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FRESH-CUT MANGOS AS A VALUE-ADDED PRODUCT (LITERATURE REVIEW AND INTERVIEWS)

Adel A. Kader
Postharvest Horticulture Consultant, Kader Consulting Service, P.O.Box 600, Davis, CA 95617, USA; email: adelkader41@gmail.com

Executive Summary

A review of available printed and electronic sources of information about fresh-cut mango quality attributes and their maintenance between preparation and consumption points was conducted. Interviews (by email, telephone, and/or in person) of representatives of the fresh-cut fruit industry were focused on their challenges in sourcing desired mango cultivars and fruit sizes, preparing, and marketing fresh-cut mango products. Lack of consistency in availability, quality and ripeness stage of the whole mangoes was the most frequent challenge mentioned by the processors. They would like to receive defect-free, large fruit size (10 or fewer per 4 kg) with small seed size, firm-ripe (almost ready-to-eat) that is ready-to-cut mangoes. 'Kent' and 'Keitt' are the preferred cultivars for fresh-cut processing and there is increasing customer demand for 'Ataulfo'. Most processors are aware of the factors that influence shelf-life of the fresh-cut products and are implementing the proper sanitation and cold chain maintenance procedures. Packaging to reduce water loss is commonly used and modified atmosphere packaging (2-4% oxygen + 8-12% carbon dioxide) is used to a limited extent. Only a few processors use chemical treatments for delaying softening and browning of the fresh-cut mangoes. There is good potential

for increasing the share of fresh-cut mangoes from the current 3% to a much higher percentage of the total fresh-cut fruit products marketed through foodservice and retail outlets.

Based on analysis of the literature review and interviews of many fresh-cut fruit processors, future research needs include the following:

1. Identifying the optimal ripeness stage (based on firmness and soluble solids content) for whole mangoes to be used for fresh-cut products to provide good flavor to the consumer and adequate shelf-life.
2. Evaluating how the various procedures (chemical dips, modified atmospheres, ethylene action inhibitors, etc) influence flavor in addition to texture (softening) and appearance (browning) of fresh-cut mangoes. Understanding mechanisms and factors that affect flavor retention in fresh-cut mangoes could lead to new technologies for the preservation of flavor quality.
3. Comparing the efficacy of water disinfection and fruit cleaning procedures in reducing microbial contamination to select the best method for cleaning mangoes before processing.
4. Developing new technologies for reducing labor costs by automation of as many of the processing steps as possible without significant losses in yield (weight of fresh-cut products relative to weight of the intact fruits) or quality of the fresh-cut mangoes.
5. Developing new value-added fresh mango products that appeal to various consumer groups.

FACTORS AFFECTING QUALITY OF FRESH-CUT MANGOES

Quality of the intact mangos depends upon the cultivar, preharvest cultural practices and climatic conditions, maturity at harvest, and harvesting method. Handling procedures, conditions, and time between harvest and preparation as a fresh-cut product also have major impacts on quality of intact fruits and vegetables and, consequently, quality of the fresh-cut products. Additional factors that influence quality of fresh-cut mangos include method of preparation (sharpness of the cutting tools, size and surface area of the cut pieces, washing, and removal of surface moisture) and subsequent handling conditions (packaging, speed of cooling, maintaining optimum ranges of temperature and relative humidity, expedited marketing, and proper sanitation procedures). An effective quality assurance program must take into consideration all the factors that affect quality of the intact mangos and their fresh-cut products.

Effects of maturity and ripeness stage

In most production areas, mangos reach their best eating quality when allowed to ripen on the tree. However, mangos are usually picked mature-green so that they can withstand the postharvest handling system when shipped long-distance. Most currently used maturity indices are based on a compromise between those indices that would ensure the best eating quality to the consumer and those that provide the needed flexibility in marketing.

Ripening is the composite of the processes that occur from the mature-green stage through the early stages of senescence and that result in the desirable color, textural, and flavor (taste and aroma) quality. Mangos produce relatively small quantities of ethylene (0.1 to 2 microliters per kilogram per hour) in association with their ripening, and exposure to ethylene treatment (100ppm for 1-2 days at 20 - 25°C) will result in faster and more uniform ripening. Once fruits are ripened they require more careful handling to minimize bruising. Mangos must be ripened, at least partially (almost ready-to-eat), before cutting to assure better flavor quality in the fresh-cut products.

Limbanyen et al (1998) reported that 'Tommy Atkins', 'Haden', and 'Palmer' mangoes with yellow flesh color (no green color remaining) were optimum maturity for fresh-cut in terms of maintenance of acceptable appearance, texture, and taste. Riper fruit developed flesh breakdown and more browning. Post-cutting life of fresh-cut mango at 5C was 8 to 10 days and was limited by flesh browning and loss of firmness. Peeling to a depth of at least 2mm and trimming flesh near the stem was necessary to minimize browning (Limbanyen et al, 1998). They also concluded that mangoes with slight to moderate anthracnose symptoms on their peel can be used for fresh-cut.

Tovar et al (2000) reported that partially-ripe ‘Kent’ mango slices continued to ripen after cutting, but did not reach the same level of ripeness as whole mangoes did after 5 to 7 days at 13C or 23C. Allong et al (2000) found that fresh-cut slices made from half-ripe (12.5 to 14% soluble solids) and firm-ripe (14.5 to 17% soluble solids) ‘Julie’ and ‘Graham’ mangoes had a shelf-life of 8 days at 5C or 4 days at 10C. They concluded that half-ripe (13-16% soluble solids) mangoes are ideal for fresh-cut purposes in terms of maintenance of acceptable appearance, texture, and taste during post-cutting life at 5C.

Rattanapanone et al (2001) recommended that ‘Tommy Atkins’ and ‘Kent’ mangoes should be 13 to 27 N (3 to 6 lbf) firmness (penetration force with an 11mm probe) when cut to have an acceptable quality and reasonable shelf-life as a fresh-cut product. Marketability was limited by development of watery condition, slight darkening, and microbial growth on the cubes.

Beaulieu and Lea (2003) compared volatile and quality changes in stored fresh-cut mango cubes prepared from firm-ripe (86-92 N = 19-20.5 lbf flesh firmness as penetration force with 11-mm probe and 9-10% soluble solids) and soft-ripe (27-29 N = 6-6.5 lbf flesh firmness and 12.5-14% soluble solids) ‘Keitt’ and ‘Palmer’ mangoes. They found that most soft-ripe cubes were unmarketable by day 7 at 4C and that firm-ripe cubes were not ripe enough to deliver an optimum product to consumers, even though their storage-life was greater than soft-ripe cubes.

DeSouza et al (2005) reported that fresh-cut ‘Tommy Atkins’ mango had a shelf-life of 10 days at 3C. They also found that naturally-ripened mango presented the best flavor and consumer preference as compared with mature-green mangoes that were ripened with ethylene for 12 hours at 25-30C before cutting.

Effect of hot water quarantine treatment

Dea et al (2008b) concluded that the hot water quarantine treatment (dip in 46C water for 65 to 110 minutes depending on cultivar and fruit size) of whole mangoes does not significantly affect the quality of fresh-cut ‘Kent’ mango slices stored at 5C. However, if the temperature and/or duration limits of hot water treatment are exceeded resulting in heat damage, the mangoes will not be useable for fresh-cut processing. Cooling after heat treatments reduces the potential for heat damage.

Effect of washing whole magoes before cutting

Ngarmsak et al (2005) reported that washing whole ‘Chok Anun’ mangoes in warm (50C) or cold (12C) chlorinated (100 ppm) water for 5 minutes significantly reduced total microbial populations on the skin and stem end of the mangoes. Microbial populations on fresh-cut mango slices prepared from unwashed fruit were significantly higher than those prepared from washed fruit immediately following preparation and after 7 days at 5C.

Effects of wounding (peeling and cutting)

Wounding increases rates of water loss, softening, and browning. Using very sharp tools to peel mangoes and cut their flesh limits cellular damage and reduces leakage of cellular contents and enzymatic browning mediated by the enzymes polyphenol oxidase and phenol oxidase. Also, packaging in rigid containers is essential to reduce water loss and mechanical damage during distribution.

Chantanawarangoon (2000) found that mango peels had the highest respiration and ethylene production rates followed by whole mangoes and mango cubes, respectively. Peeled whole mangoes had lower respiration and similar ethylene production rates compared to mango cubes. The C_2H_4 and CO_2 production rates of whole mangoes were about 1.5-2 times higher than peeled whole mangoes. These results indicate that mango peels are major contributors to C_2H_4 and CO_2 production by mango fruits. The CO_2 production rates of mango cubes was about 1.5 times higher than peeled whole mangoes, which indicated that cutting increased respiration rates of mangoes. However, the CO_2 and C_2H_4 production rates of whole mangoes were about 1.5 times higher than those of mango cubes. This means that the preparation steps of fresh-cut mango cubes, including peeling and cutting, resulted in the reduction of the CO_2 and C_2H_4 production rates. Therefore, wounding had a minor effect on physiology of fresh-cut mangoes, which is helpful in extending post-cutting life.

Allong et al (2001) found that storage of fresh-cut 'Julie' and 'Graham' mangoes at lower temperatures (5C instead of 10C) reduced the negative effects of wounding, including the level of microbial contamination.

Gil et al (2006) recommended complete removal of the mango skin (peel) with a very sharp knife or peeler to avoid brown discoloration of the remaining peel tissues, which appears faster than flesh tissue browning of fresh-cut mango products.

Mango fruit peeling and flesh cutting by hand can result in less damage than mechanical peeling and cutting if the sharpness of the cutting tools is similar, but the latter will likely be more consistent in the extent of wounding. These factors plus efficiency and relative cost should be considered when comparing hand vs mechanical peeling and cutting.

Effects of calcium treatments for firmness retention

Shelf life (post-cutting life based on reaching limit of marketability or visual quality score = 5) of fresh-cut mango cubes was limited by softening and browning. At 5°C, shelf lives of mango cubes treated with distilled water (control), 0.5% $CaCl_2$ and 1% $CaCl_2$ were about 5, 7 and 9 days, respectively (Chantanawarangoon, 2000). Mango cubes treated with 1% $CaCl_2$ had higher flesh firmness and calcium content than those treated with 0.5% $CaCl_2$ or water (control). Firmness of mango cubes in all treatments decreased during storage. However, firmness of mango cubes treated with 1% $CaCl_2$ was significantly higher than those treated with 0.5% $CaCl_2$ or water (control). Firmness on day 9 of mango cubes treated with 1% $CaCl_2$ decreased by about 25% of initial firmness.

Banjongsinsiri et al (2004) concluded that texture of 'Kent' mango is most likely moderated by changes in the solubility of large molecular weight insoluble pectin and non-pectin components, such as cellulose and hemicellulose, in the cell wall.

Trindade et al (2003) concluded that the most suitable conditions for quality preservation of fresh-cut 'Tommy Atkins' mango were dipping in a solution of 3.5% (w/w) calcium chloride at

35C for 20 minutes and packaging under active modified atmosphere (5% oxygen + 5% carbon dioxide). Under these conditions, fresh-cut mango maintained good quality for 5 days at 5C. The relatively short shelf-life may have been due to the long period between harvest in Brazil and processing in Portugal.

Effects of atmospheric modification

Limbanyen et al (1998) reported that a modified atmosphere of 10% oxygen + 10% carbon dioxide slowed browning and softening of fresh-cut mangoes as compared to air control.

Chantanawarangon (2000) observed that the visual quality of 'Haden', 'Keitt', and 'Kent' mango cubes stored in 2% O_2 + 10% CO_2 atmosphere was much better maintained than of those stored in other atmospheres (2% O_2 or air + 10% CO_2) or in air (control) during storage at 5°C. Shelf life of mango cubes dipped in 1% $CaCl_2$ and stored in 2% O_2 + 10% CO_2 was about 12 days, compared to 9 days for those dipped in 1% $CaCl_2$ and stored in air. Firmness of mango cubes in all treatments declined during storage. However, rate of softening was slowest in mango cubes stored in 2% O_2+10% CO_2.

Rattanapanone and Watada (2000) concluded that fresh-cut 'Tommy Atkins' mango cubes can be held in low oxygen atmospheres (0.5 to 4.0% oxygen, balance nitrogen) at 5C. Marketability was limited by the development of watery condition and slight darkening only in air and 4% oxygen atmosphere, respectively. Rattanapanone et al (2001) reported that the marketable period of fresh-cut 'Tommy Atkins' and 'Kent' mango cubes was 3 to 5 days at 10C or 5 to 8 days at 5C and was extended by 1 to 2 days when cubes were held in 4% oxygen + 10% carbon dioxide or 2% oxygen + 10% carbon dioxide (balance nitrogen) atmospheres. They concluded that while CA was beneficial in maintaining quality of the cubes, temperature was more effective than CA.

Martinez-Ferrer et al (2002) working with ‘Keitt’ mangoes that were harvested at 7-8% soluble solids and kept at 13-15C until their soluble solids reached 11-12% before preparation of the cubes, found that packaging in a modified atmosphere of 4% oxygen + 10% carbon dioxide + 86% nitrogen resulted in the longest shelf-life (25 days at 5C) of the mango cubes in comparison with vacuum packaging, 100% oxygen, and air control. This treatment significantly inhibited the growth of spoilage microorganisms, particularly molds and yeasts.

Donadon et al (2004) compared three types of polymeric films for packaging ‘Tommy Atkins’ mango slices and found that those packed in the polyethylene terephthalate (PET) clamshell trays had a shelf-life of 14 days at 3C vs 11 days for the mango cubes in the other packages. Singh et al (2007) concluded that the shelf-life of fresh-cut mangoes could be extended by packaging in PET containers. Chonhenchob et al (2007) reported that extended shelf-life was observed in fresh-cut mangoes packed in PET due to reduced oxygen and elevated carbon dioxide concentrations.

Poubol and Izumi (2005a) reported that the shelf-life of fresh-cut ‘Carabao’ mangoes, based on brown discoloration and water-soaked appearance, was 6 days at 5C and 4 days at 13C. A 10% carbon dioxide-enriched atmosphere enhanced texture and retarded the development of water-soaked ‘Carabao’ cubes at 5C and 13C. The 10% carbon dioxide atmosphere also reduced bacterial count on mango cubes held at 13C.

Poubol and Izumi (2005b) found that 60% oxygen atmosphere reduced the respiration rate of fresh-cut ‘Carabao’ mango cubes kept at 5C, but stimulated the rate after 2 days at 13C.

Browning of 'Carabao' mango cubes was accelerated by 60% oxygen at 13C. Thus, they concluded that 60% oxygen is not a desirable atmosphere for mango cubes when held at 13C.

Sothornvit and Rodsamran (2008) found that a mango film provided a good oxygen barrier with sufficient mechanical properties to wrap whole and minimally-processed mangoes. When the latter were wrapped in a mango film and kept in cellophane bags, the shelf-life was extended to 6 days at 5C.

Effects of storage temperature and relative humidity

Keeping intact and fresh-cut fruits within their optimum ranges of temperature and relative humidity is the most important factor in maintaining their quality and minimizing postharvest losses. Above the minimum safe temperature for mango as a chilling-sensitive commodity, every 10°C increase in temperature accelerates deterioration and the rate of loss in nutritional quality by 2- to 3-fold. Delays between harvesting and cooling or processing can result in quantitative losses (due to water loss and decay) and qualitative losses (losses in flavor and nutritional quality). The extent of these losses depends upon the commodity's condition at harvest and its temperature, which can be several degrees higher that ambient temperatures, especially when exposed to the hot water treatment.

Chantanawarangoon (2000) found that the CO_2 production rate of mango cubes stored at 5^oC was higher that those of mango cubes stored at 2^oC and 0^oC, respectively. However, the C_2H_4 production of mango cubes stored at 0^oC was about 2.5 times higher than those stores at 5^oC and 2^oC. Normally, based on temperature effects, produce kept at lower temperature should have lower CO_2 and C_2H_4 production. However, at chilling temperatures many chilling sensitive fruits and vegetables show increased respiration and ethylene production rates. Therefore, the higher

C_2H_4 production of mango cubes stored at 0°C might be a sign of chilling injury. The symptom of chilling injury was obviously observed on day 13 as surface darkening (smoky color). None of the mango cubes stored at 0, 2 or 5°C had any juice leakage during 13 days of storage. The overall visual quality of mango cubes stored at 2°C was slightly better than those of mango cubes stored at 5°C or 0°C The results of this experiment indicate that 2°C to 5°C is the optimum storage temperature range for fresh-cut mango cubes since storage at 0°C for more than 10 days can cause chilling injury. However, for up to 10 days, 0°C can be used.

Izumi et al (2003) recommended 5C as the best temperature for maintaining quality of fresh-cut 'Carabao' (partially-ripe with 50-60% yellow skin color) mango cubes; the shelf-life was 4-6 days and CA (1-2% oxygen, balance nitrogen) had an additional benefit.

Maciel et al (2004) observed that the sensory characteristics of minimally-processed 'Espada' mangoes were significantly changed during storage limiting storage time to 4 days at 7C and 61% relative humidity.

Dea et al (2008a) found that shelf-life of fresh-cut 'Kent' mangoes was 3 to 4 days at 12C vs 5 to 6 days at 5C. It was unclear whether this storage period at 5C caused chilling injury in fresh-cut mango slices since no visual chilling injury symptoms were noted. However, reduced ascorbic acid content and increased softening at 5C suggest that the fresh-cut slices did experience chilling stress.

Effects of anti-browning chemical treatments

During storage at 5°C, mango cubes with no dipping treatment and those dipped in water had significantly lower visual quality scores than those treated with various chemical solutions

(Chantanawarangoon, 2000). On day 12 of storage, mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine, 1% $CaCl_2$ + 1% citric acid + 0.5% N-acetylcysteine or 1% $CaCl_2$ + 1% ascorbic acid had higher visual quality scores than those dipped in water. There was no significant difference in firmness of mango cubes treated with all the chemical solutions that had 1% $CaCl_2$ as a component. Firmness of mango cubes with no dipping and those dipped in water was significantly lower than those treated with the various chemical solutions that included 1% $CaCl_2$ as a component. These results showed that 1% $CaCl_2$ is essential for maintaining firmness of fresh-cut mango cubes.

Based on firmness and appearance, it is clear that 1%$CaCl_2$ is a key compound that should be applied for maintaining firmness and extending shelf life of fresh cut mango cubes regardless of the intended marketing periods. However, if the marketing period is longer than 6 days, additional chemicals, such as 1% ascorbic acid + 0.5% L-cysteine or 1% citric acid + 0.5% N-acetylcysteine, should be applied in addition to 1% $CaCl_2$ in order to delay browning. Considering cost and availability of food grade chemicals, ascorbic acid is comparable to citric acid. However, L-cysteine is less expensive and more available than N-acetylcysteine. Therefore, the mixture of ascorbic acid and L-cysteine in addition to 1% $CaCl_2$ might be a better choice for maintaining quality of fresh-cut mango cubes (Chantanawarangoon, 2000).

Plotto et al (2004) compared the effects of edible coatings on quality maintenance of fresh-cut 'Tommy Atkins' mangoes kept at 5C or 10C. Mango pieces were dipped for 30 seconds in 5ppm chlorine dioxide, 2% calcium ascorbate and 0.5% N-acetyl-L-cysteine (antioxidants) or coated with 1% carboxymethylcellulose (CMC) or CMC and 0.5% maltodextrin (CMM). Coated mango pieces and those treated with antioxidants maintained good visual quality for up to 21 days at 5C or 14 days at 10C. This study confirmed the necessity to treat fresh-cut mangoes with antioxidants to prevent color darkening in storage. Storage temperature of 5C maintained visual quality of fresh-cut mangoes, but overall volatiles were decreased. Carboxymethylcellulose alone or in combination with maltodextrin may improve fresh-cut mangoes. However, fruit quality at the time of cutting may affect storage capacity and quality more than additives on the fruit pieces.

Chonhenchob et al (2007) concluded that the most effective chemical treatment to reduce browning, softening, and decay of fresh-cut 'Namdokami' mangoes was 0.1 M ascorbic acid.

NatureSeal, Inc. (a subsidiary of Mantrose-Haeuser Co., Inc.) sells a NatureSeal formulation for fresh-cut mangoes that is promoted for extending their shelf-life to 10 to14 days at 2 to 5C. For more information, go to the company's website at: http://www.natureseal.com/ .

Effects of ethylene action inhibitors

Plotto et al (2003) investigated the effects of treating whole 'Kent' mangoes with 1-methylcyclopropene (1-MCP, 25ppm), heat (38C and 98% relative humidity for 12 or 24 hours), or ethanol (5g/kg) on quality and shelf-life of fresh-cut pieces. The fresh-cut pieces were dipped in 2% calcium ascorbate and 1% citric acid to prevent browning. They found that the 1-MCP and heat treatments decreased firmness while the ethanol treatment maintained firmness similar to the control. After 12 days at 7-8C, cut pieces from ethanol-treated mangoes maintained the best visual quality, but had off-flavor. These ripening inhibition treatments did not influence shelf-life of fresh-cut 'Tommy Atkins' mangoes but delayed spoilage of 'Kent' mangoes by 2 days.

Vilas-Boas and Kader (2007) found that softening and browning were delayed when 1-MCP (0.5 or 1.0 ppm for 6 hours) was applied directly on fresh-cut 'Kent' and 'Keitt' mango slices. Respiration rate of mango slices was not affected by 1-MCP whereas ethylene production rate was affected only towards the end of their shelf-life (9 days at 5C). Treating whole mangoes before cutting was less effective than treating the cut product.

Combination of 1-MCP treatment with calcium treatment and/or modified atmosphere packaging results in synergistic effects on maintaining good appearance and textural quality. Since 1-MCP (Smartfresh) is now available in liquid formulation (AgroFresh, Inc.), its application to fresh-cut mangoes as a dip alone or in combination with other chemicals should be evaluated.

Effects of combination treatments

Gonzalez-Aguilar et al (2000) found that combinations of antibrowning agents and modified atmosphere packaging (MAP) reduced browning and deterioration of fresh-cut 'Kent' mangoes stored at 10C for up to 14 days. A combination of 4-hexylresorcinol (0.001M), potassium sorbate (0.05M) and D-isoascorbic acid (0.5M) was more effective than the individual chemicals in inhibiting browning, decay, and deterioration of fresh-cut mangoes.

There were no significant differences in visual quality scores between mango cubes treated with 1% $CaCl_2$ + 1%ascorbic acid + 0.5% L-cysteine and stored in air or in CA (2% O_2 + 10% CO_2). Visual quality scores of mango cubes in different treatments were not significantly different until day 10, when the visual quality score of mango cubes in the control decreased to about the limit of marketability. Based on appearance, shelf lives of mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine stored in air or in CA were up to 17 days, compared to 12 days for those treated with 1% $CaCl_2$ and stored in CA and to 10 days for the control (Chantanawarangoon, 2000).

DeSouza et al (2006) indicated that the symptoms limiting shelf-life of fresh-cut ‘Kensington’ mangoes were tissue darkening, development of a glassy appearance, surface desiccation, and loss of firmness. Low (2.5%) oxygen atmosphere was effective in controlling tissue darkening and the development of a glassy appearance, while calcium (3%) application was partly effective in controlling darkening. Calcium chloride however significantly slowed loss of tissue firmness. Carbon dioxide (5-40%) and citric acid had little positive effect on shelf-life, with both treatments promoting tissue softening. A combination of 2.5% oxygen and 3% calcium allowed ‘Kensington’ mango slices to be held for at least 15 days at 3C.

Gonzalez-Aguillar et al (2008) reported that combinations of calcium chloride, antioxidants (ascorbic acid, citric acid) and two commercial film coatings resulted in a reduction of browning and deterioration of fresh-cut ‘Keitt’, ‘Kent’, and ‘Ataulfo’ mangoes stored at 5C. shelf-life of fresh-cut ‘Ataulfo’ mangoes was 21 days while that of fresh-cut ‘Keitt’ and ‘Kent’ mangoes was only 9 and 12 days, respectively. The authors related this difference to better response of ‘Ataulfo’ than ‘Keitt’ and ‘Kent’ mangoes to treatment with antioxidants.

Effect of other minimal processing methods

Boynton et al (2000 and 2002) evaluated the effects of high pressure processing (300 and 600 MPa for one minute) on sensory quality and stability of mango cubes kept for up to 9 weeks at 3C. Fresh mango flavor declined and off-flavor increased during storage, but color and other sensory attributes changed very little. They also found that high pressure prevented increases in microbial load that were noted in the control.

Tovar et al (2001a & b) concluded that a short osmotic dehydration treatment (sucrose at 65 degree Brix at 30C) under vacuum (211 mbar) together with low temperature (5C) storage may be used to extend the shelf-life of minimally processed 'Kent' mango slices for 20 days.

NUTRIENT RETENTION IN FRESH-CUT MANGOES

Chantanawarangoon (2000) found that treatment with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine for 2 min approximately doubled the reduced ascorbic acid (RAA) and total ascorbic acid (TAA) concentrations in mango cubes. During 10 days of storage at 5°C, there were no significant changes in RAA, dehydroascorbic acid (DHAA), and TAA concentrations of mango cubes in control and those treated with 1% $CaCl_2$ and stored in CA. In contrast, RAA and TAA contents of mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine and kept in air or CA declined, while DHAA increased during storage. However, the decreases of RAA and TAA and the increase of DHAA were slower in those mango cubes stored in CA. After 17 days at 5°C, the amounts of TAA of mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine and stored in air decreased by about 29% of initial amount while TAA of the mango cubes treated with the same solution and stored in CA decreased by 18% of initial amounts. The results indicated that CA (2% O_2 + 10% CO_2) was effective in maintaining TAA by slowing the oxidation of RAA to DHAA. Therefore, the loss of RAA during storage due to the hydrolysis of DHAA to 2,3-diketogulonic acid after oxidation of RAA to DHAA were retarded under CA storage (Chantanawarangoon, 2000).

The major carotenoid in mango cubes is β-carotene with only trace quantities of α-carotene. During storage at 5°C for 17 days, there were no significant differences in β-carotene content of mango cubes in all treatments. The β-carotene content of mango cubes did not change during 10 days of storage at 5°C. However, mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine and stored in air or CA for 17 days, whose visual quality scores were still above the limit of marketability, had lower β-carotene than those stored for 10 days (Chantanawarangoon, 2000).

Gil et al (2006) reported that fresh-cut 'Ataulfo' mango cubes maintained good visual quality and there were no significant changes in soluble solids content, titratable acidity, and pH for up to 9 days at 5C. The initial Vitamin C content was 80 mg per 100 g fresh weight and there was a loss of about 10% during the 9 days at 5C. No losses in total carotenoids content were noted until day 9 when the loss was about 25%. There was a slight decrease in total phenolics after 3 days at 5C, but no subsequent losses were found between day 3 and day 9 at 5C. In general, fresh-cut mangoes visually spoil before any significant nutrient losses occur (Gil et al, 2006).

Robles-Sanchez et al (2007) concluded that low temperature and controlled or modified atmospheres can preserve quality and antioxidant capacity of fresh-cut mangoes for up to 10 days.

Gonzalez-Aguilar et al (2007) reported that exposure to ultraviolet C (UV-C) irradiation for 10 minutes appears to be a good technique to improve the total antioxidant capacity by increasing phenolic and flavonoid contents of fresh-cut 'Tommy Atkins' mangoes stored for 15 days at 5C. However, this treatment reduced vitamin C and carotenoids contents.

MICROBIAL SAFETY OF FRESH-CUT MANGOES

Generally, there is a positive correlation between longer shelf-life of fresh-cut fruits and low aerobic plate count, low total plate count, and especially low yeast and mold counts. Thus, it is very important to avoid sources of microbial contamination and to wash the fruits with disinfected water before cutting.

Thambaramala (1997) found that surface sterilization with 80% ethanol before peeling followed by storage in 1.5% O_2 and 11% CO_2 in sealed LDPE bags totally inhibited microbial spoilage of peeled mango pieces for 3 weeks at 5ºC.

Chantanawarangoon (2000) found that after 4 days at 5°C, both the total microbial and yeast and mold counts of mango cubes in the control increased rapidly. Up to day 10, there were no significant differences in total microbial and yeast and mold counts of mango cubes among all treatments except the control, which had higher microbial counts than other treatments. After 10 days at 5°C, the microbial counts of mango cubes treated with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine and stored in air increased more rapidly than those in treatments that were stored in CA. It is clear that treatment with 1% $CaCl_2$ + 1% ascorbic acid + 0.5% L-cysteine was effective in reducing microbial growth on fresh-cut mango cubes for up to 10 days in air and for up to 17 days in CA (2% O_2 + 10% CO_2) at 5°C. However, after 17 days at 5°C, microbial growth was observed only in the control mango cubes.

Narciso and Plotto (2005) pointed out that the method of whole fruit sanitation plays a role in determining the cleanliness of the cut fruit. Use of peroxyacetic acid (100ppm) to sanitize whole 'Keitt' mangoes followed by a 30-seconds dip of cut slices in peroxyacetic acid (50ppm) or acidified sodium hypochlorite (200ppm) effectively reduced microbial growth and kept microbial counts low on cut fruit surfaces for 21 days when compared to cut fruit slices from 200 ppm sodium hypochlorite-treated whole mangoes.

Plotto et al (2006) concluded that, due to inconsistent results, ethanol (5g/kg) vapor applied for 20 hours to whole ‘Kent’ mangoes prior to processing for fresh-cut is not a practical approach to delay ripening. However, at lower doses (10 hours) it could be a safe microbial control in a fresh-cut production sanitation system.

Ngarmsak (2007) found that treating fresh-cut mangoes with 80 mM vanillin solutions before packing and storage at 5C or 10C significantly delayed the growth of spoilage yeast and fungi in the fresh-cut mangoes. Although there was a noticeable faint vanilla odor immediately after processing, it was no longer evident after 7 days of storage.

Acidified sodium chlorite is a sanitizing agent recently approved by the FDA for dip or spray treatment of food items, including fresh and fresh-cut fruits and vegetables, and has shown a strong ability to control pathogens. He et al (2008) related the anti-browning action of sodium chlorite (3mM) to its inactivation of polyphenol oxidase directly and the oxidative degradation of phenolic substances. Thus, the potential effects of sodium chlorite on quality and safety of fresh-cut mangoes merit evaluation.

SUMMARY OF INTERVIEWS

Those who were interviewed included individuals from the following companies: Del Monte Fresh Produce, Dole Foods, Fresh Express – Chiquita, Garden Highway, G.O. Fresh, Ready Pac Foods, and Sun Rich Fresh Foods.

Variability in maturity and ripeness stage among mangoes within a lot is a major concern of fresh-cut processors. Most processors do not have the facilities to ripen fruits. Thus, they prefer to receive mangoes at the ready-to-cut (almost ready-to-eat) ripeness stage (flesh firmness of 3-6 lbf with an 8-mm probe and 12-14 % minimum soluble solids). Also, they prefer mango cultivars with less fiber content and good taste. Kent and Keitt cultivars were mentioned by nearly all the processors as the most preferred cultivars because of better availability of large sizes and consistency of good flavor when cut at the firm-ripe stage (flesh firmness of 3 to 6 pounds-force with an 8-mm probe) to facilitate processing and to reduce mechanical damage during processing. Some processors indicated that 'Ataulfo' is requested by some of their customers because of its superior flavor when at optimal ripeness stage (dark-yellow to orange flesh color). Lack of large sizes was mentioned as the reason 'Haden' mangoes were not used for fresh-cut processing. Higher fiber content and inconsistency of flavor when ripe were the reasons mentioned for not using 'Tommy Atkins' mangoes for fresh-cut processing unless it is the only cultivar available.

Several processors mentioned that transition periods in the mango supplies from one production area to another are particularly challenging for them. They are generally committed to providing a consistent supply to their customers and consumers, but sometimes they are unable to meet the demand during the transition periods because of lack of supplies, immaturity of the mangoes, and/or unavailability of the desired large fruit sizes.

Defects-free and large-size mangoes (8 or fewer mangoes per 4-kg box) are preferred because they give a higher yield of fresh-cut products (higher fresh-cut product weight relative the weight of the whole fruit) per labor hour. The processors indicated that fresh-cut mango yield can vary from 35 to 50%, depending on the seed size relative to fruit size and the amount of irregular cuts that are excluded to improve uniformity of the fresh-cut product in the package. Comparable yields are obtained by IQF processors of frozen mango products. In contrast, yields in-home or in a foodservice environment could be much higher. For example, a study conducted by Mattson on behalf of the NMB resulted in fresh-cut mango yields ranging from 60-70% in a foodservice setting. A high priority need is cost-effective machines for washing, peeling, flesh segmenting, washing segments, removal of surface moisture with forced cold air, and packaging. The goal is reducing labor costs and minimizing possible areas of microbial contamination to assure safety of the fresh-cut products.

Factors that influence consumer purchase of fresh-cut mango products include consistency of color and texture plus price in comparison with the price of whole mangoes at the time of purchase. Subsequent purchases depend on consumer satisfaction with the flavor (taste and aroma) of the fresh-cut mango products. Mangoes that are processed when less ripe have a longer shelf-life but lower consumer satisfaction.

Most processors indicated that it is possible to increase share of fresh-cut mango products from the current level of about 3% to a much higher percentage of the total fresh-cut fruit products if year-round availability of preferred cultivars, flavor quality, and ripeness stage that is optimal for processing become more consistent.

CONCLUSIONS

1. Demand for fresh-cut mango products via foodservice and retail channels can be stimulated if the consistency of quality, especially flavor, of these products is improved. Processors, foodservice operators, and retailers should collaborate on promoting fresh-cut mango products to consumers after they assure better consistency of flavor of the fresh-cut mango products.

2. Mango suppliers should work with processors to meet their needs in terms cultivars with less fiber, large fruit sizes, optimal ripeness stage for good flavor, and absence of defects that reduce yield (weight of fresh-cut product relative to fruit weight) per labor-hour.

3. Development of efficient mechanical systems for peeling, seed removal, and cutting mango flesh into desired segments will help reduce labor costs in processing fresh-cut mango products. The goal should be to attain an average yield of 50%.

4. If processors use firm-ripe mangoes (3 to 6 lbf flesh firmness with 8mm-tip), proper sanitation, and good temperature and humidity management, a shelf-life of 5-7 days is possible. If, in addition, they use antibrowning and antisoftening chemical dips and modified atmosphere packaging, post-cutting-life can be extended to 9 to 12 days.

5. The "Best if used by date" should be determined for each lot of mangoes when processed because the longer the duration between harvest and cutting the shorter the post-cutting life of mango products. Also, the more ripe and soft the mangoes are at processing, the shorter their post-cutting life will be.

6. Future research and development efforts should include the following:

6.1. Identifying the cultivar-specific optimal ripeness stage (based on firmness and soluble solids content) for whole mangoes to be used for fresh-cut products to provide good flavor to the consumer and adequate shelf-life.

6.2. Evaluating how the various procedures (chemical dips, modified atmospheres, ethylene action inhibitors, etc) influence flavor in addition to texture (softening) and appearance (browning) of fresh-cut mangoes. The goal is to identify the treatments that will preserve flavor in addition to texture and appearance.

6.3. Comparing the efficacy of water disinfection and fruit cleaning procedures in reducing microbial contamination to select the best method for cleaning mangoes before processing.

6.4. Evaluating the potential of irradiation (at 1 to 3 kGy) alone or in combination with other treatments on sensory quality and microbial load of fresh-cut mango products and whether any potential negative effects, such as increased rates of softening and browning can be minimized by combining irradiation with other technologies such as calcium dips, antibrowning chemical dips, and modified atmosphere packaging.

6.5. Developing new technologies for reducing labor costs by automation of as many of the processing steps as possible without significant losses in yield (weight of fresh-cut products relative to weight of the fruits) or quality of the fresh-cut mangoes.

6.6. Developing new value-added fresh mango products that appeal to various consumer groups.

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APPENDIX I: GENERAL REFERENCES ABOUT FRESH-CUT FRUITS

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APPENDIX II: PDF FILE OF PPT PRESENTATION (ATTACHED)

September 25, 2008

FRESH-CUT MANGOS AS A VALUE-ADDED PRODUCT (LITERATURE REVIEW AND INTERVIEWS)

Presented by: Adel Kader

September 25, 2008

FRESH-CUT MANGOS AS A VALUE-ADDED PRODUCT (LITERATURE REVIEW AND INTERVIEWS)

Presented by: Adel Kader

Quality of Fresh-cut Mangoes depends upon

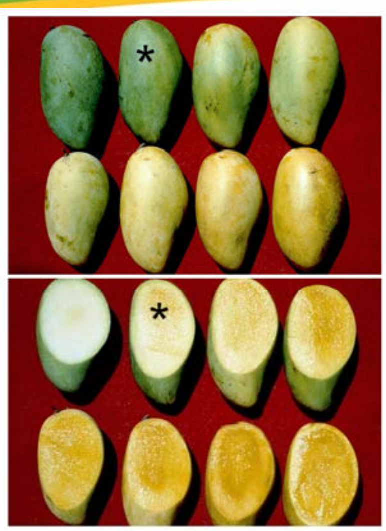
- ***Maturity and quality of the intact mangoes at harvest***
- ***Maintaining quality until preparation***
- ***Ripeness stage when cut***
- ***Method of preparation***
- ***Subsequent handling procedures***
- ***Time between harvest and consumption***

Mango Maturity Indices

- *Fruit shape (fullness of the shoulders)*
- *Skin color change from dark-green to light-green to yellow (depending on cultivar)*
- *Flesh color change from green to yellow to orange*
- *Increase in soluble solids and decrease in acidity*

Variability in maturity and ripeness stage among mangoes is a major concern of fresh-cut processors

Mango Maturity and Ripeness Stages



Manilla

Kent

* **Minimum maturity stage for harvest to assure good quality when ripe**

Ripening Conditions for Mangoes

Fruit temperature:	**20 to 22°C (68-72°F)**
Relative humidity:	**90-95%**
Ethylene concentration:	**100-150ppm**
Duration of exposure to ethylene:	**12-24 hours**
Carbon dioxide:	**<1%**

Time to ripen depends on maturity at harvest and storage temperature after ethylene treatment

Changes Associated with Mango Ripening that Improve Flavor

- ***Decrease in flesh firmness and increased juiciness***
- ***Starch conversion into sugars (increased sweetness)***
- ***Decrease in titratable acidity***
- ***Increase in soluble solids content (sugars, acids, pectins)***
- ***Increase in characteristic aroma volatiles***

Processors prefer to receive mangoes at the ready-to cut ripeness stage (flesh firmness of 2-4 lbf and 10-12% minimum soluble solids)

Laboratory-scale preparation of fresh-cut mango cubes

Ataulfo mangos

Peeled

Cut

Cubes

Average yield of fresh-cut product ranges from about 35 to 40%, depending on cultivar and fruit size

Visual Quality Scores for Mangos

9	7	5	3	1
		Limit of marketability	Limit of useability	

Temperature Effects after 13 days

Chilling injury symptoms

Best temperature range

Chemical Treatments for Delaying Softening and Browning of Fresh-cut Mangoes

- Chemicals on the FDA GRAS (generally recognized as safe) list, but considered food additives and must be labeled as such in the ingredient declaration
- A. Antisoftening chemicals:
- Calcium chloride, calcium lactate
- B. Antibrowning chemicals:
- Ascorbic acid
- Erythorbic acid (isomer of ascorbic acid)
- Cysteine
- C. Antisoftening and antibrowning chemical:
- Calcium ascorbate
- (similar to the Mantrose Hauser “Nature Seal” product)

Contribution of Modified Atmosphere Packaging (MAP) to Maintaining Quality of Fresh-cut Fruits

Providing optimal temperature range	MAP	
	Minimizing water loss	Retarding deterioration
0 – 70	70 – 85	85 – 100

Post-cutting Life (%)

Effect of Chemical Dips and Controlled Atmosphere (CA) after 10 days

CA = 2% oxygen + 10% carbon dioxide + 88% nitrogen

www.Mango.org

Effect of Chemical Dips and Controlled Atmosphere (CA) after 17 days

Effects of 1-MCP on Fresh-cut Mango Cubes

Application of 0.5 to 1 ppm 1-MCP (Smartfresh) for 6 hours directly on mango cubes delayed their softening and darkening during storage at 5ºC (41ºF) for 9 days. Combining 1-MCP with calcium treatment and/or MAP provide a synergistic effect

Commercial Preparation of **fresh-cut** mangos

Influence of Preparation Procedures on Quality of Fresh-cut Mangoes-1

1.Cleaning with chlorinated (100-150ppm) or otherwise disinfected water to remove contaminants and reduce microbial load

2.Cutting (wounding) increases rates of respiration, ethylene production, browning, water loss, and overall deterioration

Sharp blades → less injury
Greater wounding → faster deterioration

3.Washing the cut product removes tissue exudate, which can favor microbial growth

Influence of Preparation Procedures on Quality of Fresh-cut Mangoes-2

4.Uniformity (presence of off-size pieces and/or inedible tissues, such as skin or seed coat

5.Packaging to reduce water loss and tissue browning

Improper packaging → restricted gas diffusion → fermentative metabolism → off-odors

6.Sanitation procedures to minimize microbial contamination

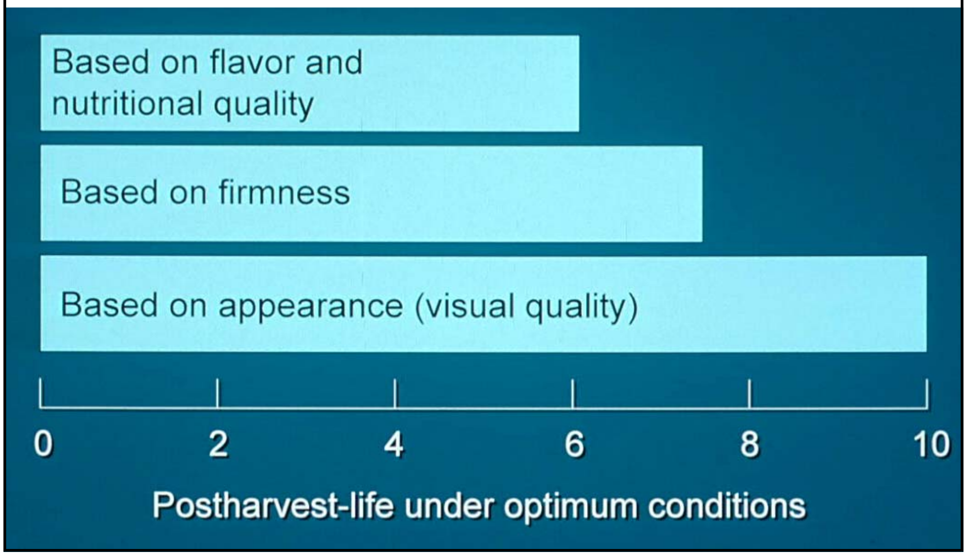
Post-preparation Factors affecting Quality of Fresh-cut Mangoes

1.Cooling to optimum temperature range of 2-5C (36-41F)

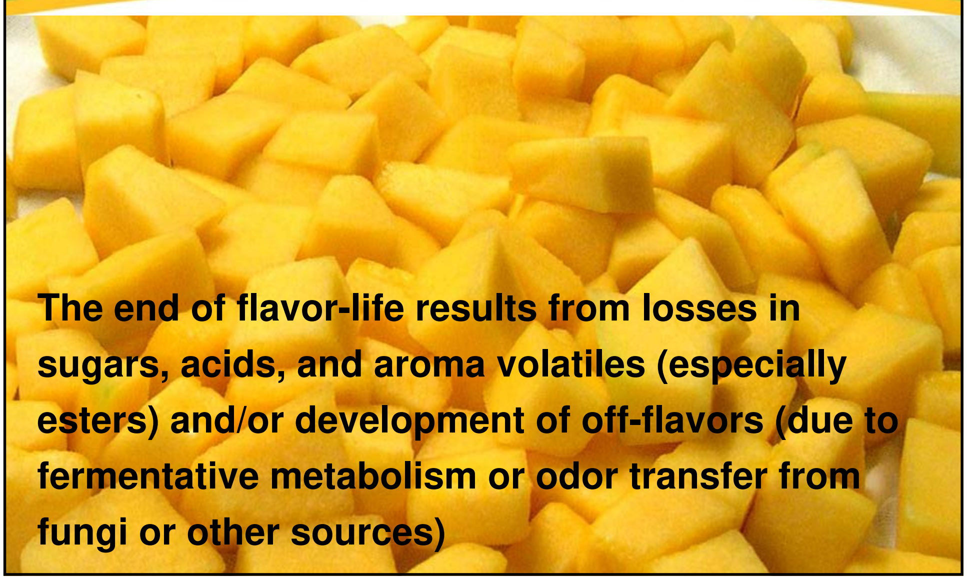
2. Maintaining optimum temperature and relative humidity (95-98%) during post-preparation handling all the way to the retail display cabinet

3. Expedited handling and marketing. Dating is highly desirable (prepartion date, sell by date, or best if used by date)

Flavor-life is shorter than Appearance-life of fresh-cut fruits



Do these fresh-cut mangoes taste as good as they look?



Classification of fresh-cut fruit products according to their potential post-cutting-life at optimum handling conditions (0-5ºC and 90-95% relative humidity)

Potential storage-life	Fresh-cut fruit products
10-14 days	Apple wedges, kiwifruit slices, mango cubes, pineapple slices and wedges, pomegranate arils
2-9 days	Banana slices, citrus segments, grape berries, melon cubes, nectarine and peach wedges, papaya cubes, pear wedges, persimmon slices, strawberry slices

Post-cutting life of fresh-cut fruit mixes is limited by the component with the shortest post-cutting life

Conclusions-1

- Demand for fresh-cut mango products via foodservice and retail channels can be stimulated if the consistency of quality, especially flavor, of these products is improved. Processors, foodservice operators, and retailers should collaborate on promoting fresh-cut mango products to consumers.
- Mango suppliers should work with processors to meet their needs in terms cultivars with less fiber, large fruit sizes, optimal ripeness stage for good flavor, and absence of defects that reduce yield (weight of fresh-cut product relative to fruit weight).

Conclusions-2

- Development of efficient mechanical systems for peeling, seed removal, and cutting mango flesh into desired segments will help reduce labor costs in processing fresh-cut mango products.
- If processors use firm-ripe mangoes (2-4 lbf flesh firmness with 8mm-tip), proper sanitation, and good temperature and humidity management, a shelf-life of 5-7 days is possible. If in addition, they use antibrowning and antisoftening chemical dips and modified atmosphere packaging, post-cutting-life can be extended to 9 to 12 days.

Conclusions-3

- The “Best if used by date” should be determined for each lot of mangoes when processed because the longer the duration between harvest and cutting the shorter the post-cutting life of mango products. Also, the more ripe and soft the mangoes are at processing, the shorter their post-cutting life will be.
- Research on how to extend flavor-life to match appearance-life of fresh-cut mangoes should be encouraged.