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Sensory Quality of Fresh-cut Mango at the Consumer Level Sampled Through the Year

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The purpose of this project was to survey the quality and condition of fresh-cut mangos available to consumers throughout the annual sequence of imports from different countries, and to learn about fresh-cut mango processing practices, identifying the reasons for both good and poor quality. Three labs, located in northern and southern Florida and in northern California purchased retail samples from nine individual stores owned by six retail chains throughout one year, measuring physical and compositional quality factors and conducting taste panels. Processor facilities supplying the stores were visited to document how fresh-cut mangos are being processed and handled. The overall objective of this project was to gain information that would enable future investigation of postharvest technologies and handling practices to maintain and improve the quality of fresh-cut mangos. We found that fresh-cut mango quality was variable, but mostly mediocre, with the total of sensory scores averaging about 30 on a scale with 20 as the lowest possible total score and 49 the highest. This was due to most fruit being processed when unripe. The product was mostly pale yellow (L*: 75–80, hue: 85–95, chroma: 45–60), with variable soluble solids content (SSC; 10% to 15%), titratable acidity (TA; 0.5% to 1.5%) and SSC/TA ratio (10 to 30). Most packaging used did not allow gas exchange, resulting in almost zero O_2 and 30% to 50% CO_2 at retail, but evidence of fermentative metabolism or tissue injury (off-odors) were not detected. Expected seasonal (import country) quality variations did not occur, apparently because processors are specifying partially ripe fruit, even when more advanced fruit are available. Processors say they use partially ripe fruit because they are easier to peel and cut, and because their customers don't demand a riper product.

Mangos are among the most widely consumed fruits in tropical and subtropical regions of the world, and mango consumption in temperate-zone countries has increased dramatically in recent years. U.S. imports comprise 43% of the total world imports and have increased annually by an average of 12% in volume and 8% in value since 1994 (National Mango Board; www.mango.org). Approximately 30% of U.S. households consume mangos. According to the U.S. Census Bureau, Foreign Trade Statistics (http://www.census.gov/foreign-trade), 98% of the mangos in the U.S. market come from Mexico, Peru, Ecuador, Brazil, Haiti, and Guatemala.) Of these, Mexico is the largest exporter (62%). Mango exports to the United States vary in cultivar and source in a yearly cycle. In January and February 'Kent' mangos are imported from Peru. From March to May, 'Tommy Atkins' mangos are imported from Central America, primarily Guatemala and Nicaragua. Puerto Rico also has a small volume of mangos at this time. April to August/September is the Mexican season, with 'Ataulfo' followed by 'Haden', 'Tommy Atkins', 'Kent', and 'Keitt' mangos. From August or September to November, 'Tommy Atkins' mangos are imported from Brazil. In November and December 'Tommy Atkins' and some 'Kent' mangos are imported from Ecuador. From the importers, mangos for fresh-cut processing are distributed to mainly regional processors across the United States.

Consumers in the United States have a wide variety of fruits and vegetables available to purchase, and will pay premium prices for produce with good flavor quality. Increasing mango consumption will require optimum preharvest management, harvesting fruit at full maturity, and paying strict attention to postharvest handling techniques, especially maintaining proper temperatures throughout the postharvest period.

Alternative markets for mango, such as fresh-cut, are important contributors to the viability of the mango industry. The convenience and quality of fresh-cut fruit are major factors that contribute to their increasing popularity in the food supply. Mango is a fruit with good potential for marketing as a fresh-cut product due to its appealing flavor and texture and the added convenience of a ready-to-eat fresh-cut product over whole fruit, which requires peeling and cutting before eating.

The National Mango Board (NMB) has as its mission to increase the consumption of mangos in the United States. The NMB has

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identified improving mango fruit quality as its primary goal for increasing consumer satisfaction and generating increased sales and benefits for members of the mango supply chain. Because most U.S. households are not regular consumers of mangos, fresh-cut mango makes an ideal introduction to the unfamiliar fruit for consumers. Fresh-cut mangos currently represent < 1% of mango category sales in the United States, but fresh-cut mango sales are growing rapidly (pers. comm., NMB). According to Nielsen-Perishables Group data, fresh-cut mango dollars grew 79.8% from 2012 to 2014 (pers. comm., NMB). Expanding sales even more depends on availability to consumers of high-quality product. Even though fresh-cut fruits and vegetables offer convenience, portion control, and labor savings, their marketability presents many challenges due to their highly perishable nature (Gorny et al., 1999).

In a report commissioned by the NMB, Kader (2008) reported that the then-current 3% market share of the total fresh-cut fruit production comprised of fresh-cut mango products could be increased to a much higher percentage if year-round availability of preferred cultivars, flavor quality, and optimal ripeness stage for processing were more consistent. It was also reported in the same report that 'Kent' and 'Keitt' were the preferred mango cultivars for fresh-cut due to better availability of large sizes (eight or fewer mango per 4.5-kg box), relatively low fiber content, and good flavor consistency.

In previous research conducted at the University of California, Davis (UC Davis) and funded by the NMB, "in store" consumer tests showed that consumers view the difficultly of peeling and cutting mangos as a barrier to increased consumption. It was predicted that consistent delivery of flavorful (high quality) fresh-cut mangos to consumers would increase consumption. As a result, a mango minimum consumer quality index to assure quality satisfaction was developed and proposed to the industry (Crisosto et al., 2014).

To help the NMB assist the industry in increasing consumer satisfaction and expanding the marketability of fresh-cut mango products, our evaluation focused on the quality of fresh-cut mangos at retail. The purpose of this project was to survey the sensory and visual condition of fresh-cut mangos available to consumers throughout the annual sequence of imports from different countries, learn about fresh-cut mango processing practices, and identify possible reasons for both good and poor quality.

Materials and Methods

Product source and sampling. Samples were purchased from three stores representing different retailers at each of the three locations (Gainesville, FL; Fort Pierce, FL; and Davis, CA) on a biweekly basis. There were six retail chains represented in the survey, with one being included in the sampling at two locations (Gainesville and Fort Pierce) and one included in the sampling at all three locations. On each sampling date, three sample packages (replicates) of 12-oz size or larger (or the appropriate number of smaller packages), all with the same "use-by" date, were purchased for each fresh-cut label offered for sale at each store. To ensure availability, we made arrangements with the produce department managers to order enough product from their distribution centers so that there would be sufficient amounts on display for our needs. However, fresh-cut mangos were not available at all stores on all sampling dates. There were a total of 40 samples evaluated in Gainesville, 53 samples in Fort Pierce, and 48 samples in Davis from week four through week 47 of 2016.

Displays at the stores were photographed and their air temperatures were measured. The samples were brought to the labs in insulated coolers with ice packs. The packages were photographed to record all label information and to document the package design or style. The product samples were held at 5 °C overnight (home refrigerator temperature). The atmospheres (O_2 and CO_2) in the sample packages were measured the following morning while they were still in the 5 °C storage room using a portable gas analyzer (MAP Analyzer, Bridge Analyzers, Inc., Bedford Heights, OH). The samples were then transferred to the laboratory and allowed to equilibrate at room temperature (about 24 °C); the person opening the packages smelled the product as each package was opened and recorded a description of the odor. Samples of three or four pieces per package were selected for instrumental analysis and another three or four pieces were taken for sensory evaluation. Uniformity of color of slices in each package was judged and, when not uniform, the percent of each color group (pale yellow, yellow, orange yellow) was recorded and samples for instrumental and sensory evaluation were taken in the same proportions.

Instrumental measurements. The color of the mango pieces was measured on two opposite sides of each piece using a Minolta Chromameter (Minolta, Tokyo) using the CIE L*a*b* color space, D65 illuminant, and 8-mm aperture. The a* and b* values were converted to hue and chroma using the following calculations, $\tan^{-1}$ b/a and sq. rt. $a^2 + b^2$, respectively. The L* value ranged from 0 (black) to 100 (white). Hue ranges from 0–360 degrees, with 0 being red, 90 being yellow, 180 being green, and 270 being blue. Chroma is the distance from the origin of the color sphere (gray), with greater numbers indicating progressively more pure or intense hue.

The pieces were homogenized in a blender with 50% H_2O by weight, placed into zipper-lock freezer bags, and stored at –20 °C for later analysis. Soluble solids content (SSC) and titratable acidity (TA) were measured using juice obtained by centrifuging the thawed mango homogenate and collecting the supernatant. The SSC percentage was measured by placing a few drops of juice on the prism of a refractometer. The TA percentage was measured by titrating 12 g juice plus 50 mL DI H_2O with 0.1 N NaOH to an endpoint pH 8.2 and was expressed as % citric acid.

Sensory evaluation. Sensory evaluations were conducted by an expert panel of five persons at each location who were familiar with mango quality factors. Each panelist evaluated three samples per store at room temperature on each date. The samples were evaluated for appearance in terms of hue (1 = pale yellow; 2 = yellow; 3 = orange), cut edge sharpness (1 = damaged edge; 2 = compressed/curvy; 3 = sharp edge); cut edge fibrousness (1 = fibrous; 2 = some fibers; 3 = smooth); flesh browning (1 = brown; 2 = some browning; 3 = no browning); moistness (1 = dry; 2 = some water loss; 3 = moist); and translucency (1 = translucent/soggy; 2 = some water soaking; 3 = no translucency). Texture was evaluated in terms of firmness (1 = hard; 2 = firm; 3 = soft); juiciness (1 = not juicy; 2 = juicy); fibrousness (1 = fibrous; 2 = not fibrous); and melting (1 = not melting; 2 = melting). Taste was evaluated in terms of sweetness (1 = not sweet; 2 = sweet; 3 = very sweet); sourness (1 = very sour; 2 = sour; 3 = not sour); bitterness (1 = bitter; 2 = not bitter); and astringency (1 = astringent; 2 = not astringent). Flavor and aroma were evaluated using the descriptors mango, tropical (1 = no mango flavor; 2 = mango flavor); green, unripe (1 = green flavor; 2 = no green flavor); piney, terpiney (1 = piney flavor; 2 = no piney flavor); fermented/fizzy (1 = fermented; 2 = not fermented/fizzy); off

flavor (1 = off flavor; 2 = no off flavor); and no flavor (tasteless) (1 = no flavor; 2 = has flavor). The scoring was structured so that higher values corresponded to better quality/more ripeness with a minimum possible total of 20 points and a maximum possible total of 49 points.

Statistical analysis. The instrumental data consisted of three replicate measurements (packages) per label, retail store, and sampling date. The values (X) measured over time (Y) during the year-long sampling period were interpolated with JMP software using the Smoother element, which calculates a cubic spline piecewise polynomial with a default lambda of 0.05 and standardized X-values (www.jmp.com).

Results and Discussion

Package atmospheres. All of the fresh-cut mangos that we purchased during this project were packed in rigid clear plastic trays with snap-on lids. In some cases, a plastic shrink-wrap seal was used around the lid seal. The O_2 and CO_2 concentrations in most packages used by the retailers were extreme, with O_2 <1% and CO_2 well over 20%, indicative of sealed packages with no gas exchange (Fig. 1). The packages used by retailer #2 in Florida had less-extreme atmospheres, with O_2 mostly > 15% and CO_2 < 10%. We later determined that the manufacturer of this particular package had designed it to allow gas exchange while the other manufacturers did not consider gas exchange when designing their packages (pers. comm.). Despite the extreme atmospheres, we detected no alcoholic, fermented or off-odors when the packages were opened. This was probably because the fresh-cut mango cold chain was being well maintained during the short time from packaging to sampling, minimizing the potential damaging effects of the extreme atmospheres. In discussions with processors and retail chain logistics personnel, and from our own observations, we determined that fresh-cut mango is processed, stored, transported and displayed at around 5 °C or less, is typically delivered to the retail distribution center on the same day or the next day after processing, and is delivered to the retail stores within the next day or two, a total of only 2–3 days from processing to consumer.

Color. The color of the fresh-cut mango slices and chunks was variable among batches and through the season without much difference among the retailers (Fig. 2). The fresh-cut

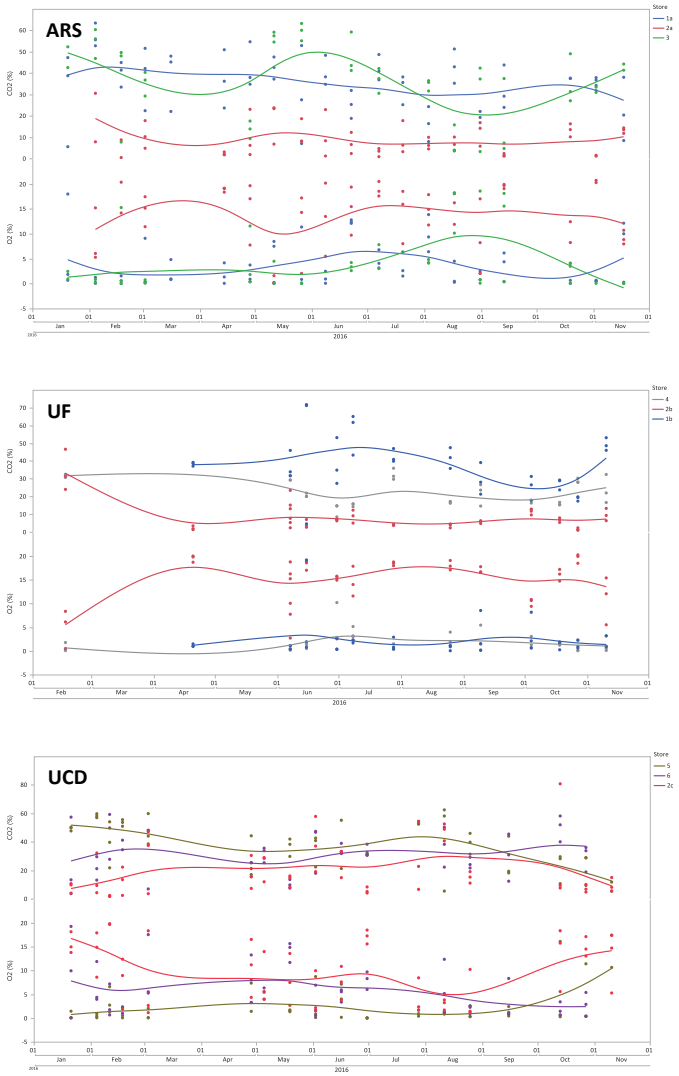

Fig. 1. CO_2 and O_2 concentrations (%) in fresh-cut mango packages purchased at retail stores and held overnight at 5 °C. ARS = Fort Pierce, FL; UF = Gainesville, FL; UCD = Davis, CA.

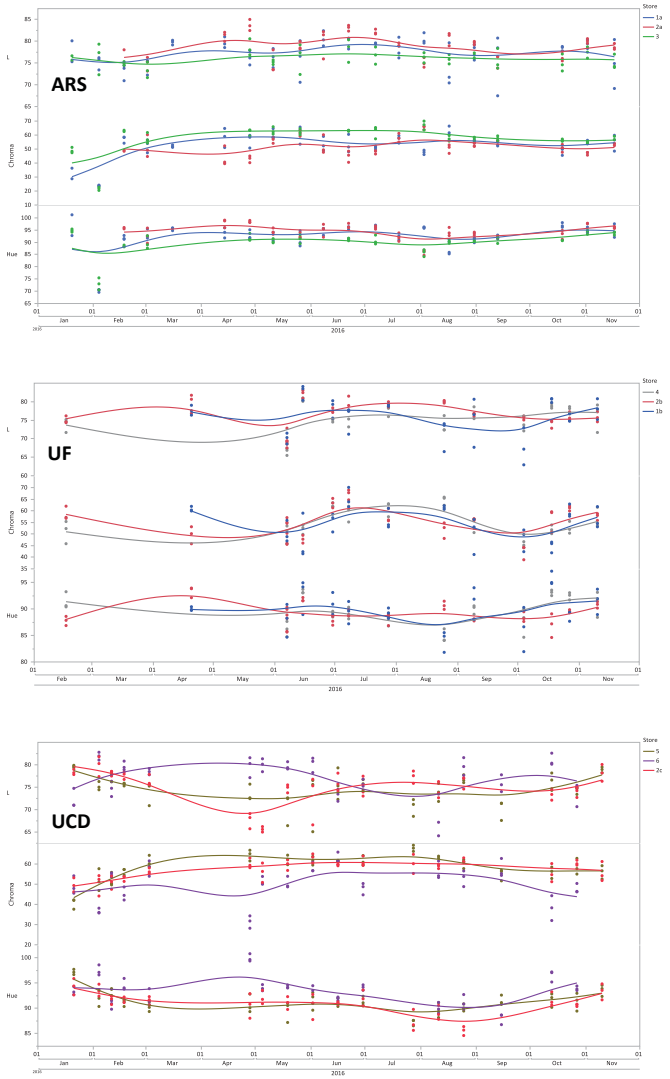

Fig. 2. Lightness (L*) chroma and hue of fresh-cut mangos purchased at retail stores and held overnight at 5 °C. ARS = Fort Pierce, FL; UF = Gainesville, FL; UCD = Davis, CA.

Fig. 3. Typical appearance of fresh-cut mango purchased at retail stores. Color values were L* = 74.6, hue = 89.2 and chroma = 55.9.

mangos were generally a pure light yellow according to the L*, hue and chroma values, with a few samples ranging either to yellowish-green or yellowish-orange. The color was indicative of partially ripe mangos as shown in the sample photograph of a sample with average color values of L* = 74.6, hue = 89.2 and chroma = 55.9 (Fig. 3).

Soluble solids content and titratable acidity. The soluble solids content, which approximates the sugar concentration of fruit, varied from < 10% to > 20% in the fresh-cut mango samples (Fig. 4). Titratable acidity varied from < 0.5% to > 1.5% and the SSC:TA ratio varied from < 10 to around 30. The higher TA values are indicative of unripe mango fruit. For mango fruit, SSC typically increases and TA decreases during ripening. However, the lower TA values observed in the Gainesville and Fort Pierce samples during August and September were not accompanied by corresponding higher SSC values, except for one sampling in Fort Pierce (ARS, store 1a, Fig. 4); likewise, the higher TA values observed in Davis during April did not correspond to reduced SSC (Fig. 4).

Sensory evaluation. Our sensory evaluations were designed to detect differences in quality of fresh-cut mangos processed at a proper stage of maturity/ripeness for good quality as a ready-to-eat, ripe product. However, the processors were preparing fresh-cut mango from fruit that were only partially ripe. Therefore, we detected little evidence of overripeness or tissue breakdown that would normally be expected to limit the shelf life of fresh-cut fruit (Figs. 5–7). This was evidenced by 2/3 or more of the samples having pale yellow or yellow color rather than orange, sharp cut edges, no browning, and no translucency, all of which are indicators of fresh-cut mango senescent breakdown. Rather, the majority of the samples were rated firm or hard, not sweet, and sour or very sour. The samples were also often judged to have texture and flavor that was fibrous, green/unripe, astringent, and piney/terpiney, which denote green/unripe mango fruit, but other samples were also judged to have melting texture, juiciness, and mango flavor.

Observations of fresh-cut processors. The processors indicated to us that their customers (the retailers) require 10- to 14-d shelf life for fresh-cut mango and that the fruit be processed at no less than maturity/ripeness stage 2 or 3 on a 5-point scale

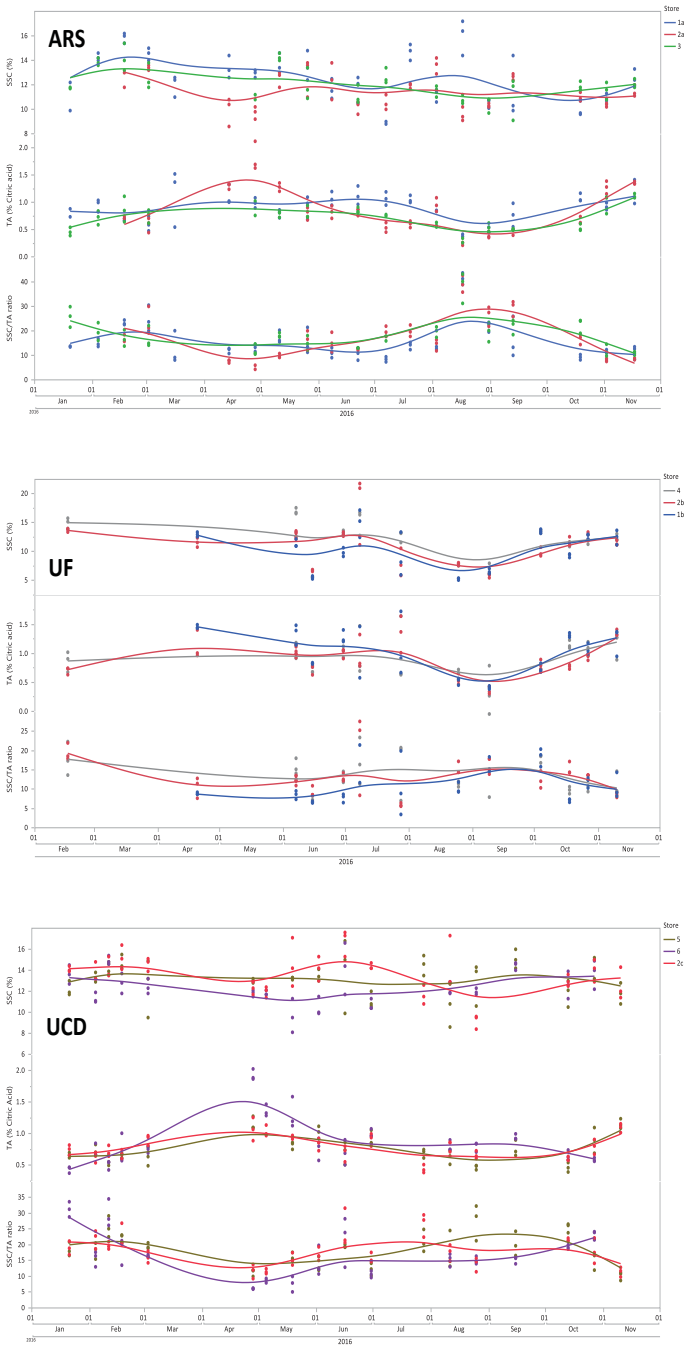

Fig. 4. Soluble solids concentration (SSC), titratable acidity (TA), and SSC/TA ratio of fresh-cut mangos purchased at retail stores and held overnight at 5 °C. ARS = Fort Pierce, FL; UF = Gainesville, FL; UCD = Davis, CA.

based on internal color development. In this scoring system, stage 1 represents preripe (no yellow color) and stages 2, 3, 4, and 5 represent 25%, 50%, 75% and 100% color development (NMB, 2016). This means that the retailers are specifying that partially ripe, not "ready-to-eat," mangos be processed into the fresh-cut product.

The processors also reported that no chemical treatments are being used to inhibit tissue browning, softening or translucency development, which would probably be necessary if riper fruit were being processed (Dea et al., 2007; 2103; Ngamchuachi et al., 2014; 2015). Modified atmosphere packaging can also help

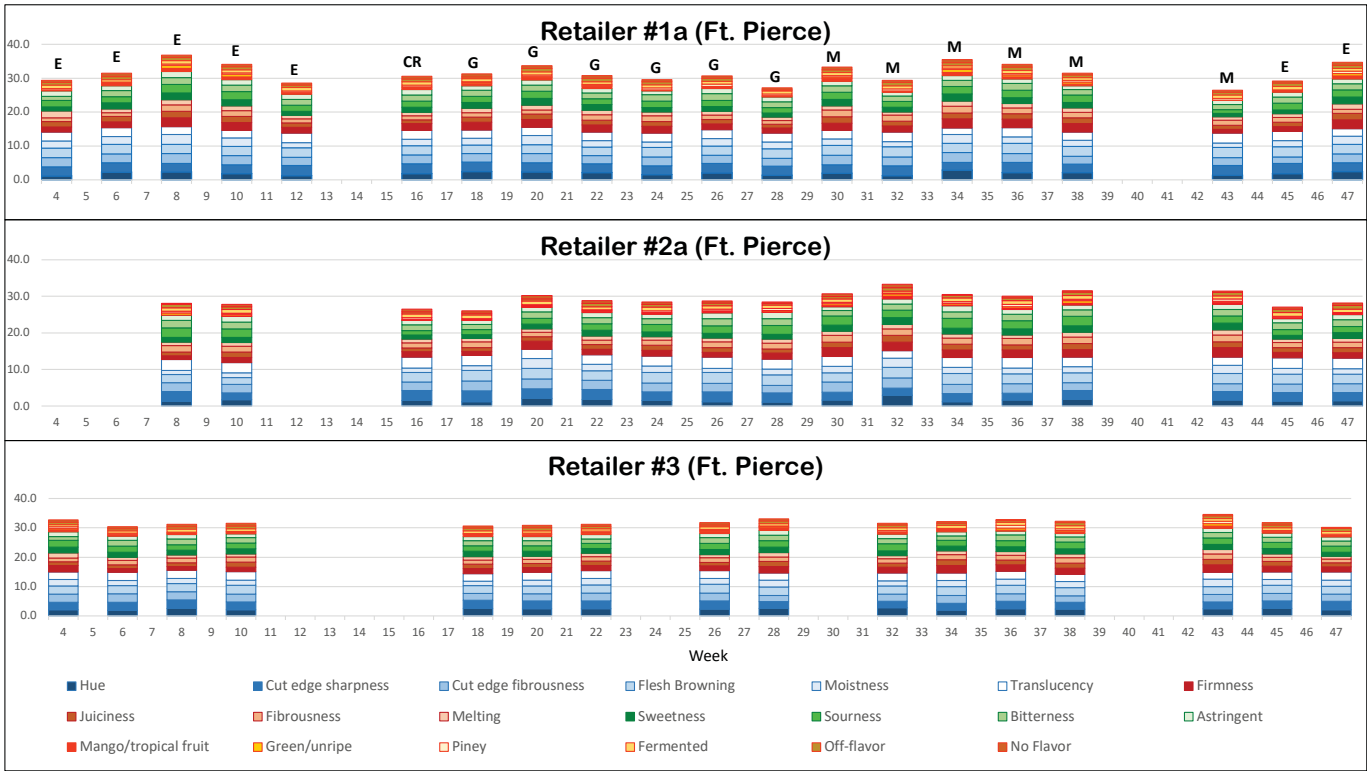

Fig. 5. Sensory evaluation scores for fresh-cut mango purchased at retail stores in Fort Pierce, FL, and held overnight at 5 °C before tasting. Cumulative scores (1, 2, or 3) for appearance attributes, firmness texture, sweetness, and sourness; scores of 1 or 2 for all other descriptors.

Fig. 6. Sensory evaluation scores for fresh-cut mango purchased at retail stores in Gainesville, FL, and held overnight at 5 °C before tasting. Cumulative scores (1, 2, or 3) for appearance attributes, firmness texture, sweetness, and sourness; scores of 1 or 2 for all other descriptors.

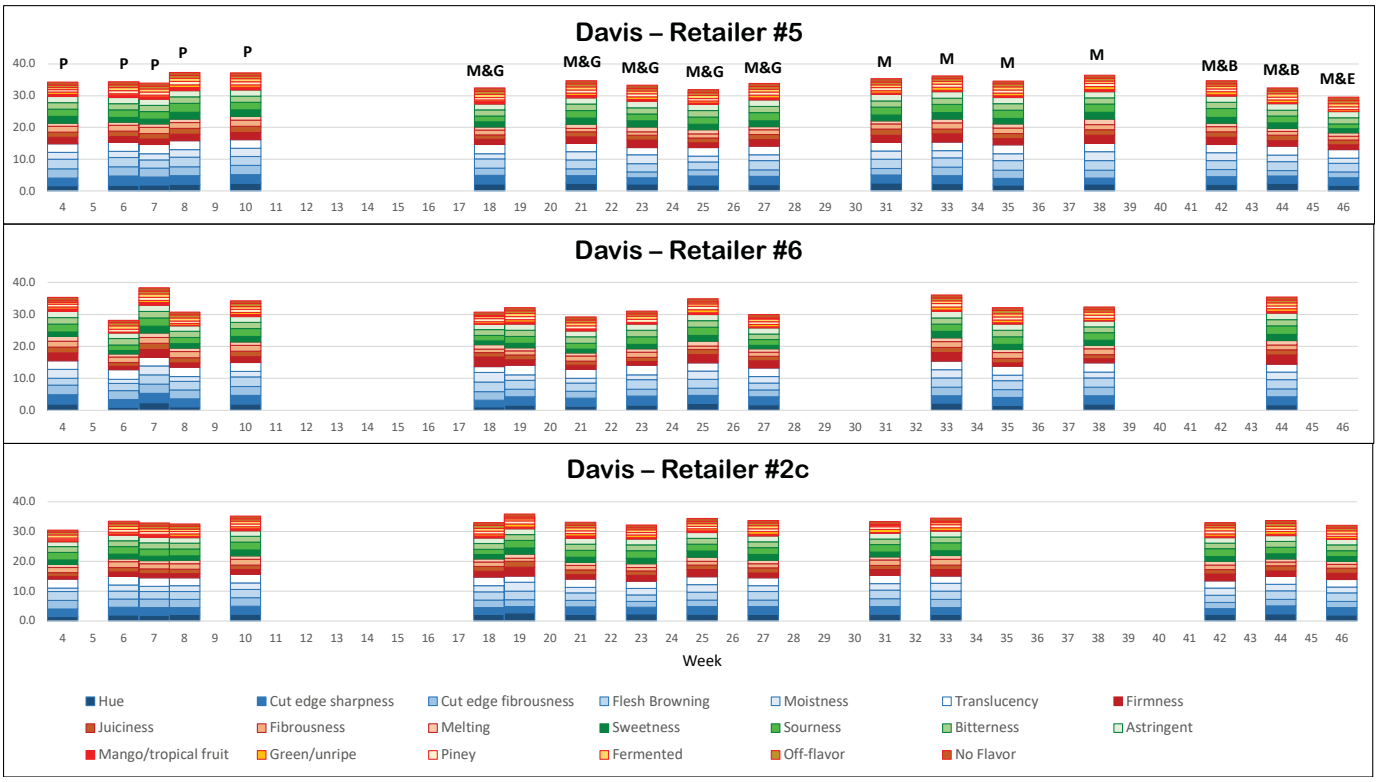

Fig. 7. Sensory evaluation scores for fresh-cut mango purchased at retail stores in or near Davis, CA, and held overnight at 5 °C before tasting. Cumulative scores (1, 2, or 3) for appearance attributes, firmness texture, sweetness, and sourness; scores of 1 or 2 for all other descriptors.

maintain fresh-cut mango quality (Dea et al., 2010). The one example we found of a package with designed gas exchange was actually intended to avoid atmosphere modification.

Processors told us that fruit-to-fruit variability is a major problem for them and that they have difficulty determining fruit maturity/ripeness other than by peeling and cutting the fruit to see the interior flesh color development. However, we observed that the processors are using fruit at the stages they are received, with no use of conditioning (ripening) programs. In our observations of the fresh-cut mango processing operations, we never saw an example of a fruit being discarded after peeling and cutting the fruit clearly showed that it was unripe. Therefore, the processors are achieving the retailers' desired 10- to 14-d shelf life by processing the mangos at unripe stages that make the fruit easier to peel and cut than if they were riper, and the retailers are not insisting that the product they receive meets even their minimal standard of stage 2 or 3 ripeness. This is resulting in poor-quality product being made available to consumers.

Conclusions

Production of high-quality fresh-cut mangos requires management of quality—starting with the best possible quality whole fruit, then preparing and handling the fresh-cut product properly to maintain that quality throughout the handling system to the ultimate consumer. For fresh-cut mangos, this requires managing the whole fruit ripening process prior to processing, following best practices for processing, and avoiding quality loss due to temperature abuse and sanitation issues. Ripening mangos before processing and knowing when the whole fruit are at the optimum stage for processing are key quality control steps in fresh-cut mango processing.

Use of optimum processing practices and proper packaging and handling after processing are also critical to deliver consumer satisfaction. Processing technology and practices should be explored that will allow riper mangos to be efficiently peeled and cut. This should include development of technologies to nondestructively judge mango fruit ripeness and determination of the optimum ripeness stage for processing that results in the best combination of fresh-cut product quality and shelf life. Achieving the retailers' desired 10- to 14-d shelf life when processing riper mango fruit will likely require supplemental treatments such as modified atmosphere packaging, antioxidants, and calcium salts to reduce browning, softening, and translucency.

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