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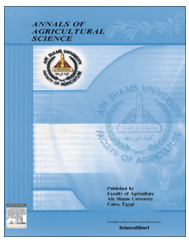

Comparative study on the quality characteristics of some Egyptian mango cultivars used for food processing

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Abstract This study aims to investigate the physical, chemical, rheological and sensorial properties of six common mango (*Mangifera indica*) cultivars in Egypt. These common cultivars were Alfonse, Sedeka, Awis, Sinara, Sukari and Zibdia. Weights of mango fruits ranged between 246.6 and 549.2 g. The highest significant value of sphericity was in Alfonse fruits (0.82), whereas the lowest value was 0.58 in Sinara fruits. The highest firmness value was 29.51 N in Sedeka fruits. The highest elasticity was 1.16 N/mm for Sukari fruits. The significantly color intensity chroma was recorded by Sinara, whereas the highest total color index (ΔE) was 88.41 for Sedeka mango cultivar. The significantly lowest pH value was 3.6 for Sinara mango fruits. Awis mango fruits had the significantly highest TSS value (23.67 °brix) whereas Sinara fruits had the lowest TSS value (11.33 °brix). Rheological properties of Sinara, Zibdia and Sedeka mango pulps are characterized by high values of consistency coeffecient 126.5–156.6 dyne s^n/cm^2. Sesonsorially, the significantly sweetest fruits were Sinara, Alfones and Awis whereas the lowest one was Zibdia. There is no bitter taste with all tested mango cultivars either with taste or after taste criteria.

Introduction

Fruits are food rich in vitamins and minerals and supply arrays of colors, flavor, texture and bulkiness to the pleasure of eating. Therefore, they are essential for the proper maintenance of human health (Nakasone and Paull, 1998).

Mango (*Mangifera indica* L., Family Anacardiaceae) is well known as the queen of fruit that has an excellent exotic flavor. Commercial mango production is reported in more than 87 countries. India, China, Thailand, Indonesia, Philippines,

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Pakistan and Mexico are the prominent mango producing countries (Sivakumar et al., 2011). Central and South America, Australia, Southeast Asia, Hawaii, Egypt and South Africa are outside the traditional geographical regions for mango production and are increasing the mango cultivations especially for export markets (Tharanathan et al., 2006). The mango fruit is large, fleshy and differs in size, shape, color, fiber content, aroma, flavor and taste depending on varieties and its shape has a characteristic conical projection termed as 'beak'. The fruit can be differentiated into three parts, i.e. exocarp, the part that protects the fruit that is initially green and later changes to yellow or reddish or orange depending on the variety and stage of ripening, and waxy. With advanced stage of maturity and ripening, chlorophyll content declines and carotenoids and/or anthocyanins tend to increase. The edible portion contains mainly glucose, fructose and sucrose and the total sugar content of mango can vary from 11.5% to 25% depending on the type of mango and stage of ripeness. Mango fruit contains citric acid which is the major acid and there were also different organic acids such as oxalic, citric, malic, succinic, pyruvic, adipic, galacturonic, glucuronic and mucic acids (Jain et al., 1959). This study investigates the chemical, physical, rheological and sensorial characteristics of some common mango cultivars in Egypt in order to establish the basic and suitable quality profile for handling and processing.

Materials and methods

At the fully ripening stage, 25 mango fruits (*Mangifera indica* L.) obtained each from six popular cultivars (Alfonse, Sedeka, Awis, Sinara, Sukari and Zibdia) were collected from two farms located in Sharkia and Ismailia governorate, Egypt. Fruit samples were collected from mango trees grown under standard agricultural practices (irrigation, fertilization, etc.) common in Egypt. Fruit samples were brought to the laboratories of Agricultural Engineering and Food Science Departments, Ain Shams University, Cairo, Egypt. These samples were evaluated in terms of physical attributes including mass (M), length (L), maximum width (W_{max}), minimum width (W_{min}), maximum thickness (T_{max}), minimum thickness (T_{min}), and volume (V). Sphericity (Φ) of the fruits was calculated according to the following equations (Mohsenin, 1978):

A. Calculation by the equivalent dimension method:

$$\Phi = (\text{length} \times \text{width} \times \text{thickness})^{1/3}/a \quad (1)$$

where a = the greatest dimension

B. Calculation by the method of inside and outside diameters of surrounding circuit:

$$\Phi = D_{inside}/D_{outside} \quad (2)$$

The firmness of mango samples was determined at two opposite sides of each fruit using benchtop materials testing machine (Tinius Olsen-model H5ks – UK) according the procedure described by Ozcan and Haciseferogullari (2007). Firmness force of mango was measured by the data acquisition system and using Qmat software (developed by Tinius Olsen Co.) based on relation between deformation distance and firmness force. Probe used in experiment was of 8 mm diameter according to Ornelas-Paz et al. (2013) connected to dynamometer of the testing machine. Experiment was conducted at a loading velocity of 50 mm/min (Vursavus et al., 2006; Ozcan and Haciseferogullari, 2007; Kheiralipour et al., 2008; Kilickan and Guner, 2008).

The same fruits were weighed and manually peeled. Each separated fraction of pulp, seed and peel was weighed. Mango pulp color was measured by a Spectrophotometer (MOM, 100 D, Hungary). The color values were expressed in Lab-system components: lightness (L), redness (a) and yellowness (b). Chroma (C), total color index (ΔE) and Hue angle ($H°$) were calculated as follows: $\Delta E = (a^2 + L^2 + b^2)^{1/2}$, Chroma = $(a^2 + b^2)^{1/2}$ and $H° = \tan^{-1}(b/a)$. Total soluble solids (TSS) of mango pulp were determined in each sample by using refractometer (Abbe, Carl zeiss, Jena, Germany) and expressed as °Brix (Ranganna, 1995). Titratable acidity (g citric acid/100 g of mango pulp) was determined according to the method of Association of Official Analytical Chemists (AOAC, 2012). The pH-values of samples were assessed using a pH meter (HANNA-Instrument, USA). Ascorbic acid was determined by titrimetric method as described by Ranganna (1995). Total phenolic compounds (g Gallic acid equivalent "GAE"/100 g of mango pulp) were determined by using Folin Ciocalteu method according to Singleton and Lamuela-Raventos (1999). Ash content of the pulp was determined according to the methods of AOAC, (2012). The determination of elements (Fe, Mn, Cu, Mg, K, P) was performed with a Perkin Elmer Atomic Absorption Spectrophotometer (Perkin-Elmer, 1982). Rheological properties of mango pulp were measured with a rotational coaxial viscometer (Rheotest, Germany). The pulp samples were subjected to different shear rates (γ-value) from 1 s^{-1} to 437.4 s^{-1} and the corresponding shear stress response (τ-values) was recorded. Dynamic viscosity (η_{dyn}) data were obtained as follows:

$$\eta_{dyn} = (\tau/\gamma) \times 100 \quad (3)$$

where: η_{dyn} = dynamic viscosity (cp)
τ = shear stress (dyne/cm^2)
γ = shear rate (s^{-1})

Shear rate/shear stress data were subjected to evaluation by the power low (Eq. (4)). Flow parameters, consistency coefficient (k) and flow behavior index (n) of mango samples were calculated from regression coefficients of ln shear rate and ln shear stress data according to Ibarz and Barbosa-Cánovas (2003). The power low equation was as follows:

$$\tau = k \cdot \gamma^n \quad (4)$$

where τ = shear stress (dyne s/cm^2)
k = consistency coefficient (dyne s^n/cm^2)
γ = shear rate (s^{-1})
n = non-Newtonian flow behavior index

Apparent viscosity (η_{app}) was estimated at γ = 81 and 145 s^{-1} using following equation:

$$\eta_{app} = k \cdot \gamma^{n-1} \quad (5)$$

Sensorial analysis of mango pulp was carried out by ten members of Food Science Department, Faculty of Agriculture, Ain Shams University. Procedure of this analysis was according to Meilgaard et al. (1991). The color, odor, taste (sweet, sour and bitter), aftertaste (sweet, sour and bitter) and texture

(firmness and juiciness) were assessed using hedonic scale in which samples were given scores of 0 (very poor) to 10 (excellent).

Analysis of variance (ANOVA) was applied to analyze the data according to Snedecore and Cochran (1980). The significant differences of means for various sensorial analysis scores were established using Duncan multiple range test as reported by Waller and Duncan (1969).

Results and discussion

Physical characteristics of mango cultivars

Weights of mango cultivars under study ranged between 246.6 and 549.2 g as presented in Table 1. The significantly greatest weight was possessed by Sinara cultivar, while the lowest one was recorded for Awis mango. The geometrical dimensions of mango fruits (L, W_{max}, W_{min}, T_{max}, T_{min}, and V) were also given in Table 1. Sinara fruits had the highest values of length, minimum width, maximum and minimum thickness and volume (159.65, 67.07, 74.08, 63.92 mm and 557 cm^3, respectively). Alphonse fruits had the lowest length value (91.26 mm), while Awis had the lowest values of maximum and minimum width, maximum and minimum thickness and volume (68.44, 60.64, 61.22, 52.64 mm and 208.5 cm^3, respectively). The highest sphericity value was recorded for Alfonse fruits (0.82), while the lowest value of sphericity (0.58) was recorded for Sinara fruits. Fig. 1 shows the photographs of mango cultivars that indicate the different kinds of fruit shape under study.

The significantly highest flesh percent was 71.08% for Sinara fruits, while Sedeka and Awis had the significantly lowest percent of seed (Table 2). Zibdia fruits had the significantly highest peel percent (37.83%) with the significantly lowest flesh percent (50.93%). The ratios of peel and flesh percent may work as a good indicator for the suitability of the different mango cultivars for industrial processing.

Mechanical properties of mango fruits such as firmness and elasticity are important attributes for fruit handling, transport, storage, and consumer acceptability, as these characteristics of fruits are essential for expecting bruising and mechanical damage probabilities. Firmness and elasticity values of tested mango cultivars are given in Table 3. As seen, there is a variation in firmness and elasticity among the different mango cultivars. The highest average firmness values (23.8–28.67 N) were recorded for Zibdia, Awis and Sedeka mango cultivars, while

Fig. 1 Photographs of mango cultivars.

Table 1 Physical properties of studied mango fruit.

Mango varieties	M, g	L, mm	W_{max}, Mm	W_{min}, mm	T_{max}, Mm	T_{min}, mm	V cm^3	Spherecity	
								A	B
Alfonse	304.8^{d}	91.30^{d}	79.44^{a}	63.24^{b}	70.73^{b}	58.00^{b}	270.80d	0.82^{a}	0.81^{a}
Sedeka	457.9^{b}	143.70^{b}	78.74^{a}	64.72^{b}	73.55^{a}	59.80^{b}	436.70b	0.61^{e}	0.61^{e}
Awis	246.6^{e}	105.50^{c}	68.44^{b}	60.64^{c}	61.22^{d}	52.60^{d}	208.50e	0.69^{c}	0.70^{c}
Sinara	549.2^{a}	159.70^{a}	77.50^{a}	67.07^{a}	74.08^{a}	63.90^{a}	557.00a	0.58^{e}	0.59^{e}
Sukari	251.6^{e}	97.20^{d}	68.35^{b}	61.62^{c}	63.45^{c}	57.40^{bc}	238.20e	0.75^{b}	0.72^{b}
Zibdia	338.4^{c}	119.50^{c}	76.97^{a}	69.40^{a}	64.65^{c}	56.30^{c}	372.50c	0.68^{d}	0.67^{d}

Means with the same letter in the same column are not significantly different (at $p < 0.05$).

Table 2 Percentage of mean mass of different mango fruit components.

Mango varieties	Flesh, %	Seed, %	Peel, %
Alfonse	68.44[b]	11.23[c]	20.33[e]
Sedeka	64.21[c]	7.450[e]	28.34[c]
Awis	62.50[c]	12.67[b]	25.28[d]
Sinara	71.08[a]	9.050[d]	19.80[e]
Sukari	51.02[d]	14.44[a]	34.54[b]
Zibdia	50.93[d]	11.24[c]	37.83[a]

Means with the same letter in the same column are not significantly different (at $p < 0.05$).

Table 4 Color parameters of studied mango fruits.

Mango varieties	Color parameters					
	a	*b*	*L*	Chroma	Δ*E*	Hue°
Alfonse	4.80[c]	59.86[e]	51.04[c]	60.05[e]	78.81[f]	85.41[c]
Sedeka	−0.44[e]	66.82[b]	57.88[a]	66.82[b]	88.41[a]	90.40[b]
Awis	6.54[a]	64.38[c]	49.75[d]	64.71[c]	81.62[d]	84.20[c]
Sinara	5.09[b]	68.94[a]	53.85[b]	69.12[a]	87.62[b]	85.77[c]
Sukari	−4.55[f]	57.15[f]	57.94[a]	57.33[f]	81.51[e]	94.57[a]
Zibdia	3.83[d]	63.41[d]	56.45[a]	63.53[d]	84.99[c]	86.54[c]

Means with the same letter in the same column are not significantly different (at $p < 0.05$).

the low firmness values were recorded for Sukari (8.74 N), Alfonse (16.64 N) and Sinara (21.33 N) mango cultivars. Also, a variation in elasticity (N/mm) was found between the tested varieties (Table 3). The higher the force (N) required inducing a 1 mm deformation, the lower is the elasticity of the fruits. Sedeka, Awis and Sinara mango cultivars showed lower elasticity (2.69, 2.11 and 1.82 N/mm, respectively) while Zibdia, Alfonse and Sukari varieties showed higher elasticity with values ranging from 1.67 to 1.16 N/mm. Firmness and elasticity values of fruits are essential for expecting bruising and mechanical damage probabilities during transport and handling as well as for designing processing equipments (peeling, cutting, crushing, etc.). The values obtained in the present study agree with those reported by Kader (2008) and Diniz (2013), who reported firmness values of 18.34–65.14 N for ripe mango fruits. On the other hand, the firmness and elasticity values of the tested mango cultivars were relatively higher than those reported by Brecht (2010) and Devanesan et al. (2011); (7.5 N and 0.5–0.8 N/mm), due to variation in maturity stage.

Color attributes (*a*, *b*, *L*, Δ*E*, chroma and Hue angle) of mango pulp are also an important quality index. The results of these attributes of pulps for studied mango cultivars are shown in Table 4. The highest values of brightness (*L*-value) were in the range from 56.45 to 57.94 for Sukari, Sedeka and Zibdia pulps, while the lower *L*-values varied between 45.75 and 53.85 for Sinara, Alfonse and Awis. The *L*-values of pulp are indicators of browning during fruit processing as a result of contact between oxygen and polyphenoloxidase-substrates found in the mango pulp (Robles-Sanchez et al., 2009). On the other side, reddish/yellow color shade was shown in the pulps of Awis, Sinara, Alfonse and Zibdia, while those of Sukari and Sedeka were shown a greenish/yellow color shade. The strongest color intensity (chroma and Δ*E*) was recorded for the pulps of Sinara, Sedeka, Awis, and Zibdia (69.12–63.53 for chroma and 88.41–84.99 for Δ*E*), while the chroma and Δ*E* values of Alfonse and Sukari mango pulps were ranged from 57.33 to 60.05 and 81.51 to 78.81, respectively. The color types (Hue-values) were also included in Table 4. Alfonse, Awis, Sinara and Zibdia showed orange-yellow color type, while a pure yellow and yellow-green color are shown in Sedeka and Zibdia mango, respectively. Studies reported by Spinelli et al. (2013), Vásquez-Caicedo et al. (2002), and Singh et al. (1999) showed similar values of the obtained *a*, *b*, chroma and Hue angle parameters, while Okoth et al. (2013) reported that pulps Hue-values of different mango varieties were in the range of 82.57–95.8.

Chemical characteristics of mango cultivars

As shown in Table 5, the pH value of mango pulps indicated that the significantly highest pH values were 5.1, 4.8 and 4.7 for Awis, Alfonse and Sukari cultivars, respectively. Meanwhile, the significantly lowest pH value was 3.6 for Sinara mango fruit. This result means that the mango cultivars with pH values of more than 4.5 require the acidification before thermal preservation at temperatures less than 100 °C. The pH values were in accordance with those obtained from acidity determination, where the significantly highest total acidity value was 0.64 for Sinara mango. TSS and TSS/TA ratio are considered a measure of fruit quality, where the more TSS/TA ratio, the more is the pulp quality. As presented in Table 5, Awis mango had the significantly highest TSS value (23.67 °-brix), whereas Sinara fruit had the lowest TSS value (11.33 °-brix). This variation in TSS between different varieties may be due to the alteration in cell wall structure during ripening process and as a result of hydrolysis of complex carbohydrates into smaller compound by hydrolytic enzyme activities (Kays,

Table 3 Mechanical properties of studied mango fruits.

Mango varieties	Firmness, N				Elasticity, N/mm	
	Side 1		Side2		Side1	Side 2
	Range	Mean	Range	Mean		
Alfonse	11.88–23.58	16.46	11.68–27.76	17.77	1.31	1.33
Sedeka	24.75–32.08	28.67	19.92–31.50	29.51	2.69	2.61
Awis	16.50–34.75	24.97	16.08–32.68	26.61	2.11	2.02
Sinara	11.43–27.68	21.33	14.25–27.32	21.57	1.82	1.92
Sukari	6.50– 13.18	08.74	5.93–12.18	8.33	1.16	1.18
Zibdia	13.82–31.65	23.80	12.32–33.24	22.05	1.67	1.53

Table 5 Chemical characteristics of studied mango fruits.

Mango cultivar	pH	TSS, Brix	TA, g/100 g	TSS/TA	Vit. C, mg/100 g	TPC, g/100 g
Alfonse	4.8[a]	16.00[c]	0.18[d]	88.89[b]	91.20[ab]	22.86[b]
Sedeka	4.1[b]	19.07[b]	0.46[b]	41.46[d]	76.00[c]	20.36[c]
Awis	5.1[a]	23.67[a]	0.19[d]	124.58[a]	22.80[e]	20.95[c]
Sinara	3.6[c]	11.33[d]	0.64[a]	17.70[f]	95.00[a]	21.18[b]
Sukari	4.7[a]	18.80[b]	0.32[c]	58.75[c]	83.60[bc]	19.52[c]
Zibdia	4.4[b]	17.33[c]	0.46[b]	37.67[e]	59.53[d]	26.59[a]

Means followed by the same letter are not significantly different (at $p < 0.05$).

1991; Kittur et al., 2001; Rathore et al., 2007 and Rajwana et al., 2010). From the previous data, it is worth mentioning the inverse relation between TSS values and TA values of mango pulps. This relation may be due to the decrease in acidity as a result of their further utilization in metabolic process in fruits. At the same way, Awis fruit had the significantly highest value (124.58) of TSS/TA ratio, while Sinara fruits had the significantly lowest record (17.70). The TSS/TA ratio (sweet taste) was found to be significantly affected by the fruit cultivar. Ascorbic acid content (Vit. C) ranged between 95 and 22.8 mg/100 g pulp. The significantly highest value was recorded by Sinara and Alfonse cultivars whereas the lowest value was recorded by Awis cultivar. Total phenolic compound (TPC) varied significantly between mango cultivars. The highest value was 26.59 for Zibdia mango compared with the lowest values 20.95, 20.36 and 19.52 which were possessed by Awis, Sedeka and Sukari cultivars, respectively.

Element analyses of mango cultivars are presented in Table 6. Awis mango had the significantly highest values of all detected elements as well as the highest percent of ash followed by Sinara cultivar.

Rheological properties of mango cultivars

Crude pulp (un-centrifuged) obtained from the tested mango fruits was subjected to rheological analysis at different shear rates ranging from 1 to 437.45 s^{-1}. The resulting rheograms of tested fruits (shear rate/shear stress relationship) are presented in Fig. 2. As seen, all mango pulps showed non-Newtonian behavior as the relationship between shear rate and shear stress was nonlinear. The shear stress response of

Table 6 Element analyses of mango fruits.

Mango cultivar	Fe	Mn	Cu	Mg	K	P	Ash
	ppm						%
Alfonse	1.10[c]	0.29[c]	0.33[b]	18.81[c]	187.4[d]	10[c]	0.33[c]
Sedeka	1.43[c]	0.25[d]	0.32[c]	16.25[d]	162.7[e]	10[c]	0.29[d]
Awis	9.20[a]	0.63[a]	0.41[a]	37.39[a]	313.9[a]	30[a]	0.57[a]
Sinara	4.95[b]	0.46[b]	0.34[b]	24.70[b]	240.9[b]	20[b]	0.43[b]
Sukari	1.86[c]	0.30[c]	0.34[b]	13.27[e]	140.9[f]	10[c]	0.28[d]
Zibdia	0.98[d]	0.19[e]	0.32[c]	24.16[b]	212.8[c]	10[c]	0.30[d]

Means followed by the same letter are not significantly different (at $p < 0.05$).

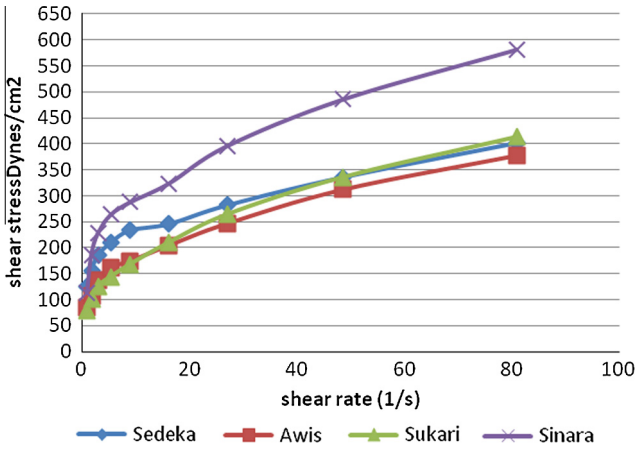

Fig. 2 Flow curves of different mango cultivars pulp.

Table 7 Rheological parameters of mango pulp.

Mango varieties	η_{81} (cp)	η_{145} (cp)	Power low equation		
			K (dyne s^n/cm^2)	n (–)	R^2
Alfonse	474.85	316.72	98.06	0.31	0.99
Sedeka	520.09	339.20	126.90	0.27	0.98
Awis	463.12	312.55	87.59	0.33	0.99
Sinara	709.07	465.22	165.60	0.28	0.99
Sukari	503.22	348.72	78.10	0.38	0.99
Zibdia	721.63	485.72	139.20	0.33	0.98

tested pulps to the applied shear rates varied according to the physical characteristics of tested mango cultivar. Although Sinara mango contained low TSS of 11.33% (Table 5), its pulp showed higher response of shear stress. This is due to its high firmness, moderate elasticity (Table 3) and higher insoluble fibrous texture (texture firmness) as judged by panelists (Table 8). Similar trend was observed for Zibdia pulp. On the contrary, pulps of Sukary showed lower response of shear stress due to its juicy character, low firmness (Table 3) and low sensorial fibrous texture.

The shear rate/shear stress data of the mango pulp samples were used to calculate the dynamic viscosities (η), consistency coeffecient (k-values) according to Eqs. (3) and (4) and the results are also given in Fig. 3 and Table 7. As seen in Fig. 3, values of dynamic viscosity were dramatically decreased by increasing shear rate and reached almost a plateau range thereafter at $\gamma = 16.45\ s^{-1}$. Pulps of Sinara, Zibdia and Sedeka mango cultivars are characterized by high values of consistency coefficient 126.5–156.6 dyne s^n/cm^2 (Table 7) and low values of flow behavior index (0.27–0.33). The other tested cultivars (Alfonse, Awis and Sukari) showed a relatively juicy pulps with lower values of consistency coeffecient (78.1–98.06 dyne s^n/cm^2) and relatively higher index values (0.31–0.38), which also correspond to their textural sensation (Table 8). Apparent viscosity values (η_{81} and η_{145}) showed that pulps of Zibdia and Sinara cultivars gave the highest values (721.63 and 709.07 cp, respectively) of apparent viscosity measured at $\gamma = 81\ s^{-1}$, while the lowest apparent viscosity value was recorded for pulp of Awis mango cultivar (463.12 cp). Values of η_{app} were decreased by increasing the shear rate from

Table 8 Sensory evaluation of mango pulp.

Mango varieties	Color	Odor	Taste			After taste			Texture	
			Sweet	Sour	Bitter	Sweet	Sour	Bitter	Firmness	Juiciness
Alfonse	9.7^{a}	9.2^{a}	9.2^{a}	0.0^{d}	0	9.1^{a}	1.2^{d}	0	0.1^{f}	9.6^{a}
Sedeka	6.7^{cd}	6.4^{c}	3.3^{d}	7.2^{a}	0	2.4^{e}	3.4^{b}	0	3.6^{b}	7.6^{c}
Awis	7.4^{c}	9.4^{a}	9.1^{a}	0.0^{d}	0	9.2^{a}	2.3^{c}	0	1.4^{d}	9.5^{a}
Sinara	9.4^{ab}	8.7^{a}	9.3^{a}	1.0^{c}	0	8.6^{b}	4.6^{a}	0	8.2^{a}	8.2^{b}
Sukari	6.2^{d}	7.4^{b}	7.2^{b}	3.4^{b}	0	5.6^{d}	2.4^{c}	0	2.2^{c}	8.5^{b}
Zibdia	8.7^{b}	6.3^{c}	5.6^{c}	3.3^{b}	0	7.1^{c}	3.4^{b}	0	0.6^{e}	9.5^{a}

Means followed by the same letter are not significantly different (at $p < 0.05$).

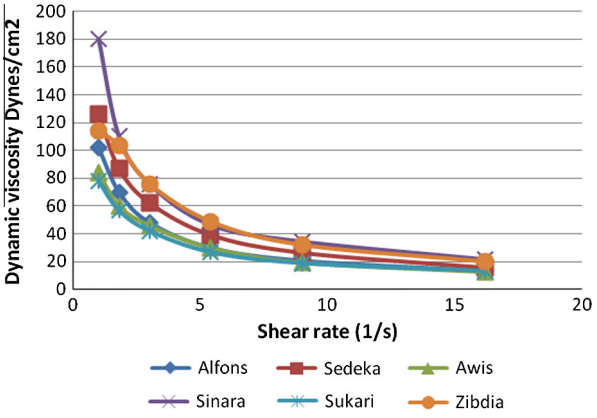

Fig. 3 Dynamic viscosity of mango cultivars pulp.

81 to 145 s^{-1} confirming the pseudoplasticity of tested mango pulps The flow curves obtained in the present work agree with those of Pelegrine et al. (2002) for mango pulp, while the obtained rheological parameters (k and n values) agree with those published by Swami et al. (2013) for mango pulp measured at 20 °C. Sreenath et al. (1995) confirmed a variation of 13.5–20 °brix in TSS of some Indian mango cultivars and suggested that the insoluble fibers are mainly responsible for the viscous behavior of mango pulp.

Sensory characteristics of mango cultivars

Table 8 and Fig. 4 show sensory characteristics of mango cultivars: color, odor, taste (sweet, sour and bitter), after taste (sweet, sour and bitter) and texture (firmness and juiciness). Fruit color is one of the important quality parameters for consumers to select their favorite choice. The significantly best color scores were with Alfonse and Sinara fruit. At the same time, Zibdia color had no significant difference with Sinara color. The significantly lowest mango in color criteria was Sedeka and Sukari (highest Hue-values in Table 4). It should be noted that any mango cultivar had not less than half of color scores. The significantly highest odor degrees were recorded for Awis (9.4), Alfonse (9.2) and Sinara (8.7),

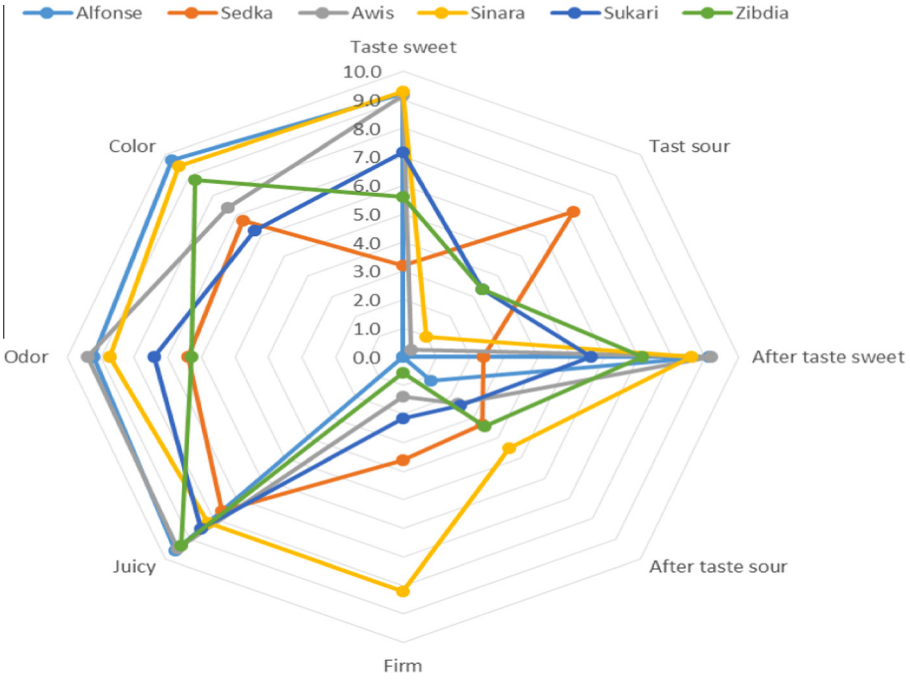

Fig. 4 Spider diagram of mean ratings for sensory attributes.

whereas the lowest values were for Sedeka (6.4) and Zibdia (6.3). The significantly sweetest fruits were Sinara, Alfones and Awis whereas the lowest one was Zibdia (low TSS/TA ratio in Table 5). The lowest score for sour taste was recorded for Alfonse and Awis varieties, whereas the highest sour score was that of Sedeka (7.2) which also possessed low TSS/TA ratio (Table 5). There is no bitter taste with all tested mango cultivars either with taste or after taste criteria. Sweetness after taste was scored the significantly highest values with Awis and Alphons mango fruits (the highest TSS/TA ratio in Table 5) but the lowest sweetness was scored by Sukari fruits. The highest sour after taste score was by Sinara mango (the lowest TSS/TA ratio in Table 5). According to the texture criteria, Sinara cultivar provided significantly the firmest pulp followed by Sedeka and the lowest one was Alfonse which confirm the values for elasticity reported in Table 3. There is no significant difference in juiciness scores between Alfonse, Awis and Zebdia and they had the significantly highest scores.

Conclusion

Sinara fruits had the significant highest flesh percent and moderate firmness and elasticity values among the other five cultivars. The strongest color intensity was recorded for pulps of Sinara, Sedeka, Awis, and Zibdia. The lowest pH value was observed by Sinara cultivar supported that it contained the highest value of TA and Vit. C. Sinara as well as Zibdia cultivar pulp showed higher response of shear stress. According to the sensory evaluation, the significantly sweetest fruits were Sinara, Alfones and Awis and there is no bitter taste with all tested mango cultivars. Based on the aforementioned characteristics, it could be recommended that the Sinara mango cultivar is the most suitable one for Juice processing and preservation.

References

AOAC, 2012. Official Methods of Analysis, International, 19th ed. Association of Official Analytical Chemists, Gaithersburg, Maryland, USA.

Brecht, J.K., 2010. Mango postharvest best management practices manual. Project Report Submitted to University of Florid, USA, p. 30.

Devanesan, J.N., Karuppiah, A., Abiram, C.V.K., 2011. Effect of storage temperatures, O_2 concentrations and variety on respiration of mangoes. J. Agrobiol. 28 (2), 119–128.

Diniz, Mayra, M.S., 2013. Textural, physicochemical, rheological and enzymatic properties of mango fruits "Tommy Atkins" during modified atmosphere storage under refrigeration. <http://www.tede.Ufv.br/tedesimplificado/tde_busca/arquivo.php?-codArquivo=5261> (English abstract).

Ibarz, A., Barbosa-Cánovas, G.V., 2003. Unit Operation in Food Engineering. CRC Press, pp. 96–99.

Jain, N.L., Krishnamurthy, G.V., Lal, G.C., 1959. Non-volatile organic acids in unripe pickling mangoes and salted mango slices by paper chromatography. Food Sci. 3, 115–118.

Kader, A.A., 2008. Fresh-cut mangos as a value-added product. Postharvest Horticulture Consultant Kader Consulting Services, USA. <http://www.mango.org/media/31003/fresh_cut_report.pdf>.

Kays, S.J., 1991. Post harvest physics of perishable plant products. Vas Nostrand Rein Hold Book. AVI Publishing Co, pp. 149–316.

Kheiralipour, K., Tabatabaeefar, A., Mobli, H., Rafiee, S., Sahraroo, A., Rajabipour, A., Jafari, A., 2008. Some physical properties of apple. Pakistan J. Nutr. 7 (5), 667–672.

Kilickan, A., Guner, M., 2008. Physical properties and mechanical behavior of olive fruits (*Olea europaea* L.) under compression loading. J. Food Eng. 87, 222–228.

Kittur, F.S., Saroja, N.H., Tharanathan, R.N., 2001. Polysaccharide-based composite coating formulations for self-life extension of fresh banana and mango. Eur. Food Res. Technol. 213, 306–311.

Meilgaard, D., Civille, B.S., Carr, M.S., 1991. Sensory Evaluation Techniques, second ed. CRC Press, Boca Raton, FL.

Mohsenin, N.N, 1978. Physical Properties of Plant and Animal Materials. Vol. I, Part II. Gordon and Breach Bcience Publishers, New York.

Nakasone, H.Y., Paull, R.E., 1998. Tropical Fruits. CAB International, Wallingford, England, pp. 445.

Okoth, E.M., Sila, D.N., Onyango, C.A., Owino, W.O., Musyimi, S. M., Mathooko, F.M., 2013. Evaluation of chemical and nutritional quality attributes of selected mango varieties at three stages of ripeness, grown in lower eastern province of Kenya – Part 2. J. Anim. Plant Sci. 17 (3), 2619–2629.

Ornelas-Paz, J. de J., Yahia, E.M., Ramírez-Bustamante, N., Pérez-Martínez, J.D., Escalante-Minakata, M.P., Ibarra-Junquera, V., Acosta-Muñiz, C., Guerrero-Prieto, V., Ochoa-Reyes, E., 2013. Physical attributes and chemical composition of organic strawberry fruit (Fragaria x ananassa Duch, Cv. Albion) at six stages of ripening. Food Chem. 138, 372–381.

Ozcan, M.M., Haciseferogullari, H., 2007. The strawberry fruits; Chemical composition, physical properties and mineral contents. J. Food Eng. 78, 1022–1028.

Pelegrine, D.H., Silva, F.C., Gasparetto, C.A., 2002. Rheological behavior of pineapple and mango pulps. Lebensm-wiss. u.-Technol. 35, 645–648.

Perkin-Elmer, 1982. Analytical Methods for Atomic Absorption Spectrophotometry. Perkin-Elmer Corp., USA.

Rajwana, I.U., Malik, A.U., Khan, A.S., Saleem, B.A., Ahmed, S., 2010. A new mango hybrid shows better shelf life and fruit quality (M.Sc.). Uni. College of Agric., Bahauddin Zakariya Uni., Multan, Pak.

Ranganna, S., 1995. Manual Analysis of Fruits and Vegetable Products. Tata Mc Graw Hill publishing Co., Ltd., New Delhi.

Rathore, H.B., Masud, T., Sammi, S., Soomro, A.H., 2007. Effect of storage on physic-chemical composition and sensory properties of mango (*Mangifera indica L.*) variety dosehari. Pakistan J. Nutr. 6 (2), 143–148.

Robles-Sanchez, R.M., Islas-Osuna, M.A., Astiazaran-Garcia, H., Vazquez-Ortiz, F.A., Martin-Belloso, O., Gorinstein, S., Gonzalez-Aguilar, G.A., 2009. Quality index, consumer acceptability, bioactive compounds and antioxidant activity of fresh-cut "Ataulfo" mangoes (*Mangifera indica* L.) as affected by low-temperature storage. J. Food Sci. 74 (3), S126–S134.

Snedecore, G.W., Cochran, W.G., 1980. Statistical Methods, seventh ed. Iowa State Univ., Press, Ames, Iowa, USA, pp. 507.

Singh, N.I., Dhuique-Mayer, C., Lozano, Y., 1999. Physico-chemical changes during enzymatic liquefaction of mango pulp (cv. Keitt). J. Food Process. Preserv. 24 (1), 73–85.

Singleton, V.L., Lamuela-Raventos, R.M., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol. 299, 152–178.

Sivakumar, D., Jiang, Y., Yahia, E.M., 2011. Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. Food Res. Int. 44, 1254–1263.

Spinelli, L., Rizzolo, A., Vanoli, M., Grassi, M., Zerbini, P.E., Pimentel, R.M., Torricelli, A., 2013. Nondestructive assessment of fruits biological age in Brazilian mangoes by time-resolved reflectance spectroscopy in the 540–900 nm spectral range. In: Inside Food Symposium, 9–12 April, Leuven, Belgium.

Sreenath, H.K., Sudarshana, K.R., Santhanam, K., 1995. Enzymatic liquefaction of some varieties of mango pulp. Lebensm-Wiss. u.-Technol. 28, 196–200.

Swami, S.B., Thakor, N.J., Wagh, S.S., 2013. Effect of temperature on viscosity of kokum, karonda, mango pulp and cashew apple syrup. Agric. Eng. Int.: CIGR J. 15 (4), 281–287.

Tharanathan, R.N., Yashoda, H.M., Prabha, T.N., 2006. Mango (*Mangifera indica* L.), "The King of Fruits": an overview. Food Rev. Int. 22, 95–123.

Vásquez-Caicedo, A.L., Neidhart, S., Pathomrungsiyounggul, P., Wiriyacharee, P., Chattrakul, A., Sruamsiri, P., Manochai, P., Bangerth, F., Carle, R., 2002. Physical, chemical and sensory properties of 9 Thai mango culitvars and evaluation of their technological and nutritional potential. In: International Symposium 'Sustaining Food Security and Managing Natural Resources in Southeast Asia: Challenges for the 21th Century, 08.-11.01.2002, Chiang Mai, Thailand.

Vursavus, K., Kelebek, H., Selli, S., 2006. A study of some chemical and physico-mechanic properties of three sweet cherry variety (*prunus avium* L.) in Turky. J. Food Eng. 74, 568–575.

Waller, P.A., Duncan, D.B., 1969. A basic rule for the symmetric multiple comparison problem. Am. Statistic. Ass. J., 1485–1503