Transitions in mesocarp colour of mango fruits kept under variable temperatures

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Abstract The impact of variable temperatures on mesocarp colour development and physico-chemical changes of mango fruits cv. Langra during ripening has been investigated. Physiological mature mango fruits were kept in temperature regulated chambers (20 and 25 °C) and at room temperature (29.8–33.6 °C). Progress in development of mesocarp colour, β -carotene, sensory quality (SQ) and total soluble solids (TSS) content of fruits were analysed periodically from 48 to 168 h of ripening period. The progress of ripening period was accompanied by an overall increase in colorimetric value redness (a^*), yellowness (b^*), chroma or saturation (C^*), a reduction in lightness (L^*) and hue angle (h^0) values. Colour development was found to be more in fruits ripened at higher temperatures than the fruits at lower temperature. β -carotene content of pulp improved with ripening of fruits up to 120 h of ripening period. Fruits ripened at 25 °C recorded maximum sensory quality score. Pearson's correlation matrix studies revealed that fruit mesocarp colour a^* , b^* , C^* values were directly correlated with β -carotene, SQ and TSS with progress of ripening period.

Keywords Mango · Temperature · Ripening · Colour development · Sensory quality

Introduction

Mango cultivar Langra, primarily grown in northern India is harvested during the 2nd week of July. Being climacteric fruit, mango ripens rapidly after harvest (Yadav and Patel 2014). India leads in production of mango worldwide. Under natural conditions, ripening of mango fruits produce heterogeneous batches, therefore, major challenge is to ensure uniform ripening of mango and reduce post harvest losses. To address the purpose, many methods have been invented, amongst which the methods gaining importance these days involves the use of ethephon (Tan et al. 2014) and ripening under controlled temperature conditions (Emongor 2015). The required optimum temperature for mango ripening varied from cultivar type and ecological conditions (Thomas and Oke 1983; Nair and Singh 2009).

Storage temperature is a key factor affecting fruit quality (Nunes et al. 2007), changes in pulp colouration (Phakawatmongkol et al. 2004) and carotenoid content of mango pulp (Medlicott et al. 1986). Colour is an important food quality parameter that affects the consumer acceptance (Crisosto et al. 2003). The advancement of mango ripening period is accompanied by characteristic colour development which involves a progressive loss of chlorophyll and an increase in carotenoid composition (Kalra and Tandon 1983). Carotenoids are coloured pigments responsible for the characteristic colour of mango skin and pulp. Pulp colour is one of the most reliable maturity indices for mango. Colour correlates with physical, chemical and sensory evaluation of fruit, so consumers associate colour with perception of sweetness and flavour of fruit (Bayarri et al. 2001). Thus, the present experiment was undertaken with a view to study the changes in mesocarp colour development and quality of mango fruit cv. Langra during ripening under variable temperatures.

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Materials and methods

Sampling of mango fruit

The experiment was carried out at Department of Fruit Science, Punjab Agricultural University, Ludhiana, India during the year 2015. Uniform sized fruits of mango cv. Langra were hand harvested with long stem, during morning hours from mango orchard (33°54'N, 75°47'E, 247 amsl) of the department. Fruits were immediately transported to Post-Harvest Laboratory. Fruits were desapped and were sorted to discard any misshaped, over-ripped and externally defects. Physiologically mature fruits were selected by following the specific gravity (> 1.0) method. Selected fruits were washed with chlorinated water (sodium hypochlorite 4% @ 2.5 ml/l) to remove surface microbial load and dirt adhered to fruit surface and then air dried. Fruits were then divided into three experimental sets and packed in corrugated fibre board boxes consists of one ply of fluted paper glued between two plies of cardboard with 5% ventilation. On the day of storage experimental fruits were analyzed physico-chemical properties viz; mesocarp colour ($L^* = 85.6$, $a^* = 1.8$, $b^* = 28.7$, $C^* = 28.76$ and $h^0 = 86.4$), sensory quality rating (4.0) and TSS contents (9.2%).

Ripening conditions and analysis interval

To study the ripening behaviour of fruits at specific temperatures (20 and 25 °C), isothermal chambers, made from PUF panels (Acme, India) having temperature regulation provision were used. The temperature in the cold chambers was regulated through inbuilt thermostat in unit coolers (BM 15, Patton Aero Co Ltd, Thailand) with temperature differential of 1 °C. Experimental fruits were placed at 20 and 25 °C and at room temperature (29.8–33.6 °C) for ripening studies and temperature was recorded by using Thermometer (Fisher ScientificTM 11-661-13, USA). Fruits from each set were analysed for colour development and physico-chemical parameters after 48, 72, 96, 120, 144 and 168 h of ripening.

Determination of mesocarp colour parameters

The mesocarp colour parameters of mango were assessed by using Color Flex meter (Hunter Lab Color Flex, Hunter Associates Inc., Reston, VA, USA) (Hunter 1975). The instrument was set up at D65 as illuminate and 10° observer angle and calibrated with standard white and black ceramic tile. Each treatment was replicated four times. Quartz cuvette was loaded with pulp sample and mesocarp colour of fruits was recorded as L^* , a^* and b^*

coordinates from opposite positions of each fruit in CIE units. Hue angle ($h^0 = \tan^{-1} (b^*/a^*)$) and Chroma ($C^* = [a^{*2} + b^{*2}]^{1/2}$) were calculated. L^* , a^* and b^* describe a three dimensional space, where L^* is the vertical axis, represents lightness or luminosity ($L^* = 0$ for black and $L^* = 100$ for white). On horizontal axis, positive a^* is indicative of redness while negative a^* is indicative of green. On the vertical axis, b^* represent the degree of yellowness, where negative b^* is indicative of blueness and positive b^* indicates yellowness. Hue angle is an indicative of colour change of fruits from green to yellow and chroma describes colour saturation, which varies from a dull to vivid colour (Malik and Singh 2006).

Extraction and analysis of β -carotene content

The extraction of β -carotene of fruit pulp was carried out as described by Ranganna (1977) by using acetone and petroleum ether. The colour intensity of β -carotene eluent was measured by Spectronic 20 D⁺ (Thermo Fischer Scientific, USA) at 452 nm using petroleum ether as blank. β -carotene content was expressed as mg/100 g of pulp.

Evaluation of SQ and TSS content of mango

Sensory quality of fruits was evaluated by panel of 10 judges on the basis of appearance, pulp texture, taste and flavour by using 9 point hedonic scale (1-dislike extremely; 2-dislike it very much; 3-dislike moderately; 4-dislike it; 5-neither like it nor dislike it; 6-like it; 7-like it moderately; 8-like it very much; 9-like it extremely) as described by Amerine et al. (1965). Total soluble solids content was determined with help of hand held digital refractometer of 0–53% range (ATAGO, PAL-1, Japan). The values obtained were corrected at 20 °C with the help of temperature correction chart and expressed in percent.

Statistical analysis of data observations

Statistical analysis of data observations was done by 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 design (factorial) with four replications. Data were analysed for analysis of variance (ANOVA) using Tukey's HSD ($p < 0.05$) for significant difference test and results were expressed as mean $\pm$ standard deviation. Further, data was subjected to Pearson correlation analysis to find out the correlation between variables.

Results and discussion

Developmental transitions in mesocarp colour of mango

Effect of temperature on mesocarp L^ values*

The changes in luminosity (L^*) of ‘Langra’ mango mesocarp with its ripening at variable temperatures is presented in Fig. 1a. L^* values of mango mesocarp showed a continuous decrease with the progress of ripening period for the fruits ripened in all the treatments. L^* values for the internal colour of mango decreased due to colour turning from white to yellow (Nambi et al. 2015). For some mango cultivars, colour has been proposed as reliable maturity indices (Padda et al. 2011). Highest L^* value of 83.30 was recorded after 48 h of ripening period for fruits kept at 20 °C, indicative of its unripe stage while the lowest value (59.90) was recorded at the end of ripening period for the fruits ripened at room temperature. Throughout the ripening period minimum L^* values were recorded for fruits at room temperature, while the maximum were observed for fruits ripened at 20 °C.

Effect of temperature on mesocarp a^ values*

Different temperature treatments effected a^* value of mango mesocarp (Fig. 1b). During ripening of mango fruit, a^* values continuously increased for fruits kept at 20 °C while, for fruits ripened at 25 °C and room temperature it increased up to 144 h of ripening period followed by a non significant decline. This increase in a^* values of mesocarp was indicative of shift from greenness with the progression of ripening and might be attributed to an increase in carotenoid content in pulp (Ribeiro et al. 2007). Colour values a^* , b^* play an important role in determination of maturity index and describes the transition of mango colour during ripening process (Jha et al. 2007). After 168 h of ripening, higher mesocarp a^* value was registered in fruits kept at 20 °C.

Effect of temperature on mesocarp b^ values*

The colour of the mesocarp gradually turned to yellowish during progress of ripening (Fig. 1c). Maximum increase in b^* values from 50.70 (after 48 h) to 64.90 (after 168 h) during ripening was recorded in fruits kept at room temperature followed by fruits kept at 25 °C for which an increase in b^* values was from 45.30 (after 48 h) to 63.20 (after 168 h). With the advancement of time period, the yellow–orange colour of the mesocarp becomes more intense with an increase in carotenoids (Ornelas-Paz et al. 2008). At the end of ripening period, highest b^* (64.90) was recorded in fruits ripened at room temperature

followed by value of 63.20 recorded for fruits ripened at 25 °C.

Effect of temperature on mesocarp C^ and h^0 values*

Effect of different ripening temperatures on chroma and hue values of mesocarp is represented in Fig. 1d, e. The increase in intensity of yellowness of mesocarp was accompanied by an increase in a^* , b^* and C^* values and a reduction in L^* and h^0 values (Ornelas-Paz et al. 2008). During the ripening interval of 48–168 h, chroma values showed an increase from 30.34 to 63.50, 45.48 to 65.79 and 50.88 to 67.38 for fruits ripened at 20, 25 °C and room temperature, respectively, and for hue angles, the transition during this interval was recorded as a decrease in value from 84.14 to 72.02, 84.95 to 73.85 and 85.15 to 74.42 for fruits ripened at 20, 25 °C and room temperature, respectively. Similar trend of increase of C^* values and decrease in h^0 values was observed in Cat Hoa Loc mango (Thinh et al. 2013).

Developmental changes in β -carotene content of mango

The changes in β -carotene of ‘Langra’ mango with the progress of ripening at variable temperatures is presented in Fig. 1f. Carotenoids are the pigments responsible for the yellow–orange colour of mango mesocarp (Vásquez-Cai-cedo et al. 2005). Irrespective of temperature conditions, mango fruits registered an increase in β -carotene of pulp with the enhancement of ripening up to 120 h followed by a non significant decline till the end of ripening period. Maximum β -carotene content (2.23 mg/100 g) was recorded after 120 h of ripening for fruits ripened at room temperature. There is an increase in carotenoid content from mature green to ripe stage of mango (Mercadante and Rodriguez-Amaya 1998). The maximum increase in β -carotene by the end of ripening period was noticed in fruits ripened at room temperature followed by fruits kept at 25 °C. Similar trend of maximum carotenoids synthesis and accumulation in flesh of fruits ripened at ambient temperature was observed in ‘Alphonso’ mangoes (Thomas and Janave 1975). β -carotene content throughout the ripening period was recorded higher for fruits ripened at room temperature, whereas, the minimum was recorded for fruits kept at 20 °C.

Developmental changes in SQ and TSS content of mango

Effect of temperature on SQ of mango

Consumer acceptability in terms of sensory quality of mango fruits was significantly affected by ripening

Fig. 1 Developmental response of mango fruits cv. Langra with respect to parameters i.e. L^* value (a), a^* value (b), b^* value (c), C^* value (d), h° value (e), β -carotene (f), SQ (g) and TSS (h) during ripening under different temperature treatments. Data represented mean $\pm$ SD (n = 4)

conditions (Fig. 1g). SQ of fruits improved up to 120 h of ripening period in all the treatments. The lower sensory quality during the initial period of storage was because of high firmness, poor taste, flavor and colour development of fruits. After 120 h of ripening fruit kept at 25 °C were evaluated as ‘very much liked’ while fruits placed at 20 °C

and room temperature were categorized as ‘moderately liked’. A decline in sensory quality score was also noticed at the later stages of ripening studies. After 168 h fruits kept at room temperature scored significantly lower sensory quality rating in contrast to fruits ripened under controlled temperature conditions. Gill et al. (2017) also

Table 1 Pearson correlation matrix of mesocarp colour values, β -carotene, SQ and TSS during ripening of Langra mango fruits under different temperature treatments

Pearson correlation coefficients $p < 0.0001$								
	a^*	b^*	L^*	C^*	h^0	β -Carotene	SQ	TSS
a^*	1.000							
b^*	0.842	1.000						
L^*	− 0.912	− 0.827	1.000					
C^*	0.877	0.967	− 0.847	1.000				
h^0	− 0.955	− 0.792	0.896	− 0.813	1.000			
β -Carotene	0.911	0.781	− 0.876	0.845	− 0.863	1.000		
SQ	0.813	0.825	− 0.749	0.836	− 0.812	0.793	1.000	
TSS	0.944	0.873	− 0.934	0.906	− 0.919	0.906	0.835	1.000

Negative values indicate inverse correlation between the parameters, whereas positive values is an indicative of direct relationship between the parameters at the significant level of $p < 0.0001$

reported better sensory quality in ‘Dashehari’ mangoes ripened at 25 °C.

Effect of temperature on TSS content

The total soluble solids content of mango fruits significantly improved with advancement of ripening period irrespective of ripening conditions (Fig. 1h). The mean TSS content increased from 12.3% (after 48 h) to 17.9% (after 168 h). However, there was no difference in TSS content among various treatments up to 72 h of ripening period. After 96 h of ripening fruits kept at room temperature and 25 °C registered significantly higher TSS contents as compared to fruits ripened at lower temperature of 20 °C. This augment in TSS content of fruits may be attributed to onset of ripening associated changes at rapid rate at higher temperatures. At the end of ripening studies no differences in TSS contents was observed among various treatments. Similarly, Baloch and Bibi (2012) also observed greater TSS at high storage temperature.

Multivariate analysis of parameters

Correlation matrix studies between colour values, β -carotene, SQ and TSS

The Pearson correlation matrix to study the correlation behaviour between various parameters for ‘Langra’ mango is given in Table 1. L^* values had a high positive correlation ($r = 0.896$) with h^0 values and high negative correlation with a^* , b^* , C^* values, β -carotene, SQ and TSS content. Highest positive correlation ($r = 0.967$) amongst all the parameters was observed between C^* and b^* values indicating direct relationship between these parameters during ripening period whereas, highest negative correlation ($r = -0.955$) was recorded for h^0 and a^* values showing the inverse relation between these colour

parameters at the high significant level ($p < 0.0001$). Moreover, it was observed that β -carotene content had a direct positive correlation with b^* , C^* values, SQ and TSS. From these observations, it is opined that mesocarp colour a^* , b^* , C^* values were directly correlated with β -carotene, SQ and TSS content during ripening of fruits under different temperature treatments.

Conclusion

The mesocarp colour development of Langra mango fruits accelerated with increase in ripening temperature. β -carotene content showed highly positive correlation with a^* and b^* values of mesocarp. Among various ripening temperatures 25 °C was found most effective for developing high sensory quality of fruits.

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