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Influence of cultivar and ripeness stage at the time of fresh-cut processing on instrumental and sensory qualities of fresh-cut mangos

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ABSTRACT

Mango cultivar and ripeness stage at the time of cutting are important factors that consequently affect the quality of the fresh-cut mango product. In this study, physico-chemical and sensory qualities were measured instrumentally, with sensory descriptive analysis, and by consumer acceptance tests. All tests were performed on fresh-cut 'Kent' and 'Tommy Atkins' mangos from different initial ripeness stages (45 N, 35 N, and 25 N). Instrumental quality parameters (color, firmness, soluble solids, titratable acidity) and sensory descriptive analysis were assessed periodically during 9 days of storage at 5 °C. During storage, the sensory profile of fresh-cut 'Kent' mango was predominant in fruity aroma, overall aroma intensity and orange flesh color, whereas fresh-cut 'Tommy Atkins' had less aroma and orange flesh color, but had greater edge sharpness, edge fibrousness, moist and glossy appearance and fibrous texture. Fresh-cut mango consumers found the 'Kent' cultivar more desirable than 'Tommy Atkins'. The initial ripeness stage of 35 N for 'Kent' mango and 25 N for 'Tommy Atkins' mango were optimal ripeness stages for fresh-cut mango in terms of handling, visual quality, and quality maintenance during storage, and were also well received by consumers. The a^*/b^* value and instrumental firmness of 'Kent' mango were correlated well with edge sharpness, sensory hue, and tartness. In addition, the L^* value and instrumental firmness of fresh-cut 'Tommy Atkins' mango were demonstrated to be useful predictors for the texture attributes, including melting, slipperiness, chewiness and firmness. Interestingly, SSC and SSC/TA were not good predictors of sensory sweetness.

1. Introduction

Consumer demand for a convenient, nutritious, and uniquely flavored fresh-cut mango product has led to continued growth in the sales of mango fruit in retail stores and foodservice operations. To satisfy consumer expectation, fresh-cut products should be free from defects, at optimal maturity and ripeness stage, and have a fresh appearance (Bruhn, 1995; Gorny et al., 1998). At the time of purchase, appearance and freshness are the primary criterions for consumers in terms of product quality; however, subsequent purchases depend upon their satisfaction with the texture and flavor (aroma and taste) quality of fresh-cut products (Beaulieu and Baldwin, 2002; Kader, 2002). Moreover, the consumer also takes the nutritional value and product safety into consideration.

In addition to pre-harvest practices such as cultural practices, harvesting methods, and harvest maturity, to obtain optimal fresh-cut quality, post-harvest factors are also important. These factors include time between harvest and fresh-cut processing, fresh-cut preparation procedures (sharpness of cutting implements, size and cut surface, washing, and removal of surface moisture), and subsequent handling conditions, (packaging, speed of cooling, maintenance of optimal storage temperature and relative humidity, and proper sanitation procedures) (Kader, 2002).

For commercial operations, somewhat immature fruits are usually selected for fresh-cut processing due to the ease of shipping, handling and storability of the whole fruits, and minimal change in visual and textural quality of the fresh-cut products. Even though less ripe fruits provide longer shelf life, previous authors have found that the fresh-cut products prepared from them are insufficiently ripe to satisfy consumer liking in firmness or provide acceptable volatiles and flavor/aroma attributes (Beaulieu et al., 1999; Beaulieu and Lea 2003; Gorny et al., 1998, 2000; Hodges and Toivonen, 2008; Soliva-Fortuny et al., 2002).

Despite numerous studies related to the effect of initial ripeness and maturity stages on the physicochemical characteristics of

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fresh-cut mangos, the effect of initial ripeness stage on the sensory quality and consumer acceptance of fresh-cut mangos has not been well established. There are 2 main approaches generally used to assess the product sensory quality: descriptive analysis and consumer acceptance tests. Descriptive analysis provides detailed sensory profiles of products and/or product categories. Quantitative descriptive analysis (QDA) has been widely used. Stone and Sidel (2004) suggested that the method should have 10–12 trained panelists who are used as an instrument to identify and characterize the perceived sensory attributes of the products. Trained panelists should have the same understanding in terminology and be able to distinguish between products, be consistent, and be reproducible (Lawless and Heymann, 2010b). Consumer acceptance tests, on the other hand, are useful methods to measure consumer liking of the product of interest by rating a degree of liking on a 9-point hedonic scale (Lawless and Heymann, 2010a).

Relationships between the soluble solids content (SSC), titratable acidity (TA), and pH and flavor attributes of mango were reported by Malundo et al. (2001). Their study suggested that sugars (sucrose and fructose) and acid (citric acid) enhance human perception of specific flavor notes in mango, including aromatics. In fact, sugar enhanced the perception of all flavor attributes except for sour taste. Moreover, they also reported that soluble solids content (SSC) was not a good indicator for sweetness, whereas titratable acidity (TA), pH, and SSC/TA were good predictors for sourness, astringency and biting in 'Tommy Atkins' mangos. However, the information about color and textural quality on sensory attributes was limited.

The objectives of this study were (1) to determine the effect of initial ripeness of intact mango fruits on the sensory quality of 'Tommy Atkins' and 'Kent' mangos as evaluated by descriptive sensory analysis, (2) to determine consumer acceptance of fresh-cut mango products, and (3) to determine the relationship between the sensory attributes and instrumental measurements, including CIE L^*, a^*/b^*, firmness, SSC and TA.

2. Materials and methods

2.1. Plant material

'Kent' (8 count, mean fruit weight of 537 g, product of Brazil) and 'Tommy Atkins' (8 count, mean fruit weight of 541 g, product of Peru) mangos were obtained from a commercial wholesale store in Woodland, California. The fruit were transported to the Postharvest Pilot Plant at the University of California, Davis in an air-conditioned vehicle. On the same day they were acquired, mangos from each cultivar were visually sorted to eliminate damaged and defective fruit, and then whole mangos were sorted nondestructively using a compression test (described under firmness below) to divide the mangos into 2 groups, less mature fruit which had firmness levels of 90–120 N (Group A) and more mature fruit which had firmness levels of 60–89 N (later randomly divided into Groups B and C). Mangos were ripened under different temperature regimes to obtain the 3 target initial firmness levels, e.g. 45 N, 35 N and 25 N, and to allow direct sensory comparison of mangos cut at different firmness levels. The less mature fruit (Group A) were ripened at 20 °C, while half of the 60 to 89 N fruit was ripened at 15 °C (Group B) and the other half at 20 °C (Group C). All fruit were ripened at >90% relative humidity to prevent dehydration.

Flesh firmness of mangos from groups A, B and C were measured daily on 10 fruit from each group which were randomly selected each day. Flesh firmness was destructively measured using a penetrometer (described under firmness below) until the fruit reached as close to the mean of 45 N, 35 N, and 25 N, respectively, as possible. For each firmness level, 80 mangos were selected and divided into 4 replicates for fresh-cut processing and instrumental and descriptive sensory evaluations. The individual replications were evaluated when they reached the proper firmness level, but not necessarily on the same day. The selected whole mangos were subjected to fresh-cut processing and mango cubes were evaluated by instrumental and sensory measurements on day 1, 5 and 9 of storage at 5 °C. On each evaluation day (1, 5 and 9) during storage, 15 mango cubes per each of 4 replicates were sampled for instrumental measurements including color, firmness, soluble solids content (SSC) and titratable acidity (TA) and 4 mango cubes for each of 12 panelists were also sampled for descriptive analysis. For the consumer acceptance test, 20 mangos representing 45 N, 35 N and 25 N were sorted using a similar process, cut into cubes, and mango cubes were prepared 1 day before the consumer testing and refrigerated overnight.

2.2. Mango cube preparation

The cutting and packaging process was held in a 10 °C sanitized room. Whole mangos from each firmness stage were immersed into an antimicrobial solution containing 1.34 mM sodium hypochlorite (NaOCl) at pH 7 for 3–5 min, and then peeled with non-serrated knives. All cutting equipment, including knives, cutting boards and stainless steel strainers were immersed in 2.68 mM NaOCl solution overnight at 10 °C prior to use. Each mango was sliced from stem to blossom end into 2 slabs on either side of the seed. To obtain more uniform flesh firmness, 2 cm of mango flesh at the stem end, the blossom end, and the sides of each slab were discarded, and the remaining flesh was cut into $1.5 \times 1.5 \times 1.5$ cm cubes. All mango cubes from the same treatment were pooled together before being dipped into antimicrobial solutions containing 1.34 mM NaOCl (pH 7) at 10 °C for 2 min, drained, and blotted dry with cheesecloth. The cubes were then transferred to 163 mL polystyrene containers with lids (Solo Cup Co., Highland Park, IL, USA).

2.3. Color evaluation

The color of 15 mango cubes in each replicate was measured using a Minolta Colorimeter (Model CR-300, Minolta, Ramsey, NY, USA), calibrated with a standard white plate. Each cube was measured on two opposite sides in the CIE $L^*a^*b^*$ mode, where L^* expresses lightness, a^* green to red, b^* blue to yellow, and a^*/b^* the intensity of orange coloration (Mitcham and McDonald, 1992).

2.4. Firmness

Nondestructive (compression) and destructive (penetration) firmness measurements of mangos were measured using a Texture Analyzer (Model TA.XT plus, Texture Technologies Corp., Scarsdale, NY, USA) equipped with a 5 kg load cell, and using a test speed of 5 mm/s. Individual fruit were supported with an 8.5 cm diameter aluminum cradle, manufactured at the University of California, Davis. For the compression test, firmness of unpeeled whole mango was recorded when the 35-mm flat-tipped cylindrical probe reached 2.5 mm deformation. For the penetrometer test, the firmness of whole mangos or fresh-cut mango cubes was measured as the maximum force required to penetrate 5 mm into the cut surface with an 8 mm (whole mango) or a 3 mm (mango cubes) diameter flat-tipped cylindrical probe. For the penetration test on whole mangos, a vegetable slicer (Oxo Softworks Mandoline, Oxo Chambersburg, PA, USA) with a 2 mm blade gap was used to remove a 5 cm diameter section of the peel from both sides of the mango cheeks prior to measurement of flesh firmness of whole mango. For the penetration test on mango cubes, each cube was measured on two randomly selected, opposite sides of the cube.

2.5. Soluble solids content (SSC) and titratable acidity (TA)

After penetration firmness measurements of mango cubes, the 15 cubes from each replicate were juiced together through 2 layers of cheesecloth with a manual juicer (Hamilton Beach Model 932, Hamilton Beach Brands, Inc. Southern Pines, NC, USA) for SSC, TA and pH determination. A few drops of juice were collected for SSC measurement by refractometer (Reichert AR6 Series, Depew, NY, USA) and 4 g of juice was diluted in 20 mL deionized water for determination of TA (citric acid equivalents) using an automatic titrator (Radiometer Tim850 titration manager connected to an SAC80 sample changer, Radiometer TitraLab Lyon, France).

2.6. Quantitative descriptive analysis (QDA)

The sensory descriptive analysis of mango samples from each firmness levels (45 N, 35 N, and 25 N) was performed by 12 judges recruited on the UC Davis campus. The panelists (6 male and 6 female, ages 20 to 65) were trained in 5 1-h training sessions to evaluate the samples. In the first training session, the panelists were allowed to taste different mango cultivars and ripeness stages and to develop terms for fresh-cut mango attributes in aroma (smell), texture, and taste. During the 2 subsequent sessions, reference standards for the sensory attributes and refinement of the attributes were discussed. In the following sessions, the panelists practiced evaluating the sensory attributes using an unstructured 10 cm line scale on a score sheet, to achieve a consensus for how to define and rate the attributes. During the last training session, panelists practiced evaluating mango samples in the actual sensory booths, using Compusense 5 software (Compusense, Ontario, Canada) for descriptive analysis data collection. The final attributes used are listed in Tables 1 and 2.

The actual descriptive analysis sessions required the panelists to evaluate 4 replicates for all mango products. The individual replications were evaluated when the whole mango reached the proper firmness level, but not necessarily on the same day. Fresh-cut mango samples from each firmness level were evaluated on day 1, 5, and 9 of storage at 5 °C. Three mango cubes from each firmness level (45 N, 35 N, and 25 N) were placed in a 59 mL polystyrene plastic cup with a lid (Solo Cup Company, Highland Park, IL, USA). A randomized block design was used for sample presentation sequences and samples were labeled with random 3-digit numbers before being presented to each panelist. Mango samples were served with a cup of water and some unsalted crackers as palate cleansers between samples. Panelists evaluated the mangos in individual sensory booths under the white light at room temperature (20 °C). The reference standards for aromas (smell) and tastes and the summary of definitions and reference standards (Tables 1 and 2) for all attributes were also provided in the tasting room. The panelists were asked to evaluate the mango attributes for aroma, appearance, texture, taste, aftertaste using an unstructured 10 cm line scale using Compusense 5 software (Compusense, Ontario, Canada). Panelists rated each of the attributes compared to the score given to the reference standards, as shown in Tables 1 and 2.

2.7. Consumer acceptance test

A hedonic liking test on the mango cube samples was performed by a total of 140 participants on the University of

Table 1
Fresh-cut mango aroma and appearance attributes, definitions, and standard references for descriptive analysis.

Attributes	Definitions	Reference	
		Standards	Score
Aroma (smell)			
Aroma intensity	Intensity of overall aroma in the sample	Honey	10
Fruity	Aroma associated with ripe fruits	'Welch' passion fruit juice	10
Sweet	Aroma associated with sweet fruits	15% honey (w/w)	8
Acidic	Aroma associated with sour fruits	Freshly extracted grapefruit juice	10
Green	Aroma associated with unripe fruit	Freshly ground watermelon rind	8
Piney	Aroma associated with pine	A drop of pine, Wild Scotch Essential Oil on the cotton ball	10
Appearance			
Hue	The development of flesh color from pale yellow to orange	Pale yellow	0
		Yellow	5
		Orange	10
Edge sharpness	Degree of sharpness at the cut surface of the sample	Severe edge damage	0
		Compressed-like edge	2.5
		Curvy edge	5
		Slightly curvy edge	7.5
		Sharp edge	10
Translucency	The presence of water soaking region on the cut surface	None	0
		Slightly water soaked	2.5
		1–2 mm water soaked	5
		2–3 mm water soaked	7.5
		Soggy appearance	10
Edge fibrousness	The presence of visible filamentous structural elements at the cutting surface	None	0
		Slightly visible fiber	2.5
		50% visible fiber	5
		75% visible fiber	7.5
		100% visible fiber	10
Glossiness	The reflective property of the samples	Dull	0
		Waxed paper	10
Moistness	The appearance of moisture on the surface of the sample	Severe tissue drying	0
		Slightly dehydrated	2.5
		Visible water loss	5
		Slight water loss	7.5
		Very fresh with a wet glean	10

Table 2
Fresh-cut mango texture and taste attributes, definitions, and standard references for descriptive analysis.

Attributes	Definitions	Reference	
		Standards	Score
Texture			
Melting	The ease of compressing the mango cube to the upper part of the mouth with tongue	Raw zucchini	3
		Ripe banana[1]	8
Slipperiness	Ease of product sliding around in the mouth during chewing	Raw zucchini	4
		Ripe banana	8
Firmness	The force required for the first bite to bite completely through the sample placed between front teeth	Ripe banana	0.5
		Raw zucchini	5
		Raw carrot	10
Juiciness	The amount of juice released from the sample during the first 3 bites	'Dole' canned mandarin orange segment	10
Chewiness	The number of chews required to break down the sample for swallowing	Ripe banana	0.5
		Raw carrot	10
Fibrousness	The presence of fibers in the mouth cavity	Raw celery	9
Taste			
Sweetness	Taste associated with sucrose solution	2% sucrose	1
		10% sucrose	7
Tartness	Taste associated with citric acid solution	1% citric acid	10
Bitterness	Taste associated with caffeine solution	0.2% caffeine	10
Aftertaste			
Astringency	Dry puckering sensation of the tongue surface	'Welch' grape juice	7
Starchy	The sensation associated with boiled sweet potato coating the tongue	boiled sweet potato	10

[1] Ripe banana = stage 5 (yellow with green tips) (Kader, 2010).

California, Davis campus. The participants (95 females and 45 males, ages 19 to 65) were recruited during one-day annual festival held on the University of California, Davis, which drew many residents and non-residents of Davis. The consumers were asked to complete a questionnaire about their liking of the 6 fresh-cut mango samples from 2 mango cultivars, 'Kent' and 'Tommy Atkins', and 3 firmness levels using a 9-point hedonic scale (1 = "extremely dislike," 5 = "neither like nor dislike," 9 = "extremely like") and demographics. The 3 mango cubes of each sample were placed in a 59 mL polystyrene plastic cup with a lid (Solo Cup Company, Highland Park, IL, USA.). A randomized block design was used for sample presentation sequences and samples were labeled with random 3-digit numbers. Consumers were given a cup of water and unsalted crackers as palate cleansers between samples. Percentage of acceptance was calculated as the number of consumers liking the sample (score > 5.0) divided by the total number of consumers within that sample (Crisosto et al., 2003; Lawless and Heymann, 2010a)

Table 3
Means values for color, firmness, soluble solids and titratable acidity in fresh-cut 'Kent' and 'Tommy Atkins' mangos.

Attributes	Days at 5 °C	Kent									Tommy Atkins								
		45 N[1]			35 N			25 N			45 N			35 N			25 N		
L^* value	1	74.37	A[2]	a[3]	73.82	A	a	75.81	A	A	74.21	A	a	75.10	A	a	71.26	A	a
	5	75.89	A	a	75.07	A	a	73.13	B	B	75.21	A	a	74.97	A	a	72.68	B	a
	9	75.53	A	a	74.13	AB	a	72.08	B	B	74.10	AB	a	74.82	A	a	73.20	B	a
a^*/b^* value	1	0.00	A	a	0.01	A	b	0.01	A	B	−0.03	A	a	−0.05	A	a	−0.03	A	a
	5	0.01	B	a	0.03	B	a	0.04	A	A	−0.03	A	a	−0.04	A	a	−0.03	A	a
	9	0.03	C	a	0.04	B	a	0.05	A	A	−0.03	A	a	−0.04	B	a	−0.04	AB	a
Cube Firmness[4] (N)	1	4.43	A	a	3.94	AB	a	3.27	B	A	4.00	A	a	2.64	B	a	1.69	C	a
	5	4.05	A	a	3.52	B	ab	2.75	C	A	3.41	A	ab	2.79	B	a	1.59	C	a
	9	3.30	A	b	3.18	A	b	2.63	A	A	3.70	A	b	2.58	B	a	1.54	C	a
SSC[5] (%)	1	14.40	A	a	14.39	A	ab	14.35	A	A	11.49	A	c	11.89	A	b	12.15	A	a
	5	14.60	A	a	14.62	A	a	14.24	A	A	11.78	A	b	11.66	A	c	12.02	A	a
	9	13.68	A	a	14.19	A	b	14.35	A	A	12.08	A	a	12.21	A	a	12.14	A	a
TA[5] (%)	1	0.35	A	a	0.32	A	a	0.33	A	A	0.45	A	a	0.41	A	a	0.39	A	a
	5	0.32	A	b	0.31	A	a	0.30	A	b	0.46	A	a	0.42	A	a	0.44	A	a
	9	0.31	A	b	0.32	A	a	0.29	A	b	0.44	A	a	0.39	B	a	0.37	B	a
SSC/TA[5]	1	40.81	A	a	44.56	A	a	43.91	A	b	25.68	B	a	29.29	AB	a	31.42	A	ab
	5	46.76	A	a	47.75	A	a	48.20	A	ab	25.56	A	a	27.87	A	a	20.26	A	b
	9	44.47	A	a	44.29	A	a	50.25	A	a	27.20	B	a	31.38	A	a	32.99	A	a

[1] Initial firmness at the time of cutting (45 N, 35 N, and 25 N), measured with a 5 mm probe.
[2] Within each row of each cultivar, values with the same capital letter are not significantly different across ripeness stage ($P < 0.05$).
[3] Within each column of each cultivar, values with the same lower case are not significantly different across day at 5 °C ($P < 0.05$).
[4] Cube firmness, measured with a 3 mm probe.
[5] SSC, soluble solids content; TA, titratable acidity.

2.8. Statistical analysis

The sensory profiling data for each sensory attribute was analyzed across mango samples from each day of storage (1, 5, and 9). A 3-way analysis of variance (3-way ANOVA) was conducted to test the effects of treatment, panelists, replicates, and all 2-way interactions for each sensory attribute using a pseudo-mixed model with the panelist by treatment interaction as denominator (SAS version 9.0, Cary, NC, USA). The mean values of attributes that showed significant differences across treatments were exposed to principal component analysis (PCA), using the covariance matrix (XLSTAT version 2010, Addinsoft, Paris, France).

A cluster analysis was performed on the mean consumer liking score to identify the clusters or groups of consumers that shared similar preferences. Pearson's dissimilarity matrix and the complete linkage agglomerative hierarchical clustering analysis were utilized. Fisher's least square difference (LSD) at $P < 0.05$ was used to determine the differences within the clusters. Internal preference mapping was carried out and projected onto the same space with the mango samples (by cultivar and initial firmness) to identify which mango samples correspond to particular preference groups of consumers.

3. Results

3.1. Physico-chemical analysis

Instrumental quality measurements for fresh-cut 'Kent' and 'Tommy Atkins' mangos were monitored on days 1, 5 and 9 of storage at 5 °C (Table 3). Lightness (L^*) measured at the surface of fresh-cut mangos cubes was significantly affected by initial firmness levels in both varieties, and after 5 days storage with less mature mangos (having firmer textures) being lighter in flesh color. In general, fresh-cut mangos prepared from riper intact fruit showed higher a^*/b^* value (more orange). Fresh-cut 'Kent' had a higher a^*/b^* than 'Tommy Atkins' mangos. During storage for 9 days, the a^*/b^* of 'Kent' mango cubes prepared from riper intact fruit increased ($P < 0.05$), whereas a^*/b^* value stayed constant for fresh-cut 'Kent' cubes prepared from 45 N intact fruit and for all of the ripeness stages of 'Tommy Atkins' mangos.

Our results indicate that the use of riper intact fruit resulted in significantly softer texture in fresh-cut stored mangos in both cultivars studied (Table 3). In addition, the firmness of fresh-cut 'Kent' mangos was higher than 'Tommy Atkins', except when fruit was cut at 45 N. In mango cubes from less mature 'Kent' mango (45 N and 35 N), the firmness decreased significantly during storage, while it remained constant for cubes prepared from riper fruit (25 N). The firmness of 'Tommy Atkins' mango cubes remained more constant during storage than those from 'Kent' mangos. Only cubes prepared from 45 N intact 'Tommy Atkins' mango decreased significantly in firmness during storage.

Sugar and acid content were evaluated in terms of SSC and TA. Fresh-cut 'Kent' mangos had higher SSC and SSC/TA than 'Tommy Atkins' mangos and did not change during storage (Table 3). Intriguingly, there was no effect of initial firmness level of the intact fruit on the SSC and SSC/TA of fresh-cut 'Kent' mangos. However, there was a significant effect of initial ripeness of the whole fruit on the fresh-cut products made with the 'Tommy Atkins' cultivar. TA decreased significantly during storage for 'Kent' mangos. The TA of fresh-cut 'Tommy Atkins' mangos were generally higher than that of 'Kent' mangos. On day 9 during storage of 'Tommy Atkins' mangos, TA was higher in fruit that had been processed at higher initial firmness.

3.2. Descriptive sensory analysis

There were a total of 23 sensory attributes developed by our descriptive panel for fresh-cut mangos: 6 aroma, 6 appearance, 6 texture, 3 taste and 2 aftertaste attributes. In general, fresh-cut comparing to 'Tommy Atkins', fresh-cut 'Kent' mangos had significantly higher ($P < 0.05$) aroma intensity, fruity and sweet aromas, orange color and translucent appearance, firmer texture and sweeter taste (data not shown).

An ANOVA using a pseudo-mixed model determined that on the first day of storage at 5 °C, 14 specific sensory attributes were significantly different ($P < 0.05$) across mango cultivars and firmness levels (Fig. 1A). These attributes included: 2 aroma attributes (overall aroma intensity and fruity aroma), 4 appearance attributes (hue, edge fibrousness, moistness, and glossiness), 4 textural attributes (melting, slipperiness, firmness, and fibrousness), 3 taste attributes (sweetness, tartness and bitterness) and 1 aftertaste (starchy). The principal component analysis (PCA) was developed, only for significant attributes, to illustrate the similarity and dissimilarity among the various fresh-cut mango samples (Fig. 1A).

On the first day of storage, the first 2 principal components accounted for 93.1% of the total variance (PC1 = 58.8%, PC2 = 34.3%). Principal component 1 (PC1) explained most of the variation between fresh-cut mangos, and was defined by edge fibrousness, moistness, glossiness, fibrousness, bitterness, and starchy, which

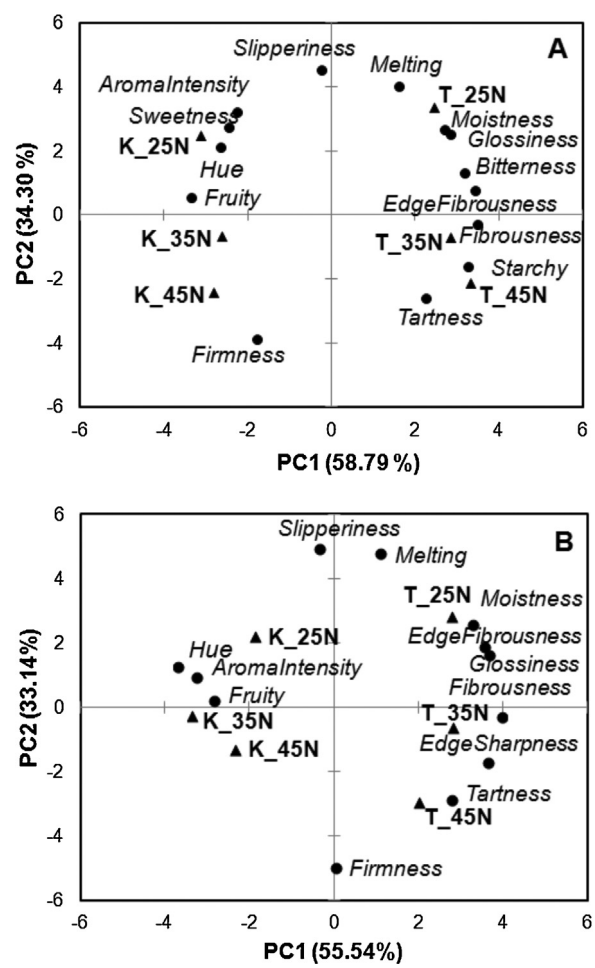

Fig. 1. Principal component analysis (PCA) of sensory profiles of fresh-cut 'Kent' (K) and 'Tommy Atkins' (T) mangos from different initial whole fruit firmness levels (45 N, 35 N, and 25 N) on day 1 (A) and day 9 (B) of 5 °C storage. Only significant sensory attributes in fresh-cut samples are included.

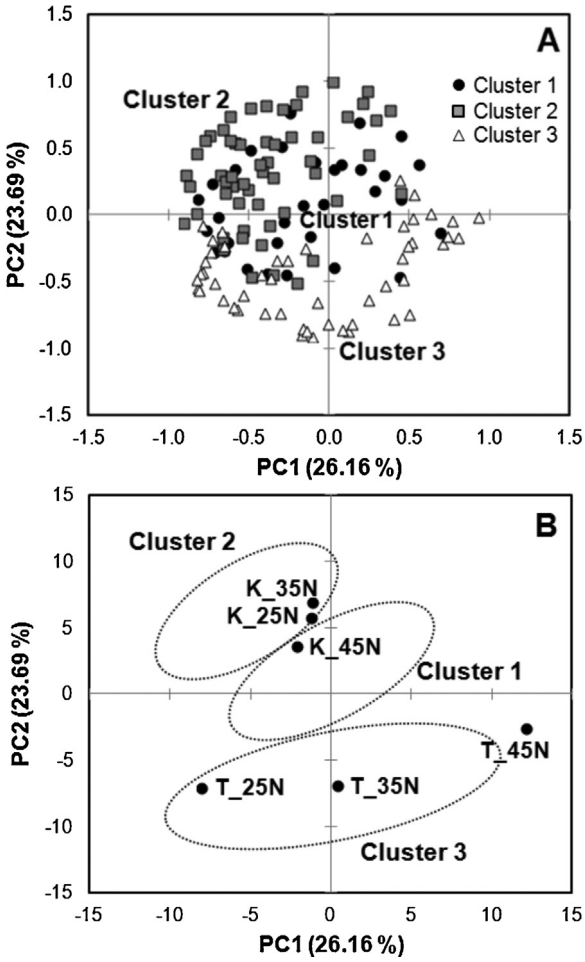

Fig. 2. Internal preference mapping. (A) Principal component analysis of consumer liking segments. (B) Principal component analysis of 'Kent' (K) or 'Tommy Atkins' (T) mangos from different initial whole fruit firmness levels (45 N, 35 N, and 25 N).

were negatively associated with overall aroma intensity, fruity aroma, hue, and sweetness. 'Kent' mango cubes were particularly associated with more intense overall aroma intensity, especially fruity aroma, more orange color development (Hue), and sweetness, especially mango cubes from the ripest whole fruits (25 N). Fresh-cut 'Tommy Atkins' mangos from the 45 N and 35 N initial firmness stages were also described by PC1, but were negatively associated with fresh-cut 'Kent' mangos. 'Tommy Atkins' fresh-cut mangos were more moist and glossy, with a more fibrous appearance and texture, as well as more bitter and tart tastes, and a starchy aftertaste. PC2 was explained by melting and slippery texture, which negatively correlated with firmness and tartness. 'Tommy Atkins' mango cubes from the ripest intact fruit (25 N) tended to have a melting and slippery texture, but less tartness.

After 9 days of storage at 5 °C, 12 sensory attributes were significantly different ($P < 0.05$) across mango cultivars and firmness level (Fig. 1B). These included 2 aroma attributes (overall aroma intensity, fruity), 5 appearance attributes (hue, edge sharpness, edge fibrousness, moistness, and glossiness), 4 textural attributes (melting, slipperiness, firmness and fibrousness), and 1 taste attribute (tartness). The first 2 PCs accounted for 88.7% of the variation (PC1 = 55.5%, PC2 = 33.1%). PC1 was described by edge sharpness, edge fibrousness, moistness, glossiness, and fibrousness, which were negatively correlated with aroma intensity, fruity aroma and hue. Fresh-cut 'Kent' mangos prepared from intact fruit at all 3 ripeness stages were associated more with aroma intensity, fruity aroma and hue (more orange color). At the other extreme, fresh-cut 'Tommy Atkins' mangos made from intact fruit at 35 N and 25 N were associated with moistness, glossiness, sharpness at the cut surface, and a more fibrous texture than fresh-cut mango samples from 45 N 'Tommy Atkins' and especially all 'Kent' samples. PC2 was described primarily by melting and slippery textures, which were all negatively correlated with firm texture and tartness. Fresh-cut 'Tommy Atkins' mangos from intact fruit at 45 N were associated with firmness and tartness.

3.3. Consumer studies

A cluster analysis on liking scores was performed to determine consumer groupings for fresh-cut mangos on day 1 of storage. Three different consumer clusters were identified by cluster analysis (data not shown). From principal component analysis (Fig. 2), 49.9% of the variation in the consumer data was explained by the first 2 principal components (PC1 = 26.2% and PC2 = 23.7%). The observations from this internal preference mapping were confirmed by an examination of the mean liking scores and percentage of consumer acceptance for the 3 consumer clusters (Fig. 3).

Cluster 1 ($n = 33$) illustrated a strong preference for fresh-cut 'Kent' mangos prepared from intact fruit at the 45 N firmness stage (Fig. 2), with a liking score of 7.1 and 97% consumer acceptance

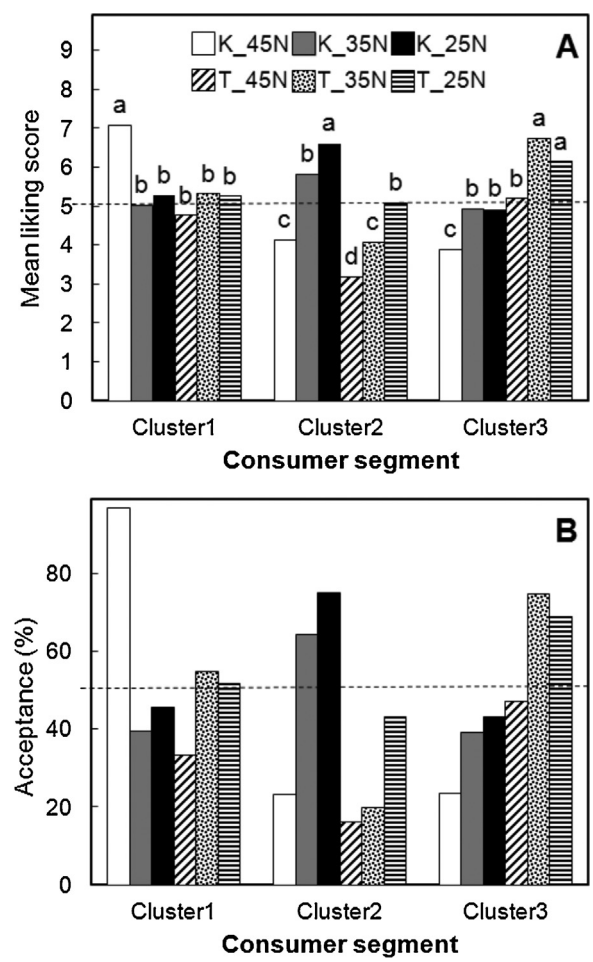

Fig. 3. Mean liking score for overall liking (A) and percentage of consumer acceptance (B) of fresh-cut 'Kent'(K) and 'Tommy Atkins' (T) mangos from different initial whole fruit firmness levels (45 N, 35 N, and 25 N). Values with the same letter were not significantly different within a cluster ($P < 0.05$). The percentage of consumer acceptance was calculated by the number of consumers liking the sample (score > 5.0) divided by the total number of consumers within that sample.

Table 4
Pearson correlation matrix of the mean sensory score and instrumental measurements across 'Kent' mango samples ($N = 9$).

Sensory variables		L^*		a^*/b^*		Firmness (N)		SSC[1] (%)		TA[1] (%)		SSC/TA[1]	
Aroma	Aroma intensity	0.69[2]	*	ns		ns		ns		ns		ns	
	Fruity	**0.74**[3]	*	**−0.71**	*	ns		ns		ns		ns	
	Sweet	ns		ns		ns		ns		ns		ns	
	Acidic	ns		**−0.75**	*	**0.70**	*	ns		ns		ns	
	Green	ns		**−0.73**		ns		ns		ns		ns	
	Piney	ns		ns		ns		ns		ns		ns	
Appearance	Hue	ns		**0.92**	***	**−0.92**	***	ns		**−0.77**	*	**0.70**	*
	Edge sharpness	ns		**−0.94**	***	**0.79**	*	ns		**0.78**	*	**-0.80**	**
	Translucency	ns		ns		ns		ns		ns		ns	
	Edge fibrousness	ns		**0.70**	*	ns		ns		**−0.78**	*	**0.87**	**
	Glossiness	ns		ns		ns		ns		ns		ns	
	Moistness	ns		ns		ns		ns		ns		ns	
Texture	Melting	ns		0.69	*	**−0.89**	**	ns		**−0.72**	*	0.69	*
	Slipperiness	ns		ns		**−0.71**	*	ns		ns		ns	
	Firmness	ns		**−0.76**	*	**0.94**	***	ns		0.67	*	ns	
	Juiciness	ns		ns		ns		ns		ns		ns	
	Chewiness	ns		ns		**0.73**	*	ns		ns		ns	
	Fibrousness	ns		ns		ns		ns		ns		ns	
Taste	Sweetness	ns		0.68	*	**−0.73**	*	ns		ns		ns	
	Tartness	0.68	*	**−0.92**	***	**0.77**	*	ns		ns		ns	
	Bitterness	ns		ns		ns		ns		ns		ns	
Aftertaste	Astringency	ns		ns		ns		ns		ns		ns	
	Starchy	ns		ns		ns		**0.74**	*	ns		ns	

[1] SSC, soluble solids content; TA, titratable acidity.
[2] ns, Not significant or *,**,*** significant at $P < 0.05$, 0.01 or 0.001, respectively.
[3] Values in bold indicate $|r| \geq 0.7$.

(Fig. 3) and this consumer cluster tended to neither like nor dislike other fresh-cut mango samples (score 5.0, Fig. 3A). Cluster 2 ($n = 56$) showed high preference for fresh-cut 'Kent' mangos prepared from intact fruit at either 35 N or 25 N firmness (Figs. 2 and 3), with liking scores of 5.8 and 6.6, and acceptance scores of 64% and 75%, respectively, followed by 'Tommy Atkins' mangos from intact fruit at 25 N with a liking score of 5.1 and consumer acceptance of 43%. The least liked samples by the cluster 2 group was fresh-cut 'Tommy Atkins' mangos prepared from intact fruit at the 45 N firmness stage, followed by 'Kent' mangos prepared from intact fruit at 45 N stage as well as 'Tommy Atkins' mangos from intact fruit at the 35 N stage (Fig. 3). The cluster 3 group ($n = 51$) displayed a strong preference for fresh-cut 'Tommy Atkins' mangos, with those prepared from intact fruit at the 35 N and 25 N firmness stages preferred the most (Fig. 2), with liking scores of 6.7 and 6.1 and acceptances of 75% and 69%, respectively (Fig. 3). These were followed by fresh-cut 'Tommy Atkins' mangos from intact fruit at 45 N and fresh-cut 'Kent' mangos from intact fruit at the 35 N and 25 N firmness stages. Fresh-cut 'Kent' mangos from intact fruit at 45 N, on the other hand, were least liked by this cluster (Fig. 3).

3.4. Correlation between instrumental measurement and sensory attributes

The relationship between sensory and instrumental measurements was also determined using the Pearson correlation coefficient (Table 4 and 5). There were various significant correlations between the instrumental measurements and sensory attributes, and some of these correlations indicate that instrumental measurements may be used as predictors for descriptive sensory attributes. Bourne (2002) suggested that a correlation coefficient of $|r| \geq 0.90$ for the instrumental measurements provides the best predictor of descriptive sensory ratings. He further suggested that correlation coefficients between 0.80 and 0.90 ($0.80 < r < 0.90$) can also be utilized as reasonable predictors with less confidence, whereas those between 0.70 and 0.80 ($0.70 < r < 0.80$) are marginal predictors of sensory attributes.

Our results for 'Kent' mango (Table 4) indicate that the L^* value was a marginal predictor for fruity aroma ($r = 0.74$, $P < 0.05$). The a^*/b^* value was strongly correlated with edge sharpness, sensory hue, and tartness ($r = -0.94$, 0.92 and −0.92, $P < 0.001$). Instrumental firmness was the best predictors for sensory firmness and hue color ($r = 0.94$ and −0.92, $P < 0.001$). SSC can be a marginal predictor for starchy texture, whereas SSC/TA was a reasonable predictor for edge fibrousness and edge sharpness ($r = 0.87$ and −0.80, $P < 0.01$). Neither SSC nor SSC/TA was a reasonable predictor for sweetness. TA can be a marginal predictor for edge sharpness, edge fibrousness, hue color and melting aroma ($r = 0.78$, −0.78, −0.77 and −0.72, $P < 0.05$).

For 'Tommy Atkins' mango (Table 5), L^* was the best predictor for juiciness ($r = -0.94$, $P < 0.001$). Instrumental firmness was the best predictor for the texture attributes, melting, slipperiness, chewiness and firmness ($r = -0.94$, −0.93, 0.93 and 0.90, $P < 0.001$).

4. Discussion

The inherent characteristics of 'Kent' and 'Tommy Atkins' mangos have an impact on eating quality (appearance, texture, and flavor) (Allong et al., 2000; Gorny et al., 2000). In our studies, fresh-cut 'Kent' and 'Tommy Atkins' differed in their initial flesh color (a^*/b^* value), SSC, TA, SSC/TA and firmness. Fresh-cut 'Kent' mangos had a deeper orange flesh color (higher a^*/b^* value) than fresh-cut 'Tommy Atkins' mango. Manthey and Perkins-Veazie (2009) found that ß-carotene pigments which contribute to red-orange color had twice in 'Kent' comparing to 'Tommy Atkins' mango pulp. The firmness of fresh-cut 'Kent' was higher than that of 'Tommy Atkins'. In agreement with our previous studies (Ngamchuachit et al., 2014), 'Tommy Atkins' had lower firmness and higher electrolyte leakage than 'Kent' mango cubes from the

Table 5
Pearson correlation matrix of the mean sensory score and instrumental measurements across 'Tommy Atkins' mango samples ($N = 9$).

Sensory variables		L^*		a^*/b^*		Firmness (N)		SSC[1] (%)	TA[a] (%)	SSC/TA[a]
Aroma	Aroma intensity	ns[2]		ns		−0.68	*	ns	ns	ns
	Fruity	ns		ns		−0.68	*	ns	ns	ns
	Sweet	ns		ns		ns		ns	ns	ns
	Acidic	ns		ns		ns		ns	ns	ns
	Green	ns		ns		ns		ns	ns	ns
	Piney	ns		ns		ns		ns	ns	ns
Appearance	Hue	ns		0.68	*	ns		ns	ns	ns
	Edge sharpness	ns		ns		ns		ns	ns	ns
	Translucency	**−0.80**[3]	**	ns		ns		ns	ns	ns
	Edge fibrousness	ns		ns		−0.68	*	ns	ns	ns
	Glossiness	**−0.84**	**	ns		**−0.77**	*	ns	ns	ns
	Moistness	**−0.82**	**	ns		−0.67	*	ns	ns	ns
Texture	Melting	**−0.75**	*	ns		**−0.94**	***	ns	ns	ns
	Slipperiness	−0.69	*	ns		**−0.93**	***	ns	ns	ns
	Firmness	**0.74**	*	ns		**0.90**	***	ns	ns	ns
	Juiciness	**−0.94**	***	ns		**−0.83**	**	ns	ns	ns
	Chewiness	**0.74**	*	ns		**0.93**	***	ns	ns	ns
	Fibrousness	ns		ns		ns		ns	ns	ns
Taste	Sweetness	ns		ns		**−0.83**	**	ns	ns	ns
	Tartness	ns		ns		**0.76**	*	ns	ns	ns
	Bitterness	ns		ns		ns		ns	ns	ns
Aftertaste	Astringency	ns		ns		**0.72**	*	ns	ns	ns
	Starchy	ns		ns		−0.68	*	ns	ns	ns

[1] SSC, soluble solids content; TA, titratable acidity.
[2] ns, not significant or *,**,*** significant at $P < 0.05$, 0.01 or 0.001, respectively.
[3] Values in bold indicate $|r| \geq 0.7$.

same initial ripeness level which may be due to the mechanical membrane damage during cutting process of the higher fiber content in 'Tommy Atkins' cultivar. The loss of membrane integrity leads to turgor loss and tissue softening. The SSC and SSC/TA of fresh-cut 'Kent' mango were higher than those of 'Tommy Atkins' mango. Finally, fresh-cut 'Kent' had less acidity than 'Tommy Atkins' mangos.

A deeper orange color (a^*/b^* value) in fresh-cut 'Kent' mango was also detected by the descriptive panelists. The higher values in SSC and SSC/TA in fresh-cut 'Kent' mango tended to accompany a perception of greater sweetness, and more intensity in overall and fruity aromas, supporting a previous report by Malundo et al. (2001) that sugar (sucrose and fructose) could enhance the perception of flavor attributes. Plotto et al. (2003) and Rattanapanone et al. (2001) also found higher SSC values in fresh-cut 'Kent', as compared to 'Tommy Atkins' mangos. In contrast to our findings, these authors determined slightly higher acidity in fresh-cut 'Kent' over 'Tommy Atkins', which could possibly result from different origins and cultivation practices (Kays, 1991). We also found greater firmness for all ripeness stages as determined by both sensory and instrumental measures of 'Kent' mango cubes over 'Tommy Atkins' mango cubes.

Besides the influence of cultivar, mango ripeness at the time of cutting has a strong influence on quality. Several studies have reported that cutting at more advanced ripeness stages increased susceptibility of the fruit to wounding during processing, subsequently affecting the overall quality of fresh-cut products (Gorny et al., 1998, 2000; Soliva-Fortuny and Mart'ın-Belloso, 2003). Limbanyen et al. (1998) suggested that the optimal maturity for maintenance of acceptable appearance, texture, and taste for 'Tommy Atkins', 'Haden', and 'Palmer' mangos to be used for fresh-cut, occurred when the inner flesh was full yellow-colored with no presence of green hues. However, they found that the riper fruit developed flesh breakdown and more browning. Beaulieu and Lea (2003) reported that firm-ripe (initial intact firmness of 86–92 N) 'Keitt' and 'Palmer' mango cubes did not provide sufficient ripeness character to the consumer, while the soft-ripe (27–29 N) mangos were unmarketable by 7 days.

We found that, in both cultivars, mango cubes cut at a riper stage (35 N and 25 N) had deeper orange flesh, softer texture, slightly higher SSC and SSC/TA, as well as lower TA, in agreement with previous reports by Allong et al. (2000) and Dea (2009). The sensory characteristics of fresh-cut mangos made from riper mangos had a sweeter aroma and taste, more orange color, were more moist and glossy, and had more melting and slippery texture. In addition, use of riper mangos resulted in more visible fibers at the cut surface of the fresh cut product, Dea (2009) also found more edge tissue damage, more water soaking and darker flesh color in 'Kent' slices cut at a riper stage.

During day 9 of storage, even though the instrumental measures of flesh color, firmness and TA of fresh-cut 'Tommy Atkins' mango from all ripeness levels were consistent, the sensory profile of fresh-cut 'Tommy Atkins' mangos showed that at the end of storage, the descriptive panelists could distinguish the firmer and tarter characters from fresh-cut 'Tommy Atkins' at 45 N initial firmness stage from any of the other mango samples (35 N and 25 N). Fresh-cut 'Kent' mango developed a deeper orange color and decreased in firmness and TA, indicating continued ripening at 5 °C after cutting. However, the sensory profile of 'Kent' mango from descriptive panelists were very consistent attributes throughout storage and were associated with ripe fruit characteristics, particularly a fruity aroma, strong aroma intensity, and orange color. It can be implied that mango descriptive panelists could better detect the difference in firmness of fresh-cut mango when it has more in TA and less in SSC/TA, orange flesh color and aroma intensity. Moreover, the descriptive panelists distinguished more fibrousness in fresh-cut 'Tommy Atkins' mangos than 'Kent' mangos which agrees with the reported 1.6 times more crude fiber content in 'Tommy Atkins' mangos then in 'Kent' mangos (Abourayya et al., 2011)

Consumer liking was determined for fresh-cut mango samples from the 2 mango cultivars and 3 ripeness stages at cutting. The consumers from clusters 1 and 2 preferred fresh-cut 'Kent' mangos, mango cubes from the 45 N initial ripeness stage were preferred by cluster 1 and those from 35 N and 25 N were preferred by cluster 2. The consumers from clusters 1 and 2 accounted for 64% of the consumers polled and preferred fresh-cut 'Kent' mango, which has more aromatic intensity, fruity aroma and flesh color development, as well as less visible fibrous appearance and fibrous texture. Cluster 1 (24% of consumers) preferred a firmer texture. Kader (2008) found that 'Kent' and 'Keitt' mango were preferred cultivars for fresh-cut processors. Cluster 3 consumers preferred fresh-cut 'Tommy Atkins' mangos, especially those prepared from the 35 N and 25 N initial ripeness stages, indicating that consumers from this cluster were likely to favor fresh-cut mango samples with less aroma and color development, but with more edge sharpness, edge fibrousness, moistness, glossy appearance, and fibrous texture.

Physico-chemical measurements, including flesh color, SSC, TA, and firmness (by penetrometer) are current standards for objectively evaluating the eating quality of fruit and vegetables (Alavoine et al., 1990; Malundo et al., 2001). Developing correlations between instrumental measurements and more time consuming and costly evaluation of sensory quality can be useful if one can identify instrumental measurements that correlate best to the sensory attributes of interest (Lee et al., 1999). The Pearson correlation matrix of the mean sensory ratings and instrumental parameters revealed that aroma descriptors were weakly explained with instrumental measures, confirming a previous study by Malundo et al. (2001). The SSC, SSC/TA, and TA which are widely used as measures of sweetness and sourness, were not good instrumental parameters for predicting taste quality of 'Kent' and 'Tommy Atkins' mangos. In agreement with previous studies with pear (Makkumrai, 2011; Malundo et al., 2001), the correlation coefficient of the SSC/TA ratio was not high enough to be considered an important predictor for sensory sweetness. However, SSC/TA was a reasonable predictor of the appearance descriptor edge fibrousness ($r = 0.87$) in 'Kent' mango. The best predictors of 'Kent' mango quality were a^*/b^* value and instrumental firmness, of which the former can predict hue (orange), edge sharpness, and tartness ($r = 0.92$, -0.94, -0.92) and the latter can predict hue (orange) and sensory firmness ($r = -0.92$, 0.94). For 'Tommy Atkins' mango, L^* and instrumental firmness were the best predictors for texture quality, and L^* can also predict juiciness ($r = -0.94$) and the instrumental firmness could predict the texture attributes, melting, slipperiness, sensory firmness, and fibrousness texture ($r = -0.94$, -0.93, 0.9, 0.93).

5. Conclusions

The 2 mango cultivars and 3 ripeness stages evaluated in this study varied greatly in physico-chemical characteristics, which consequently affected the overall quality (appearance, aroma, and taste) of fresh-cut mangos. The 'Kent' cultivar is particularly desirable for production of fresh-cut mangos due to its consistent sensory quality during storage, as compared to the 'Tommy Atkins' cultivar. Our results suggest that an initial ripeness stage of 35 N for 'Kent' mango and 25 N for 'Tommy Atkins' mango were most suitable for fresh-cut processing based on ease of handling, visual quality (the primary product quality criteria at the time of purchase (Bruhn, 1995)), quality maintenance during storage, and consumer acceptance.

Although descriptive analysis provided a better assessment of the sensory quality of the fresh-cut mango than the instrumental measurements, understanding the physico-chemical measurements that contribute to sensory quality, including color, SSC, TA, and firmness, is necessary for fresh-cut improvement efforts. The a^*/b^* value and instrumental firmness of 'Kent' mango and L^* and instrumental firmness of 'Tommy Atkins' mango can be used as useful tools to predict fresh-cut mango quality.

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References

Abourayya, M.S., Kassim, N.E., El-Sheikh, M.H., Rakha, A.M., 2011. Fruit physical and chemical characteristics at maturity stage of Tommy Atkins, Keitt and Kent mango cultivars grown under Nubariya conditions. J. Am. Sci. 7, 228–233.
Alavoine, F., Crochon, M., Bouillon, C., 1990. Practical methods to estimate taste quality of fruit: how to tell it to the consumer. Acta Hort. 259, 61–68.
Allong, R., Wickham, L.D., Mohammed, M., 2000. The effect of cultivar fruit ripeness, storage temperature and duration on quality of fresh-cut mango. Acta Hort. 509, 487–494.
Beaulieu, J.C., Baldwin, E.A., 2002. Flavor and aroma of fresh-cut fruits and vegetables. In: Lamikanra, O. (Ed.), Fresh-cut Fruits and Vegetables Science, Technology, and Market. CRC Press, Boca Raton, FL, pp. 387–421.
Beaulieu, J.C., Lea, J.M., 2003. Volatile and quality changes in fresh-cut mangos prepared from firm-ripe and soft-ripe fruit, stored in clamshell containers and passive MAP. Postharvest Biol. Technol. 30, 15–28.
Beaulieu, J.C., Bett, K.L., Champagne, E.T., Ingram, D.A., Miller, J.A., 1999. Flavor, sensory and postharvest evaluations of commercial- versus tree-ripe fresh-cut 'Bounty' peaches. HortScience 34, 504 (abstract).
Bourne, M.C., 2002. Correlation between physical measurements and sensory assessments of texture and viscosity. In: Bourne, M.C. (Ed.), Food Texture and Viscosity: Concept and Measurement. Academic Press, New York, NY, pp. 293–323.
Bruhn, C., 1995. Consumer perception of fresh-cut produce. Perish. Handl. Newsl. 81, 18–19.
Crisosto, C.H., Crisosto, G.M., Metheney, P., 2003. Consumer acceptance of 'Brooks' and 'Bing' cherries is mainly dependent on fruit SSC and visual skin color. Postharvest Biol. Technol 28, 159–167.
Dea, S., 2009. Establishment of favorable physical and environmental conditions for the optimization of the total product quality of fresh-cut 'Kent' mangoes. Ph.D. Thesis. University of Florida, Gainville, FL.
Gorny, J.R., Hess-Pierce, B., Kader, A.A., 1998. Effects of fruit ripeness and storage temperature on the deterioration rate of fresh-cut peach and nectarine slices. HortScience 33, 110–113.
Gorny, J.R., Cifuentes, R.A., Hess-Pierce, B., Kader, A.A., 2000. Quality changes in fresh-cut pear slices as affected by cultivar, ripeness stage, fruit size, and storage regime. J. Food Sci. 65, 541–544.
Hodges, D.M., Toivonen, P.M.A., 2008. Quality of fresh-cut fruits and vegetables as affected by exposure to abiotic stress. Postharvest Biol. Technol. 48, 155–162.
Kader, A.A., 2002. Quality parameters of fresh-cut fruit and vegetable products. In: Lamikanra, O. (Ed.), Fresh-cut Fruits and Vegetables Science, Technology, and Market. CRC Press, Boca Raton, FL, pp. 11–20.
Kader, A.A., 2008. Fresh-cut mangos as a value-added product (literature review and interviews). National Mango Board. www.mango.org. (accessed 18 July 2009).
Kader, A.A., 2010. Banana ripeness chart, Fruit ripening and ethylene management. University of California, Davis, California, pp. 51.
Kays, S.J., 1991. Development of plants and plant parts. In: Kays, S.J. (Ed.), Postharvest Physiology of Perishable Plant Products. Van Nostrand Reinhold, New York, NY, pp. 257–333.
Lawless, H.T., Heymann, H., 2010a. Acceptance testing. In: Lawless, H.T., Heymann, H. (Eds.), Sensory Evaluation of Food: Principles and Practices. Springer, New York, NY, pp. 325–344.
Lawless, H.T., Heymann, H., 2010b. Descriptive analysis. In: Lawless, H.T., Heymann, H. (Eds.), Sensory Evaluation of Food: Principles and Practices. Springer, New York, NY, pp. 227–253.
Lee, S.Y., Luna-Guzman, I., Chang, S., Barrett, D.M., Guinard, J.X., 1999. Relating descriptive analysis and instrumental texture data of processed diced tomatoes. Food Qual. Prefer. 10, 447–455.
Limbanyen, A., Brecht, J.K., Sargent, S.A., Bartz, J.A., 1998. Fresh-cut mango fruit slices. Acta Hort. 33, 457 (abstract).
Makkumrai, W., 2011. Effect of ethylene and temperature conditioning on sensory quality of european pear fruits. Master Thesis. University of California, Davis, CA.
Malundo, T.M.M., Shewfelt, R.L., Ware, G.O., Baldwin, E.A., 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica*). J. Am. Soc. Hort. Sci. 126, 115–121.
Manthey, J.A., Perkins-Veazie, P., 2009. Level of ß-carotene ascorbic acid, and total phenols in the pulp of five commercial varieties of mango (*Mangifera indica* L.). Proc. Fla. State Hort. Soc. 122, 303–307.

Mitcham, E.J., McDonald, R.E., 1992. Cell wall modification during ripening of 'Keitt' and 'Tommy Atkins' mango fruit. J. Am. Soc. Hort. Sci. 117, 919–924.
Ngamchuachit, P., Sivertsen, H.K., Mitcham, E.J., Barrett, D.M., 2014. Effectiveness of calcium chloride and calcium lactate on maintenance of textural and sensory qualities of fresh-cut mangos. J. Food Sci. 79, C786–C794.
Plotto, A., Bai, J., Baldwin, E.A., Brecht, J.K., 2003. Effect of pretreatment of intact 'Kent' and 'Tommy Atkins' mangoes with ethanol vapor heat or 1-methylcyclopropene on quality and shelf life of fresh-cut slices. Proc. Fla. State Hort. Soc. 116, 394–400.
Rattanapanone, N., Lee, Y., Wu, T., Watada, A.E., 2001. Quality and microbial changes of fresh-cut mango cubes held in controlled atmosphere. HortScience 36, 1091–1095.
Soliva-Fortuny, R.C., Mart'ın-Belloso, O., 2003. New advances in extending the shelf-life of fresh-cut fruits: a review. Trends Food Sci. Technol. 14, 341–353.
Soliva-Fortuny, R.C., Oms-Oliu, G., Mart'ın-Belloso, O., 2002. Effects of ripeness stages on the storage atmosphere, color, and textural properties of minimally processed apple slices. J. Food Sci. 67, 1958–1963.
Stone, H., Sidel, J.L., 2004. Descriptive analysis, In: Stone, H., Sidel, J.L. (Eds.), Sensory Evaluation Practices. third ed. Elsevier, San Diego, CA, pp. 201–245.