A Comparison of Sanitation Systems for Fresh-cut Mango

Jan Narciso[1] and Anne Plotto

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Summary. **A comparison of sanitizers for fresh-cut mango (*Mangifera indica* cv. Keitt) was made. Mangos were obtained from a farm in Homestead, Fla., and stored at 15 °C until processed. Before cutting, fruit were dipped in solutions of either sodium hypochlorite (NaOCl) (200 ppm) or peroxyacetic acid (100 ppm). The cut pieces were dipped in acidified sodium chlorite ($NaClO_2$) (200 ppm, pH 2.6) or dilute peroxyacetic acid (50 ppm) for 30 seconds. Resulting cut slices were placed in polystyrene clamshell food containers and stored at 5 °C for 21 days. Samples in the clamshells were tested for changes in microbial stability and for quality parameters every 7 days. Results showed that even though the fruit slices were sanitized after cutting, cut fruit microbial populations were related to the method of whole fruit sanitation. After 15–21 days in storage at 5 °C, cut slices from whole fruit sanitized with peroxyacetic acid that were subsequently treated with dilute peroxyacetic acid or acidified $NaClO_2$ had less contamination [<1 colony-forming unit (cfu) per gram] than samples cut from whole fruit sanitized with NaOCl (<1000 to 3700 cfu/g). These data demonstrate that the method of whole fruit sanitation plays a role in determining the cleanliness of the cut fruit. These sanitizer systems (peroxyacetic acid on whole fruit followed by peroxyacetic acid or acidified $NaClO_2$ on cut slices) effectively reduced microbial growth and kept microbial counts low on cut fruit surfaces for 21 days when compared to cut fruit slices from NaOCl-treated whole fruit.**

Demand for fresh fruit and vegetables has increased along with consumption of minimally processed foods (Brackett, 1992; DeRoever, 1998). The increase in volume and sales of these fresh products has necessitated changes in how fresh commodities are produced, transported, processed, stored, and marketed (Buck and Walcott, 2003; DeRoever, 1998). An important result of these changes is an increase in microbially related postharvest problems due to plant pathogens, and in some instances, human pathogens (Brackett and Splittstoesser, 2001; Buck and Walcott, 2003; DeRoever, 1998; Garg et al., 1990; Martinez et al., 2000). Factors leading to this increase in microbial contamination are numerous and include higher instances of contamination in the field, during transport, at packinghouses, in storage, at markets, and possible consumer abuse. In the field, contaminating factors include soil, irrigation waters, animals, insects, and handling by workers (Brackett and Splittstoesser, 2001; Buck and Walcott, 2003; DeRoever, 1998; Nguyen-the and Carlin, 1994; Stanley, 1999). Harvest maturity can also affect susceptibility of the fruit to decay (Hobbs, 1986; Waller, 2002). At the time of harvest, contamination can come from workers, contaminated bins and equipment, and transport vehicles. During packing and storage operations, wash water and temperature are important contributors to the contamination problem (DeRoever, 1998; Garg et al., 1990; Martinez et al., 2000).

Many plant pathogens are in contact with preharvest fruit and these organisms may remain latent and result in fruit decay during storage, transit, or at market (Brackett and Splittstoesser, 2001; Waller, 2002). These spoilage organisms can cause a change in pH (e.g., loss of acidity) as they degrade the fruit. These changes in pH allow secondary organisms to grow that might include human pathogens picked up from soil, animals, or human handling (Buck and Walcott, 2003; Conway et al., 2000; DeRoever, 1998; Waller, 2002).

In addition to whole fruit sales, fresh-cut fruit has become a significant component in the fresh produce industry. Fresh-cut fruit has become an important addition to fruit salads sold as a packaged fresh-cut product. As the market grows for fresh-cut fruit, contamination with harmful microorganisms has become problematic (Penteado et al., 2004; Sapers, 2001; Sivapalasingam et al., 2003). Organisms remaining on the surface of intact fruit can result in contamination of the fresh-cut product, and rapidly develop large populations on freshly cut tissue.

Sanitation of fresh-cut mango was studied. The goals of this study were to look quantitatively at microflora normally occurring on the fruit surface after harvest, and with the use of sanitizers, reduce this population both on the intact fruit and the cut fruit product to ensure their quality and safety.

Material and methods

Mango fruit (cv. Keitt) were harvested during Summer 2004 in Homestead, Fla., and brought back to the USDA Citrus and Subtropical Products Laboratory in Winter Haven, Fla. Fruit were divided into two groups based on fruit maturity following classification defined by Miller et al. (1986). Keitt 1, 82 fruit at the RS3 maturity stage: firm, well formed, with some yellow color development; and Keitt 2, 90 fruit at the RS1–RS2 maturity stage, fruit green, hard, well formed with slight blush. All fruit were held at 15 °C until testing. Keitt 2 was held in storage 8 d longer than Keitt

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
3.7854	gal	L	0.2642
2.5400	inch(es)	cm	0.3937
25.4000	inch(es)	mm	0.0394
6.4516	$inch^2$	cm^2	0.1550
0.4536	lb	kg	2.2046
28.3495	oz	g	0.0353
1	ppm	$\mu L \cdot L^{-1}$	1
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

USDA/ARS Citrus and Subtropical Products Laboratory, 600 Ave. S, NW, Winter Haven FL 33881.

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[1]Author for correspondence. Phone: 863-293-4133; fax: 863-299-8678; e-mail: jan@citrus.usda.gov

1 to bring fruit to RS3–RS4 maturity stages for processing (fruit fairly firm with yellow ground color development). Both groups, Keitt 1 and Keitt 2, received the same treatments but at different times.

WHOLE FRUIT MICROFLORA ASSESSMENT. Because organisms on the surfaces of intact fruit can result in contamination of the fresh-cut product, initial microbial populations of fruit surfaces were assessed. Twenty-four fruit from Keitt 1 (evaluated 48 h after harvest) and Keitt 2 (evaluated 10 d after harvest) were taken from storage and fruit surfaces were quantitatively assessed for microflora population. All fruit were measured (horizontally and vertically) with a digital caliper (Control Co., Friendswood, Texas) so that surface areas could be determined. By our measurements, mango shape most closely resembled a prolate spheroid. Surface area (SA) determination was estimated using measured parameters and standard formula for a prolate spheroid:

$$e = \sqrt{\frac{1 - r_e^2}{r_p^2}} \qquad SA = 2\pi r_e^2 + 2\pi \frac{r_p r_e}{e} \sin^{-1} e$$

where e = eccentricity; r_e = equatorial radius; and r_p = polar radius.

Microorganisms on the epidermis of the fruit were removed using a sterile Whirl-Pak Speci-sponge (Nasco Sampling Products, Modesto, Calif.) and 99 mL of sterile phosphate buffer (0.1% KH_2PO_4, pH 7.2). Sponges were hydrated with buffer, and using sterile gloves, the entire fruit surface was wiped with the moist sponge for 2 min. The sponge was placed into the bag with the remaining buffer and massaged for 1 min. Five-milliliter aliquots of the buffer were analyzed for microbial populations (method modified from Evancho et al., 2001).

PROCESSING. Before cutting, all ripened whole fruit were sanitized with 5 L of either sodium hypochlorite (NaOCl) at 200 ppm adjusted to pH 6.5 with a solution of 2 M citric acid, or peroxyacetic acid (PA) (100 ppm) (pH 3.2) (StorOx; BioSafe Systems, Glastonbury, Conn.). Temperature of all solutions was 25 ± 1 °C. Fruit were held in NaOCl or PA for 3 min. Four or five fruit, representing a treatment replication, were sanitized at one time with three replications. The sanitizing bath was changed every 12–15 fruit. After sanitation, whole fruit firmness was measured on two opposite sides of each fruit with an FT-327 fruit pressure tester (Wilson, Yakima, Wash.) mounted on a drill stand and equipped with an 11-mm probe. About 2 cm^2 of peel was removed prior to puncturing the fruit for firmness measurements. The firmness probe, which penetrates 5 mm into the flesh, was wiped with 70% ethanol between each measurement.

Before and during cutting, all fruit, both whole and cut, were handled with gloved hands. Fruit were peeled, halved on each side of the seed, and cut into three or four longitudinal slices with a sterile blade and placed in a sanitized colander. A sterile foil sheet was placed on the sanitized cutting board before cutting each fruit to avoid fruit-to-fruit cross-contamination. Colanders containing each treatment replication were dipped for approximately 30 s in the sanitizing solution. The two sanitizing solutions were a commercial acidified sodium chlorite ($aNaClO_2$) (final pH 2.6, 200 ppm) (Sanova, Alcide Corp., Redmond, Wash.), and a 50 ppm solution of PA, both prepared in 1500 mL at 15 ± 2 °C. These sanitizers were used on the cut fruit surfaces because they have been approved for food contact without a rinse step. Control samples were not dipped in any solution. After dipping, fruit slices were drained and not rinsed to avoid surface re-contamination. They were then randomly distributed in 970-mL non-vented polystyrene clamshell containers (Pactiv Corp., Lake Forest, Ill.), with approximately 8 to 10 slices per container. Prior to use, the interiors of random containers were swabbed with sterile cheesecloth moistened with sterile buffer. After swabbing, the cheesecloth was washed in buffer for 30 min. Buffer samples were placed on agar plates to test for the presence of any microorganisms. The plates showed no growth from these buffer samples from the clamshells. Clamshells were stored at 5 °C for 3 weeks.

SLICED FRUIT MICROFLORA ASSESSMENT. Three representative slices (total average weight = 45.8 g) from each experimental treatment were taken from the clamshells at 0, 7, 15, and 21 d after cutting, and placed in sterile Whirl-Pak bags. After weighing, 99 mL of sterile phosphate buffer was added to the bags and slices were gently agitated and massaged manually for 2 min to remove any microorganisms present on cut surfaces. Five-milliliter aliquots of buffer from each sample were analyzed for microbial populations.

MICROBIAL SAMPLE ANALYSIS. All buffer samples (for both whole and cut fruit) were analyzed using a Whitley Automatic Spiral Plater (DW Scientific, Shipley, U.K.). Each sample was plated onto three different types of media: potato dextrose agar (PDA), orange serum agar (OSA), and plate count agar (PCA) (All agars BD/Difco Brand, Sparks, Md.). The different media types were chosen to isolate a broad range of organisms (PCA for bacteria and OSA and PDA for yeasts and molds). Plates were incubated at 35 °C for 48 h, and results were read on a ProtoCOL colony counter (Synoptics, Cambridge, U.K.). The plates were then left for 2–3 d at room temperature (25 °C) and additional colonies added to the first assessment. Colony counts for replicate plates were averaged and combined with surface area or weight data to report cfu/cm^2 of fruit surface for whole fruit, and cfu/g for fruit slices.

QUALITY PARAMETERS. Cut fruit were evaluated weekly for surface color and firmness. Surface color of cut fruit was measured with a Minolta CR-300 Chroma Meter (Minolta, Tokyo) calibrated to a white plate using the CIE L*, a*, and b* system. Cut fruit firmness was determined using an XT2 texture analyzer (Stable Micro Systems, Surrey, U.K.), calibrated with a 5-kg weight and equipped with a 1-cm-diameter probe. The rectangular slices were probed on the flat side of the slice, one-third from the top and one-third from the bottom end. The insert distance was 5.0 mm, with a stroke speed of 5.0 mm·s^{-1}. Two measurements were taken per slice. At the end of the experiment, the experimenter rated visual quality using a 1–5 scale, where "5" is excellent, "3" acceptable (lower limit for shelf life), and "1" unacceptable.

STATISTICAL ANALYSIS. Microbial counts were analyzed with the non-parametric one-way analysis of variance (PROC NPAR1WAY) SAS procedure (SAS Institute, Cary, N.C.). The Wilcoxon two-sample test was used to compare whole fruit initial population data: Keitt 1 vs. Keitt 2. The Kruskal–Wallis test was used to test differences between sanitizers used on cut fruit. Quality parameters were analyzed using the SAS general linear model procedure (PROC GLM).

Separation of means between sanitation treatments was performed for each storage day using the least significant difference test with $P < 0.05$.

Results and discussion

Whole fruit before sanitation. Mango fruit samples were quantitatively assessed for the microflora populations naturally found on their surfaces. These populations were enumerated before any treatment and as a comparative number to measure the efficiency of the sanitizers (Fig. 1).

In our study, we found variability in microflora on mango surfaces from fruit of the same harvest between mangos stored 2 d (Keitt 1) and 10 d (Keitt 2) at 15 °C. Keitt 2 had significantly lower ($P < 0.05$) microbial populations on untreated mango surfaces when compared with Keitt 1 (Fig.1).

For the Keitt 1 group sampled 2 d after harvest, counts on fruit surfaces were 2500, 6400, and 5000 cfu/cm^2 on OSA, PCA, and PDA respectively (Fig. 1). For Keitt 2 (stored 10 d at 15 °C), surface organisms numbered 740, 1000, and 980 cfu/cm^2 on OSA, PCA, and PDA, respectively (Fig. 1). Differences in microflora populations between groups (Keitt 1 and Keitt 2), could have resulted in part because the second group of fruit (Keitt 2) was stored at 15 °C for 8 d longer than Keitt 1 (fruit surface microbial populations are dynamic and change with environmental changes that affect the fruit) , and also because of a difference in maturity.

Cut fruit after sanitation. Whole fruit mangos were sanitized in NaOCl (200 ppm acidified to 6.5 with 2 M citric acid) or peroxyacetic acid (PA) (100 ppm) for 3 min before cutting. Average of initial (field microflora) counts on Keitt 1 fruit (Fig. 1) was 4600 cfu/cm^2, reduced to approximately 300 cfu/cm^2 per fruit for PA-treated whole fruit and 930 cfu/cm^2 for NaOCl-treated whole fruit. For Keitt 2, average of initial microflora counts (Fig. 1) was 907 cfu/cm^2, reduced to approximately <10 cfu/cm^2 on PA-treated whole fruit and 102 cfu/cm^2 on NaOCl-treated whole fruit. The sanitized whole fruit were processed into slices, sanitized by experimental treatment, and stored in polystyrene clamshell containers at 5 °C. The microbial populations on these slices were assessed after 0, 7, 15, and 21 d in storage (Tables 1 and

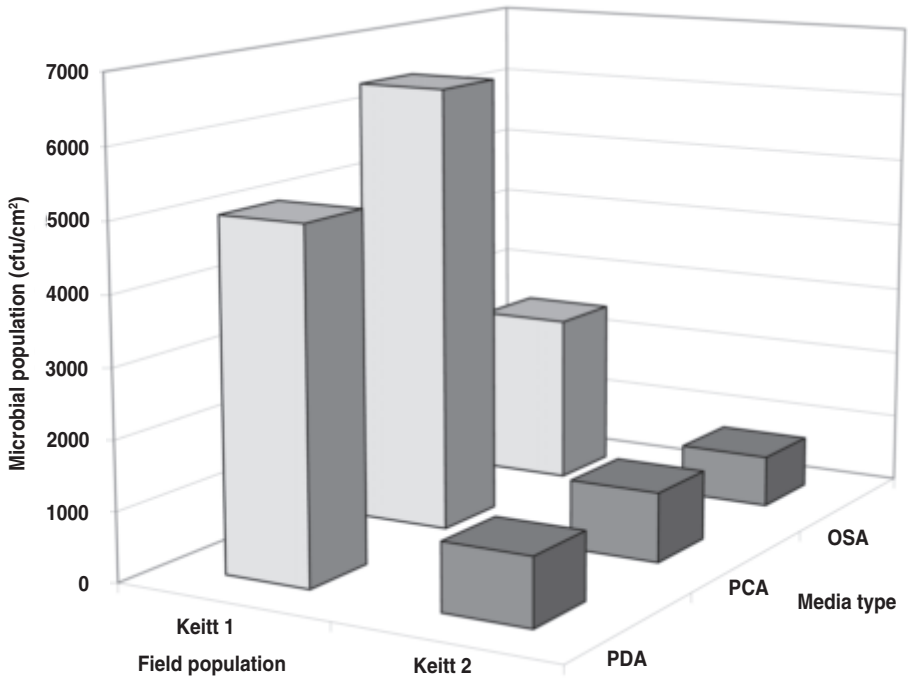

Fig. 1. Microbial populations on whole 'Keitt' mangos prior to any sanitation treatment: Keitt 1 = fruit stored for 2 d before processing, Keitt 2 = fruit stored for 10 d before processing. Both Keitt 1 and Keitt 2 were stored at 15 °C (59.0 °F). Media types used for isolation were: OSA = orange serum agar; PCA = plate count agar; PDA = potato dextrose agar. Microbial counts are presented in exponential format as colony-forming units per square centimeter of fruit surface area.

Table 1. Microbial populations counted as colony-forming units (cfu) per gram for fresh-cut slices of Keitt 1 [whole 'Keitt' mangos stored 2 d at 15 °C (59.0 °F) before processing] after 0, 7, 15, and 21 d in storage at 5 °C (41.0 °F). Whole fruit were treated with 200 ppm (μL·L^{-1}) sodium hypochlorite (NaOCl) and 100 ppm peroxyacetic acid (PA) prior to cutting. Cut slices were treated with 200 ppm acidified sodium chlorite (aNaClO$_2$) and 50 ppm PA.

Time in storage (d)	Cut fruit treatment	Whole fruit treatment: NaOCl	Whole fruit treatment: PA	Significance[y]
		Microbial counts on cut fruit surfaces after treatments (cfu/g)[z]		
0	Control	190	3780	NS
	aNaClO$_2$	3711	<1	*
	PA	4	1993	NS
	Significance[y]	*	NS	
7	Control	661	88	NS
	aNaClO$_2$	<1	297	NS
	PA	772	<1	**
	Significance	**	NS	
15	Control	1200	276	*
	aNaClO$_2$	<1	NS	
	PA	38	<1	NS
	Significance	***	NS	
21	Control	6703	<1	*
	aNaClO$_2$	3689	<1	**
	PA	<1	<1	NS
	Significance	**	NS	

[z]1 cfu/g = 28.35 cfu/oz.
[y]Significant differences per day between whole fruit treatments are indicated in italics horizontally, and within whole fruit treatment, vertically (N = 9); *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

2). Numbers shown are averages of replicate sample plates.

In general, microbial counts for slices from PA-sanitized Keitt 1 whole fruit were lower than for slices from NaOCl-sanitized whole fruit, especially after 21 d in storage (Table 1). Data for Keitt 1 show that for fruit slices from whole fruit sanitized with NaOCl, microbial counts of the control were higher than for slices sanitized with $aNaClO_2$ (days 7, 15, and 21) or with PA (days 0, 15, and 21). Untreated (control) slices from NaOCl-sanitized whole fruit tended to have increasing microbial counts in storage. In contrast, for Keitt 1-treated slices from whole fruit sanitized with PA, there were no significant differences in microbial counts between treated slices for days 0, 7, 15, or 21. The lack of significant differences in cut fruit treatments for Keitt 1 fruit pre-sanitized with PA is due to the low cfu/g. Therefore it is concluded that for Keitt 1, microbial populations on treated cut fruit slices were related to the method of whole fruit sanitation before cutting (Table 1).

More specifically, on day 0 and after 21 d in storage, slices treated with $aNaClO_2$ from NaOCl-sanitized whole fruit had microbial counts of 3700 cfu/g. But in contrast, on days 0 and 21, slices treated with $aNaClO_2$ from PA-sanitized whole fruit had negligible microbial growth (<1.0 cfu/g) for both days.

On day 7, 50 ppm PA-treated slices from NaOCl-sanitized whole fruit had microbial counts of 770 cfu/g, while 50 ppm PA-treated slices from PA-sanitized whole fruit was negligible (<1.0 cfu/g).

After 15 and 21 d in storage, slices from the control group (no treatment) had higher microbial counts when the whole fruit was sanitized with NaOCl (1200 and 6700 cfu/g, respectively) than when the whole fruit was sanitized with PA (280 and <1.0 cfu/g, respectively) (Table 1).

Mangos from the Keitt 2 group (whole fruit stored for 10 d) were processed using the same protocol as those mangos in Keitt 1. Data for Keitt 2 (Table 2) show that for fruit slices cut from whole fruit sanitized with NaOCl, results were different between treatments after 15 ($P < 0.05$) and 21 ($P < 0.001$) d in storage. For Keitt 2, treated sliced fruit from whole fruit sanitized with PA were different after 0 ($P < 0.05$), 15 ($P < 0.001$,) and 21 ($P < 0.05$) d in storage (Table 2).

Table 2. Microbial populations counted as colony-forming units (cfu) per gram for fresh-cut slices of Keitt 2 [whole 'Keitt' mangos stored 10 d at 15 °C (59.0 °F) before processing] after 0, 7, 15, and 21 d in storage at 5 °C (41.0 °F). Whole fruit were treated with 200 ppm (μL·L^{-1}) sodium hypochlorite (NaOCl) and 100 ppm peroxyacetic acid (PA) prior to cutting. Cut slices were treated with 200 ppm acidified sodium chlorite ($aNaClO_2$) and 50 ppm PA.

Time in storage (d)	Cut fruit treatment	Whole fruit treatment: NaOCl	Whole fruit treatment: PA	Significance[y]
		Microbial counts on cut fruit surfaces after treatments (cfu/g)[z]		
0	Control	987	1234	NS
	$aNaClO_2$	3	159	NS
	PA	577	<1	NS
	Significance[y]	NS	*	
7	Control	108	68	NS
	$aNaClO_2$	125	160	NS
	PA	184	<1	**
	Significance	NS	NS	
15	Control	1133	3609	NS
	$aNaClO_2$	1959	<1	NS
	PA	3602	<1	***
	Significance	*	***	
21	Control	692	206	*
	$aNaClO_2$	254	<1	**
	PA	1778	<1	**
	Significance	***	*	

[z]1 cfu/g = 28.35 cfu/oz.
[y]Significant differences per day between whole fruit treatments are indicated in italics horizontally, and within whole fruit treatment, vertically (N = 9); *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

As in Keitt 1, differences in cut fruit microbial counts were found to be related to the method of whole fruit sanitation, with slices from PA-sanitized whole fruit having generally fewer microbial counts, especially later in storage.

More specifically, after 7, 15, and 21 d in storage, slices treated with 50 ppm PA from NaOCl-sanitized whole fruit had microbial counts of 180, 3600, and 1800 cfu/g, respectively. On these same days, slices treated with 50 ppm PA from PA-sanitized whole fruit had microbial counts of <1.0 cfu/g on all days.

After 21 d in storage, slices treated with $aNaClO_2$ from NaOCl-sanitized whole fruit had microbial counts of 250 cfu/g. On the same day, cut fruit treated with $aNaClO_2$ from PA-sanitized whole fruit had negligible microbial counts (<1.0 cfu/g).

Also on day 21, control (untreated) slices cut from NaOCl-sanitized whole fruit had microbial counts of 690 cfu/g, while cut fruit control from PA-sanitized whole fruit were 200 cfu/g (Table 2).

The whole and cut fruit data from Keitt 1 and Keitt 2 show that the efficiency and consistency of PA as a sanitizer surpasses that of NaOCl (Tables 1 and 2). Overall, pre-sanitization of whole fruit with PA followed by treatment of cut fruit slices with either $aNaClO_2$ or 50 ppm PA resulted in low cfu/g in the fruit slices.

It has been shown that total plate counts (TPC) give an estimate of microbial growth on cut fruit surfaces (Beaulieu and Gorny, 2004). Low TPC correlate with a longer shelf life and could be used as an indicator of the quality of fresh-cuts (Beaulieu and Gorny, 2004; Hobbs, 1986; Zhuang et al., 2003). However, low numbers of organisms do not indicate an absence of pathogenic microorganisms (Brackett and Splittstoesser, 2001). It is also possible to have high numbers of spoilage organisms present and have no symptoms of decay (Brackett and Splittstoesser, 2001).

Quality parameters. Fresh-cut slices were assessed for firmness and surface color to evaluate any adverse effects of the sanitizers. Mangos in the first experiment (Keitt 1), being more mature at harvest, ripened non-

uniformly. Thus firmness was variable, but generally declined during storage (Fig. 2A). The differences observed between sanitation treatments were not consistent over time in storage. Mangos in the second experiment (Keitt 2), being less mature at harvest and allowed to ripen before cutting, exhibited more uniform ripening, and also softened during storage (Fig. 2B). Control slices from fruit sanitized with NaOCl were firmer 15 d in storage, but did not remain firmer after 21 d. Overall, none of the sanitation treatments affected cut mango firmness.

For fresh-cut mangos, a lower L* and hue, and higher a* values indicate browning and flesh color that turns from light yellow to orange (Chantanawarangoon, 2000; Gonzalez-Aguilar et al., 2000). In the first experiment, (Keitt 1), slices from whole fruit sanitized with PA had lower ($P < 0.05$) L* and hue and higher a* at day 0 and 7 (only hue shown, Fig. 3A), regardless of which treatment was subsequently used on the cut fruit. There were no differences between treatments after 15 d, and at 21 d, PA-sanitized slices from NaOCl-sanitized whole fruit and $aNaClO_2$-sanitized slices from whole fruit sanitized with PA had higher hue. This would indicate that these slices remained light yellow; however, visual quality did not show differences between treatments due to the different degrees of ripeness between slices.

In the second experiment (Keitt 2), hue was higher for PA and $aNaClO_2$-treated slices from PA-sanitized whole fruit, except for 7 d in storage (Fig. 3B). After 21 d in storage, PA-sanitized whole fruit followed by a sanitation treatment (PA or $aNaClO_2$) on cut fruit had higher hue (Fig. 3B) and lower a* values, indicating these treatments maintained mangos' light color. Untreated (control) slices, regardless of whole fruit sanitation, had the lowest hue (Fig. 3B) and highest a*, possibly indicating surface deterioration from higher microbial growth. Visual quality was higher for $aNaClO_2$-treated slices at the end of the second experiment (Keitt 2), regardless of whole fruit sanitation (data not shown).

Results in this study support findings of low colony counts, correlating with a longer shelf life for cut fruit. Factors other than microbial contamination that affect the longevity of cut fruit include fruit maturity, processing treatment, storage temperature, firmness, and cultivar (DeRoever, 1998; Hobbs, 1986).

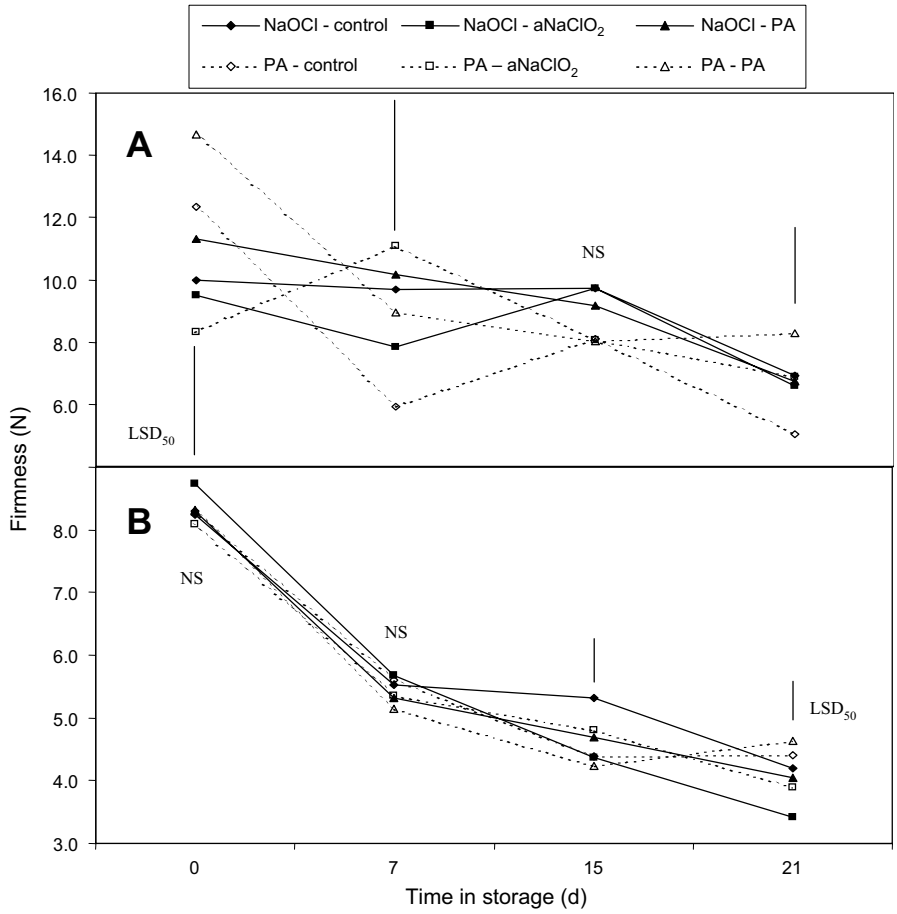

Fig. 2. Firmness of fresh-cut slices obtained from 'Keitt' mangos processed from whole fruit sanitized with either sodium hypochlorite (NaOCl) at 200 ppm ($\mu L \cdot L^{-1}$) or peroxyacetic acid (PA) at 100 ppm. Slices were then treated with a commercially acidified solution of sodium chlorite ($aNaClO_2$) at 200 ppm, PA at 50 ppm, or unsanitized (control), and stored 21 d at 5 °C (41.0 °F). (A) Keitt 1 (mangos stored for 2 d before processing). (B) Keitt 2 (mangos stored for 10 d before processing). Each point is the mean of 25 to 40 measurements. Vertical bars indicate least significant difference (LSD) values ($P < 0.05$) for treatment comparison at a given day in storage.

The variables involved in sanitizing fresh fruit and vegetables are numerous. The character of the fruit in conjunction with events during preharvest and harvest periods, harvest maturity, handling, grading, packing, transport, and market storage, to just mention a few, all determine the microbial safety of the product (Brackett and Splittstoesser, 2001; DeRoever, 1998 ; Nguyen-the and Carlin, 1994; Waller, 2002). In addition, there are many factors that influence efficiency of sanitizers, including type of commodity, concentration of the sanitizer, and contact time (Zhang and Farber, 1996; Zhuang et al., 2003).

Because fresh produce has no thermal or "lethal" treatment, it is essential that the product is properly sanitized. The inconsistency in results between sanitizers, commodities, and the immediate environmental parameters that influence them make it obvious that no one sanitizer will be equally effective for all fruit and vegetables under all conditions. A system of cleaning and disinfecting a specific commodity is necessary to ensure the safety of the product (Brackett, 1987, 1992; DeRoever, 1998; Stanley, 1999; Zhang and Farber, 1996; Zhuang et al., 2003). Our studies show that a system of sanitation for whole and cut fruit mangos that includes 100 ppm peroxyacetic acid (PA) whole fruit dip and a 50 ppm PA or an acidified sodium chlorite ($aNaClO_2$) (200 ppm) dip for

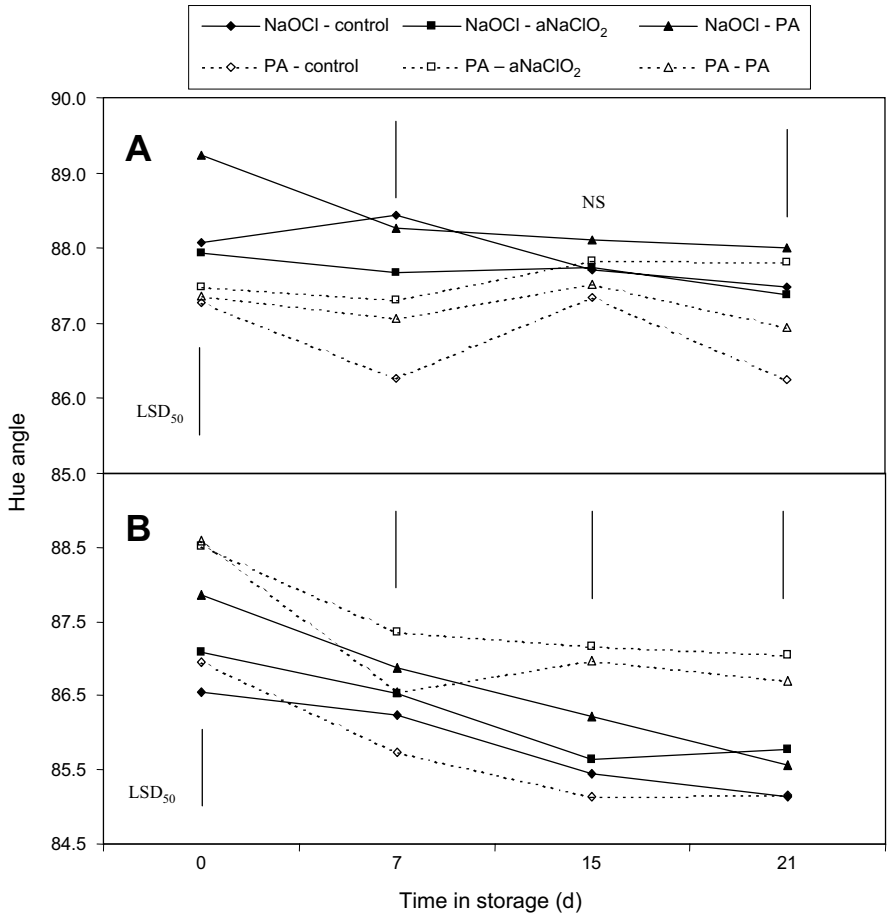

Fig. 3. Data are surface color (hue) of fresh-cut slices obtained from 'Keitt' mangos processed from whole fruit sanitized with either sodium hypochlorite (NaOCl) at 200 ppm ($\mu L \cdot L^{-1}$) or peroxyacetic acid (PA) at 100 ppm. Slices were then treated with a commercially acidified solution of sodium chlorite ($aNaClO_2$) at 200 ppm, PA at 50 ppm, or unsanitized (Control), and stored 21 d at 5 °C (41.0 °F). (A) Keitt 1 (mangos stored for 2 d before processing). (B) Keitt 2 (mangos stored for 10 d before processing). Each point is the mean of 30 measurements. Vertical bars indicate least significant difference (LSD) values ($P < 0.05$) for treatment comparison at a given day in storage.

cut surfaces reduces surface microbial population.

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