Combined Effect of Calcium Chloride and Peroxyacetic Acid on Quality and Shelf Life of Minimally Processed Longan Fruit

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ABSTRACT

Efficacies of calcium chloride solution (CaCl2, 0.25-1.0%), a texture-improving agent, and peroxyacetic acid (PAA) solution, a microbial population reducing sanitizer, on the peel and aril of two whole longan fruit cultivars, "Daw" and "Beawkeaw," were investigated. A solution of 0.5% $CaCl_2$ increased aril firmness by 29.4 and 18.2% for cv. Daw and Beawkeaw, respectively, and did not cause any undesirable bitter taste. A dip of whole longan or peeled aril in 100 or 50 mg/L PAA solution for 3 min, respectively, efficiently reduced microbial load (total bacteria, yeast and mold) in comparison to unwashed controls. Longan aril were processed and stored in clear clamshell containers at 4±1°C for 8 days. The aril firmness, L* value and TA content decreased but weight loss, pH level, reducing sugar, total bacteria and yeast-mold count increased while the TSS and total sugar content only slightly changed throughout the storage period. The immersion of longan aril in PAA and CaCl2 solutions resulted in the decrease in pH, TSS, total sugar and reducing sugar contents while firmness, weight loss and L* value increased. The treatment had no effect on TA content but could delay microbial growth when compared with the control. The shelf lives of longan aril at 4±1°C of the control and the treatments were 3 and 5 days for cv. Daw and 3 and 4 days for cv. Beawkeaw, respectively.

Keywords: Minimally processed longan fruit, Peroxyacetic acid, Calcium chloride

INTRODUCTION

Longan *(Dimocarpus longan Lour.*) is grown commercially in Thailand with increasing acreage because it can be produced, both during the traditional season and the off-season with use of chemicals. The major factors reducing the storage

life and marketability of longan fruit are microbial decay and pericarp browning. Longan fruit has a very short shelf life, deteriorating easily and quickly within 3-4 days at ambient temperatures (Jiang et al., 2002; Drinnan, 2004). Longan fruit can be canned, frozen or dried, but no research has been conducted on minimally processed longan fruit products, whereby the peel and seed are removed prior to sale. The demand for minimally processed fruit in the market has been increasing because it is like-fresh, healthy, convenient, highly nutritious, flavorful and can still be eaten like whole fruit (Rico et al., 2007). Several studies have been conducted to determine the efficacy of sanitizers in order to delay the spoilage in minimally processed fruit. Peroxyacetic acid is attractive because it decomposes to non-toxic acetic acid. Research on the efficacy of peroxyacetic acid for sanitizing fruit and vegetables has been reported for carrot (Ruiz-Cruz et al., 2007), potato (Beltran et al., 2005), lettuce (Martinez-Sanchez et al., 2006) and mango (Narciso and Plotto, 2005). However, there has been no reported research on the efficacy of peroxyacetic acid for sanitizing longan fruit and its aril.

Calcium chloride is commonly used industrially as a firming agent for fresh-cut fruit. Calcium ions help maintain cell structure by increasing the cross linkages among pectin polymers, mainly in the middle lamella (Durigan et al., 2005). Calcium chloride applications have been shown to increase the shelf life of many fresh-cut fruit such as cantaloupe (Luna-Guzman and Barrett, 2000), peach (Manganaris et al., 2007) and strawberries (Aguayo et al., 2006).

The objective of this study was to determine the efficacy of peroxyacetic acid in reducing microorganisms and calcium chloride in maintaining the firmness for minimally processed longan fruit.

MATERIALS AND METHODS

Plant material

Longan (*Dimocarpus longan Lour.*) fruit cv. Daw and Beawkeaw, at the commercially mature stage (18-20% total soluble solids, TSS), were harvested from local growers in Lampoon Province, Thailand in July 2009 and transported by car to the laboratory at the Postharvest Technology Research Institute, Chiang Mai University. Fruit were then kept at 4±1°C overnight and selected for uniformity of size (Ø 3 cm, weight 10-13 g), shape and lack of physical damage and injury caused by insects prior to use in the experiments.

Experiment 1. Effects of different calcium chloride ($CaCl_2$) concentrations and contact times on the firmness of longan aril

The experiment was designed as a completely randomized design (CRD) with three replications. Five fruits per replication were deseeded and peeled. Then, the aril were dipped in CaCl2 (Calcium chloride; OV Chemical and Supply Ltd., Thailand) at four levels of concentration (0.25, 0.50, 0.75 or 1.00%) and three levels of contact time (1, 3 or 5 min). After draining, fruits were evaluated for firmness (N) using a Texture analyzer (TA-XTi/50, Stable Micro Systems, Ltd., Godalming, UK). Treatments were compared with the un-dipped control and the

experiment was repeated three times using longan fruit from different sources.

Experiment 2. Effects of different peroxyacetic acid (PAA) concentrations and contact times on the reduction of total bacteria and yeast-mold populations from whole longan fruit

The experiment was designed as CRD with three replications. Five fruits per replication were dipped in PAA (5% Peroxyacetic acid; Thaiperoxide Co., Ltd., Thailand) at three levels of concentration (75, 100 or 150 mg/L) and three levels of contact time (1, 3 or 5 min). After draining, fruits were evaluated for total bacteria (Bacteriological Analytical Manual, 2001) and yeast-molds (AOAC, 2000). Treatments were compared with the un-dipped control and the experiment was repeated three times using longan fruit from different sources.

Experiment 3. Effects of different peroxyacetic acid (PAA) concentrations and contact times on the reduction of total bacteria and yeast-mold populations from longan aril

The experiment was designed as CRD with three replications. Five fruits per replication were washed with the best treatment of PAA for whole fruit (based on the results from Experiment 2). The seeds were removed prior to the step of peeling. Then, the aril were dipped in the best treatment of $CaCl_2$ (based on the results from Experiment 1). After draining, the aril were dipped in PAA at three concentration levels (50, 65 or 80 mg/L) and three levels of contact time (1, 3 or 5 min). After draining, fruits were evaluated for total bacteria (Bacteriological Analytical Manual, 2001) and yeast-molds (AOAC, 2000). Treatments were compared with the un-dipped control and the experiment was repeated three times, using longan fruit from different sources.

Experiment 4. Quality of minimally processed longan fruit

Minimally processed longan fruit were prepared in three different treatments and tested for quality:

- Whole fruits were deseeded and peeled.
- Whole fruits were dipped in the best treatment of PAA obtained from Experiment 2 and drained for 1 min prior to the step of deseeding and peeling. Then, the longan aril were dipped in the best treatment of PAA obtained from Experiment 3 and drained for 1 min.
- Whole fruits were dipped in the best treatment of PAA obtained from Experiment 2 and drained for 1 min prior to the step of deseeding and peeling. The longan aril were dipped in $CaCl_2$ obtained from Experiment 1 and drained for 1 min. Then, the longan aril were dipped in the best treatment of PAA obtained from Experiment 3 and drained for 1 min.

The longan aril of the above three treatments were packaged in a polystyrene clear clamshell of 13 x 14 x 8 cm, 20 aril per clamshell, and then stored at 4±1°C and 90-95% RH for 8 days. The samples were examined for physicochemical and microbial changes after initial treatment on day 1 and then again on day 2, 4, 6, 8. Sensory evaluation was performed each day by 15 untrained panelists.

Microbiological quality evaluation

For whole longan, five fruits were transferred to a sterile bag containing 50 ml of 0.1% phosphate buffer pH 7.2. The five fruits and phosphate buffer in bags were then firmly hand-rubbed for 2 min. For longan aril, the pulp was cut into 10 g pieces with sterile stainless steel scissors. The samples were transferred to a sterile bag containing 90 ml of 0.1% phosphate buffer pH 7.2 and samples were macerated by stomacher for 30 sec.

Samples were serially diluted by a factor of ten in 0.1% phosphate buffer. The undiluted mixture and serially-diluted mixture (0.1 ml in duplicate) were spread on plate count agar (PCA) and potato dextrose agar (PDA) for total bacteria and yeast-mold count, respectively. Then, PCA and PDA were incubated at 35°C for 48 hr and 25°C for 48 hr, respectively. For whole longan and aril, values are reported as log cfu/fruit and log cfu/g, respectively.

Texture, color and weight loss measurement

Firmness was determined with a Texture Analyzer (TA-XTi/50, Stable Micro Systems, Ltd., Godalming, UK) by measuring the penetration force required for a 2-mm cylindrical probe. Values are reported as Newton (N). Color on opposite sides of each sample was measured with a Colorimeter (ColorQuestXE, Hunter Laboratory Inc., Virginia, USA) and reported as L* value. Weight loss was calculated based on a comparison of sample weights on the initial day compared to various storage days, and then expressed as a percentage.

Chemical quality evaluation

Samples (aril) were homogenized and the pH was measured using a pH meter (Model C831, Consort, Turnhout, Belgium). Titrable acidity (TA) was determined by titrating 10 g of homogenized aril after mixing with 40 ml of distilled water to pH 8.1, using 0.1 M NaOH and the result was expressed as percentage of citric acid per 100 gram aril. Total soluble solids were measured by Digital Refractometer (Model PR-101, Atago, Japan, 0-45%) and reported as a percentage. Total sugar and reducing sugar contents were analyzed by reacting with 3,5-dinitrosalicylic acid and measured at wavelength 540 nm on a UV-Visible spectrophotometer (Specord 40, Analytik jena, Germany), compared with the glucose standard curve and reported as a percentage (Miller, 1959).

Sensory quality evaluation

Aril samples were placed in plastic cups labeled with three-digit random number codes. The sensory evaluations, in terms of color, appearance, flavor, texture and overall visual appearance were conducted by 15 untrained panelists (male and female, ages 21-25), using a 5-point hedonic scale. The scores were: like very much = 5; like moderately = 4; neither like nor dislike = 3, (limit of unacceptability); dislike moderately = 2; and dislike very much = 1.

Statistical analysis

There were three replications per treatment with each replication repeated

three times. All data represent the mean of nine readings. Duncanís multiple range test was used for comparing means to determine the differences between treatments. Differences are reported as significant to 95% and were performed on the data using SPSS.

RESULTS AND DISCUSSION

Effectiveness of calcium chloride on two cultivars of longan aril

Treatments of longan aril in (0.25-1.00%) $CaCl_2$ solutions resulted in a significant increase in firmness when compared with the control (Table 1). Immersion of the longan aril in 1.00% $CaCl_2$ solution for 5 min increased the firmness by 39.1 and 32.3% for cv. Daw and Beawkeaw, respectively, when compared to the un-dipped control. The aril of cv. Beawkeaw is thicker than that of cv. Daw, which explains the higher firmness of cv. Beawkeaw. Higher concentrations of $CaCl_2$ were more effective than lower concentrations in improving the firmness. However, 0.75 and 1.00% $CaCl_2$ solutions resulted in an undesirable bitter taste. In addition, dipping for 5 min was more effective than 1 and 3 min in improving the firmness. Therefore, 0.50% $CaCl_2$ solution for 5 min was selected as the most optimal. Dipping longan aril in 0.50% $CaCl_2$ solution for 5 min increased firmness by 29.4 and 18.2% for cv. Daw and Beawkeaw, respectively.

Table 1. Firmness of longan aril treated with $CaCl_2$ at different concentrations and contact times.

Contact time (min)	Concentrations (%)	Firmness (N)	
		Cultivars	
		Daw	Beawkeaw
control	0	2.56±0.50e	3.04±0.41e
1	0.25	2.92±0.40d	3.13±0.45de
	0.50	3.22±0.43bc	3.33±0.40cd
	0.75	3.34±0.62abc	3.50±0.38bc
	1.00	3.51±0.54ab	0.65±0.52b
3	0.25	2.86±0.50d	3.09±0.39de
	0.50	3.13±0.50cd	3.51±0.53bc
	0.75	3.28±0.52abc	3.52±0.42bc
	1.00	3.49±0.57ab	3.64±0.63b
5	0.25	2.94±0.50d	3.17±0.33de
	0.50	3.31±0.49abc	3.59±0.50b
	0.75	3.44±0.42ab	3.62±0.43b
	1.00	3.56±0.56a	4.02±0.42a

Notes: Values are means ± SD of nine readings.
Values in each column with distinct letters represent the significantly different results ($p \leq 0.05$).

The effect of calcium ion on tissue firmness is generally explained by its complex formation to cell wall and middle lamella polygalacturonic acid residues, imparting improvement of structural integrity. The de-esterified pectin chains may crosslink with either the endogenous calcium ion or added calcium ion to form a tighter and firmer structure (Grant et al., 1973).

Luna-Guzman et al. (1999) reported that 1.0, 2.5 and 5.0% $CaCl_2$ dips improved firmness of fresh-cut cantaloupe. The higher the calcium concentration applied, the greater the improvement in firmness, with 1 min dips showing the same effect as 5 min dips. Furthermore, Luna-Guzman and Barrett (2000) reported that the application of 2.5% $CaCl_2$ solutions for fresh-cut cantaloupe caused an undesirable bitter taste, as was found in our experiment at 0.75% for longan aril.

Effectiveness of peroxyacetic acid on two cultivars of whole longan fruit

The effect of PAA treatments on the microbial population of whole longan fruit is shown in Table 2. The number of total bacteria and yeast-molds on the untreated surface of whole longan fruit were 7.13 and 6.09 log cfu/fruit for cv. Daw and 7.14 and 6.65 log cfu/fruit for cv. Beawkeaw, respectively. It was found that immersing the fruit in 150 mg/L PAA solution for 5 min decreased microbial population the most: 2.23-2.28 cfu/fruit and 1.31-1.81 cfu/fruit for total bacteria and yeast-molds, respectively. Treatments with 150 and 100 mg/L PAA were more effective than the treatment at 75 mg/L PAA, with no significant differences between the two. These results agree with those of Klaas (2002) who showed that 4.33 mM PAA was more effective than 2.60 and 1.30 mM PAA on the reduction of *B. subtilis* spores. Treatments for 5 and 3 min were clearly more effective than treatment for 1 min in reducing populations, with no significant difference between the two. This is in agreement with previous studies in whole apple fruit, which showed that PAA for 5 min was more effective than 1 min on the reduction of *Enterobacter sakazakii* (Kim et al., 2006).

Efficacy of PAA as a sanitizer is based on the release of active oxygen. It is likely that sensitive sulfhydryl and sulfur bonds in proteins, enzymes and other metabolites are oxidized and that double-bonds are reacted. Moreover, PAA disrupts the chemiosmotic function of the lipoprotein cytoplasmic membrane and transport through dislocation or rupture of cell walls. The attractiveness of PAA for use in foods is that it decomposes to non-toxic acetic acid (Klaas et al., 2002; Kitis, 2004).

Table 2. Reductions of total bacteria and yeast-molds from whole longan fruit dipping in peroxyacetic acid solution at different concentrations and contact times.

Contact time (min)	Concentrations (mg/L)	Reductions (cfu/fruit)			
		Cultivars			
		Daw		Beawkeaw	
		TBC	Y&M	TBC	Y&M
1	75	1.60b	0.60b	1.43b	1.05b
	100	1.65b	0.65b	1.64b	1.18b
	150	1.70b	0.71b	1.68b	1.23b
3	75	1.64b	0.64b	1.51b	1.18b
	100	2.17a	1.23a	2.13a	1.69a
	150	2.22a	1.26a	2.19a	1.76a
5	75	1.56b	0.69b	1.55b	1.20b
	100	2.20a	1.26a	2.18a	1.77a
	150	2.28a	1.31a	2.23a	1.81a

Notes: TBC = Total bacteria count, Y&M = Yeast and molds, Values are means of three replicates, which were plated in duplicate.

Populations of TBC on un-dipped control were 7.13 and 7.14 log cfu/fruit on Daw and Beawkeaw, respectively.

Populations of Y&M on un-dipped control were 6.09 and 6.65 log cfu/fruit on Daw and Beawkeaw, respectively.

Values in each column with distinct letters represent the significantly different results ($p \leq 0.05$).

Effectiveness of peroxyacetic acid on two cultivars of longan aril

The reduction of total bacteria and yeast-molds on longan aril was studied after sanitation (Table 3). The number of total bacteria and yeast-molds on untreated longan aril cv. Daw were 1.50 and 1.29 log cfu/g and longan aril cv. Beawkeaw were 1.53 and 1.38 log cfu/g, respectively. Dipping of longan aril in 80 mg/L PAA for 5 min resulted in the highest reduction of microbial population: 0.31-0.43 cfu/g and 0.22-0.38 cfu/g for total bacteria and yeast-molds, respectively.

The immersion in 50, 65 or 80 mg/L PAA solutions for 3 or 5 min resulted in no significant difference in microbial population reduction. These results agree with those of Kim et al. (2006) who showed that 40 and 80 mg/L PAA resulted in no significant difference on the reduction of *Enterobacter sakazakii* in fresh-cut lettuce. Pathogenic bacteria associated with fresh-cut fruits include *Campylobacter jejuni, Escherichia coli* O157:H7, *Salmonella* spp., *Listeria monocytogenes* and *Staphylococcus aureus* (Raybaudi-Massilia et al., 2009). From the results in Table 3, 50 mg/L PAA for 3 min in reducing the microbial population on the longan aril was selected for further experiment. Dipping longan aril cv. Daw and cv. Beawkeaw in 50 mg/L PAA solution for 3 min resulted in 0.38 and 0.30 cfu/g for total bacteria and 0.22 and 0.19 cfu/g for yeast-molds, respectively.

Table 3. Reductions of total bacteria and yeast-molds of longan aril dipping in peroxyacetic acid solution at different concentrations and contact times.

Contact time (min)	Concentrations (mg/L)	Reductions (cfu/g)			
		Cultivars			
		Daw		Beawkeaw	
		TBC	Y&M	TBC	Y&M
1	50	0.16bc	0.06ab	0.05b	0.02cd
	65	0.21ab	0.12ab	0.03b	0.13bcd
	80	0.26ab	0.16ab	0.08b	0.13bcd
3	50	0.38a	0.22a	0.30a	0.19abcd
	65	0.38a	0.26a	0.30a	0.25abc
	80	0.43a	0.26a	0.30a	0.25abc
5	50	0.40a	0.22a	0.29a	0.21abcd
	65	0.38a	0.24a	0.29a	0.28ab
	80	0.43a	0.22a	0.31a	0.38a

Notes: TBC = Total bacteria count, Y&M = Yeast and molds, Values are means of three replicates, which were plated in duplicate.

Populations of TBC on un-dipped control were 1.50 and 1.53 log cfu/g on Daw and Beawkeaw, respectively.

Populations of Y&M on un-dipped control were 1.29 and 1.38 log cfu/ g on Daw and Beawkeaw, respectively.

Values in each column with distinct letters represent the significantly different results ($p \leq 0.05$).

Quality changes during storage of longan aril

Physical changes

Firmness of longan aril decreased throughout 8 days of storage as shown in Figures 1 and 2 (A). Initially, firmness of cv. Daw was 3.22 N for control, 3.20 N for PAA only and 3.50 N for dipping in both $CaCl_2$ and PAA. For cv. Beawkeaw, it was 3.49, 3.29 and 4.46 N, respectively. After 8 days of storage at 4°C, the texture of cv. Daw reduced to 2.94, 2.84 and 3.15 N and for cv. Beawkeaw, reduced to 2.43, 2.52 and 3.46 N, respectively. Longan aril of cv. Beawkeaw had higher firmness than cv. Daw, and the $CaCl_2$ treatment helped maintain higher firmness during storage. Calcium chloride helps maintain cell structure since it increases the cross linkages among pectin polymers, mainly in middle lamella (Durigan et al., 2005). The major factor in the loss of texture in climacteric fruit is the degrading of pectin by polygalacturonase (Toivonen and Brummell, 2008). This is in agreement with previous studies in fresh-cut mango, which showed that the texture of mango flesh stored at 3°C for 15 days decreased throughout storage (Souza et al., 2006).

Weight loss of longan aril increased throughout the 8-day storage as shown in Figures 1 and 2 (B). After eight days of storage, the weight losses of cv. Daw were: 1.55% for control, 1.76% for PAA only, and 2.17% for dipping in both $CaCl_2$ and PAA; and for cv. Beawkeaw, they were 1.03, 1.20 and 1.13%, respec-

tively. The tissue of longan aril was damaged during deseeding and peeling, which might increase weight loss. However, weight loss can be greatly retarded by appropriate packaging (Toivonen and Brummell, 2008). That longan aril cv. Beawkeaw had a lower percent weight loss than cv. Daw might be due to its thicker and stronger texture.

L* values of longan aril slightly decreased throughout eight days of storage as shown in Figures 1 and 2 (C). Initially, L* values of cv. Daw were 66.81 for control, 67.09 for PAA only and 68.65 for dipping in both $CaCl_2$ and PAA and of cv. Beawkeaw were 66.69, 67.20 and 67.47, respectively. After eight days of storage, L* values of cv. Daw were 65.79, 66.69 and 67.52 and L* values of cv. Beawkeaw were 64.81, 65.01 and 65.75, respectively. Longan aril cv. Daw had higher L* value than cv. Beawkeaw. Dipping the longan aril in both $CaCl_2$ and PAA solutions slightly increased the L* value.

Chemical changes

The pH values of longan aril increased throughout the eight days of storage as shown in Figures 1 and 2 (D). Initially, the pH values of cv. Daw were 6.91 for control, 6.83 for PAA only and 6.82 for dipping in both $CaCl_2$ and PAA and of cv. Beawkeaw were 6.88, 6.84 and 6.96, respectively. During storage, the pH slightly increased and after eight days of storage, the pH of cv. Daw were 7.21, 7.17 and 7.10 and of cv. Beawkeaw were 7.24, 7.23 and 7.22, respectively. The control aril had a higher pH level than treated fruit. Dipping longan aril in 0.5% $CaCl_2$ and 50 mg/L PAA solutions decreased the pH level. However, the pH level of longan aril was higher than 4.6 and increased throughout storage. This may result in the short shelf life due to both pathogenic and spoilage microbial infections.

Longan aril has very low acidity. The TA of longan aril decreased through the first four days of storage. After four days of storage, TA became stable. TA is shown in Figures 1 and 2 (E). Initially, TA of cv. Daw and cv. Beawkeaw in all treatments were 0.05%. After eight days of storage, TA of cv. Daw and cv. Beawkeaw were in the range of 0.03-0.04%. TA of fresh-cut kiwifruit slices stored at 2°C for five days also decreased throughout the storage period (Agar et al., 1999).

TSS of longan aril exhibited the smallest changes throughout eight days of storage as shown in Figures 1 and 2 (F). Initially, TSS of cv. Daw were 17.90 for control, 16.43 for PAA only and 16.13% for dipping in both $CaCl_2$ and PAA and of cv. Beawkeaw were 19.93, 17.67 and 16.90%, respectively. After eight days of storage, TSS of cv. Daw became 18.37, 16.43 and 15.70% and of cv. Beawkeaw became 18.53, 16.60 and 16.57%, respectively. These results agree with those of Aguayo et al. (2007) who showed that TSS of melon flesh stored at 5°C for eight days presented the smallest changes throughout storage. Longan aril cv. Beawkeaw had a slightly higher TSS level than cv. Daw. Dipping of longan aril in both $CaCl_2$ and PAA solutions decreased TSS level.

Total sugars showed small changes during eight days of storage as shown in Figures 1 and 2 (G). The initial total sugars of cv. Daw were 17.02 for control,

16.19 for PAA only and 15.74% for dipping in both $CaCl_2$ and PAA solutions and of cv. Beawkeaw were 18.10, 17.27 and 15.85%, respectively. The control aril had higher total sugar than both treatments and total sugar of cv. Daw and cv. Beawkeaw were almost of similar concentrations. On day 8, the sugar contents were 18.05, 16.26 and 15.26% for cv. Daw and 18.12, 16.17 and 15.63% for cv. Beawkeaw, respectively. The main sugars present in longan fruit are sucrose, fructose and glucose (Jiang et al., 2002). Each dipping of longan aril in both $CaCl_2$ and PAA solutions decreased total sugar about 4-6% because sugars dissolved in the solutions.

Reducing sugar of longan aril increased throughout the eight days of storage as shown in Figures 1 and 2 (H). The reducing sugars of cv. Daw were quite similar to those of cv. Beawkeaw in the range of 8.96-9.72%. During storage, reducing sugar of both cultivars increased to 10.21-11.06%. The increase in reducing sugar could be explained by the hydrolysis of sucrose. In fresh-cut melon, reducing sugar also increased throughout of storage at 5°C for eight days, (Aguayo et al., 2007).

Microbiological changes

The initial total bacterial counts of cv. Daw were 2.87 for control, 1.20 for PAA only and 1.10 log cfu/g for dipping in both $CaCl_2$ and PAA solutions and of cv. Beawkeaw were 2.92, 1.72 and 1.66 log cfu/g, respectively. Yeast-molds counts of cv. Daw were 2.73, 1.00 and 1.00 log cfu/g and of cv. Beawkeaw were 2.43, 1.46 and 1.20 log cfu/g, respectively (Figures 1 and 2 [I and J]).

At the end of storage, total bacteria populations of cv. Daw were 5.29, 2.54 and 2.34 log cfu/g and of cv. Beawkeaw were 5.43, 3.72 and 3.55 log cfu/g, respectively. Yeast-molds populations of cv. Daw were 4.95, 2.12 and 2.01 log cfu/g and cv. Beawkeaw were 4.96, 3.22 and 3.18 log cfu/g, respectively.

The untreated aril had higher microbial populations than other treatments. The results showed that PAA could retard the microbiological deterioration of longan aril. Martinez-Sanchez et al. (2006) showed that 300 mg/L PAA for 1 min was effective in retarding the microbiological deterioration in rocket leaves during 15 days of storage at 4°C.

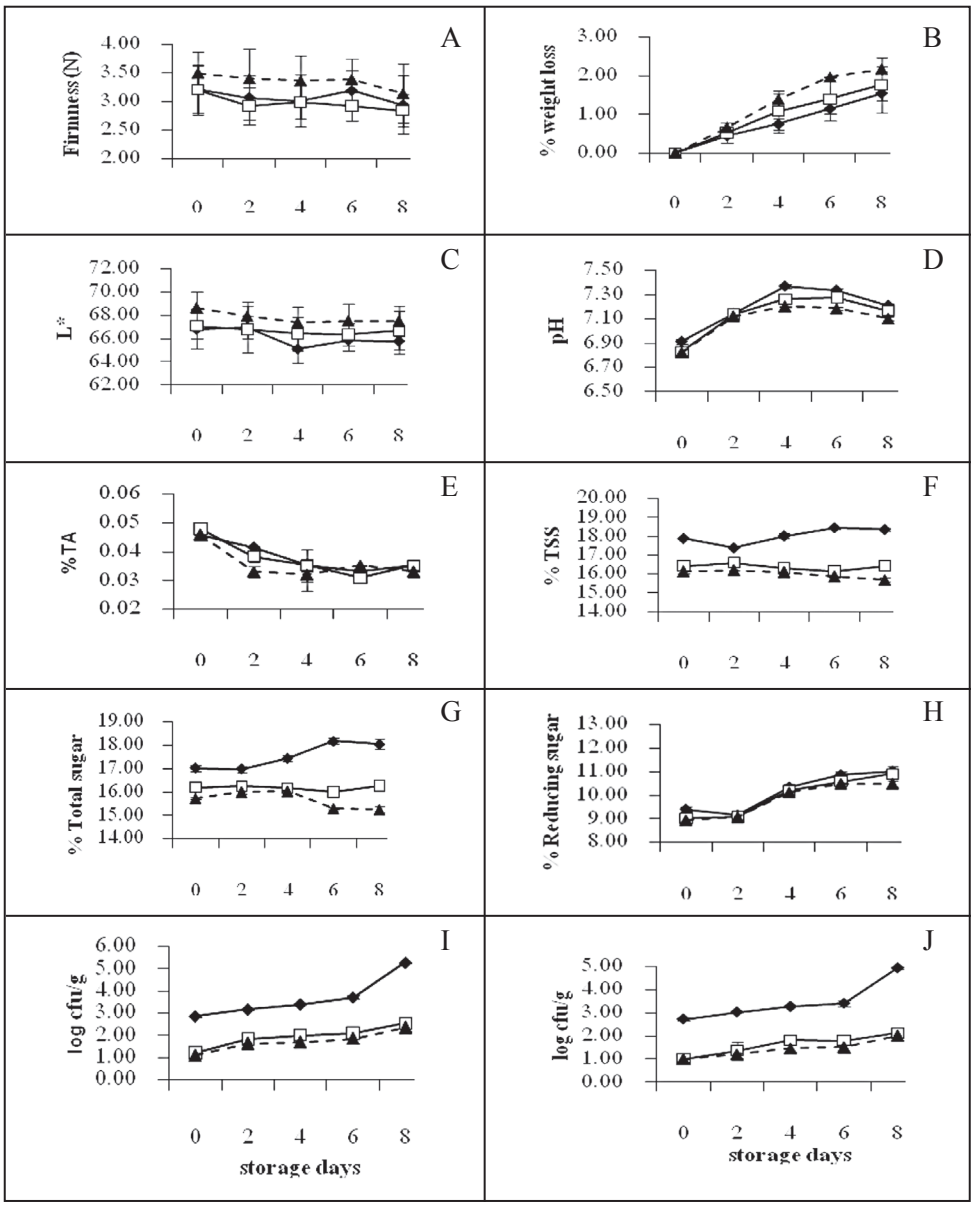

Figure 1. Firmness (A), weight loss (B), L* values (C), pH (D), TA (E), TSS (F), total sugar (G), reducing sugar (H), total bacteria (I) and yeast-mold population (J) of minimally processed longan fruit cv. Daw during storage at 4±1°C for 8 days.

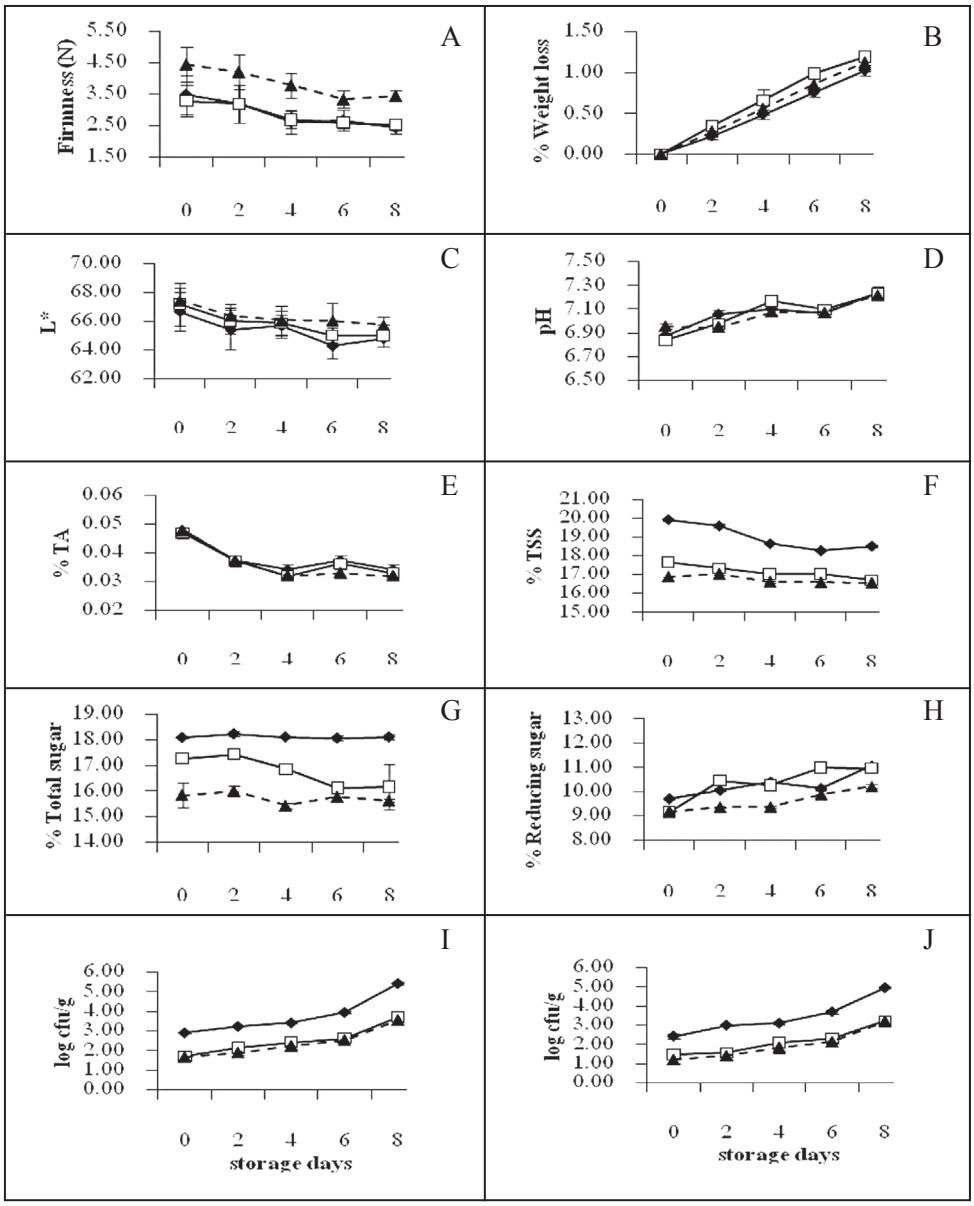

Figure 2. Firmness (A), weight loss (B), L* values (C), pH (D), TA (E), TSS (F), total sugar (G), reducing sugar (H), total bacteria (I) and yeast-mold population (J) of minimally processed longan fruit cv. Beawkeaw during storage at 4±1°C for 8 days.

Sensory evaluation

The color, appearance, flavor, texture and overall visual appearance acceptability of longan aril decreased during storage (data not shown). Color and appearance acceptability of both treatments were scored higher than the control but the flavor acceptability of the control was similar to both treatments. The

aril dipped in 0.5% calcium chloride had higher visual appearance scores than other treatments. Both $CaCl_2$ and PAA solutions delayed the decline in sensory scores and extended the shelf life of longan aril. The scores of the control and both treatments of cv. Daw reached "unacceptable" on days 4, 5 and 6 of storage, respectively, so the shelf life should be 3, 4 and 5 days, respectively. For cv. Beawkeaw, the control was unacceptable on day 4 of storage while both treatments became unacceptable on day 5 of storage. The panelists rated color, appearance and flavor acceptability of cv. Daw higher than for cv. Beawkeaw but the texture acceptability was the inverse.

CONCLUSION

Dipping whole longan fruit or aril in 100 or 50 mg/L PAA solutions for 3 min, respectively, was most effective in reducing the microbial load on the peel or aril of longan fruit. The 0.5% $CaCl_2$ solution was the best for improving the texture of the longan aril without creating an undesirable taste. During storage of longan aril at 4±1°C for eight days, the firmness, L* value and TA content decreased but weight loss, pH level, reducing sugar, total bacteria and yeast-mold increased while TSS and total sugar content were changed little. Dipping longan aril in both $CaCl_2$ and PAA solutions resulted in a decrease in pH, %TSS, total sugar and reducing sugar contents while the texture, weight loss and L* value increased. Both $CaCl_2$ and PAA solutions could delay the microbial growth when compared with the control. The shelf lives of treated longan aril cv. Daw and Beawkeaw at 4±1°C were 5 and 4 days, respectively.

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