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EFFECT OF POLYSACCHARIDE COATINGS ON QUALITY OF FRESH CUT MANGOES (*MANGIFERA INDICA*)

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Abstract. **Mango, the "king of the fruits", has great potential as a fresh-cut product. However, preliminary tests showed that stored cut fruit becomes dry and looses flavor. Fruit coatings may decrease gas exchange, thereby retaining moisture and flavor. Ripe mango fruit (cv. Tommy Atkins), were washed, peeled and cut into 2 × 2 cm pieces. Pieces were dipped for 30 seconds in 5 ppm chlorine dioxide, 2% calcium ascorbate and 0.5% *N*-acetyl-L-cysteine (antioxidants), or coating solutions of 1% carboxymethylcellulose (CMC) or CMC and 0.5% maltodextrin (CMM). Two controls were used: no dip and chlorine dioxide dip only. Cut pieces were drained and stored on trays in Ziplock® sandwich bags at 5 or 10 °C. Coated fruit, and fruit treated with antioxidants stored at 5 °C maintained good visual quality after three weeks as compared to controls. L* value and hue angle were the highest for CMC-treated fruit stored 21 days at 5 °C. When stored at 10 °C, visual quality of the two controls was the lowest, but overall, none of the treatments were acceptable after 14 days. CMC-treated fruit tended to be firmer when stored at 5 °C after 11 days, but not at 10 °C. Taste panels did not detect any difference between treatments. In a second experiment, more coatings were investigated, including chitosan, potato starch, whey protein, and soybean oil emulsion. CMM coating was rated highest, and the two controls and whey protein were rated lowest for visual quality and flavor.**

"Eating healthier food", promoted by the public health officials, and the increasing demand for convenience foods, may explain the continuing rise of fresh-cut produce sales (Hodge, 2003). With the increasing market, there is an increasing demand for variety of fresh-cut produce. Currently, the most common fresh-cut fruit found on the market include pineapple, melon, watermelon, apple and grape (Cooperhouse, 2003). There is a great interest in fresh-cut mangoes, however, many technical issues prevent meeting this potential demand (A. Beaudoin, Del Monte Fresh, personal communication).

The procedure of cutting fruit induces wound responses from the tissue, increases metabolic activity and sensitivity to microbial spoilage, thus reduces shelf-life from weeks to days (Ahvenainen, 1996; Wong et al., 1994a). The typical response in mango is fruit softening and decrease in overall appearance by darkening of the fruit surface (the surface acquires a deeper orange) (Chantanawarangoon, 2000; González-Aguilar et al., 2000; Plotto et al., 2003; Purwadaria and Wuryani, 2000; Rattanapanone et al., 2001). Treatments with calcium salts, antioxidants, or the combination of both were effective at maintaining firmness and preventing browning (Chantanawarangoon, 2000; González-Aguilar et al., 2000; Trindade et al., 2003). Additionally, edible coatings can reduce gas exchange and water loss, creating a modified atmosphere around the fruit tissue, and thus can maintain firmness and flavor (Baldwin et al., 1995a, b; Wong et al., 1994a). Edible coatings with antibrowning agents effectively reduced browning and extended apple slices shelf-life (Lee et al., 2003), although some coating formulations decreased the level of aroma-active volatile compounds in apples (Bai and Baldwin, 2002). An edible coating reduced the respiration rate, and improved firmness and visual appearance on fresh-cut mangoes (Purwadaria and Wuryani, 2000).

The availability of ingredients for edible coatings and possible combinations are immense, however few formulations have been used on minimally processed fruits and vegetables. Polysaccharide or protein coatings are poor barrier to water loss, but have the advantage of limiting gas exchange (Baldwin, 1994), and they adhere well to the highly hydrophilic fresh-cut fruit surface. Fresh-cut apples coated with carrageenan (a polysaccharide) or with whey protein concentrate (a protein) and carboxymethylcellulose (CMC) had reduced respiration rate, but the best storage potential was observed when an antibrowning agent was added (Lee et al., 2003). Addition of peptides or a soy protein to the polysaccharide polymer CMC, at specified pH, decreased water and oxygen permeability and decreased water loss in cut apples, possibly by forming cross-links between the different components and changing the structure of the film matrix (Baldwin et al., 1996). Lipid coatings are usually most effective at reducing water loss (Baldwin, 1994), but they do not adhere well to wet cut fruit surfaces, and, as emulsions, they do not dry and are difficult to handle (Wong et al., 1994a). A soybean oil emulsion was the most effective coating at controlling water loss on fresh-cut apples, but ethylene production and respiration rates were increased (Bai and Baldwin, 2002). Composite coatings of alginic acid (a polysaccharide polymer), casein (a milk protein), and acetylated monoglyceride (acting as a plasticizer) reduced fresh cut apple weight loss (Wong et al., 1994a), and a bilayer coating of polysaccharides with acetylated monoglyceride decreased water loss, respiration and ethylene production of fresh cut apples (Wong et al., 1994b). Finally, chitosan, a polysaccharide derived from crustacean

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chitin, has an interesting potential because it additionally has antifungal properties (El Ghaouth et al., 1991, 1992; El Ghaouth and Wilson, 1997). Applications of chitosan coatings to fruit was reviewed by Baldwin (1994). More recent reports using chitosan coatings on fresh fruit include peeled litchi (Dong et al., 2004), peeled water chestnut (Pen and Jiang, 2003), whole longan (Jiang and Li, 2001), banana and mango (Kittur et al., 2001), strawberries and raspberries (Zhang and Quantick, 1998).

In this research, the effect of polysaccharide coatings with antioxidants was measured on fresh-cut mango storage. Additional coatings were applied and effects on visual and sensory quality evaluated.

Materials and Methods

Procedure. 'Tommy Atkins' mangoes imported from Ecuador, average size and firmness 560 g and 58-80 N (13-18 lb), respectively, and with red surface and yellow ground color development, were divided into three lots of 11 fruits representing each replication. A lot of green fruit was set aside to ripen at room temperature and was used in the second coating experiment. Before cutting, fruit firmness was measured with a FT-327 fruit pressure tester (Wilson, Yakima, Wash.) mounted on a drill stand and equipped with an 11 mm probe. Firmness measurements were taken on the two opposite narrow sides of the fruit, which would not be used as cut fruit. Whole fruits were sanitized for 2 min. in a solution of 2.7 mM (400 ppm) sodium hypochlorite adjusted to pH 6.5 with 2M citric acid, and air-dried. Mangoes were manually peeled, cut on each side of the seed, and each half cut into nine 1.5-2 cm^3 pieces which were randomly distributed between five 1.5 L colanders (one colander per treatment). Each colander was dipped for 30 sec in the following solutions: 1) 5 ppm chlorine dioxide (ClO_2) (sanitizer); 2) ClO_2 + 2% calcium ascorbate and 0.5% *N*-acetyl-L-cycteine (antibrowning agents) (CAS); 3) CAS + 1% carboxymethylcellulose (CMC); 4) CMC + 0.5% maltodextrin (CMM). The control included untreated cut pieces. Cut pieces were allowed to drain, and approx. 15 pieces were placed on polystyrene trays in 18 × 20 cm sandwich zipper bags (The Glad® Products Company, Oakland, Calif.). Cut mangoes were stored at 5 or 10 °C for 21 or 14 days, respectively.

A second experiment was performed to test for more coatings. The lot of green fruit was ripened to an average firmness of 22 N (5 lb). This time, cut pieces were dipped sequentially 20 sec in 5 ppm ClO_2, 20 sec in 2% calcium ascorbate (without acetyl cysteine), and 20 sec. in a coating. Pieces were stored at 5 °C.

Aqueous solutions and coatings preparation. The 5 ppm chlorine dioxide solution was prepared by mixing an equal amount of 2% chlorine dioxide and 5% phosphoric acid as recommended by the manufacturer (Aquamira®, McNett Corp., Bellingham, Wash.). Antioxidants were 2% (by weight) calcium ascorbate (Fluka, New-Ulm, Germany) and 0.5% acetyl cysteine (SIGMA, St. Louis, Mo.) in water. The carboxymethyl cellulose sodium salt (CMC), medium viscosity, was from SIGMA. The 1% CMC solution was prepared by adding CMC to the solution containing ClO_2 and both antioxidants in the first experiment, and in pure water in the second experiment. The second polysaccharide coating combined 1% CMC and 0.5% maltodextrin (Maltrin M040, Grain Processing Co., Muscadine, Iowa) mixed with ClO_2 and the antioxidant solution.

In the second experiment, the coatings used are listed in Table 1. Material sources were the following: carboxymethylcellulose and maltodextrin as above; peptone: WE 80M, enzymatically hydrolyzed whey protein concentrate, DMV International, Fraser, N.Y.; starch: "amylogum CLS" (potato starch), AVEBE America, Inc., Princeton, N.J.; whey protein isolate (WPI): ALACEN 895, NZMP, Santa Rosa, Calif.; chitosan: practical grade, from crab shell, Sigma, St. Louis, Mo.; soybean oil: The Hain Food Group, Inc., Uniondale, N.Y.; Polyoxyethylenesorbitan monostearate (Tween 60): Sigma, Saint Louis, Mo.; Sorbitan monostearate: Uniqema, Wilmington, Del.

Quality parameters. For the first experiment, cut fruit were evaluated 11 and 21 d, and 7 and 14 d for fruit stored at 5 and 10 °C, respectively. Each tray was visually rated for quality on a 1 to 5 scale (1 = unacceptable; 3 = sellable; 5 = excellent quality) just before proceeding to the analytical measurements.

Surface color of cut fruit was measured with a Minolta CR-300 Chroma Meter (Minolta, Tokyo, Japan) calibrated to a white plate using the CIE L*, a*, and b* system. Cut fruit firmness was determined using a XT2i texture analyzer (Stable Micro Systems, Surrey, England), calibrated with a 5-kg weight and equipped with a 1-cm diameter probe. The insert distance was 5.0 mm, with a stroke speed of 5.0 mm s^{-1}. For color and firmness, one measurement was taken on each mango cube.

After firmness and color measurements, pieces were homogenized with 1 ml water per g of fruit tissue for 75 s, and frozen. The supernatant of thawed homogenates, centrifuged at 12,100 × g_n for 15 min, was analyzed for titratable acidity (TA), pH, and soluble solids concentration (SSC). For titratable acidity, a 10-ml sample of the supernatant was titrated with 0.1 N NaOH to a pH 8.1 endpoint using an Orion 950 titrator (Thermo Electron Corporation, Beverly, Mass.). Soluble solids were determined with a digital ATAGO PR-101 refractometer (Atago Co, Ltd., Tokyo, Japan).

Volatile compounds of the homogenate headspace (3 mL homogenate in 10-mL glass vials) were analyzed with an Agilent 6890N GC (Agilent technologies, Wilmington, Del.) equipped with the Gerstel autosampler MPS2GC (Gerstel, Baltimore, Md.) and with a 0.53 mm × 30 m, 1.0 µm film thickness, polar Stabilwax column (Restek, Bellefonte, Pa.) and a FID detector (Malundo et al., 1997).

Table 1. Coatings used in the second experiment.

Code	Coating
CMC	1% carboxymethylcellulose (CMC)
CMM	1% CMC + 0.5% maltodextrin
CMP	1% CMC + 0.25% maltodextrin + 0.25% peptone
Starch	1.5% starch + 0.25% maltodextrin + 0.25% peptone
WPM	1.5% whey protein + 0.5% maltodextrin
Chitosan	0.5% chitosan in 0.5% glacial acetic acid
Soybean oil	soybean oil emulsion (4%): 2.66% soybean oil + 0.77% polyoxyethylenesorbitan monostearate + 0.56% sorbitan monostearate

Table 2. Visual quality of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

	Storage temperature					
	5 °C			10 °C		
	Days in storage			Days in storage		
	0	11	21	0	7	14
Control	5.00 A	5.00 A	2.33 b B	5.00 A	4.17 A	1.67 ab B
ClO_2	5.00 A	5.00 A	3.00 ab B	5.00 A	3.50 B	1.17 bc C
CAS	5.00 A	5.00 A	4.00 a B	5.00 A	4.30 AB	2.00 ab C
CMC	5.00 A	5.00 A	4.00 a B	5.00 A	4.30 AB	2.30 a C
CMM	5.00 A	5.00 A	4.00 a B	5.00 A	4.17 B	2.00 ab C

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

Sensory evaluation was performed with laboratory staff, consisting of 16 experienced panelists. Fruits were evaluated 7 and 11 d after storage at 10 and 5 °C, respectively. Taste panels took place at the research facility in individual booths equipped with a red light. Each treatment was served as three 2-cm^3 cubes of mangoes in a 118 mL (4-oz) plastic soufflé cup with a lid, coded with a 3-digit random number, and presented in a randomized order. On the first panel (day 7, 10 °C storage), panelists were asked to rate mango pieces for overall liking, firmness and flavor acceptability on a 9-point hedonic scale. On the second panel, (day 11, 5 °C storage), panelists were asked to rate mango pieces for overall liking on a 9-point hedonic scale, and rate firmness and flavor acceptability on a 5-point just-right scale. For each sample, panelists were asked if they could perceive any off-flavor.

For the second experiment, cut coated fruit were only evaluated by the two experimenters and two other staff members for visual, odor and overall flavor qualities.

Statistical analyses. Quality parameters were analyzed using the SAS (SAS System Software Version 8, SAS Institute, Cary, N.C.) general linear model procedure (PROC GLM) (SAS, 1999). Separation of means was performed with the Duncan's multiple range test (alpha = 0.05).

Results and Discussion

Experiment 1. Mangoes treated with antioxidants, with or without coating, maintained better visual quality after 21 and 14 d in storage, at 5 and 10 °C, respectively (Table 2). Generally, visual quality was better maintained at 5 °C than 10 °C, and fruit had an acceptable appearance up to 21 d in storage at 5 °C. Chantanawarangoon (2000) had earlier established that optimum storage temperature for fresh-cut mangoes was between 2 and 5 °C. L* value decreased in storage, except for the untreated control, and the antioxidant treatment, CAS (Table 3). L* decreased faster at 10 °C storage, indicating darker and less attractive fruit at this temperature. Hue angle decreased and a* increased in storage at 10 °C (Tables 4 and 5), except for the control and CMM treated fruits, indicating some browning had occurred (González-Aguilar et al., 2000). Cut pieces treated with CMC and stored at 5 °C for 21 d had higher L*, hue and lower a* values, indicating lighter and brighter fruit; however, the visual quality evaluation on that day also showed both coatings and the antioxidant treatments were superior (Table 2). Therefore the differences found by color measurements were not perceived visually. Calcium ascorbate and acetyl-L-cycteine were chosen as antioxidants because solutions of $CaCl_2$ + ascorbic acid + L-cysteine, and $CaCl_2$ + citric acid + L-cysteine were effective at increasing firmness and appearance, and therefore shelf-life, of Kent, Haden, and Keitt mangoes (Chantanawarangoon, 2000). Also, ascorbic acid was more effective at preventing cut apple browning when applied in a CMC/soy protein coating formulation in comparison to an aqueous solution (Baldwin et al., 1996). However, the present results on cut mangoes did not confirm former results on apples. Calcium ascorbate was chosen for both the firming capacity due to the calcium ion, and the antioxidant activity of the ascorbic acid. However, firm-

Table 3. Changes in L* values of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

		Storage temperature			
		5 °C		10 °C	
		Days in storage		Days in storage	
	Initial	11	21	7	14
Control	72.18	70.59	72.42 ab	71.55	72.00
ClO_2	71.06 A	70.13 AB	68.56 b AB	66.37 B	67.56 AB
CAS	71.66	67.64	69.64 b	68.80	67.17
CMC	70.20 B	68.20 B	75.76 a A	67.61 B	69.81 B
CMM	72.40 AB	68.44 AB	70.88 b AB	66.21 B	69.00 AB

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

Table 4. Changes in a* values of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

		Storage temperature			
		5 °C		10 °C	
		Days in storage		Days in storage	
	Initial	11	21	7	14
Control	-0.152	0.743	0.793 a	0.842	1.383
ClO_2	0.389 AB	0.386 AB	-0.247 a B	0.750 AB	1.623 A
CAS	-0.434 B	-0.303 AB	-0.073 a AB	0.176 AB	1.485 A
CMC	1.233 A	0.223 A	-2.084 b B	0.187 A	1.584 A
CMM	0.033	0.072	0.386 a	0.598	1.714

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

ness was not different between treatments (Table 6) except at 11 d of storage at 5 °C where the opposite was observed: mangoes treated with the calcium ascorbate + acetyl cycteine alone were softer, and mangoes treated with chlorine dioxide only were firmer (Table 6). Firmness decreased in storage, regardless of storage temperature. Titratable acidity also decreased in storage, except mangoes treated with chlorine dioxide only, which were low from the beginning of the experiment (Table 7). A steeper decrease in titratable acidity was observed for mangoes treated with calcium ascorbate and acetyl cysteine; however, these cut pieces had the highest acidity initially, and maintained acidity levels higher than the other treatments most of the time (Table 7). pH levels increased from 3.42-3.51 to 3.67-3.77 after 14 and 21 d in storage at 10 and 5 °C, respectively, with no differences between treatments (data not shown). There was no difference for total soluble solids, either between treatments or over time in storage. Total soluble solids ranged from 12.2 to 13.9. Total volatiles were higher for fruit stored 7 d at 10 °C than fruit stored 11 d at 5 °C (Fig. 1). Coated mangoes and mangoes treated with antioxidants had lower volatiles than the two controls initially, but there were no differences in mid-storage at either temperature (Fig. 1). It could be that initially, the coatings "absorb" the volatiles, instead of acting as a barrier to volatile escape, but the effect is diffused over time. At the end of the experiment, mangoes treated with ClO_2 and CMC had the most volatiles at 10 °C, but the only significant (alpha = 0.05) differences were between mangoes treated with antioxidants and coated with CMM, which produced more volatiles at 5 °C. Overall, there was a large variation in volatile production within treatments.

Taste panels indicated that untreated control fruit were preferred when stored 7 d at 10 °C (Table 8), but there was no preference for fruit stored 11 d at 5 °C (Table 9). For fruit stored at 10 °C for 7 d, untreated control had the most and CMM the least preferred flavor, respectively (Table 8). Firmness of untreated control was also the closest to just right (where 1 = too soft, 2 = just right, 3 = too firm) (Table 8). For the fruit stored at 5 °C for 11 d, flavor was slightly below the "just right" point (where 3 = just right on a 1 to 5 scale), and firmness was slightly "too firm", with CMM fruit the closest to "just right" (Table 9). Most of the panelists were regular consumers of mangoes, and liked their mangoes soft and juicy. Previous work suggested that mangoes should be cut at an optimum firmness of 13 to 27 N for acceptable eating quality and shelf-life (Chantanawarangoon, 2000; Rattanapanone et al., 2001). Mangoes in experiment 1 were cut at 58-80N, which would indicate hard fruit. However, commercial fresh cut mangoes were found that had high firmness. This indicates there is still much work to be done to optimize maturity stage at which cutting of mango should proceed, and standardize among commercial companies.

In summary, coatings applied to fresh-cut mangoes did not improve mango flavor or texture in this experiment. They did, in combination with antioxidants, improve appearance for the longest storage periods.

Table 5. Changes in hue angle of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

		Storage temperature			
		5 °C		10 °C	
		Days in storage		Days in storage	
	Initial	11	21	7	14
Control	90.20	89.35	89.33 b	89.05	88.69
ClO_2	89.75 AB	89.67 AB	90.25 b A	89.30 AB	88.32 B
CAS	90.53 A	90.33 A	90.13 b AB	89.90 AB	88.38 B
CMC	88.94 B	89.85 B	92.31 a A	89.91 B	88.56 B
CMM	90.06	89.97	89.72 b	89.45	88.20

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

Table 6. Changes in firmness of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

		Storage temperature			
		5 °C		10 °C	
		Days in storage		Days in storage	
	Initial	11	21	7	14
Control	49.63 A	29.42 ab B	34.08 B	30.05 B	27.37 B
ClO_2	46.94 A	39.88 a AB	30.41 BC	24.38 C	27.00 BC
CAS	51.47 A	24.99 b B	30.55 B	29.00 B	35.45 B
CMC	62.48 A	31.21 ab B	37.64 B	30.57 B	27.28 B
CMM	48.99 A	30.60 ab B	26.92 B	25.36 B	31.23 B

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

Experiment 2. Mangoes treated with whey protein, chlorine dioxide alone, and untreated control had the worst appearance and taste after 7 d at 5 °C. They looked dehydrated and the chlorine dioxide treated mangoes were very fibrous. Overall, all coatings improved the appearance of fresh cut mangoes, except for the combination of whey protein with maltodextrin, indicating that this coating formulation probably did not have any beneficial effect on water permeability. Protein-based coatings are known to be poor barrier to water (Baldwin et al., 1995a), and in this experiment, addition of maltodextrin did not improve the coating. Whey protein coated mango pieces had a "flat" taste, while chitosan had imparted a metallic off flavor to the fruit, and soybean oil treated mangoes tasted oxidized and, according to panelists, like paint. Chitosan is a potentially interesting component of fresh cut fruit coatings; however, some experimenters have reported off flavor (Lee, personal communication), while others have not (Dong et al., 2004), indicating the source, purity, and interaction with the fruit on which it is applied are factors to be considered. The polysaccharide coatings (except chitosan) were rated similarly. When peptone was added (CMP and starch formulations), the mango flavor became flat. Gas exchange was not measured in this experiment, but it would be worth investigating, since Baldwin and co-workers have shown that adding peptides to CMC decrease water and oxygen permeability (Baldwin et al., 1996). Oxygen and CO_2 permeability may give an indication of permeability to other gases, such as volatile compounds, and allow understanding of changes in fruit flavor. In this experiment, addition of peptone to starch or CMC seems to have increased permeability to gas, since the typical mango flavor was not present. CMC and calcium ascorbate alone were acceptable in terms of visu-

Table 7. Changes in titratable acidity of fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-L-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

		Storage temperature			
		5 °C		10 °C	
		Days in storage		Days in storage	
	Initial	11	21	7	14
Control	0.863 a A	0.687 AB	0.683 AB	0.630 B	0.597 B
ClO_2	0.693 b	0.647	0.597	0.640	0.607
CAS	0.847 a A	0.737 B	0.613 C	0.617 C	0.677 BC
CMC	0.730 ab A	0.643 AB	0.650 AB	0.727 A	0.567 B
CMM	0.737 ab A	0.743 A	0.595 B	0.620 AB	0.587 B

[z]Mean separation in a column (lower case) or in a row (capital letter) by Duncan's multiple range test, 5% level.

Table 8. Sensory ratings for fruit stored at 10 °C for 7 days. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-l-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

	Overall preference (1 to 9 hedonic)	Flavor preference (1 to 9 hedonic)	Firmness preference (1 to 9 hedonic)	Just-right firmness (1 to 3)
Control	5.93 a	5.87 a	5.33	2.27 b
ClO_2	4.73 b	4.87 ab	4.53	2.67 a
CAS	5.33 ab	5.60 ab	5.21	2.43 ab
CMC	4.80 b	5.00 ab	4.73	2.67 a
CMM	4.73 b	4.73 b	5.40	2.60 ab

[z]Means separation by the Fisher Protected LSD test (alpha = 0.1).

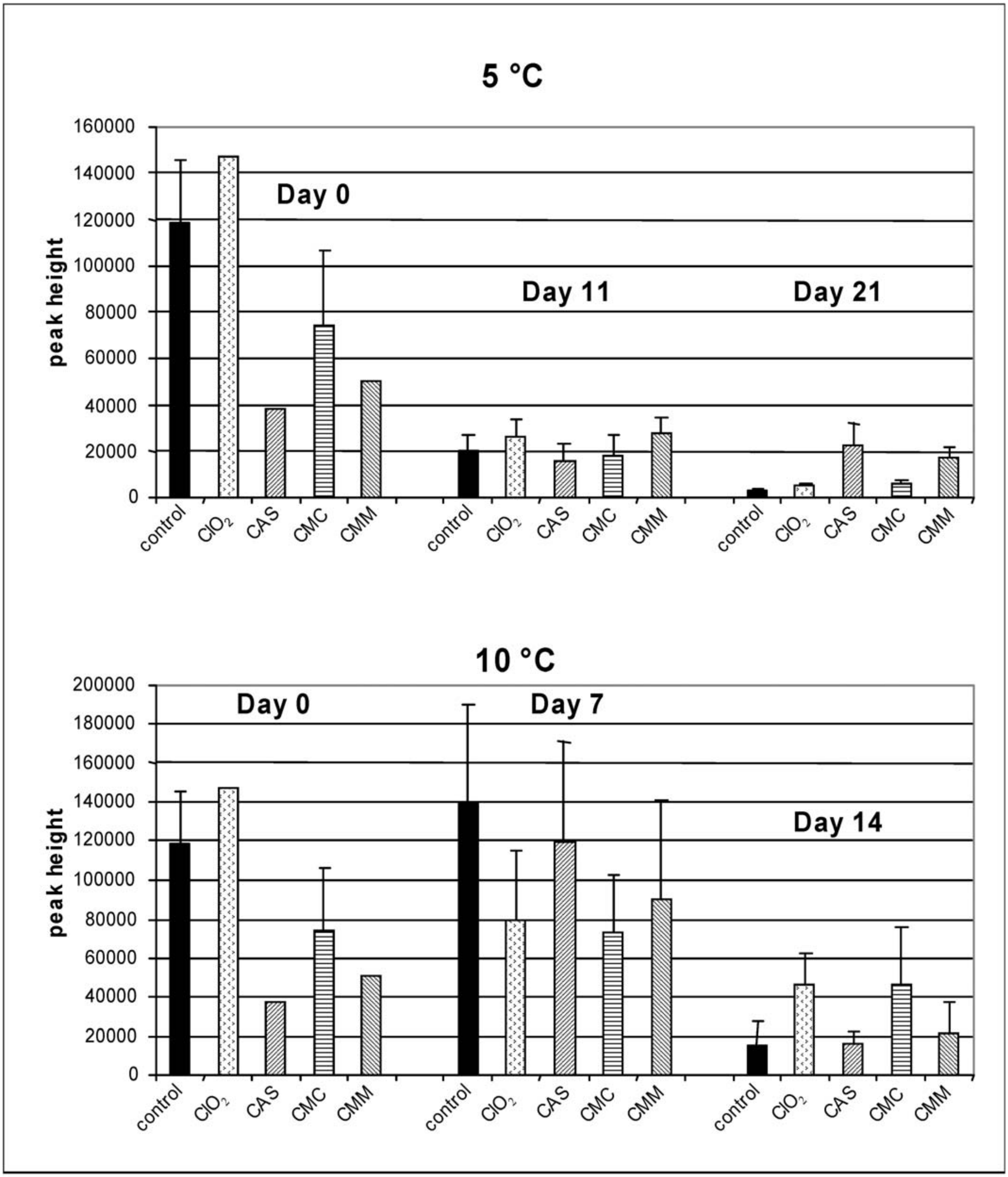

Fig. 1. Changes in volatiles produced by fresh cut mangoes treated with coatings and antioxidants and stored at 5 and 10 °C. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-l-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.

al appearance and taste, while CMM was rated best unanimously. The smaller maltodextrin molecules would act to emulsify the CMC long chain molecules, and possibly increase the gel-like properties of CMC. In this case, it is possible that the coating became thicker, and acted as a better protectant against water loss by having a higher water holding

Table 9. Sensory ratings for fruit stored at 5 °C for 11 days. ClO_2 = Chlorine dioxide, CAS = Calcium ascorbate + acetyl-l-cysteine, CMC = carboxymethylcellulose, CMM = carboxymethylcellulose + maltodextrin.[z]

	Overall preference (1 to 9 hedonic)	Flavor just right (1 to 5)	Firmness
Control	5.00	2.53	3.60 ab
ClO_2	4.87	2.60	3.33 ab
CAS	4.60	2.67	3.73 a
CMC	5.00	2.47	3.60 ab
CMM	5.47	2.53	3.13 b

[z]Means separation by the Fisher Protected LSD test (alpha = 0.1).

capacity; the coating layer acts as a "sacrifice layer", losing water first before the fruit (Baldwin et al., 1995a). It may also be more efficient in preventing loss of aroma compounds, therefore improving the flavor.

In conclusion, this work confirmed the necessity to treat fresh-cut mangoes with antioxidants to prevent color darkening in storage. Storage temperature at 5 °C maintained fruit storage up to 21 d but overall volatiles were decreased. Carboxymethylcellulose, alone or 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.

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