Ripening quality of Dusehri mango in relation to harvest time

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Abstract The effect of different harvesting time on ripening quality of mango cv. Dusehri was investigated under sub-tropics of northwestern India. Fruits were harvested at 101, 106 and 111 days after fruit set (DAFS) and kept at 25 °C in temperature controlled chamber for ripening. Fruits were analyzed periodically for physico-chemical characteristics at the time of harvest (0 h) and after 72, 96 and 120 h of ripening period. With advancement in ripening period, an increase in physiological loss in weight, soluble solids content (SSC), sensory quality rating, β -carotene and pulp colour development of mango fruits was recorded. While a decline in fruit firmness and titratable acidity (TA) was observed with ripening period. Fruits picked at 111 DAFS recorded highest SSC (8.01%), sensory rating (4.67), β -carotene (0.427 mg/100 g) vis-à-vis lowest fruit firmness (15.3 lbf) and TA content (1.56%). The luminosity of fruit pulp decreased with the storage period. The redness and yellowness of the fruit pulp represented by a^* and b^* values, respectively increased with delay in harvesting period. The rate of ripening was rapid in late harvested fruits as compared to early harvested fruits. After 96 h of ripening period, fruits harvested at 111 DAFS showed very much desirable quality whereas fruits harvested at 101 DAFS showed moderately desirable quality. Results showed that harvesting of mango fruits can be extended to 111 days and such fruits attained optimum ripening quality after 96 h at 25 °C.

Keywords Colour changes · Harvest date · *Mangifera indica* · Fruit quality

Introduction

In northern region of India, Dusehri is a leading cultivar of mango due to its high productivity and good fruit quality. In Punjab state its cultivation is confined to sub-montane zone adjoining to the *Shivalik* foothills between 32°17'N and 75° 42'E to 30°73'N and 76°78'E. Being a climacteric fruit its harvest period is generally regulated by market prices. However, early harvesting of mango may result in loss in fruit yield due to underdeveloped fruits. Under local conditions fruits of Dusehri mango are harvested during first week of July (101 DAFS). Mango is a climacteric fruit (Sane et al. 2005) and its ripening process occurs rapidly after harvest depending on cultivar, stage of maturity at harvest and postharvest conditions (Vazquez-caicedo et al. 2004). Therefore, rapid fruit ripening changes after harvest leads to short post-harvest life. At ambient temperatures, fruits exhibit a sharp rise in respiration and ethylene production after 3rd–4th day of harvesting (Narayana et al. 1996). Post harvest losses can be reduced either by storage of fruits at 10–13 °C temperature (Nair and Singh 2009) or by extending the harvesting period. However, the existing infrastructure for storage of mango fruits at this specific temperature is limited. Hence, extension in harvest period can become another alternative to regularize the mango marketing for fresh consumption. Harvesting of fruits at different stages (on the basis of days after fruit set) influence the ripening quality (Kaur and Dhillon 2015) and duration for ripening (Chen and Mellenthin 1981). Harvest maturity was found to be most important determinant of storage life and final fruit quality (Jha et al. 2007).

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Therefore, information on ripening quality of fruits harvested at different maturity stages is essential to elucidate the feasibility of extension in harvesting period of mango. Keeping this in view, the present investigation was carried out to determine the effect of harvest date of mango fruits on ripening quality to extend the marketing period in Dusehri mango.

Materials and methods

Uniform sized and physiologically mature fruits of mango cv. Dusehri were manually harvested in the morning hours 101 DAFS, 106 DAFS and 111 DAFS from the mango orchard of Department of Fruit Science, Punjab Agricultural University Ludhiana during the year 2016. After harvest, the fruits were desapped and immediately transported to Post-Harvest Laboratory of the department. Fruits were sorted and misshapened, immature fruits were discarded. Sorted fruits were washed with chlorinated water and dried in laboratory at ambient temperature (30.5 °C). Afterwards, they were packed in ventilated CFB boxes by using paper cushioning material and kept for ripening at 25 °C in temperature controlled chamber as described by Gill et al. (2017). Physico-chemical analysis of fruits was done at the time of harvest (0 h) and after 72, 96 and 120 h of ripening intervals. A random sample of 20 fruits from each replication was taken for physico-chemical analysis. PLW of fruit was determined on the basis of initial fresh weight and the final weight of the fruit 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 weight, respectively.

Firmness of fruits 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 from the fruit. The maximum force required to plunge a spherical tip into the peeled skin of fruit was recorded and expressed in lbf. SSC were determined with the help of handheld digital refractometer (Atago, Japan) and expressed in °Brix. The reading were corrected with the help of temperature correction chart at 20 °C, whereas, TA was estimated by taking 2.0 ml of stained juice and was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator and expressed in percentage (AOAC 2000). The aroma, taste and flavor of all the samples were determined by using nine point Hedonic scale (Amerine et al. 1965). A panel of 5 judges was made based on their consistency and reliability of judgment. Panelists were asked to score the samples by allotting the scores (9-extremely desirable, 8-very much desirable, 7-moderately desirable, 6-slightly

desirable, 5-neither desirable or undesirable, 4-slightly undesirable, 3-moderately undesirable, 2-very much undesirable, 1-extremely undesirable). β -carotene content of the fruit pulp was extracted using 3% acetone in petroleum ether as blank (Ranganna 1977). The colour intensity for 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. The mesocarp color parameter of mango were assessed by using Color Flex meter (Hunter Lab Color Flex, Hunter Associates Inc., 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 five times. The mesocarp colour of fruits was recorded as L^* , a^* and b^* coordinates from opposite position of each fruit in CIE units. 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 greenness. On the vertical axis, b^* represents the degree of yellowness, where negative b^* is indicative of blueness and positive b^* indicates yellowness.

Statistical analysis

The experiment was laid out in Completely Randomized Design (Factorial) with five replications for each treatment. Ten fruits per replication were used for the study. Data were analyzed for Analysis of Variance (Proc GLM) using statistical package SAS 9.3 (The SAS system for Windows, Version 9.3, SAS Institute, Cary, NC). Values of different parameters were expressed as the mean $\pm$ standard error using Fisher LSD test ($P < 0.05$).

Results and discussion

Physiological loss in weight

Loss in weight of fruits increased with the progression of fruit ripening and the maximum weight loss was recorded at the end of ripening period (Fig. 1a). Loss in weight during ripening may be due to loss of water from the fruits through various metabolic processes viz. respiration and transpiration. PLW of fruits also varied significantly ($P < 0.05$) in response to different harvesting dates. Fruits harvested at later stages showed significantly higher rate of PLW throughout the ripening period. After 120 h of ripening, the PLW of fruits harvested at 101 DAFS, 106 DAFS and 111 DAFS was 5.21, 5.62 and 6.12%, respectively. Fruits harvested at 111 DAFS showed significant

Fig. 1 Effect of harvesting time on PLW (a), SSC (b), Fruit firmness (c), TA (d), SQ (e), β -carotene (f) of Dusehri mango fruits during ripening at temperature 25 °C. Vertical bar represents $\pm$ SE of mean

higher PLW as compared to fruits harvested at 101 DAFS. Our results are also to confirm to the work of Guerra and Casquero (2008) who revealed that late harvested plum fruits showed higher loss in weight than early harvested fruits. Apples picked at 138–145 days after full bloom were found more metabolically active as compared to fruit picked after 117 days after full bloom (Kvikliene et al. 2011). Similar results were reported by Dick et al. (2009) in mango cultivar Kent.

Fruit firmness

Fruit firmness showed a linear decline with advancement in ripening period (Fig. 1b). The mean fruit firmness decreased drastically from 19.07 to 1.27 lbf from harvest time to 120 h of ripening. The fruit firmness also declined significantly with delay in harvest. Fruits harvested at 101 DAFS recorded significantly maximum firmness of 23.2 lbf as compared to firmness of fruits harvested at 106 DAFS (18.7 lbf) or 111 DAFS (15.3 lbf). The rate of decline in fruit firmness during ripening period was higher in fruits harvested at 101 DAFS, though these fruits also retained significantly greater firmness after 120 h of ripening over

the fruits harvested at later stages. A similar reduction in firmness of fruits with delay in harvest date has also been reported by Jha et al. (2013) and Ornelas-Paz et al. (2018). The minimum fruit firmness was observed after 120 h of ripening in fruits harvested at 111 DAFS. The softening of fruit is associated with changes in cell wall composition, carbohydrates structure, pectin, hemicellulose and cellulose (Goncalves et al. 2006).

Soluble solids content

The analysis of harvested fruit indicated that the SSC increased with delay in harvesting or during the ripening process. Similar observations were made by Bhat et al. (2012) in pear fruits in response to delay in harvesting time. SSC in the fruit increased gradually with increase in ripening irrespective of harvesting dates (Fig. 1c). The mean SSC content of fruits increased 2.12 times from harvest stage to 120 h of ripening. Change in fruit SSC is correlated with hydrolytic changes in carbohydrates that involves breakdown of complex organic metabolites into simple molecules (Kishore et al. 2011; Sakhale et al. 2018). Highest SSC of 17.93° Brix was recorded after 120 h of ripening period in fruits harvested at 106 DAFS while fruits harvested 101 DAFS showed lowest SSC of 8.01° Brix. Different harvesting dates did not have a significant influence on SSC contents of freshly harvested fruits. However, after 72 and 96 h of ripening period fruits harvested at 111 DAFS recorded significantly ($P < 0.05$) higher SSC contents as compared to fruits harvested at 101 DAFS. After 120 h of ripening there was no statistical variation in SSC contents in fruits harvested at different dates. Usually later picked fruits show higher SSC value not only at harvest time, but at the end of storage also (Yong Soo et al. 1998).

Titrateable acidity

The change in titrateable acid content of fruits in response to different harvest dates and with progress of ripening is presented in Fig. 1d. It was observed that TA decreased significantly ($P < 0.05$) with ripening of fruits. The mean titrateable acid content of mango fruits declined from 1.66% at harvest to 0.28% after 120 h of ripening. The decrease in acidity was attributed towards the conversion of citric acid into sugars and their further utilization in metabolic process of the fruit (Velez-Rivera et al. 2014). Delay in fruit harvest period also resulted in significant ($P < 0.05$) decrease in TA content. Fruits picked at 111 DAFS recorded lowest acidity of 1.56% followed by TA content (1.68%) in 106 DAFS harvested fruits, while fruits harvested at 101 DAFS had highest acid content of 1.75%. Lalel et al. (2003) also reported higher acid content in early harvested mango and

lowest in late harvested fruit. TA content decreased sharply up to 72 h of ripening and thereafter a steady decline was noticed up to 120 h of ripening. At the end of studies no significant differences in acid content was observed among fruits harvested at various harvesting dates. These results correspond with the observations of Gill et al. (2015) who reported constant decrease in acidity of mango fruits during ripening.

Sensory quality

Sensory quality of mango fruits harvested at different dates improved during ripening at 25 °C irrespective of harvest date (Fig. 1e). At harvest, fruit were very firm in texture, highly acidic and were of poor edible quality. Overall sensory quality of fruits changed from slightly undesirable from harvest to very much desirable after 120 h of ripening indicating that fruits attained desirable quality characteristics with progress of ripening. Sensory quality of fruits harvested at 101 DAFS improved significantly ($P < 0.05$) throughout the ripening period while those harvested on following stages showed significant increase in sensory quality up to 96 h of ripening period. Sensory quality also improved with delay in harvesting and fruits harvested at 111 DAFS registered higher sensory quality score (4.67) over fruit harvested at 101 DAFS with sensory score of 4.07. After 72 h of ripening period fruits harvested at 111 DAFS recorded moderately acceptable quality while fruits harvested at 101 DAFS were of slightly desirable quality. However after 120 h of ripening period, fruits from all harvest dates attained very much desirable quality. The increase in sensory quality score is attributed to reduction in fruit firmness and acid content in fruit and concomitant augment of SSC and sugars. Saranwong et al. (2004) also observed that mangoes harvested at later stage ripened well and lead to better eating quality than the mangoes harvested at early stage.

β -carotene content of pulp

The analysis of fruits indicated that β -carotene content of pulp increased with the harvest stage or during the ripening process (Fig. 1f). At the time of harvest, mango fruits recorded low β -carotene content which increased to four-folds after 120 h of ripening period. The increase in β -carotene was maximum from 90 to 120 h suggesting rapid development of yellow pigment during this period. β -carotene also increased in the fruits which were picked at later stages as compared to earlier harvested fruits. These results are in agreement with reports of Baloch and Bibi (2012) who noted increased carotenoids content with the harvest stage and ripening of fruits. The maximum β -carotene content (1.55 mg/100 g) was recorded after 120 h of

Table 1 Effect of time of harvesting on colour values of mango fruits during ripening at 25 °C

Time of sampling	'L*' value				'a*' value				'b*' value			
	Ripening period (h)				Ripening period (h)				Ripening period (h)			
	0	72	96	120	0	72	96	120	0	72	96	120
10 DAFS	80.16 ± 0.60 ^a	73.65 ± 2.84 ^{cd}	70.1 ± 3.68 ^{cd}	63.962.54 ^{ab}	12.98 ± 0.43 ^{cd}	17.67 ± 1.05 ^d	22.29 ± 1.22 ^c	28.84 ± 1.21 ^a	48.68 ± 0.55 ^f	61.63 ± 0.96 ^c	65.66 ± 0.86 ^{ab}	65.81 ± 0.78 ^{ab}
106 DAFS	80.82 ± 2.27 ^a	74.96 ± 2.81 ^{bc}	64.86 ± 2.92 ^{fg}	60.83 ± 2.14 ^{hi}	11.47 ± 0.85 ^f	18.13 ± 1.11 ^d	23.9 ± 1.44 ^c	29.51 ± 0.25 ^a	53.46 ± 0.61 ^e	62.02 ± 1.20 ^{bc}	65.01 ± 0.47 ^{ab}	66.08 ± 1.28 ^a
111 DAFS	78.2 ± 0.05 ^e	68.0 ± 0.11 ^{de}	59.8 ± 0.13 ^c	57.7 ± 0.04 ^a	14.98 ± 1.29 ^{de}	25.22 ± 0.98 ^{bc}	28.16 ± 1.69 ^{ab}	29.46 ± 1.26 ^a	56.82 ± 1.97 ^d	63.55 ± 0.36 ^{bc}	66.5 ± 2.44 ^a	66.83 ± 2.44 ^a
LSD (0.05)	T = 1.98, S = 2.29, T*S3.96				T = 1.60, S = 1.86, T*S = 3.20				T = 1.20, S = 1.44, T*S = 2.50			

ripening in fruits harvested at 111 DAFS while the lowest β -carotene (0.322 mg/100 g) was recorded in fruits harvested at 101 DAFS. With the progression of ripening period an increase in β -carotene was more prominent due to an increase in mevalonic acid and geraniol synthesis that lead to higher level of carotene (Mitra and Baldwin 1997). During the ripening process, the transition of chlorophyll into carotenoids, biochemical conversion of starch into sugar and loss of organic acid through oxidation are responsible for increase in sugar and carotenoids (Campestre et al. 2002).

Changes in 'L,' a*, b* value of pulp

Changes in L^* , a^* and b^* colour values of mango pulp in relation to harvest dates and ripening has been presented in Table 1. Overall, the L^* value decreased with ripening of fruit at different ripening time as well as with delay in harvest period. At the time of harvest there was no difference in L^* value among fruits picked at different dates. However, after 72 h of ripening fruit harvested at 111 DAFS showed lower L^* values as compared to fruits harvested at erstwhile stages. This may be due to rapid development of coloured pigments in late harvested fruit which decreased pulp luminosity. The maximum pulp brightness was recorded in fruits harvested at 106 DAFS. The lowest ' L^* ' value (57.7) was recorded in fruits harvested at 111 DAFS after 120 h of ripening while the highest (80.82) was observed at 0 day in fruits harvested at 106 DAFS. The lightness value for the inner surface of mangoes decreased due to the internal colour turning from white to yellow (Eyarkai Nambi et al. 2015). Similar results were also reported by Gill et al. (2015) in mango fruits.

Significant changes in ' a^* ' value were recorded in pulp colour of fruits. Mean value of a^* increased 2.22 times from harvest to 120 h of ripening. Fruits harvested on different dates showed significant variation for colour development of pulp. Fruits harvested at 111 DAFS recorded maximum ' a^* ' value of 29.46 while minimum (11.47) was observed for fruits harvested at 106 DAFS. The pulp colour development of fruits was apparent from 0 to 96 h of ripening, afterwards no significant change in a^* value was noted among different harvesting dates. The change in colour of mango due to ripening may be due to higher level of carotenoid and synthesis of other pigments along with degradation of chlorophyll (Jha et al. 2006).

The ' b^* ' value represents to yellowness of the pulp. b^* value also exhibited a similar trend to that of a^* value. At all harvesting dates the ' b^* ' value of fruit pulp increased gradually up to 96 h of ripening and subsequently no changes in b^* value was recorded. However, the rate of increase in b^* value was highest from 0 to 72 h. Harvesting dates have significant influence on development of pulp yellowness. Delay in harvesting significantly increased b^* value and

fruits harvested at 111 DAFS showed higher b^* value (56.82) while fruits harvested at 101 and 106 DAFS showed b^* values of 48.68 and 53.46, respectively. But the effect of harvest was significant up to 72 h of ripening and afterwards no change in colour was noticed with respect to different harvest dates. The yellow colour development and increase in carotenoid content of mango fruits during storage has also been reported by Jha et al. (2007).

Conclusion

The results from this studies revealed that ‘Dusehri’ mango fruits can be retained on tree up to 111 DAFS to prolong the availability of fresh fruits. Fruits harvested at 111 DAFS attained best ripening quality after 96 h, while earlier harvested fruits attained similar fruit quality characteristics after 120 h of storage at 25 °C.

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