Final report for National Mango Board

Effect of fruit characteristics and postharvest treatments on the textural quality of fresh-cut mangos

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Project Overview This report covers progress for one year and eight months (January 2010-August 2011) in the study of textural quality of fresh-cut mangos. The results of our research studies will be divided into three parts and are reported separately.

i. The normal variability in texture, color, soluble solids content, titratable acidity and pH within single mango fruits.
ii. Fresh-cut mango processing, quality evaluation and observation of quality changes during storage at 5°C
iii. Influence of ripeness stage at the time of fresh-cut processing of 'Kent' and 'Tommy Atkins' mangos on sensory and textural quality of fresh-cut mangos.

Part I: The normal variability in texture, color, soluble solids content, titratable acidity and pH within single mango fruits. The purpose of this preliminary study was to evaluate whether there were qualitative differences in color, texture and composition in different positions within a single mango. If significant differences existed, it would be necessary to control for location in further studies.

Materials and Methods

Tommy Atkins mangos with red and green background color were purchased from a local wholesale market, and the average weight of each fruit was 550g. Mangoes were sorted using a nondestructive firmness tester called the Durometer, and eleven mangos with a similar initial texture (15-16lb firmness) were used in this investigation. Each mango was sliced into 2 slabs (cutting the cheeks from the fruit on either side of the seed), and a 5mm diameter section of the peel was removed. Inner and outer color and firmness were evaluated in 2 different positions in the outer flesh (just under the peel) and in 4 different positions on the inner flesh (near seed side) (Figure 1). These different positions will be referred to ask being in the 'stem scar to blossom end' axis or the 'side to side' axis.

Color was measured with a Minolta CR300 (Konica Minolta, Tokyo, Japan) colorimeter and destructive firmness with a Texture Analyzer (TA.XT Plus) equipped with an 8mm probe. Specific color values measured included L* (white to black), a* (green to red), b* (yellow to blue), chroma (intensity) and hue angle (overall color by eye). Each slab was then peeled and sliced into three parts. The titratable acidity (% citric acid), pH and % soluble solids content of each part was also determined. The data were analyzed by SAS software (version 9.2, SAS Institute, Inc., Cary, NY). Positional differences within the same mango were investigated for 11 different mangos.

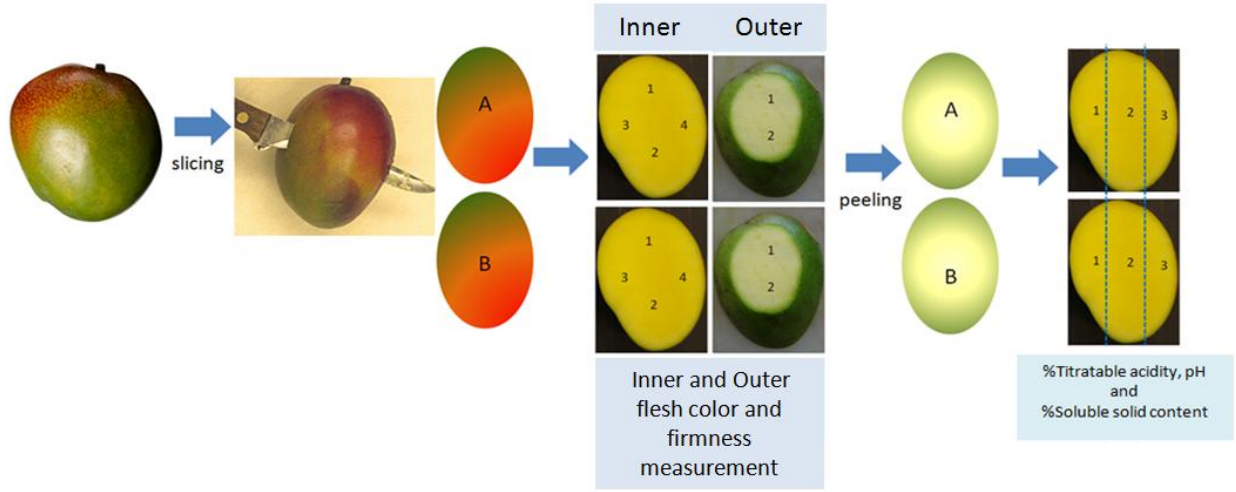

Figure 1. Quality evaluation of various positions within a single mango.

Results and Discussion

Firmness: Using the 8 mm puncture probe, which is similar to the penetrometer currently used by the mango industry, the outer firmness (near the peel) was 5.0-7.5 lbs while the inner firmness (near the seed) was significantly lower, with an average of 5.5-6.0 lbs (Figure 2). The four different positions measured within the inner fruit slab had no significant differences in terms of fruit firmness. However the outer flesh firmness showed a significant difference between the two locations measured, with the stem end being significantly softer than the blossom end by about 1.5 lbs.

Color: The lightness (L*) of the outer flesh (L* =73-75) and inner flesh (L* = 75-76) were not affected by position within the mango. For the a*, b*, chroma (C) and hue angle (h) color values, both outer and inner flesh showed a significant position effect. For the inner tissue, there was significantly difference between a*, b*, C or h between the center axis and the side measurements for each slab of mango.

The a* value indicates a green color when it is negative and a red color when it is positive. The a* value of the stem scar and the blossom end of the inner flesh were more red (or less green) than the sides. For the outer flesh, the top part (closer to the stem scar) showed more red (or less green) than the bottom part (near the blossom end). For the inner flesh, the b*value of the stem

scar and the blossom end was more yellow than the sides and for the outer flesh, the stem scar end was more yellow than the blossom end.

The chroma color parameter indicates intensity or saturation of color, with a value of '0' indicating low saturation (i.e. a neutral grey, black or white) and a value of '100' for very high chroma or saturation. The blossom and stem scar end of the inner flesh was more saturated than the sides, and the stem scar end of the outer flesh was more saturated than the blossom end. The hue angle parameter ranges from 0° (red) through 90° (yellow), 180° (green), 270° (blue). The hue angle was higher at the side of the inner flesh than the blossom end and stem scar end, and higher at the blossom end of the outer flesh than the stem scar end. Both inner and outer flesh tissues had hue angle about 90°, which means that they were in yellow colored. However, if the hue angle is closer to 180°, this means that the color has shifted to green. Therefore, the higher the hue angle at the sides of inner flesh vs. the ends, and the higher values at the blossom end vs. the stem scar of the outer flesh indicate more green.

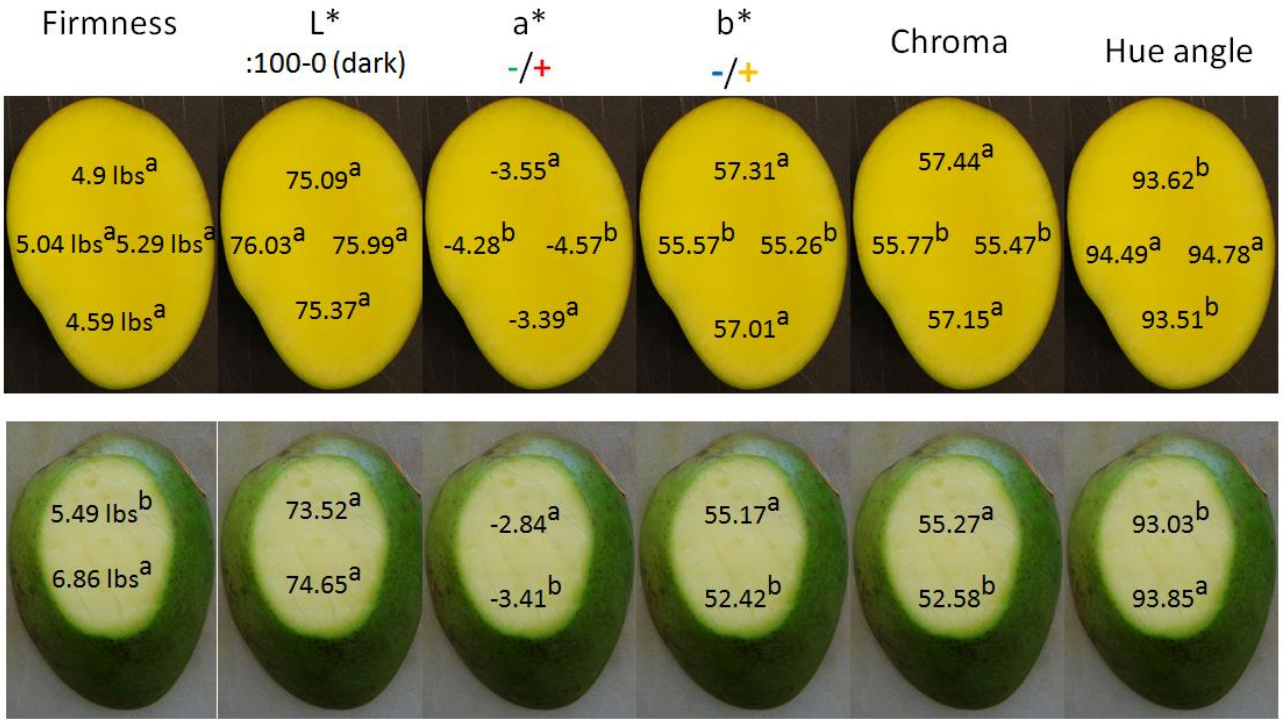

Figure 2. Average inner and outer flesh firmness and color values (L*, a*, b*, chroma and hue angle) of whole Tommy Atkins mangos. The upper row illustrates inner flesh firmness and color and the lower row is outer flesh firmness and color.

Soluble solids content (% SSC), Titratable acidity (% TA), Sugar:acid ratio and pH: There was no significant effect of position in the mango slab on soluble solids content (Figure 3). The acidity was higher along with a correspondingly lower pH in the stem scar and blossom ends of the mango slab. The sugar:acid ratio was higher at the positions along the sides of the mango than in the stem scar and blossom ends of mango slab.

Conclusions

From the results on Tommy Atkins mangos described above, the inner flesh has a softer texture and is more yellow along the stem scar to blossom ends of the mango slab. The a*value and Hue angle also indicated more green color along the side positions of mango slab. Additionally, mango firmness tended to be softer in the inner versus the outer tissue. In the outer tissue, the firmness was higher at the blossom end, which was also greener in color (more negative a*value and higher hue angle value) than the stem scar end. This indicates that the mango initiates ripening from the center (near the seed area) and then ripening spreads out to the outer part of the flesh (near the peel area). The direction of softening in the peel slab tended to begin at the stem end and progress to the blossom end of the mangos. From this experiment, we learned that there are some significant differences in firmness and color in various locations of the same mango, and these must be considered when fruit are used for fresh-cut products.

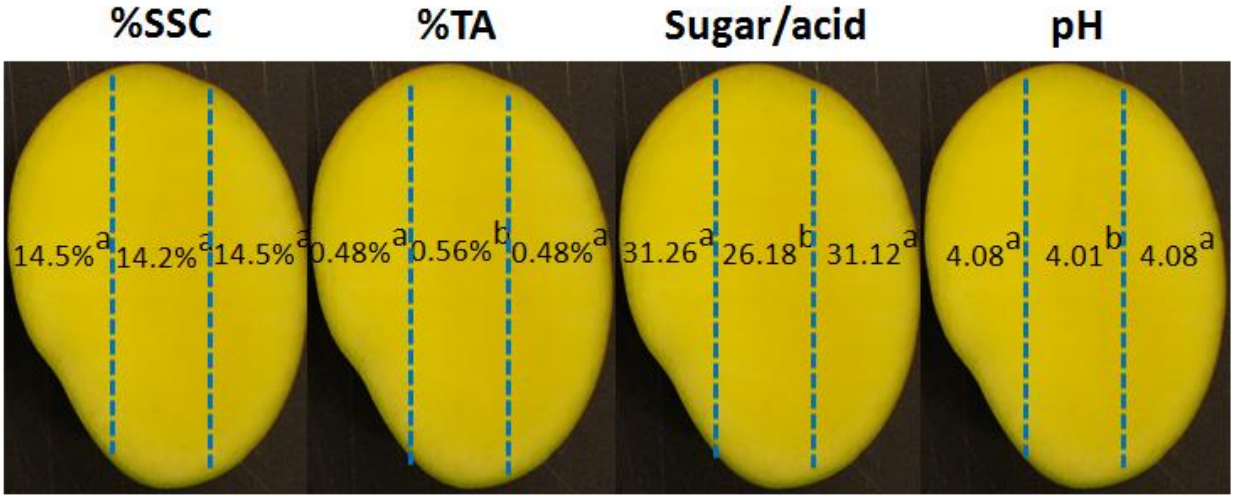

Figure 3. Average soluble solids content (% SSC), total acidity (% TA), sugar/acid ratio and pH of Tommy Atkins mangos.

Part II: Fresh-cut mango processing, quality evaluation and observation of quality changes during storage at 5°C

Material and Methods

Sorting*:* Tommy Atkins mangos with an average size of 550g and green background color were purchased from a local wholesale market. Mangos were sorted using the Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) with 8mm puncture probe. Mangos of 4 different firmness levels, from soft to firm, e.g. 0.5 lbs, 7.5 lbs, 10 lbs, and 12 lbs, were used in this investigation.

Fresh Cut Mango Cube Preparation*:* Each mango was immersed in 100 ppm NaOCl at pH 7 for 2 min, sliced from stem to blossom end into 2 slabs on either side of the seed, and then peeled with non-serrated knives (Figure 4). All cutting equipment, including knives, cutting boards and

stainless steel strainer were immersed in 200ppm NaOCl solution overnight prior to use. The entire cutting and packing process was conducted in a 10°C (50°F) room. The peel at the mango shoulder was removed with a vegetable slicer. Only the third slice (from the peel) was used for dry matter analysis.

Both slabs from each side of the whole mangos were evaluated for inner and outer flesh color and firmness using a Minolta Colorimeter and a Texture Analyzer equipped with an 8mm probe. Firmness measurements were made in 4 different positions on each of the slabs, 2 different positions near the blossom end and near the stem end on the outer flesh and 2 different positions at near blossom end and near stem end on the inner flesh. The mango slabs were cut into cubes and then dipped in 100 ppm NaOCl at pH 7 for 2 min to reduce microbial load, and then were drained and blotted with cheesecloth.

Quality Evaluation:

Visual quality evaluation: Quality of the mango cubes was measured over time after cutting. Comparison of the mango cubes was made with a 9-point rating scale as shown in Figure 5, where 9 = excellent, 7 = very good, 5 = good (limit of marketability), 3 = fair (limit of usability), 1 = poor (unusable).

Instrumental quality evaluation: Two mango cubes per slab were used for inner and outer color and firmness measurements using a Minolta Colorimeter and a Texture Analyzer equipped with a 3mm probe, followed by juice extraction with a hand juicer. Juice soluble solids content was measured by a refractometer. Two grams of juice were diluted with 22 ml distilled water for pH and titratable acidity (citric acid equivalent) determination. Mango cubes from each mango were placed in a clear deli container (16 ounces) and stored at 5°C (41°F) for 9 days.

The quality evaluations, including visual quality evaluation, color, firmness, soluble solid content, titratable acidity (citric acid equivalent) and pH of the cubes were determined for each mango on days 1, 3, 5, 7 and 9 of storage.

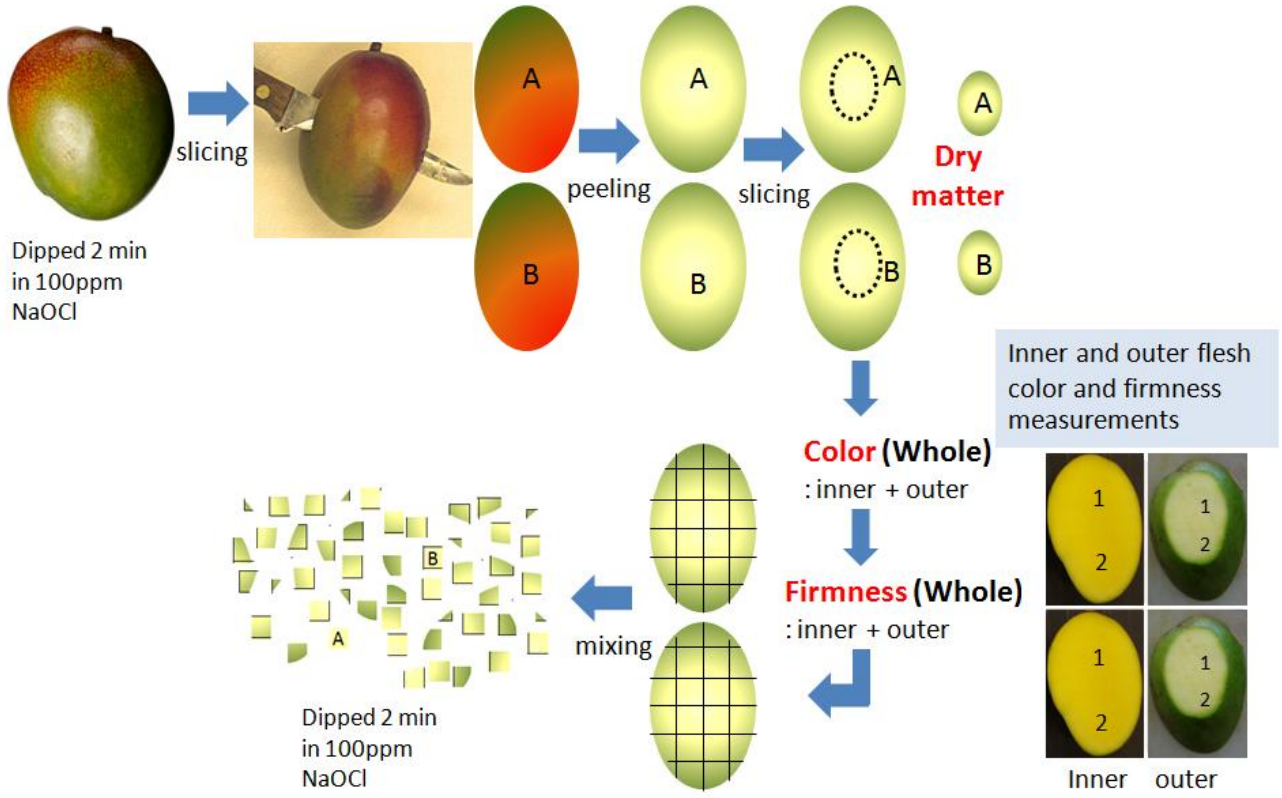

Figure 4. Process for fresh cut mango processing in 10°C (50°F) room.

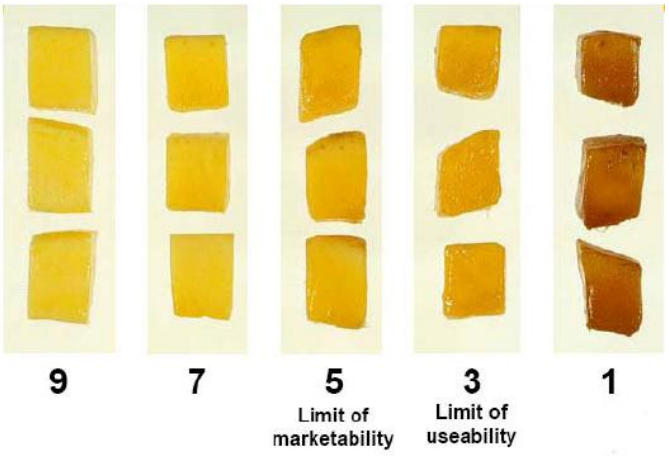

Figure 5. The 9-point rating scale used for overall visual quality evaluation.

Results and Discussion

Visual quality evaluation: Visual quality of mango cubes declined faster in the mangos with lower firmness at the time of cutting (Figure 6 and 7). The lower the quality scores, the poorer the visual quality, which also correlated with greater translucency in the mango cubes. The ripest mango, which had 0.5 lbs outer flesh firmness in the whole fruit at the time of cutting, rapidly reached the limit of usability stage, in less than 2 days, with very high levels of translucency. However, whole

mangos that were 7.5, 10.0 and 12.0 at the time of cutting were equally marketable until day 5, at which time the 12.0 lb mangos had higher quality until day 9 of storage.

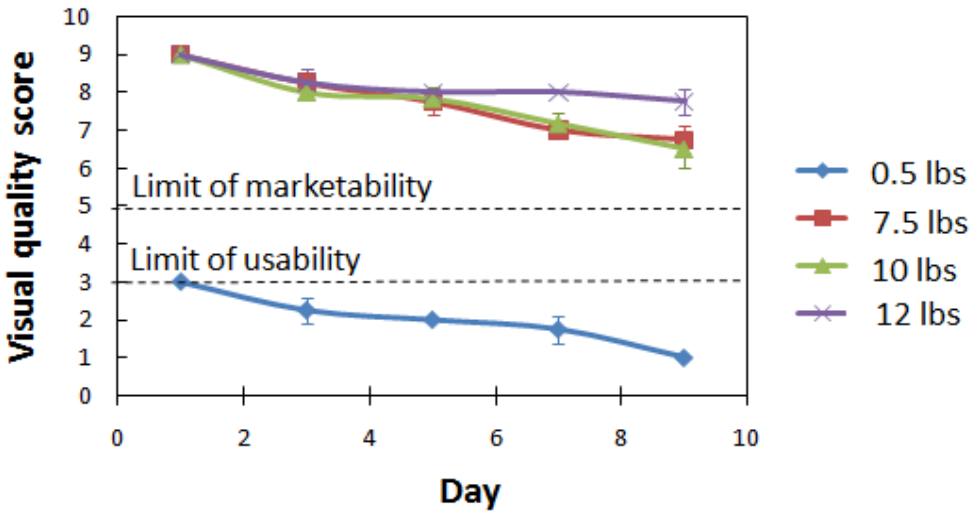

Figure 6. Visual quality scores of quality of stored fresh-cut mangoes cut at different initial whole fruit firmness values.

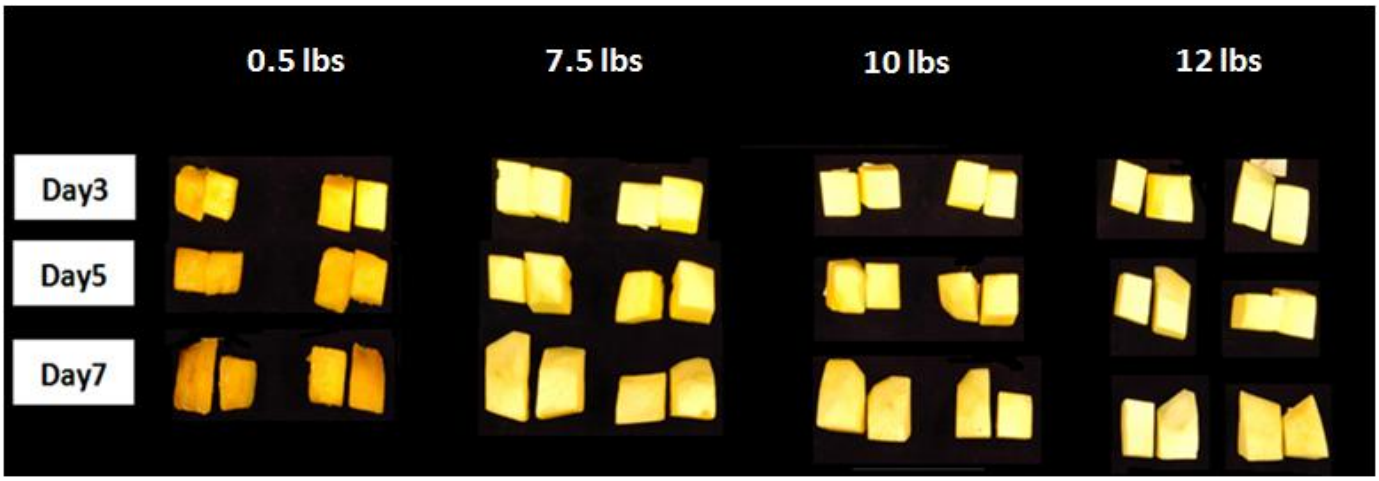

Figure 7. Changes in visual quality of stored fresh-cut mangoes cut at different initial whole fruit firmness values.

Firmness: The firmness results for cubes taken from the outer slab are presented in Figure 8a, followed by the inner slab cubes in Figure 8b, and finally Figure 8c displays both inner and outer slab cubes from mangoes with different initial firmness values.

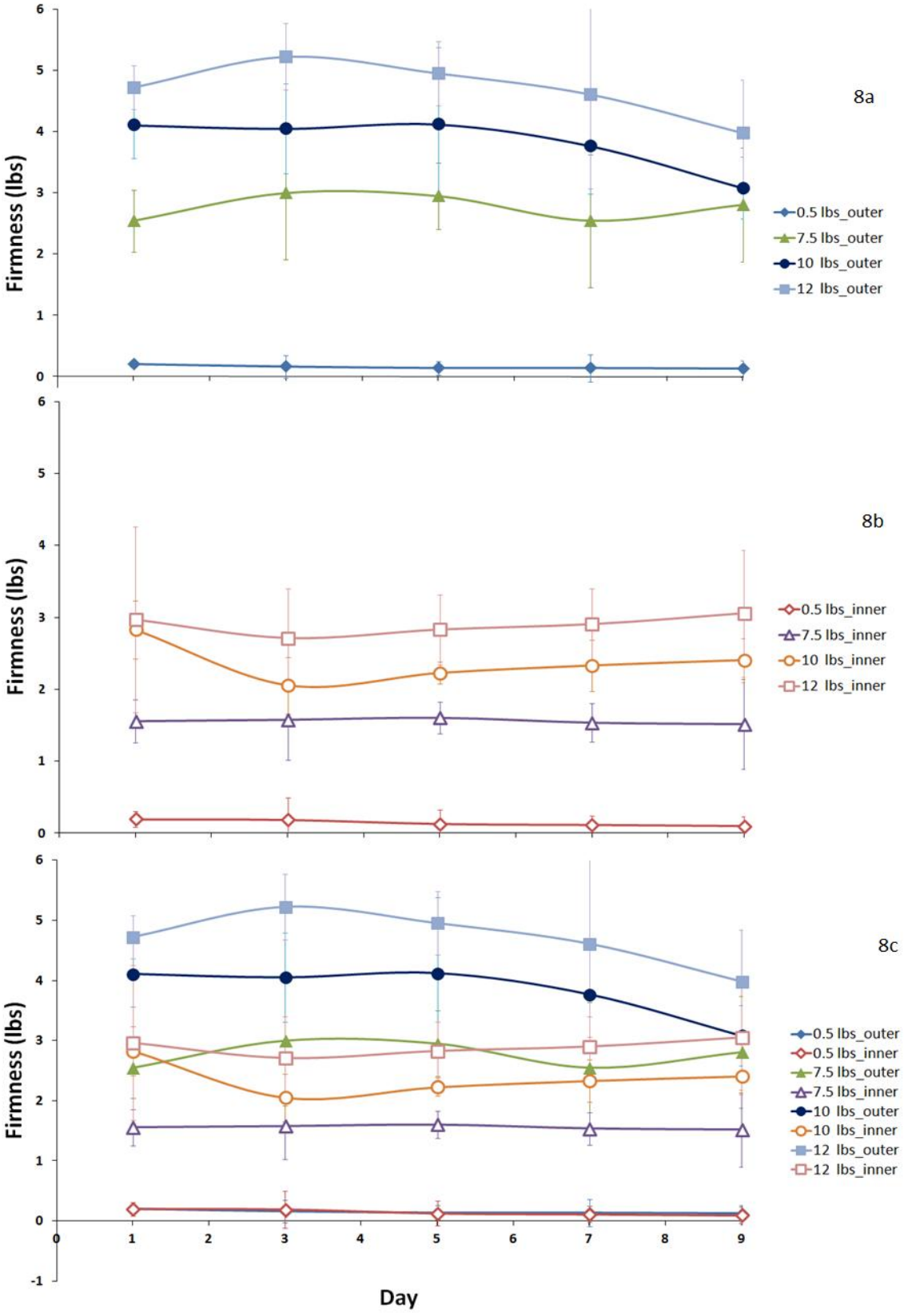

Figure 8. Outer-side (8a), inner-side (8b) and both outer-side and inner-side (8c) slab firmness of fresh-cut mango cubes cut from mangos of different initial whole fruit outer flesh firmness, e.g. 0.5 lbs, 7.5 lbs, 10 lb , and 12 lbs.

The firmness of cubes taken from the outer-side slab was higher than those from the inner-side slab, except for the ripest fruit (0.5lb), which had about the same low level of firmness throughout the 9 days of storage. The softer nature of inner-side of the cubes implies that mango fruit initiate ripening from the inside to the outside of the mango (Figure 8c). There were few significant changes in mango cube firmness during the 9 day storage period as well, but there was an insignificant decrease in outer-side cube firmness during the last few days of storage. Our results indicate that the Tommy Atkins mangos with an initial firmness of 7.5 lbs or greater will have no significant change in texture of fresh-cut mango cubes during storage.

Color: The cubes cut from the softest whole mangos, 0.5 lbs, showed pronounced decreases in color parameters (L*, b* and C), as compared with the cubes cut from whole mangoes that were initially firmer, during the 9 day storage period (Figure 9). Only hue angle and a* did not change during storage time. The mango cubes cut from firmer fruit (7.5 – 12.0 lbs) showed very little change in color parameters during the storage period. The firmer fruit showed a slower browning rate, yellow color reduction rate and color saturation reduction rate, as compared to cubes cut from mangos that were initially softer. This indicates that mangos with an initial firmness of 7.5 – 12.0 lbs will retain color in fresh-cut stored products. Moreover, the changes in cubes taken from the outer slab were smaller than those taken from the inner slab, which supports the previous experiment on whole fruit, which indicated that ripening is initiated from the inner to the outer part of mangos.

Soluble solids content (% SSC), Titratable acidity (% TA) and pH: There was no significant change in the soluble solids content, titratable acidity or pH of mango cubes stored at 5°C in all ripeness stages (0 lbs, 7.5 lbs, 10 lbs and 12 lbs) Moreover, the mango cubes prepared from the fruits with initial ripeness stage of 7.5 lbs or higher (10 lbs and 12 lbs), did not have significant differences in the soluble solids content, titratable acidity or pH during storage among the groups (Figure 10). However, the cubes prepared from the ripest mangos (0.5 lbs) showed significantly lower soluble solids content, titratable acidity and pH during storage. Figure 10 shows that there was high variation within the group of mangos at each stage, especially in the 0.5 lbs mangos. This may resulted from dissimilarity of harvest maturities of the mangos from the same initial firmness. There was also showed significantly lower soluble solids content in the mango cubes prepared from the 0.5 lbs mangos.

Conclusions

From our results, they were indicate that the Tommy Atkins mangos with initial firmness of 7.5 lbs or greater were the most desirable for fresh-cut processing because there were no significant changes in the color, firmness, soluble solids content, titratable acidity or pH of fresh-cut mango cubes during 9 days of storage at 5°C. These fruit also showed high acceptability in visual quality evaluation.

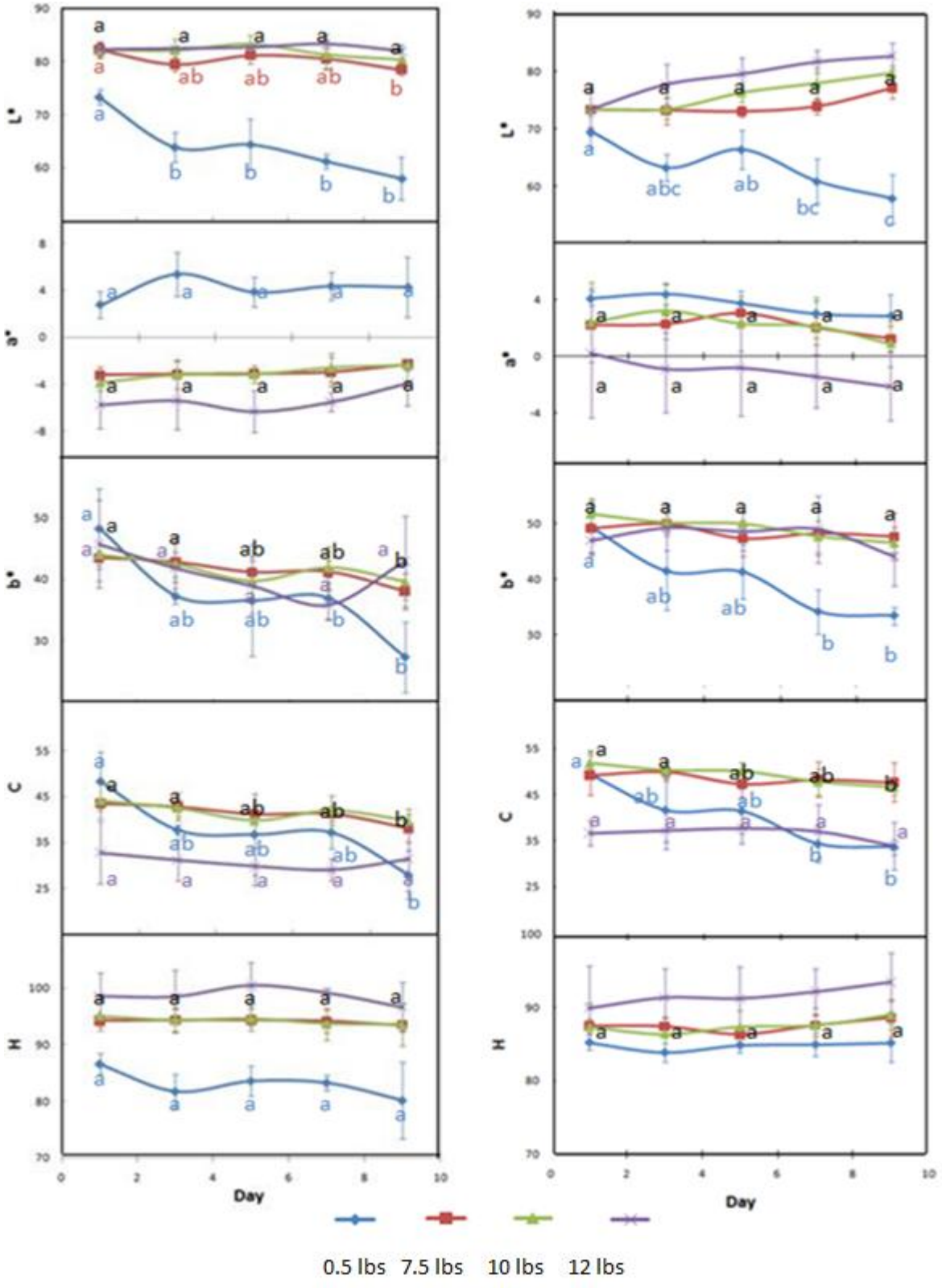

Figure 9. Changes in L* (Lightness), a* (Green/red color), b* (Blue/yellow color), C (chroma or color saturation and hue angle (H) of fresh-cut mango cubes cut from whole mangoes with different outer flesh firmness at time of cutting. Slabs were taken from the outer side (left) and inner side (right) and were stored at 5°C for 9 days.

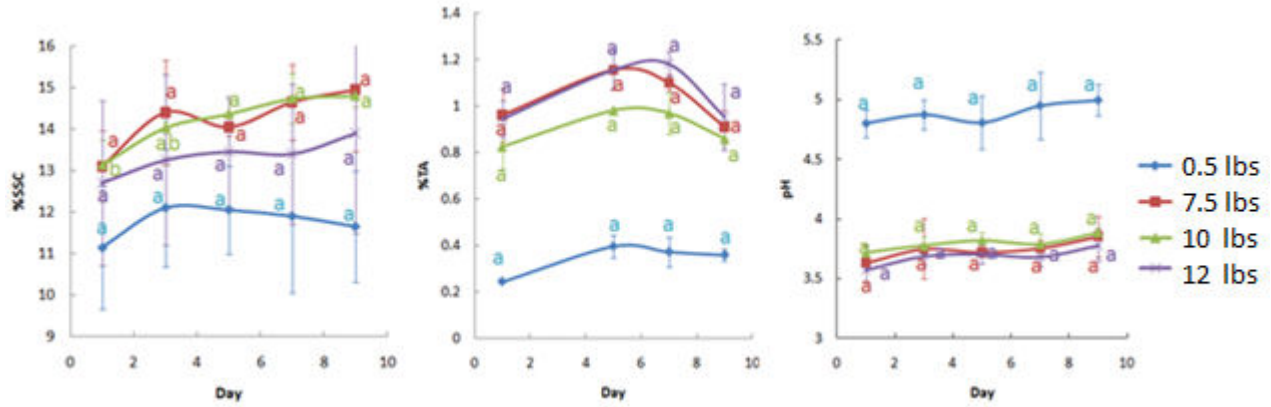

Figure 10. Changes in soluble solids content (% SSC), titratable acidity (% TA) and pH of fresh-cut mango cubes stored at 5°C.

Part III: Influence of ripeness stage at the time of fresh-cut processing of 'Kent' and 'Tommy Atkins' mangos on sensory and textural quality of fresh-cut mangos.

Material and Methods

***Sorting**:* 'Kent' and 'Tommy Atkins' mangos with an average size of 550 g were obtained from a local wholesale store in Woodland, CA between March and April 2011. They were presorted nondestructive using a TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) to have relatively similar initial firmness for homogeneity of mango fruit during ripening process. A 35mm compression probe was used and the mango fruit were allowed to ripen at 20°C and 90-95% RH until the initial firmness of whole fruit reached 6.0 lbs, 8.0 lbs and 10.0 lbs, based on a puncture test with an 8mm diameter probe to a 5 mm depth. Ripeness indicators included puncture firmness and inner flesh color as described in figure 11 using maturity and ripeness guides from the National Mango Board.

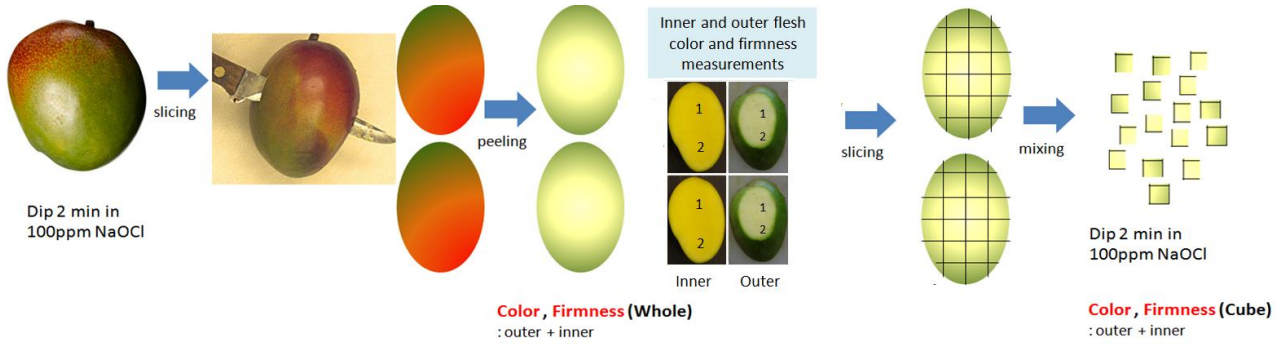

Figure 11. Fresh-cut mango cube processing diagram.

***Fresh-Cut Mango Cube Preparation**:* The mangos at each ripeness stage including 6 lbs, 8 lbs and 10 lbs were immersed in 100 ppm NaOCl at pH 7 for 2 min, sliced from stem to blossom end into 2 slabs on either side of the seed, and then peeled with non-serrated knives. All cutting equipment, including knives, cutting boards and stainless steel strainer were immersed in 200ppm NaOCl solution overnight prior to use. The entire cutting and packing process was conducted in a 10°C

(50°F) room. The mango slabs were cut into 1.5cm^3 cubes, dipped in 100 ppm NaOCl at pH 7 for 2 min to reduce microbial load, and drained and blotted with cheesecloth (Figure 11).

Instrumental Evaluation: Mango cubes were evaluated for color and firmness using a Minolta Colorimeter and a Texture Analyzer equipped with a 3mm probe, followed by juice extraction with a hand juicer. The soluble solids content was measured by a refractometer. Four grams of juice were diluted to 20 ml distilled water for pH and titratable acidity (citric acid equivalent) determination. Mango cubes from each mango were placed in a clear deli container (5½ ounces) and stored at 5°C (41°F) for 9 days. The quality evaluations, including color, firmness, soluble solids content, titratable acidity (citric acid equivalent) and pH of the cubes were determined for each mango on day 1, 5 and 9 of storage.

Sensory Evaluation: Mango cubes were evaluated by quantitative descriptive analysis (QDA) and a consumer test.

a) **Quantitative Descriptive Analysis (QDA)**: Twelve judges (6 male and 6 female) ages 20-65 were trained for 5 hours in 5 sessions and allowed to generate terms for fresh-cut mango attributes, taste the mango samples and rate the 9 point hedonic scales. The 20 significant fresh-cut mango attributes included 5 aroma attributes (aroma intensity, fruity, honey, acidic and greeny aromas), 5 appearance attribute (Hue color, edge sharpness, translucency, translucency, glossiness and moistness), 5 textural attributes (Disintegration, slipperiness, firmness, juiciness and chewiness) and 5 taste attributes (sweetness, tartness, bitterness, astringency and starchy).

b) **Consumer Test:** The consumer test was conducted by 140 consumers (95 females, 45 males). Consumers were asked to complete a questionnaire which included demographic questions, liking score and ranking of 5 purchase factors including price, fruit color, fruit appearance, variety and packaging. The descriptive sensory and instrumental data were compared and correlated using principal component analysis (PCA) and partial least squares (PLS) regression analysis. Moreover, the consumer test results were grouped using Agglomerative Hierarchical Clustering (AHC).

Results and Discussion

Principal component analysis (PCA): The samples and the experimental design are shown in Table 1. Fresh-cut mango samples were obviously separated into four groups as follows (Figure 12):

a) Fresh-cut 'Tommy Atkins' mangos with an initial firmness of 10 lbs and 8 lbs had more acidic and green aroma, appeared sharper at the cut edge, felt more fibrous and had greater tartness, bitterness and astringency than other groups, and also had a starchy aftertaste.

b) Fresh-cut 'Tommy Atkins' mangos cut from fruit at 6 lbs tended to have a glossier and moist appearance, with fibrousness at the cut edge than other groups. Their texture was easily disintegrated and also had slipperier and juicier character.

c) Fresh-cut 'Kent' mangos from all ripeness stages tended to have riper characters than 'Tommy Atkins', except for fresh-cut mangos from the 10 lbs stage stored for 1 day, which were less ripe. In general 'Kent' cubes had a more intense, honey, fruity and piney aroma. The appearance showed more water-soaking. Fresh-cut mangos made from the 'Kent' variety were obviously sweeter tasting, in general, than 'Tommy Atkins'.

d) The 10.0 lb_f 'Kent' mangos stored for 1 day had firmer and chewier texture than other samples.

Table1 **:** Sample identification and codes for the figures

Sample code	Variety	Ripeness stage	Day in storage	Sample code	Variety	Ripeness stage	Day in storage
T10D1	Tommy Atkins	10 lbs	1	**K10D1**	Kent	10 lbs	1
T10D5	Tommy Atkins	10 lbs	5	**K10D5**	Kent	10 lbs	5
T10D9	Tommy Atkins	10 lbs	9	**K10D9**	Kent	10 lbs	9
T8D1	Tommy Atkins	8 lbs	1	**K8D1**	Kent	8 lbs	1
T8D5	Tommy Atkins	8 lbs	5	**K8D5**	Kent	8 lbs	5
T8D9	Tommy Atkins	8 lbs	9	**K8D9**	Kent	8 lbs	9
T6D1	Tommy Atkins	6 lbs	1	**K6D1**	Kent	6 lbs	1
T6D5	Tommy Atkins	6 lbs	5	**K6D5**	Kent	6 lbs	5
T6D9	Tommy Atkins	6 lbs	9	**K6D9**	Kent	6 lbs	9

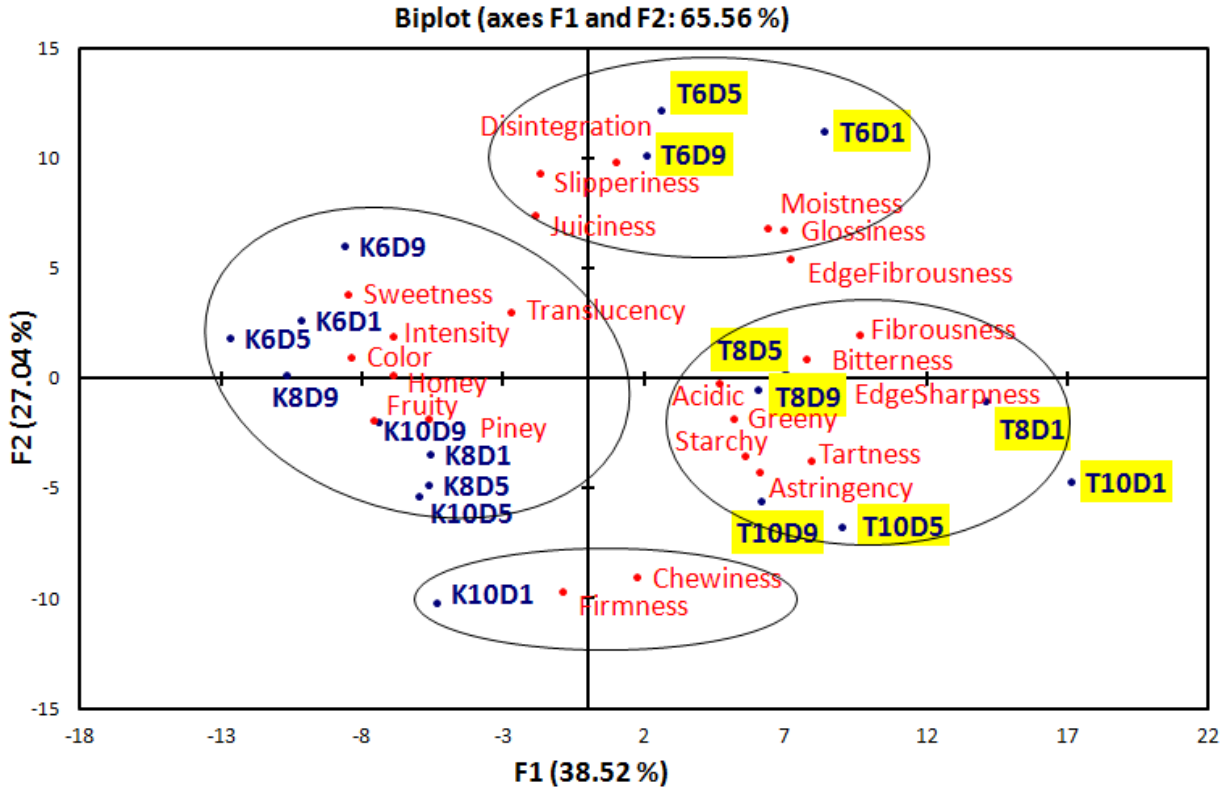

Figure 12. Bi-plot of mango samples and sensory attributes. Sensory descriptors are in red, mango cultivars, initial lbs and number of days in refrigerated storage are in blue.

Partial least squares (PLS) correlation of sensory attributes and instrumental measures: The a* color parameter, pH, SSC and dry matter measurements were correlated with the color of fresh-cut mango. Titratable acidity correlated well with tartness and fibrousness. Hue angle correlated with cut edge sharpness (Figure 13).

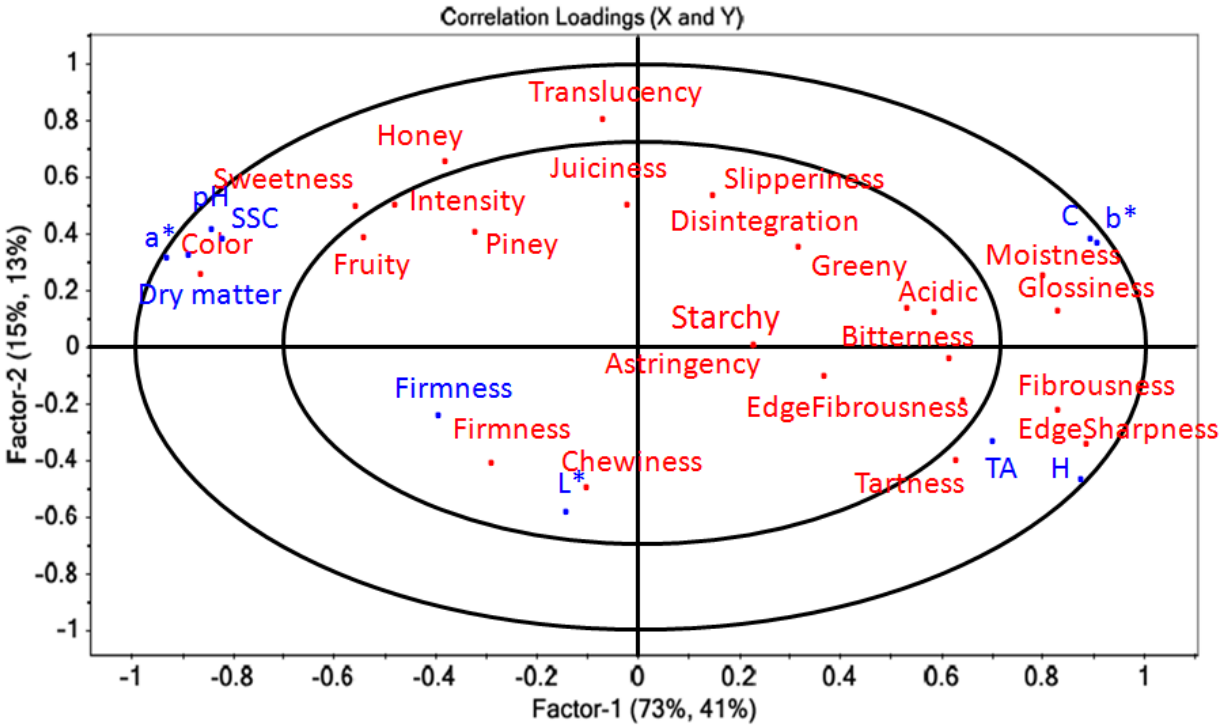

Figure 13. Partial least squares correlation of sensory descriptors to instrumental quality measurement. Sensory descriptors are in red, instrumental values in blue.

Consumer test: Consumer liking scores are distinguished into three clusters (Figure 14.), with each icon representing each of the 140 individual consumers. The largest cluster of consumers (n = 66) preferred fresh-cut 'Kent' mangos prepared from all ripeness levels, followed by fresh-cut 'Tommy Atkins' prepared from mangos with an initial firmness of either 6lbs or 8lbs (n = 54). The smallest cluster of consumers (n = 20) liked 'Tommy Atkins' at the ripest stage (6 lbs) This indicates that the 'Kent' cultivar is particularly desirable for production of fresh-cut mangos, and consumers did not discriminate between the three ripeness stages. Even firmer (10.0 lbs initial firmness) 'Kent' mangos which would be better for shipping were desirable. Furthermore, for fresh-cut 'Tommy Atkins' mango fresh-cut processing, the mango industry should be more concerned with the initial ripeness stage at the time of cutting in order to meet consumer needs. In terms of the purchase factors, more consumers were concerned about the appearance of fresh-cut mangos than the price, followed by fruit color, variety and package (Table 2). In this regard, mango processors should pay more attention in the fresh-cut process that may affect the fruit appearance, for example, using sharp knives to avoid bruising the products.

Table2 :	Consumer initial purchase influence factors without the opportunity to taste the products
Cluster	Purchase influence factors
1, 2	Fruit appearance > Price > Fruit color > Variety > Packaging
3	Price > Fruit appearance > Fruit color > Variety > Packaging

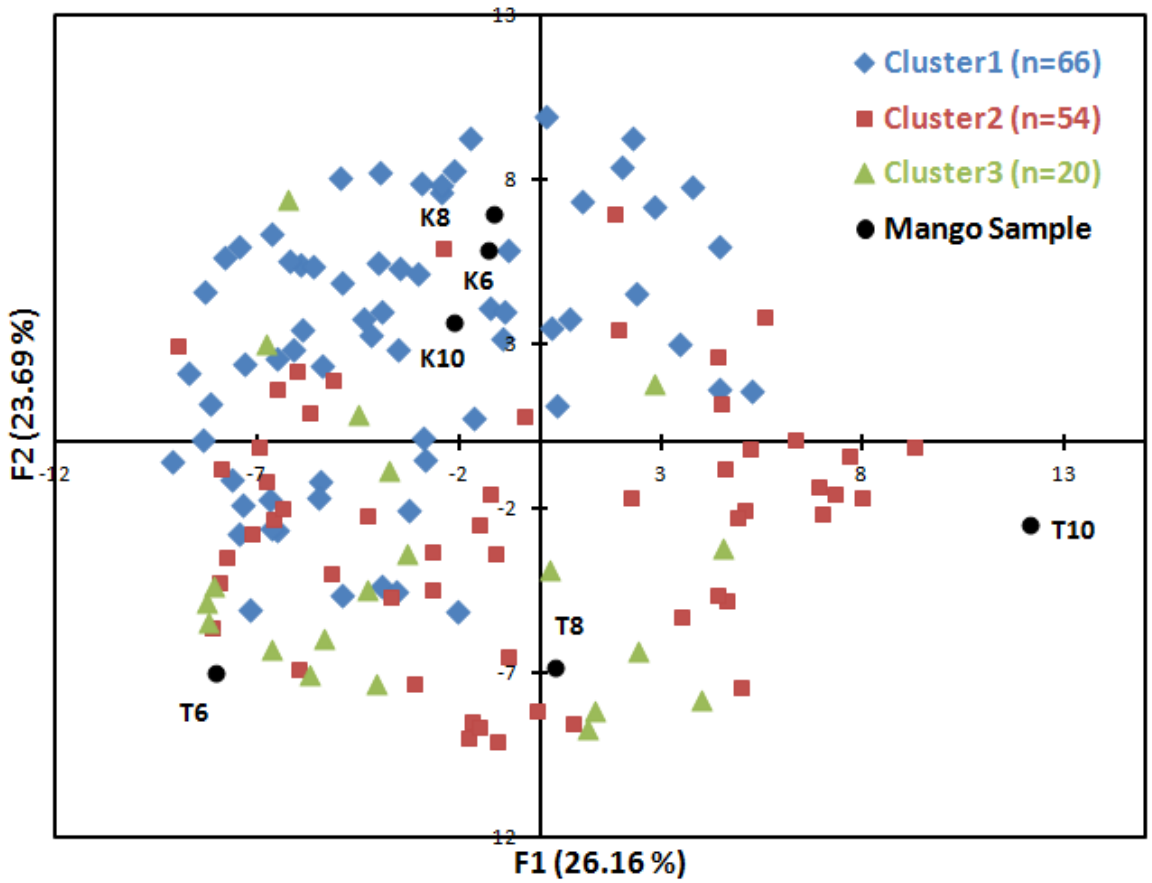

Figure 14. Principal component analysis of consumer liking segments of fresh-cut mango at different initial ripeness stage at the time of cutting

Conclusions

These results illustrate that firmness measurements of whole mango fruit can be used as an indicator for sorting mangos preferable for fresh-cut processing. 'Kent' mangos are more suitable than Tommy Atkins for fresh-cut processing in terms of consumer preference. The optimal ripeness stage for fresh-cut 'Tommy Atkins' was 6 lbs and 'Kent' was 10 lbs, based on consumer preferences, sensory characters and the ease of handling and processing.