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Impact of harvesting method on cosmetic appeal, physiological and biochemical attributes of mango fruits (*Mangifera indica* L.)

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Abstract
Postharvest quality of mango fruits comprises of external and internal quality and is representative of overall appeal and hidden valued biochemical of mango fruits respectively. Postharvest quality of mango fruits is an important factor for trade at the national and international level, and it not only determines the price of fruit, but also consumer preference to the purchase at marketing place. Mango fruits are very prone to postharvest quality loss, deterioration of which starts right from harvesting and increases tremendously during transport, retail and marketing. Hence, an attempt was made to observe the effect of harvesting technique on cosmetic appeal, physiological and biochemical attributes of mango fruits. The studies were attempted on four commercial cultivars of mango ('Amrapali', 'Chausa', 'Dushehari' and 'Langra') grown at ICAR-IARI, New Delhi. Fruits were harvested mechanically (pole mount harvester) and manually under two different lots, which were then de-saped, precooled and stored separately in corrugated fibre board boxes (CFB) at ambient conditions for 10 days. Fruits were recorded for observations on attributes such as postharvest cosmetic appeal (glossiness, face value and lenticel browning), physiological (ethylene evolution and respiration rate), biochemical (total soluble solids, total carotenoids and antioxidant activity) and overall acceptability, till the end of shelf life to draw a conclusion. Our results revealed that significant differences occurred for cosmetic appeal, physiological, biochemical and overall acceptability, in both manual and mechanically harvested fruits. Further, mechanical harvesting was found better to control loss in postharvest quality and thus will help growers in in getting enhanced returns.

Keywords: cosmetic appeal; mango; postharvest quality; mechanical harvesting; manual harvesting

Introduction
Mango (*Mangifera indica* L.), is one of the most important fruit crop in India due to its immense value at internal (Chattopadhyay, 2014; Anonymous, 2017a) [10, 6] and external trade (Anonymous, 2017a) [6]. India's shares 56 % of world's mango production and is witnessing a continuous upsurge in export worldwide (Anon., 2017b) [7]. Occurrence of high postharvest losses of this important fruit crop at state (Anon., 2003) [4], national (Jha *et al.*, 2015; Verma *et al.*, 2015) [14, 28] and international level (Cruz-Medina and Garcia, 2002; Kitinoja and Kader, 2015) [11, 16] is prime concern for researchers (Roy, 1993; Jha *et al.*, 2015) [26, 14].
Among the various forms of postharvest loss, loss in postharvest quality supposed to affect farmers the most (Subramanian *et al.*, 2014; Kitinoja and Kader, 2015) [27, 16]. Postharvest quality loss primarily starts with improper harvesting, subsequent handling, storage and cold chain management techniques (Cruz-Medina and Garcia, 2002; Kitinoja and Kader, 2015) [11, 16]. Improper harvesting method, directly and indirectly, enhances bio-chemical deterioration, and thereby decreases fruit quality, ultimately affecting fruit marketability and consumer preference for the purchase of fruits at retail (Roy, 1993; Wills *et al.*, 2007; Jha *et al.*, 2015) [26, 29, 14].
Till date, there is a lack in systematic study to observe the effect of harvesting method on cosmetic appeal, physiological and biochemical, and overall acceptability of mango fruits (Pacheco *et al.*, 2017) [18]. Mango is supposed to be very responsive towards mechanical harvesting but on the same time, its effect on postharvest quality is needed to be addressed (Abu-Gaukh *et al.*, 2004, Pacheco *et al.*, 2017) [2, 18]. Knowledge of mechanical harvesting and its effect on postharvest quality, will not only improve farmers/growers income but on the same time, it also helps to meet the expectation of consumers and quality inspection authorities (Pacheco *et al.*, 2017) [18].

Materials and Methods
These studies were conducted at the Division of Food Science and Postharvest Technology,

ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India in the year 2015-18. To study the effect of harvesting technique on postharvest quality attributes of mango fruits, four commercially grown mango cultivars such as 'Amrapali' ('Dushehari' x 'Neelum'), 'Dushehari', 'Langra' and 'Chausa' were selected. The fruits were harvested by two methods i.e., manually and mechanically (pole mounted mechanical harvester) in two different lots. at appropriate maturity (specific gravity > 1) from the orchard of the Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi. After harvesting, fruits were de-saped, precooled and stored in CFB (corrugated fiber board boxes) under ambient storage conditions (25 ± 4º C and 65 ± 5% RH) for normal ripening. Fruits were recorded for observations on postharvest cosmetic appeal (glossiness, face value and lenticel browning), physiological (ethylene evolution and respiration rate), biochemical (total soluble solids, total carotenoids and antioxidant activity) and overall acceptability till the end of shelf life to draw a conclusion.

Cosmetic appeal of mango fruits

Glossiness, face value and lenticel browning of mango fruits

The glossiness of mango fruits was determined by 'Panel method' i.e. getting the feedback based on the gloss of fruit from a panel of ten semi-technical experts on hedonic scale, following standard procedure (Panse and Sukhatme, 1984) [19], ranging from 0 to 9 scale in ascending order of gloss, in which 9 indicates extremely glossy, whereas 1 indicated extremely non glossy. The score was given on the basis of parameterss such as colour, shine, and appearance of fruit. The average values were included in assessing the overall gloss of mango fruits.

In a similar way, by panel method, the face value of mango fruits was determined and results were represented in hedonic scale, ranging from 0 to 9 (Panse and Sukhatme, 1984; Prasad *et al.*, 2016a) [19, 23]. The score was given to the fruits on the basis of parameters such as colour, brushing, browning and appearance of fruit.

Lenticel browning percentage was estimated as per the method followed by Prasad and Sharma (2016) [21], by counting the number of lenticels browned on the fruit peel with respect to total lenticels present per cm^2 and represented as a percentage (%). Lenticel browning being an irreversible process, data of last observation were presented to draw a conclusion. The extent, to which the browning of lenticels occurred on mango fruits, was calculated and compared among the varieties.

Physiological attributes

Respiration rate was determined by the method followed by Prasad *et al.* (2016a) [23]. Auto gas analyzer (Model: Checkmate 9900 O^2/CO^2, Dansensor PBI, Denmark) was used for measuring respiration rate of mango fruits, the results were then expressed in ml CO_2 kg^{-1} h^{-1}. Following formula was used further for the calculation of the respiration rate.

$$\text{Respiration rate } (CO_2 \text{ ml kg}^{-1} \text{ h}^{-1}) = \frac{\text{Evolved } CO_2 \text{ (\%) x Head space of the container (ml)}}{\text{100 x Weight of the trapped fruit in kg x Time (h)}}$$

Ethylene evolution rate was determined by using Hewlett Packard (H.P.) gas chromatograph (model 5890 Series II). The fruits were weighted and then kept inside a specially designed airtight container of 330 ml and 500 ml capacity according to the size of fruits results were expressed in terms of µl kg^{-1} h^{-1} of evolved ethylene.

Biochemical attributes and overall fruit appeal

Roy (1973) [25] method was used for the determination of total carotenoids content of mango fruit pulp. 5 g mango pulp was homogenized/crushed 15 ml acetone after extraction of pigments by this method samples recorded for absorbance at 452 nm wavelength with the help of spectrophotometer. Petroleum ether was used as a blank. The carotenoids content were expressed as mg 100 g^{-1} FW (fresh weight).

The total soluble solids of mango fruit pulp samples were estimated using FISHER Hand Refractometer (range 0 to 50), at the room temperature between 18-28 ºC and expressed in ºB (AOAC, 2006) [1]. Antioxidant activity in mango fruit was determined by following CUPRAC method (Apak *et al.*, 2004) [8] with slight modifications. CUPRAC stands for 'cupric reducing antioxidant capacity'. It measures the copper (II) or cupric ion reducing ability of polyphenols.

The overall fruit appeal of mango fruits with respect to consumer was determined in terms of degree of liking the fruits based on organoleptic properties such as taste, colour, aroma flavor and mouth feel as per 'Panel method' using hedonic scale (Panse and Sukhatme, 1984) [19] and the results were presented in 0-9 Scale depicting the ascending order of degree of likeness.

The experiment was carried out by using factorial completely randomized design (2 factor CRD) with three replications, having 100 fruits in each cultivar.

Results and Discussion

Cosmetic appeal of mango fruits

Glossiness and face value

Glossiness and face value are parameters to depict cosmetic appeal of the fruits and has a great influence on consumer attraction and thereby acceptability (Oosthuyse, 2002) [17]. Fruits having attractive colour, free from defects, bruising, browning etc., fetch better price in the market than those having bruises and other defects (Du-Plooy *et al.*, 2006) [12].

Results of glossiness score of fruits results reveal that significant differences were recorded among the varieties (Table 1). Irrespective of varieties fruits of cultivar 'Amrapali' recorded for highest gloss when harvested manually (6.5) and mechanically (7.5). This differences might be due to the genetic makeup of fruits. Whereas, among harvesting technique, an overall increase of 1.1 unit gloss was recorded when fruits were harvested mechanically (6.6) compared to that of manual harvesting (5.5). This might be due to occurrence of high incidence of oil gland rupture (Anon 2013) [4], abrasion on fruit surface (Anon 2013) [4], sap burn and incidence of superficial blemish on fruit surface (Prasad *et al.*, 2016b) [22], when harvested manually (Table 1).

Table 1 reveals that significant differences were recorded for face value score among the varieties in both manually and mechanically harvested fruits. Irrespective of varieties highest face value was recorded by 'Amrapali' fruits when harvested manually (6.2) as well as mechanical means (6.7), whereas fruits of cultivar 'Langra' shown the least (Table 1). These differences might be due to the genetic makeup of the cultivar (Prasad *et al.*, 2016a) [23] and their response towards harvesting method (Abu-Gaukh *et al.*, 2004) [2]. Further, irrespective of varieties, there was an overall increase in face value of mechanically harvested fruits (6.2) compared to that of fruits harvested manually (5.4). Our results collaborate with findings of Abu-Gaukh *et al.*, 2004 [2], who reported that mechanical harvesting supposed to improve the external appeal of mango fruits due to decreased susceptibility of fruits to the factors which deteriorate external quality attributes such as surface colour, gloss, texture, aroma, consumer attraction and overall acceptability.

Lenticel browning percentage

Significant differences occurred among the varieties for lenticel browning in both manually as well as mechanically harvested fruits (Table 1). Fruits of cultivar 'Amrapali' recorded for the lowest lenticel browning percentage in both manual (9.5) and mechanical harvesting (6.1), while fruits of cultivar 'Langra' recorded for least. These differences might be due to the genetic makeup of the fruits and its susceptibility towards lenticel discoloration (Prasad and Sharma, 2016) [21]. Among the harvesting methods, there was a decrease in lenticel browning incidence of mechanically harvested fruits (35.2 %) compared to that of fruits harvested manually (44.3%). This difference might be due to the fact that mechanical harvesting might have reduced fruit abrasion and sap contact to fruit, which are one of the main reasons for lenticel discoloration on mango fruits (Prasad and Sharma, 2018) [20].

Physiological attributes

Ethylene evolution and respiration rate

Ethylene evolution and respiration rate determines the shelf life of fruits (Jhalegar *et al.*, 2014) [15]. Significant differences occurred among cultivars and storage days for ethylene evolution and respiration rate in the manual as well as mechanically harvested fruits (Table 2). This differences might be due to varietal differences as reported by Prasad *et al.*, 2016a [23] in his studies on mango fruit. Further the similar pattern of ethylene and respiration rates among manually and mechanically harvested fruits (Table 2), which might be due to the fact that both these processes are directly associated with ripening and decay in mango fruits (Baloch and Bibi, 2012) [9] and thereby follow a synergistic pattern in mango fruits (Islam *et al.*, 2013; Reddy and Sharma, 2014; Prasad and Sharma, 2018) [13, 24, 20].

From Table 2, it is evident that mechanically harvested fruits shown an overall decreased respiration (87.31ml CO_2 kg^{-1} h^{-1}) and ethylene evolution rate (0.934µl kg^{-1} h^{-1}) compared to respiration (95.97ml CO_2 kg^{-1} h^{-1}) and ethylene evolution (1.003µl kg^{-1} h^{-1}) rate of manually harvested mango fruits of all four cultivars under study. This overall increase in respiration and ethylene evolution rate in manually harvested fruits might be due to increased senescence of fruits by manual harvesting compared to that of mechanical harvesting method (Abu-Gaukh *et al.*, 2004; Islam *et al.*, 2013) [2, 13].

Biochemical attributes and overall fruit appeal

Total soluble solids

Irrespective of storage days, significant differences occurred for total soluble solids among manually and mechanically harvested fruits (Table 3). 'Amrapali' fruits were recorded for highest total soluble solids when harvested manually and mechanically (22.1 and 22.6 ºB, respectively) (Table 3). Results reveal that irrespective of cultivar and storage day, there was no significant difference in total soluble solids between the manually harvested (20.4 ºB) and mechanically harvested (20.6 ºB) fruits (Table 3). The insignificant difference in TSS might be due to the fact that mechanically harvested fruits succeeded in attaining higher TSS with the progression of shelf life, whereas manually harvested fruit does attain early ripening only (Abu-Gaukh *et al.* 2004; Pacheco *et al.* 2017) [2, 18]. This pattern of total soluble solids depict its dependence on both varietal fruit characteristic and opted harvesting method.

Total carotenoids content

Among manually harvested fruits, irrespective of storage days highest total carotenoids content was recorded in fruits of 'Amrapali' (6.6 mg 100 g^{-1} FW) whereas fruits of 'Langra' the least (4.3 mg 100 g^{-1} FW) (Table 3). Similarly among mechanically harvested fruits, 'Amrapali' fruits were recorded for the highest total carotenoids content (6.7 mg 100 g^{-1} FW) followed by fruits of cultivar 'Dushehari' (6.0 mg 100 g^{-1} FW) while fruits of 'Langra' (4.4 mg 100 g^{-1} FW) were least (Table 3). Differences among varieties for total carotenoids content might be due to the varietal characteristic (Prasad *et al.*, 2016a) [23] and changes due to ripening process, as the transition of chlorophyll into carotenoids, biochemical conversions of starch into sugar, insoluble protopectin into pectin and loss of organic acid through oxidation are responsible for the increase in sugar and carotenoids in mango fruits (Baloch and Bibi, 2012) [9].

Results reveal that irrespective of varieties among harvesting method, an overall slight increase in total carotenoids content was observed in the mechanically harvested fruits (5.4 mg 100 g^{-1} FW), compared to that of fruits harvested manually (5.3 mg 100 g^{-1} FW) (Table 3). This slight increase might be due to the effect of mechanical harvesting technique on proper attainment of ripening throughout the shelf life of mango fruits (Pacheco *et al.*, 2017) [18], although, total carotenoid might have directly affected by harvesting technique but its change is also subjected to varietal morphology of mango fruits (Abu-Gaukh *et al.*, 2004) [2].

Total antioxidant activity

Significant differences occurred for total antioxidant activity in both manually and mechanically harvested fruits (Table 3). Among manually harvested fruits irrespective of storage days highest total antioxidant activity was recorded in fruits of 'Amrapali' (3.86 µmol Trolox eqt g^{-1} FW) whereas, fruits of 'Chausa' cultivar recoded for the least (2.30 µmol Trolox eqt g^{-1} FW). A similar trend was observed in mechanically harvested fruits as fruits of 'Amrapali' cultivar shown the highest antioxidant activity (3.89 µmolTroloxeqtg^{-1}FW) and fruits of 'Chausa' cultivar the least (2.31 µmol Trolox eqtg^{-1} FW) (Table 3). These differences among cultivar might be due to varietal and genotypic characteristic of fruit.

From Table 3, it is also evident that slight increase of antioxidant activity was observed in fruits harvested mechanically (3.00 µ mol Trolox eqt g^{-1} FW) than that of manually harvested fruits (2.98 µmol Trolox eqt g^{-1} FW), this difference was even more at 9th day of storage as fruits harvested mechanically were recorded for antioxidant activity of 4.29 µmolTroloxeqtg^{-1}FW compared to that of 4.23 µmol Trolox eqt g^{-1} FW recorded in manually harvested fruits (Table 3). Our findings are in line with the findings of Abu-Gaukh *et al.*, 2004 [2] who reported that extent of physical abrasion, physical damage directly affects the antioxidant like ascorbic acid present inside the fruit, as antioxidants are used up by the fruit for combating external stresses (Pacheco *et al.*, 2017) [18].

Table 1: External quality of mango fruits as affected by harvesting method at the 9th day of ambient storage (25 ± 4º C and 65 ± 5% RH).

Cultivars	Glossiness (0 to 9 scale)		Face value (0 to 9 scale)		Lenticel browning (%)	
	Harvesting method		Harvesting method		Harvesting method	
	Hand	Mech.	Hand	Mech.	Hand	Mech.
'Dushehari'	6.0	7.0	6.0	6.4	54.5	40.4
'Chausa'	5.0	6.0	5.0	6.0	13.5	9.5
'Amrapali'	6.5	7.5	6.2	6.7	9.5	6.1
'Langra'	4.5	6.0	4.5	5.8	100.0	85.5
Mean	5.5	6.6	5.4	6.2	44.3	35.2
C.D. at p ≤0.05	0.6	0.4	0.4	0.40	2.8	4.3

Table 2: Physiological activity of mango fruits as influenced by harvesting method, stored at ambient storage condition (25 ± 4º C and 65 ± 5% RH).

Cultivars	Respiration rate (ml CO_2 kg^{-1} h^{-1})								Ethylene evolution rate (µl kg^{-1} h^{-1})							
	Hand harvesting				Mechanical harvesting				Hand harvesting				Mechanical harvesting			
	Storage days			Mean	Storage days			Mean	Storage days			Mean	Storage days			Mean
	3	6	9		3	6	9		3	6	9		3	6	9	
'Dushehari'	68.49	93.55	111.37	91.13	61.54	82.27	97.41	80.41	0.515	0.853	1.287	0.885	0.503	0.818	1.108	0.810
'Chausa'	81.61	96.30	120.19	99.37	78.68	92.24	113.50	94.81	0.797	1.151	1.591	1.180	0.751	1.119	1.446	1.105
'Amrapali'	65.44	88.09	102.44	85.32	64.47	75.60	90.540	76.87	0.554	0.952	1.136	0.881	0.522	0.918	1.047	0.829
'Langra'	85.72	103.60	134.92	108.08	72.47	98.47	120.79	97.24	0.714	1.161	1.329	1.068	0.680	1.050	1.256	0.995
Mean	75.31	95.38	117.23	95.97	69.29	87.15	105.56	87.31	0.645	1.029	1.336	1.003	0.614	0.976	1.214	0.934
C.D. at p ≤0.05	Cultivar = 1.11; Storage days = 0.96: Cultivar x storage days = 1.93				Cultivar = 1.47; Storage days = 1.27: Cultivar x storage days = 2.54				Cultivar = 0.028; Storage days = 0.024: Cultivar x storage days = 0.049				Cultivar = 0.038; Storage days = 0.033: Cultivar x storage days = 0.065			

Table 3: Effect of harvesting method on internal quality and overall fruit appeal of mango fruits stored under ambient conditions (25 ± 4º C and 65 ± 5% RH).

Cultivars	Total Soluble solids (ºB)								Total carotenoids content (mg 100 g^{-1} FW)								Total antioxidant activity (µmol Trolox eqt g^{-1} FW)								Overall fruit appeal (0 to 9 scale)	
	Hand harvesting				Mechanical harvesting				Hand harvesting				Mechanical harvesting				Hand harvesting				Mechanical harvesting				Hand harv.	Mech. harv.
	Storage days			Mean	Storage days			Mean	Storage days			Mean	Storage days			Mean	Storage days			Mean	Storage days			Mean		
	3	6	9		3	6	9		3	6	9		3	6	9		3	6	9		3	6	9		9	9
Dushehari	18.1	20.8	22.8	20.5	18.1	21.2	23.5	20.9	4.0	5.5	8.3	5.9	4.0	5.6	8.5	6.0	1.52	3.17	4.63	3.10	1.52	3.19	4.69	3.13	6.0	7.0
Chausa	16.7	20.6	22.0	19.7	16.6	20.2	22.2	19.7	3.8	4.3	5.6	4.5	3.8	4.3	5.4	4.5	1.74	1.93	3.25	2.30	1.74	1.92	3.28	2.31	4.0	6.0
Amrapali	18.9	22.3	25.1	22.1	18.9	22.8	25.9	22.6	4.2	6.5	9.1	6.6	4.3	6.7	9.3	6.7	2.63	3.55	5.42	3.86	2.63	3.54	5.51	3.89	6.0	7.0
Langra	16.7	19.3	21.6	19.2	16.7	19.0	21.9	19.2	3.5	4.0	5.4	4.3	3.5	4.1	5.6	4.4	1.94	2.41	3.65	2.66	1.94	2.41	3.69	2.68	4.0	6.0
Mean	17.6	20.7	22.9	20.4	17.6	20.8	23.3	20.6	3.8	5.0	7.1	5.3	3.9	5.1	7.2	5.4	1.95	2.76	4.23	2.98	1.95	2.76	4.29	3.00	5.0	6.5
C.D. at p ≤0.05	Cultivar = 0.27; Storage days = 023; Cultivar x storage days = 0.47				Cultivar = 0.32; Storage days = 028; Cultivar x storage days = 0.57				Cultivar = 0.29; Storage days = 025: Cultivar x storage days = 0.51				Cultivar = 0.25; Storage days = 021: Cultivar x storage days = 0.43				Cultivar = 0.02; Storage days = 0.02 : Cultivar x storage days = 0.04				Cultivar = 0.03; Storage days = 0.02: Cultivar x storage days = 0.05				0.7	0.6

Overall fruit appeal

'Amrapali' and 'Dushehari' cultivar recorded for highest overall fruit appeal score in both the case when harvested manually (6.0) and mechanically (7.0) (Table 3) This might be due to varietal characteristic of cultivar itself which further get improved by right harvesting techniques (Baloch and Bibi, 2012) [9]. Among harvesting method, mechanical harvesting contributed to the increase in overall fruit appeal score than of fruits which were harvested manually, as overall fruit appeal score of fruits harvested mechanically were recorded higher (6.5) than that of fruits harvested manually (5.0) (Table 3). This might be due to decreased incidence of physical abrasion, discoloration, rupturing of oil gland and pathological incidence along with developed fruit colour under mechanical harvesting technique which helped fruits to attain better sensory quality than that of the fruits which were harvested manually (Anon 2013) [4].

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