.

Multivariate analysis of fruit quality parameters

Correlation matrix studies between physico-chemical parameters

The Pearson's correlation was used to study the relationship between various quality parameters (Fig. 2). Highest positive correlation ($r = 0.970$) amongst all quality parameters was recorded for TA and fruit firmness indicating the direct relationship between these parameters during the ripening process whereas, highest negative correlation ($r = -0.952$) was observed between TA and SSC, indicating the inverse relationship between these quality parameters at the high significant level ($p < 0.0001$). SQ had a high positive correlation ($r > 0.830$) with SSC, β -carotene and high negative correlation ($r > -0.830$) with TA and fruit firmness. SSC

correlated negatively ($r > -0.935$) with firmness and TA. β -carotene showed positive correlation ($r = 0.875$) with SSC and was negatively correlated ($r > -0.850$) with TA and firmness. Moreover, it was observed that β -carotene content had a direct relationship ($r = 0.839$) with SQ of fruits. As observed from correlation matrix, it is opined that quality parameters SSC, β -carotene and SQ were inversely correlated with firmness and TA during progressive ripening of fruits.

Principal component analysis

Further, PCA was carried out for extensive view of changes in quality parameters and their respective contribution to overall variability. The overall variability is interpreted by five factors (F1–F6). A variance of 95.79% is accounted for by the first two factors with factor one (F1) responsible for 92.37% of total variation and second factor (F2) contributing 3.42% of total variation (Table 1). Thus, it was summarized that first factor (F1) contributed to maximum variation in ripening indices of fruit. A component pattern (Fig. 3) of first two components showed that during early stages of ripening, fruits harvested had higher TA and

Fig. 2 Scatter plot matrix of quality parameters for Dashehari mango. Carotene stands for β -carotene

Table 1 Principal component analysis of quality factors

Eigenvalues of the correlation matrix				
	Eigenvalue	Difference	Proportion	Cumulative
1	4.6186	4.4476	0.9237	0.9237
2	0.1710	0.0425	0.0342	0.9579
3	0.1285	0.0668	0.0257	0.9836
4	0.0617	0.0416	0.0123	0.9960
5	0.0200		0.0040	1.0000

Fig. 3 Component pattern by principal component analysis of first two factors (F1 and F2). Carotene stands for β -carotene

firmness which decreases with progression of ripening characterized by a shift from right to left, reflecting the beginning of ripening process. High positive scores of β -carotene, SSC, SQ along the component 1 is indicative of increase of these quality parameters with advancement of ripening. Moreover, it is shown that quality parameters β -carotene, SSC, SQ is inversely related with TA and firmness during the ripening process.

Conclusion

The results from this research showed that ripening of mango at controlled temperature proved to be effective way for safer ripening of fruits in contrast to chemical based treatments. Dashehari mango fruit kept at 25 °C can be ripened in 4–5 days and continue to maintain quality upto 6 days.

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