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Studies on Variability of Physico-Biochemical Parameters of Mango Fruit

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ABSTRACT

More than a thousand varieties of mango (*Mangifera indica* L.) are grown in India. Their quality attributes not only differed altogether but also depends on their maturity and storage after harvest. An experiment on four mango varieties harvested at pre-, optimum, and over-maturity stages from different orchards was conducted in this study. The effect of varieties and harvest stage, and their interactions on external diameters, arithmetic and geometric mean diameters, sphericity, and aspect ratio was analyzed. Similarly, the change in peel color values, specific gravity, total soluble solids, titratable acidity, and total carotenoids with respect to varieties, harvest stage, and storage periods and their interactions were analyzed statistically. Dimensions, size, weight, volume, aspect ratio, and sphericity varied significantly among the cultivars and were found to be increased significantly from the pre-to-over maturity stage. Interaction between the harvest stage and cultivars also had a significant ($p<0.05$) effect on the fruit's breadth, thickness, size, weight, volume, aspect ratio, and sphericity (except on length). Similarly, specific gravity and peel color values and biochemical attributes were also found to be changed significantly among the cultivars, maturity stages, and storage periods. The effect of their interactions on peel color values and bio-chemical properties was also significant. However, there is an insignificant effect of interactions on the specific gravity of mangoes. Results concluded that most of the physical and biochemical parameters of mangoes were variable and dependent on cultivar type, maturity stage and storage period, and on their interactions. This study, therefore, can be fruitful during the designing of processing equipment and can be helpful in the post-harvest management of mangoes.

Keywords: Mango, Cultivars, Harvest Stage, Storage, Physico-bio-chemical Parameters.

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INTRODUCTION

Mango (*Mangifera indica* L.), the king of fruits, is consumed not only ripe because of its delicious taste and high nutritional value (vitamins, minerals, etc.) but also it consumed as green/raw with salt, chili, or soya sauce. Mangoes are nutritionally rich sources of prebiotic dietary fiber, carotenoids, organic acids, polyphenols, provitamins, minerals, etc (Anon, 2010). It ranks first in the area and production of mango with 2.31 million ha and 12.75 million tonnes, respectively with a share of 56% production in the world. It has high commercial value in the international fruit market. Its richness in luscious aromatic flavour with evenly blended sweetness and acidity is commonly more significant among people (Anon, 2010). The design and development of various harvest and post-harvest equipment/machinery are, thus, of utmost importance to harvest its nutritional, medicinal, and economical values. And the designing of types of equipment (for harvesting, sorting, grading, packaging, storing, and processing) is required information on the physical properties of mangoes. Physical properties of food materials affect the handling/conveying characteristics. These properties also play important role during the estimation of cooling and heating load. Size and shape parameters among the physical attributes are often more considerable in designing drying and aeration systems, as these properties affect on the airflow of the stored mass (Razavi and Parvar, 2007).

Since, mango is the oldest, tropical, most attractive, and most popular climacteric fruit of India and India is the world's largest producer of mango fruit (Patel *et al.* 2019a, 2019b). Its quality is varied with respect to cultivar, place production, maturity status, etc. The aim of this present investigation was, thus, to study the variability of valuable physical characteristics of mangoes with reference to variety, cropped place, and harvesting stage (immature-green, mature-green, and mature ripening/partial ripened stage as independent factors and subsequently to evaluate the quality characteristics of mangoes.

MATERIALS AND METHODS

Four orchards were selected based on flowering amount, size of trees (for easy harvest) and location (easily approachable). Among these orchards, three (one for Chausa, one for Dashehari and one for Langra) orchards were from Utter Pradesh and one (for Malda) from Bihar state of India. Five trees, each from east, west, north and south, and centre of orchard were randomly selected. Ten fruits, two from each side and two from centre of tree were harvested manually at pre-, optimum and over maturity (when the majority of the

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mangoes were ripening on the tree) and all so collected 50 fruits were mixed thoroughly and 25 among them were picked randomly for experiment. Altogether 100 samples were collected from the orchards for experiment and they were brought to laboratory and kept in divisional cold store at 20±2^{0}C and 95±1% relative humidity (RH). To confirm their maturity, fruit's flotation method (Jacobi *et al.* 1995) was used for grading in ambient temperature. "Floaters" were considered immature and "sinkers" as mature. If any fruit found immature was completely rejected. All studies of fresh samples were conducted in ambient conditions (28 ± 0.1^{0}C and 70 ± 1% RH) within 24 h of harvesting and rests were done at the interval of 3 day.

Determination of physico-bio-chemical properties

Linear dimensions (a: longest intercept (length); b: longest intercept (breadth) normal to *a*; *c:* longest intercept (thickness) normal to '*a*' and '*b*') of selected samples were measured using a digital vernier calipers (model no CD-6" CSX, Mitutoyo-Japan) having least count of 0.01 mm. The arithmetic mean diameter (Da), the sizes of mango in terms of geometric mean diameter (Dg) and sphericity (Sp) were computed using equations given by Mohsenin (1978). Similarly, the aspect ratio (*Ra*) of fruits was calculated using the relationship recommended by Maduako and Faborocde (1990). However, the mass, volume and specific gravity of fruits were measured by a digital balance, with an accuracy 0.01 g and the volume of mango fruits were measured using the water displacement technique (Mohsenin, 1986) based on Archimedes principle. Each mango was submerged in a 500 cm^3 eureka container and the volume of water displaced was measured using graduated cylinder. Water temperature during measurements was kept at 25°C (Rashidi and Seyfi, 2007). After measuring the volume, the specific gravity (the density of a substance divided by the density of water) of each fruit was computed. The specific gravity is usually very close to the density. Since water has a density of 1 gram/cm^3 at standard temperature and pressure and all of the units cancel, specific gravity is unitless quantity. In addition, the HunterLab color values (*L, a,* and *b*) of all freshly harvested and stored mangoes were evaluated using a HunterLab LabScan XE spectrocolorimeter (HAL, USA, model 0^0/45^0 standard, s/n LX17760). In the Hunter scale, '*L*' measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The chromaticity dimensions 'a' measures redness when positive, gray when zero, and greenness when negative, and 'b' measures yellowness when positive, gray when zero, and blueness when negative.

For calibration of colorimeter, standard black and white tiles were provided with the instrument and displayed values were matched with the values reported in the operating manuals. To prevent leakage of light emitted by the colorimeter, proper size of port used, at which sample surface rest and contact completely, were 1.75 and 1.50mm. The color values *L, a, b* was stored automatically in the instrument. The experiment was repeated at four places i.e., top (apex), bottom and regions of both side of each mango and average values were used for further calculation. Immediately after getting the color values, the mango was peeled (0.2 to 0.3 mm thick) and pulp were used for further evaluation of biochemical properties: the total soluble solids (TSS, ^{0}brix) and titratable acidity (%) were analyzed using methods described by AOAC (1994) and total carotenoids (mg/100g) of fruit was estimated by Alasalvar *et al.* (2005).

DATA ANALYSES

Measurements of all properties were triplicate. Maximum, minimum and coefficient of variation (CV) were obtained using Microsoft Excel (2003) software and multivariate analysis were carried using SPSS software (version 16) to check the effect of main factors (cultivars, V and harvesting stages, H) and their interactions (L*H) for all two ways on physical parameter. Similarly, the effect of cultivars (V), harvest stage (H) and storage periods (S) and their interactions (H*V, H*S and S*V) on bio-chemical properties of selected mango varieties were also analyzed. To check the difference among cultivar in relation to measured physico-chemical parameters one-way MANOVA analysis was also carried out.

RESULTS AND DISCUSSION

Dimensions of Fruit

The mean values of fruit diameters (length, breadth and thickness) and standard error in estimation at every harvest stage and for each cultivar are displayed in Table 1**.** Variation in fruit's diameters was found to be significant ($p<0.05$) among the cultivars. But, the effect of harvest stages (pre-, optimum and over maturity) was found insignificant on fruit's length. However, the effect harvest stages on breadth and thickness were significant. These diameters also found to be affected significantly ($p<0.05$) by their interactions (HS*V) (Table 2). The average fruit length was found to be varied from 100.64 to 101.87mm during pre-to over maturity stage. Chausa (112.32mm) fruit was found to be the longest and fruit with maximum breadth among the cultivars. The maximum length of Chausa fruit was found to be 131.2mm. The shortest fruit length was recorded for Malda fruit (88.44mm) while the minimum mean value of breadth (53.05mm) was found for the Dashehari fruit at pre-maturity stage. Chausa fruits were noticed wider (67.56 mm) and followed by Langra (66.09mm), Malda (59.29 mm) and then Dashehari (55.53 mm) cultivar (Table 1).

Similarly, the mean values of fruit's thickness of each cultivar harvested at each stage are given in Table 2. The overall grand mean value of thickness and grand mean error in estimation was found to be as 57.21mm and 1.09mm, respectively. Chausa fruits harvested at over maturity stage were found thicker than the other cultivar's fruits harvested at any stage of maturity. The reason of increase in fruit's width and thickness from pre- maturity to over maturity was might be due to more appearance of auxins, plays a major role in fruit's growth.

Weight and Volume of Mangoes

Variation in fruit's weight and volume among the cultivars and harvesting stage from pre- to over maturity were found to be highly significant ($p<0.05$) (Table 1). The mean values of fruit's weight and volume were found to be varied from 183.47±4.39gm to 234.94±4.77gm and 188.47±4.39gm to 236.38±4.66gm during pre- to over harvesting period, respectively. Among the cultivars, Chausa fruits weighed heavy (271.32±4.78gm) with largest volume (276.25±4.64ml) and followed by Langra cultivar i.e. 230.08±5.85 gm and 231.85±5.72ml. Table 1 displays the evaluated grand mean values of fruits weight and volume i.e. 205.49±3.73gm and 209.60±3.69ml, respectively. In contrast, Table 2 shows the mean values of weight and volume of fruit's of each cultivar harvested at different stages. Chausa fruit weighed heavy

(332.47±10.13gm) with maximum volume as 326.11±9.91ml at over maturity stage might be due to that the developing fruits increased in weight. In spite of above, the effect of interaction (Table 2) between harvest stage and cultivar (HS*V) on variability of fruit's weight and volume was also found highly significant (p<0.005) and the variation in weight and volume was noticed maximum than other quality attributes.

Mango Size or GMD and AMD

The effect of harvest stage, cultivar (Table 1) and their interactions (Table 2) on the diameters (GMD or size and AMD) of fruits were found significant (p<0.05). Chausa fruit calculated with maximum AMD (80.49±0.50mm) and GMD

Table 1: Effect of harvest stage and cultivars on some important physical parameters of mango fruit.

Factors	Parameters								
	Length (mm)	Breadth (mm)	Thickness (mm)	Weight (gm)	Volume (ml)	AMD (mm)	GMD (mm)	Sphericity	Aspect ratio %
1. Harvest Stages									
Pre-mature	100.647 [a] ± 0.974	60.469 [b] ± 0.506	53.183[c] ± 0.449	183.304[c] ± 4.388	188.472[c] ± 4.388	71.431[b] ± 0.550	68.527 [b] ± 0.518	0.685[c] ± 0.004	60.60 [b] ± 0.50
Optimum mature	101.869 [a] ± 0.974	61.874[b] ± 0.506	56.506[b] ± 0.449	208.357[b] ± 4.388	211.562[b] ± 4.388	73.417 [a] ± 0.550	70.772 [a] ± 0.518	0.700[b] ± 0.004	61.4[b] ± 0.50
Over mature	101.472 [a] ± 1.059	64.002[a]± 0.550	59.407[a] ± 0.489	234.939[a] ± 4.770	236.376[a] ± 4.663	74.957 [a] ± 0.598	72.629 [a] ± 0.563	0.722[a] ± 0.004	63.90[a] ± 0.50
Significant level	NS	***	***	***	***	***	***	***	***
2. Cultivar									
Chuasa	112.32[a] ± 1.060	67.56[a] ± 0.550	61.62[a] ± 0.498	271.32[a] ± 4.777	276.25[a] ± 4.670	80.49[a] ± 0.599	77.50 [a] ± 0.563	0.693 [c] ± 0.004	60.50 [b] ± 0.50
Dashehari	106.13[b] ± 0.932	55.53[c] ± 0.484	50.06[c] ± 0.430	167.53[c] ± 4.199	170.54[c] ± 4.105	70.57[c] ± 0.527	66.49 [c] ± 0.495	0.629 [d] ± 0.004	52.60 [c] ± 0.50
Langra	99.68[c] ± 1.299	66.09[a] ± 0.674	58.89[a] ± 0.599	230.08[b] ± 5.850	231.85[b] ± 5.720	74.88[b] ± 0.734	72.83 [b] ± 0.690	0.733 [b] ± 0.005	66.60 [a] ± 0.70
Malda	87.19[d] ± 1.299	59.29[b] ± 0.674	54.90[b] ± 0.599	166.54[c] ± 5.850	169.91[c] ± 5.720	67.13[d] ± 0.734	65.68 [c] ± 0.690	0.754 [a] ± 0.005	68.10 [a] ± 0.70
Significant level	***	***	***	***	***	***	***	***	***
Grand mean	103.3900	61.9530	57.2098	205.4860	209.6040	74.1843	66.4396	0.6980	60.39
Standard error (±)	0.7444	0.6681	1.0854	3.7282	3.6878	0.5954	0.5164	0.004	0.58
Total no of fruits	303	303	303	303	303	303	303	303	303

Table 2: Combined effect of factors (harvest stage and cultivars) on some important physical parameters of mango fruit.

Combined factors	Length (mm)	Breadth (mm)	Thickness (mm)	Weight (gm)	Volume (ml)	AMD (mm)	GMD (mm)	Sphericity	Aspect ratio
H1V1	114.56 ±1.59	66.47±0.83	57.59± 0.73	239.49±7.17	255.56±7.01	79.53±0.89	75.93±0.85	0.664± 0.006	58.1± 0.80
H1V2	102.60 ± 1.59	53.05 ± 0.83	47.19± 0.73	139.45±7.17	145.00±7.01	67.61±0.89	63.49± 0.85	0.621±0.006	51.9± 0.80
H1V3	96.99 ± 2.25	64.09 ± 1.17	54.91±1.04	194.43±10.13	196.11± 9.91	71.99±1.27	69.82± 1.20	0.721±0.009	66.2±1.10
H1V4	88.44 ± 2.25	58.27 ± 1.17	53.04±1.04	159.85±10.13	157.22±9.91	66.59±1.27	64.86± 1.20	0.734±0.009	66.0±1.10
H2V1	109.44 ±1.59	64.814 ±0.83	58.84 ±0.73	242.00 ± 7.17	247.08±7.01	77.7 ± 0.89	74.68± 0.85	0.684± 0.006	59.4±0.80
H2V2	108.52 ± 1.59	56.17 ± 0.83	50.82±0.73	174.41 ± 7.17	177.22±7.01	71.84±0.89	67.63± 0.85	0.624±0.006	51.9±0.80
H2V3	101.04 ± 2.25	65.96 ± 1.17	60.02±1.04	241.07±10.13	237.78±9.91	75.67±1.27	73.52± 1.20	0.732±0.009	65.9±1.10
H2V4	88.48 ± 2.25	60.56 ± 1.17	56.34±1.04	175.94 ± 0.13	184.17±9.91	68.46±1.27	67.06±1.20	0.759±0.009	68.5±1.10
H3V1	112.97 ± 2.25	71.39 ± 1.17	68.42±1.04	332.47±10.13	326.11±9.91	84.25±1.27	81.90± 1.20	0.730±0.009	63.9 ±1.10
H3V2	107.27 ±1.66	57.36 ± 0.86	52.17±0.77	188.72 ± 7.48	189.39±7.32	72.26±0.94	68.35± 0.88	0.641±0.006	53.9±0.8
H3V3	100.99 ±2.25	68.22 ± 1.17	61.74±1.04	254.74±10.13	261.67± 9.91	76.99±1.27	75.1 ± 1.20	0.746±0.009	67.8 ±1.10
H3V4	84.66 ± 2.25	59.03 ±1.17	55.30±1.04	163.83±10.13	168.33±9.91	66.33±1.27	65.10± 1.20	0.770± 0.009	69.9 ±1.10
Significance level	**	**	***	***	***	**	***	**	NS

(77.50±0.56mm) followed by Langra cultivar (Table 1). Similarly, the size (GMD) and AMD of fruit were found to be increased significantly from pre- (68.53±0.52mm and 71.43±0.55mm) to over (72.63±0.56mm and 74.96±0.60) maturity stage, respectively. As, the average diameter calculated by the arithmetic mean and the geometric mean diameter's formulae were almost different. AMD should be used to calculate the equivalent diameter of mangoes or we should use mean diameter which has larger value to avoid failure of equipments or for better results and success.

Sphericity and Aspect ratio

Table 1 displays significant (F (2,105) = 56.263, p = 0.000) variations in the sphericity of fruits among the four cultivars and also found to be increased significantly (p<0.05) from the pre- to over maturity stage of harvesting. The average sphericity of fruits of all cultivar was calculated as 0.685±0.004 at pre-maturity stage which found to be increased to 0.722±0.004 at over maturity. The highest average sphericity value (0.754±0.005) was found for Malda fruits followed by Langra cultivar (0.733±0.005). In addition, the effect of interactions between harvest stages and cultivars were also found significant at the confidence level of 5% (Table 2). Although, for Dashehari fruit's, the variation in the sphericity of is not much considerable (Table 2). It means that the increment in sphericity was not so substantial, and only a slight change was noticed during the growth.

Table 3: Summary of effect of harvest stage, cultivar and storage period on TSS, titratable acidity, total carotenoids, specific gravity and peel colour values (L, a & b) of mango fruit.

Factors	Parameters						
	Total Soluble Solids (^{0}brix)	Titratable Acidity (%)	Total Carotenoids (mg/100g)	Specific Gravity (g/cm^3)	Colour values		
					L	a	b
1. Harvest stages							
Pre-mature	14.2528c	1.353a	0.488b	0.978b	45.89c	-7.329c	25.948c
Optimum mature	15.6278b	0.980b	0.476b	0.994b	48.17b	-6.730b	28.395b
Over mature	16.6903a	0.706c	0.597a	1.019a	50.60a	-5.615a	33.624a
Standard error (±)	1.354	0.046	0.021	0.008	0.507	0.199	0.445
Significant level	***	***	***	***	***	***	***
2. Cultivar							
Chuasa	13.2611b	0.613c	0.307c	0.981b	48.86b	-7.539b	25.406b
Dashehari	14.0056c	1.171a	0.681a	0.980b	45.30d	-5.772a	31.351a
Langra	15.3685b	1.299a	0.541b	0.996b	51.98a	-7.620b	29.855a
Malda	19.4593a	0.969b	0.554b	1.032a	46.74c	-5.301a	30.677a
Standard error (±)	1.564	0.053	0.025	0.009	0.585	0.233	0.514
Significant level	***	***	***	***	***	***	***
Storage Periods							
0 days	9.0861bf	2.011a	0.156e	0.945c	40.702f	-9.342d	28.485b
3 days	12.342e	1.538b	0.230e	0.962c	46.065e	-8.702d	28.283b
6 days	14.5444d	1.026c	0.372d	0.998b	47.902d	-7.787c	28.804ab
9 days	17.2694c	0.673d	0.562c	1.012ab	49.666c	-7.235c	29.146ab
12 days	19.2056b	0.479e	0.728b	1.023ab	51.061b	-4.178b	30.518a
15 days	20.694a	0.352e	1.074a	1.043a	53.918a	-2.106a	30.696a
Standard error (±)	1.915	0.065	0.030	0.011	0.0.404	0.282	0.630
Significant level	***	***	***	***	***	**	***
Grand mean	16.619	1.013	0.521	0.997	48.219	-6.558	29.322
Grand mean Standard error (±)	0.782	0.026	0.012	0.004	0.165	0.115	0.257
Total no of fruits	216	216	216	216	216	216	216

To analyze the fruit whether roll or slide on their flat surfaces, the knowledge of aspect ratio is very important. If the value of the aspect ratio is being close to the value of sphericity, the fruit will undergo a combination of rolling and sliding action on their flat surfaces (Razavi and Parvar, 2007). The grand mean value of aspect ratio (Table 1) of fruits was computed as 60.39 % at 95% CI. The value of highest aspect ratio (which relates the fruit width to length) was evaluated for Malda cultivar at over maturity stage (69.9%) indicates that the fruit might follow the rolling than the sliding action on their flat surfaces (Table 2). Further, the value of aspect ratio found to be changed significantly (p<0.01) from pre- and optimum maturity stage to over maturity stage. However, there was no significant variation recorded in aspect ratio of fruits harvested between pre- (60.6%) and optimum maturity stage (61.4%). But, the effect of cultivars on aspect ratio of fruits was noticed highly significant (p<0.001). Though, the interactions between harvest stages and cultivars (HS*V) were found effected insignificantly at 5% confidence level (Table 2).

Specific Gravity

Specific gravity of fruits was found to be affected significantly (p<0.001) by harvest stages, cultivars and storage periods. The mean value of specific gravity was evaluated between 0.978 g/cm^3 and 1.019 g/cm^3 from pre- to over maturity stage, respectively and among the cultivars it was varied from 0.980 g/cm^3 to 1.032 g/cm^3. The highest value (1.032 g/cm^3) was

Table 4: Summary of effect of interaction between harvest stage (HS) and cultivar (V) on TSS, titratable acidity, total carotenoids, specific gravity and colour values (L, a & b) of mango fruit.

Combined factors Harveststage (HS)*Cultivar (V)	Parameters						
	Total Soluble Solids (^{0}brix)	Titratable Acidity (%)	Total Carotenoids(mg/100g)	Specific Gravity (g/cm^3)	Colour values		
					L	a	b
H1V1	11.861	0.697	0.455	0.932	53.288	-7.508	24.214
H1V2	12.022	1.831	0.521	0.964	39.938	-6.434	27.711
H1V3	15.433	1.539	0.536	0.994	46.573	-8.445	23.155
H1V4	17.694	1.344	0.441	1.022	43.752	-6.928	28.708
H2V1	14.389	0.656	0.303	0.989	45.091	-7.703	22.510
H2V2	14.339	0.999	0.620	0.974	47.416	-5.752	31.592
H2V3	14.922	1.401	0.495	0.981	52.794	-7.750	29.651
H2V4	18.861	0.865	0.486	1.031	47.385	-5.717	29.824
H3V1	13.533	0.487	0.162	1.020	48.210	-7.407	29.489
H3V2	15.656	0.683	0.902	1.003	48.537	-5.130	34.746
H3V3	15.750	0.656	0.591	1.012	56.564	-6.666	36.760
H3V4	21.822	0.699	0.735	1.042	49.079	-3.258	33.500
Standard error (±)	0.218	0.092	0.043	0.015	0.572	0.399	0.891
Significance level	***	***	***	NS	***	***	***

evaluated for Malda cultivar (Table 3). Similarly, during the storage, the specific value was found to be varied significantly ($p<0.001$) from 0.945 g/cm^3 (at 0 day) to 1.043 (at 15th day). However, the effects of interactions [HS*V (Table 4), SP*V (Table 5) and HS*SP (Table 6)] were observed insignificant. Table 4 displays the mean values of specific gravity of each cultivar with respect to harvest stage. For instance, Malda cultivar has highest specific gravity (1.042 g/cm^3) harvested at over maturity stage. Similarly, Table 5 is showing the variation in specific gravity of cultivars with respect to storage periods while Table 6 shows the variation in specific gravity of fruits with respect to harvest stage and storage periods. The maximum specific gravity (1.089 g/cm^3) was investigated at 15th day of storage of Malda fruits while minimum value (0.901g/cm^3) was recorded at fresh condition of Chausa cultivar (Table 5).

Further, specific gravity (1.057g/cm^3) of fruits harvested at over maturity stage was found to be highest at 15th day of storage. Furthermore, the specific gravity could be tested as one maturity index from many maturity indices. But there is no consensus on maturity indices due to differences among cultivars, production conditions and locations. Specific gravity, thus, cannot be used as a reliable maturity index.

Total Soluble Solids (TSS)

Table 4 displays significant ($p<0.05$) variation in TSS among the cultivars, maturity stage and storage period. In addition, the effects of interactions such as HS*V (Table 5), SP*V (Table 6) and HS*SP (Table 7) on TSS were also found to be highly significant ($p<0.01$). As the storage periods prolonged, the TSS content of fruits was also found to be increased from 9.086 to 20.69^{0}brix (Table 4). Similarly, TSS content found to be increased from 14.25 to 16.69^{0}brix with the advancement of maturity stage. The TSS content, thus, increases slightly as the fruit matures but a significant increment was observed after the mature green stage.

Further, Malda fruits were investigated highest in TSS content i.e. 19.46 ^{0}brix among the cultivars. Table 4 shows that Malda fruits have highest TSS content at over maturity stage and at the 15th day of storage (Table 5). However, the Table 6 reveals that fruits of all cultivars harvested at over maturity stage have maximum TSS content at 15th day of storage. The increase in TSS content in every cultivar might be due to the alteration in cell wall structure and break down of complex carbohydrates into simple sugars from pre to over maturity stage. The increase in sugar content was accompanied by a decrease in acid and increase in carotene.

Titratable Acidity (TA)

Effects of harvest stage, cultivars and storage periods on titratable acidity (TA) of mangoes are presented in the Table 3 while the effects their interactions are presented in the Table 4, Table 5 and Table 6. These tables reveal that all factors (harvest stage, cultivars and storage periods) and their combined interactions have significant ($p<0.01$) effect on titratable acidity. For instant, the mean value of TA of fruits decreased significant ($p<0.01$) from pre- (1.353%) to over-maturity (0.706%) stage which is in agreement with the results reported by several researchers.

According to them the titratable acidity of mango is declined to the value of 0.5% or lowers when ripens or declined during the later stage of growth on attainment of maturity and ripening. However, in developing fruits acidity increased at early growth phase but reached to a peak and then declined gradually until harvest and again decreases with ripening. Similarly, as the storage period increased, the mean value of TA found to be decreased significantly and recorded lowest (0.352%) at 15th day of storage. In addition, a significant ($p<0.01$) variation in TA among the cultivars was also recorded and Langra fruits were evaluated sourer followed by Dashehari cultivars than fruits of other cultivars (Table 3).

Table 5: Summary of effect of interaction between storage period (SP) and cultivar (V) on TSS, titratable acidity, total carotenoids, specific gravity and colour values (L, a & b) of mango fruit.

Combined factors Storage periods (SP)* Cultivar (V)	**Parameters**						
	TSS (^{0}brix)	Titratable Acidity (%)	Total Carotenoids (mg/100g)	Specific Gravity (g/cm^3)	**Colour values**		
					L	**a**	**b**
S1V1	7.067	1.010	0.009	0.901	40.131	-9.608	26.931
S 1V2	8.644	2.411	0.157	0.933	39.665	-9.742	28.613
S 1V3	8.989	2.482	0.187	0.913	44.911	-9.923	28.918
S 1V4	11.644	2.140	0.193	0.981	38.101	-8.096	29.475
S 2V1	10.600	0.740	0.127	0.954	47.059	-8.518	25.649
S 2V2	10.956	2.041	0.254	0.957	42.060	-9.521	29.786
S 2V3	10.911	2.055	0.263	0.980	50.067	-9.202	30.286
S 2V4	16.900	1.316	0.277	1.009	45.074	-7.568	27.410
S 3V1	12.167	0.633	0.197	1.000	48.343	-8.033	25.386
S 3V2	13.044	1.137	0.480	0.980	44.692	-8.762	28.406
S 3V3	13.544	1.429	0.298	0.990	52.090	-8.240	28.740
S 3V4	19.422	0.903	0.514	1.022	46.484	-6.111	32.683
S 4V1	14.900	0.512	0.271	1.003	50.663	-8.051	24.824
S 4V2	15.300	0.731	0.750	0.989	46.077	-7.333	32.549
S 4V3	17.244	0.825	0.571	1.016	53.142	-7.878	28.523
S 4V4	21.633	0.626	0.657	1.041	48.781	-5.677	30.686
S 5V1	16.689	0.472	0.346	1.007	52.159	-6.936	25.251
S 5V2	17.078	0.392	1.039	1.002	47.178	-1.369	33.352
S 5V3	20.233	0.590	0.820	1.028	55.047	-6.281	31.812
S 5V4	22.822	0.462	0.707	1.054	49.859	-2.127	31.658
S 6V1	18.144	0.313	0.811	1.019	54.823	-4.090	24.383
S 6V2	19.011	0.314	1.404	1.022	52.111	2.095	35.394
S 6V3	21.289	0.412	1.104	1.047	56.606	-4.200	30.854
S 6V4	24.333	0.369	0.976	1.086	52.133	-2.227	32.152
Standard error (±)	0.308	0.130	0.060	0.022	0.808	0.564	1.260
Significance level	***	***	**	NS	**	***	***

Further, from the Table 4, it is also clear that the Chausa fruits have lowest titratable acidity (0.487%) or sweetest in taste at the over-maturity stage than the fruits harvested at pre- and optimum maturity stage. Similarly, the TA of fruits among the cultivars varied significantly during the storage. Chausa fruits (0.313% TA) and Dashehari fruit (0.314% TA) were recorded with lowest value of TA at 15th day of storage (Table 5). Furthermore, the Table 6 shows the combined effect of harvest stage and storage period (HS*SP) on the titratable acidity (TA). From the table it is distinct that as the storage period increases, the TA of fruits harvested at any stage decreases significantly. For instance, the value TA of fruits harvested at pre- (2.741% to 0.427% i.e. 84.4%), optimum (1.989% to 0.358 i.e. 82.0%) and over maturity (1.301% to 0.270% i.e. 79.3%) stages decreased from fresh to the 15th day of storage (Table 6). The present investigation, thus, indicates that the fruits harvested at over maturity stage when ripened are less sour in taste than the fruits ripened at other stage of maturity.

Total Carotenoids (TC)

The variation in the total carotenoids due to the factors (cultivars, harvest stages and storage periods) and due their interactions (HS*V, SP*V and HS*SP) were found highly significant ($p<0.01$) (Table 3). The mean, grand mean and standard error in mean and grand mean values of total carotenoids of fruits with respect to harvest stage, cultivar and storage are presented in the Table 3. The mean value of total carotenoids of fruits was found to be increased from 0.448 mg/100g at pre-maturity stage to 0.597 mg/100g for the fruits harvested at over maturity stage. Similarly, the total carotenoids content was also found to be increased significantly from 0.156 mg/100g (at fresh condition) to 1.074 mg/100g (at 15th day of storage) as the storage period was advanced. Among the cultivars, Dashehari fruits were evaluated with the highest value of TC content (0.681 mg/100g).

Furthermore, the Table 4, 5, and 6 show that the interactions between harvest stage and cultivar, storage period and cultivar, and harvest stage and storage period have significant effect on TC content of mango fruit. Considering the effect of interactions, Chausa fruit harvested at over maturity has

highest value of total carotenoids content (0.902 mg/100g) (Table 4). In addition, ripened (at 15th day of storage) Chausa fruit were evaluated with highest total carotenoids content (1.404 mg/100g) (Table 5).

However, mangoes harvested at optimum maturity when ripened (at 15th day of storage) have superior quality in terms of TC (Table 6). The total carotenoids content of mangoes harvested at any stage maturity, thus, found to be increased significantly during storage for ripening. Similarly, the TC content of fruits of any cultivar increased significantly as the maturity changed from pre- to optimum and then over-maturity stage. Although, the fruits harvested at optimum maturity stage and ripened after storage recorded with highest total carotenoids content than the other fruits. This was might be due to the several biochemical changes that occur rapidly during ripening after harvesting, generally depend upon the cultivar type, maturity stage and post harvest conditions.

Color Values

Peel color of mangoes were found to be changed significantly among the cultivars, during maturity stages (pre-, optimum and over maturity stages) and during storage (Table 3). Lightness (L) and yellowness (b) of fruits found to be increased significantly as harvest stage was changed from pre- (45.89 and 25.95) to optimum (48.17 and 28.40) and over maturity (50.60 and 33.62), respectively, and also when fruits were ripened during the storage (Table 3). Consequently, the value greenish colour ('a') found to be reduced significantly from pre- (-7.329) to optimum (-6.730) and to over maturity (-5.615) stage; and also, during the storage (-9.342 at 0 day to -2.106 at 15th day). This was might be due the degradation of chlorophyll as a consequence of maturation and ripening of fruits. Although, the development in peel colour is accompanied by ultra structural changes associated with chloroplast-to-chromoplast transition when ripening proceeds (Siddiqui and Dhua, 2009). Pulp carotenoids continue to increase in the detached fruit as ripening proceeds and affect the peel color. The mean, grand mean, standard error in mean and standard error in grand mean values are given in the Table 3.

Table 6: Summary of effect of interaction between harvest stage (HS) and storage period (SP) on TSS, TA, TC, specific gravity and colour values (L, a & b) of mango fruit.

Combined factor Harvest Stage(HS)*Storage periods (SP)	Parameters						
	Total Soluble Solids	Titratable Acidity	Total Carotenoids	Specific gravity	L	a	b
H1S1	8.100	2.741	0.104	0.945	36.287	-10.34	28.696
H1S2	11.517	2.203	0.148	0.896	42.669	-9.415	26.433
H1S3	14.167	1.322	0.342	0.981	45.709	-9.778	25.883
H1S4	15.708	0.820	0.619	0.998	48.065	-8.891	26.899
H1S5	17.100	0.603	0.709	1.013	49.776	-4.548	26.276
H1S6	18.925	0.427	1.007	1.036	52.819	-1.001	21.495
H2S1	9.042	1.989	0.155	0.908	41.412	-9.391	26.539
H2S2	12.583	1.531	0.191	0.982	46.781	-8.885	28.096
H2S3	14.708	0.907	0.276	0.999	47.467	-8.324	28.574
H2S4	17.650	0.656	0.406	1.017	49.401	-7.291	27.120
H2S5	19.292	0.439	0.693	1.022	50.897	-4.460	29.496
H2S6	20.492	0.358	1.135	1.037	53.073	-2.031	30.540
H3S1	10.117	1.301	0.209	0.983	44.407	-8.295	30.217
H3S2	12.925	0.880	0.352	1.007	48.746	-7.806	30.320
H3S3	14.758	0.848	0.498	1.013	50.530	-5.258	31.954
H3S4	18.450	0.544	0.662	1.022	51.531	-5.522	33.417
H3S5	21.225	0.395	0.782	1.034	52.509	-3.525	35.782
H3S6	22.667	0.270	1.080	1.057	55.864	-3.285	40.052
Standard error (±)	0.267	0.112	0.052	0.019	1.241	0.488	1.091
Significance level	***	***	**	NS	***	***	***

Further, the combined effects of the main factors on 'L', 'a' and 'b' color values were also found to be highly significant ($p<0.01$). The effect of interactions HS*V, SP*V and HS*SP on mean color values ('L', 'a' and 'b') are presented in Table 4, Table 5 and Table 6, respectively. These tables reveal that during advancement of ripening stages and the ripening mango fruits color changes from green to yellow or orange often showing red blush might be due to the loss of chlorophyll and carotenoids synthesis. However, in the initial stage of fruit development (for some cultivar), the L value (lightness) measured on the skin found to be decreased after an increment in yellowness. Similarly, an increase in 'a' & 'b' values during ripening of mango fruits indicates a development of dark green color in the earlier stages of development, followed by light yellow color when fruit starts to ripen. Although, mango harvested at optimum harvesting

stage when allowed to ripen at 22^{0}C, showed similar color development as in the fruits harvested at over maturity (partial ripened on the tree) stage.

CONCLUSION

Quality attributes of mangoes found to be dependent on storage after harvesting and almost changed at every 3 days of storage interval. The length of Chausa fruits was recorded higher than Dashehari and followed by Langra then Malda. Similarly, breadth and thickness of chuasa fruits was found to be higher than Langra followed by Malda then Dashehari. Weight, volume, AMD and GMD of fruits of Chausa were also found higher than Langra followed by Dashehari then Malda. However, specific gravity and aspect ratio of Malda fruits were found to be higher than Langra followed by Chausa and then Dashehari. Further, TSS and total carotenoids were found to higher at over maturity followed by optimum then pre maturity stage and increases during the storage. But titratable acidity was found to more at pre maturity stage and decreases during storage. Similarly, redness/greenness colour of mangoes peel obtained found to be decreased from pre-to-over maturity stage and during 15 days of storage. In contrast, the blueness/yellowness of peel found to be increased during the storage as well as from pre-to-over maturity stage.

The present investigation is, therefore, indicated that mangoes harvested at over maturity stage were superior to the fruits harvested at optimum maturity stage in relation to the fruit's physical (weight, shape & size, colour values, etc.) and biochemical properties (TSS content, total carotenoids, titratable acidity). However, the mangoes harvested at optimum harvesting stage were also showed similar characteristics as the fruits harvested at over maturity stage. Generally, the fruit designated to local markets or shipments by air (i.e. a 3-day marketing frame) are harvested after the color break or medium ripe i.e. over maturity. But, the fruits intended for longer transportation period or distances or storage (8-10 days) are harvested firm and green, but physiologically mature means harvesting should be done at optimum maturity stage.

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