

Quality and Shelf Life of Minimally-processed Litchi Fruit

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ABSTRACT

Quality and shelf life of sanitized peeled litchi arils of three cultivars, 'Honghuay', 'Gimjeng' and 'Jugkatat', were studied. The peeled and deseeded litchi arils were sanitized with 50 mg/L of peroxyacetic acid (PAA) solutions for 1 min. Subsequently, they were drained, packed in a polystyrene clamshell box and analyzed during storage at 4±1°C for 12 days. Firmness and lightness (L) values of the arils decreased and juice leakage increased during storage. The pH, total soluble solids and total titratable acidity during storage changed slightly. Ascorbic acid contents decreased after sanitation and during storage. Sanitation with PAA delayed growth of all bacteria, yeast and molds within the specified microbial criteria. The appearance of the litchi arils was not translucent, however, with the texture softening around the cut area of the stem-end. Based on organoleptic evaluation, the shelf life of peeled litchi arils was 5 days at 4±1°C. In addition, the 'Jugkatat' cultivar was the most appropriate candidate for minimally-processed produce, because of its larger fruit size, ease of deseeding, the absence of brown color on the internal surface of the arils and the high ascorbic acid content.*

Keywords: Shelf life, Peroxyacetic acid, Minimally-processed litchi fruit

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is a subtropical fruit originated from Southeast Asia. The fruit has a natural bright red peel color, sweet acidic taste and strong aroma (Jiang et al., 2003). Postharvest losses of litchi are due to microbial decay and pericarp browning within 2-3 days of harvest at 20°C (Holcroft and Mitcham, 1996). Browning is caused by the oxidation of phenolic substrates catalyzed by polyphenol oxidase (PPO) and dehydration (Zhang et al., 2001; Jieng et al., 2004). Although the litchi fruit becomes unmarketable due to browning, but the internal arils are still in good condition and edible (Shah and Nart, 2006). Therefore, min-

imal processing might be an alternative method to preserve the arils and marketability of litchi fruit. Shah and Nart (2008) reported that minimally-processed litchi was affected by mold growth, discoloration and loss of texture after one week of storage at $4\pm 2^{\circ}\text{C}$. These problems might be minimized by treatments with sanitizers that have been shown to be beneficial with other minimally-processed products.

Disinfecting treatment is an important initial step in reducing the microbial populations on the surface of whole fruit. Final washing of fresh produce after cutting, slicing, shredding or peeling helps remove some of the cellular fluids that could serve as a nutrient for microbial growth (USFDA, 2006). PAA can be used as an alternative to chlorine for reducing microorganisms in whole and litchi arils at the concentrations of 100 and 50 mg L^{-1} for 5 and 1 min, respectively. The application of PAA reduced total bacteria count, yeast and mold on the surface of whole and flesh of litchi fruit in the range of 2-3 $\log \text{CFU g}^{-1}$ (Phanumong et al., 2010). Effectiveness of PAA as a sanitizer is based on the release of active oxygen, which oxidizes sensitive sulfhydryl and sulfur bonds in proteins, enzymes and other metabolites of the bacteria and yeast-molds (Kitis, 2004). PAA is more stable and can preserve its efficacy even in the presence of organic matter (Artes et al., 2009). However, the quality and shelf life of minimally-processed litchi treated with PAA have not been reported.

The objective of this study was to evaluate the quality and shelf life of minimally-processed litchi fruit arils when treated with a sanitizer, PAA. This study included the three most prominent cultivars in northern Thailand. Analysis included physical, chemical, sensory and microbial counts of arils stored at $4\pm 1^{\circ}\text{C}$ for 12 days.

MATERIALS AND METHODS

Fruit

This study used litchi (*Litchichinensis* Sonn.) fruit of cv. 'Honghuay', 'Gimjeng' and 'Jugkat' – the three most famous commercial cultivars in northern Thailand. 'Honghuay' has a thin pericarp, with the weight per fruit about 23-35g. An aril is entangled with a big seed; the thickness of the aril is non-uniform from the top to bottom of the fruit. 'Gimjeng' has a smaller fruit size with the weight per fruit about 20-25 g. The aril of this cultivar is thick, because of its tiny seed, and flat. 'Jugkat' has a larger fruit size than the other cultivars, with the weight per fruit about 40-50 g, and a high proportion of aril and a big seed (Damrongsuk, 2004).

The litchi fruit samples were harvested at the fully-red color stage from local orchards in Fang District, Chiang Mai Province, Thailand during June-August 2008. Fruit were packed in cardboard boxes and transferred within 3 h to the laboratory of the Postharvest Technology Research Center, Chiang Mai University. After overnight storage at $4\pm 1^{\circ}\text{C}$, fruit of uniform size, shape, color and free of defects were selected for the experiment.

Minimal processing of litchi fruit

Before and during processing, all equipment was sanitized with 200 mgL⁻¹ sodium hypochlorite (CLOROX[®], Californai, USA). Gloves (Samperguard[™], Sritrang gloves, Songkhla, Thailand) were used during handling, with new gloves donned after each treatment. Fruit were randomly distributed into groups of 75 fruit per treatment. Whole fruit were dipped in 100 mgL⁻¹ peroxyacetic acid solution (BLRLOX-5[®], Thai Peroxide Co., Ltd., Saraburi, Thailand) for 5 min (Phanumong et al., 2010) to reduce initial microbial populations on the surface of the pericarp. After draining, the seed was removed with a sterilized, sharp, stainless steel knife by coring around the stem end of the fruit, followed by manual peeling. Then the arils were dipped in 50 mgL⁻¹ peroxyacetic solution for 1 min (Phanumong et al., 2010). After draining, the arils were kept in a polystyrene clamshell box (14×15×8 cm), 15 fruit pieces per box, and then stored at 4±1°C for 12 days. Treatment was compared with undipped control. Each box of 15 arils was analyzed at 3-day intervals; 5 pieces were used for each replicate.

Physical analysis

Weight loss of the samples was measured by monitoring weight changes and expressed as percentage of the initial weight, using a digital scale (Model PB 1502-5; Mettler-Toledo, Greifensee, Swizerland). Juice leakage from the arils was assessed by measuring the volume of juice at the bottom of the containers using a graduated cylinder. The color of the arils was measured with a colorimeter (ColorQuestXE; HunterLab, Virginia, USA) and the lightness (L*) value was reported. Firmness of the arils was measured with a texture analyzer (TA-XTi/50; Stable Micro System Ltd., Surrey, UK), using a P/2 cylindrical probe and test speed of 5 mm per second.

Chemical analysis

For chemical analysis, five pieces of arils per replication were macerated in a blender (AW9, Moulinex, France) and samples were analyzed for total soluble solids (%TSS, w/v) with a digital refractometer (Model PR-101; Atago, Tokyo, Japan), pH with a microprocessor pH meter (Consort; Turnhout, Belgium) and titratable acidity (%TA, w/v) as described in AOAC (AOAC, 2000). TSS/TA ratio was calculated by percent total soluble solids and percent titratable acidity. Ascorbic acid (Vitamin C) content was determined by diluting 10 g of macerated sample with 0.4% oxalic acid solution and 10 mL of the filtrate titrated with 0.04% 2,6-dichlorophenol indophenol dye solution to pink color compared with standard 1 mg per mL ascorbic acid solution. Ascorbic acid content was expressed as mg per 100 g (Ranganna, 1986). Each replication was determined in triplicate.

Determination of microbial population

Changes in the microbial population of minimally-processed litchi were evaluated by total bacteria count (TBC), yeast and molds (Y&M) during 12 days of storage. Five peeled litchi arils per replication were cut with sterilized stainless steel scissors. A 10 g sample was transferred to a sterilized bag containing 90

ml of phosphate buffer pH 7.2 and macerated with a stomacher (IVL Masticator 400; IUL Instruments, Barcelona, Spain) for 30 sec. The homogenized sample was serially diluted by a factor of ten in 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 TBC (BAM, 2001) and Y&M (AOAC, 2000), respectively. Then, PCA and PDA were incubated at 35°C for 48 h and 25°C for 48 h, respectively. Values are reported as log CFU g⁻¹.

Sensory evaluation

Fifteen semi-trained panelists evaluated changes in appearance, color, flavor, texture and overall acceptability, using a 9-point hedonic scale (Martínez-Sánchez et al., 2006; Shah and Nart, 2008). Appearance was evaluated for freshness, translucency, visual softening and color uniformity. Overall acceptability was evaluated based on acceptability for consumption. A score of 5 (neither like nor dislike) was considered the lower limit of acceptance from the consumers' point of view. Sensory quality attributes were evaluated on the day of processing and everyday during storage at 4±1°C.

Statistical analysis

The experiment was designed as a completely randomized design with three replicates. The values of physicochemical indices of litchi arils during storage were compared between varieties. Data were analyzed using SPSS program V.13 for analysis of variance at $p<0.05$. Duncan's multiple range test was used for comparison of mean values.

RESULTS

Physical changes

The percentage of weight loss of peeled arils of all three cultivars increased during the 12 days of storage at 4±1°C (Fig. 1A-C). The least weight loss, 1.1%, was found in the minimally-processed litchi of 'Jugkapat', followed by 1.8% in 'Gimjeng' and 2.1% in 'Honghuay'. Juice leakage from the arils was 10.9, 8.9 and 5.5 ml/100g after 3 days of storage and increased significantly ($p<0.05$) to 23.3, 21.4 and 16.6 ml/100g after 12 days of storage in 'Honghuay', 'Gimjeng' and 'Jugkapat', respectively (Fig. 2A-C). Juice leakage of the three control cultivars was lower than the treated samples at 18.1, 18.8 and 14.1 ml/100g in 'Honghuay', 'Gimjeng' and 'Jugkapat', respectively, after 12 days of storage. The percentage decrease in the firmness value of treated arils was less than the control at the end of storage, which decreased approximately 20-34% from initial values (Fig. 3A). The L* value of three cultivars of peeled arils decreased from the initial value of 67.1-70.8 by about 5-10% after storage for 12 days (Fig. 4A-C).

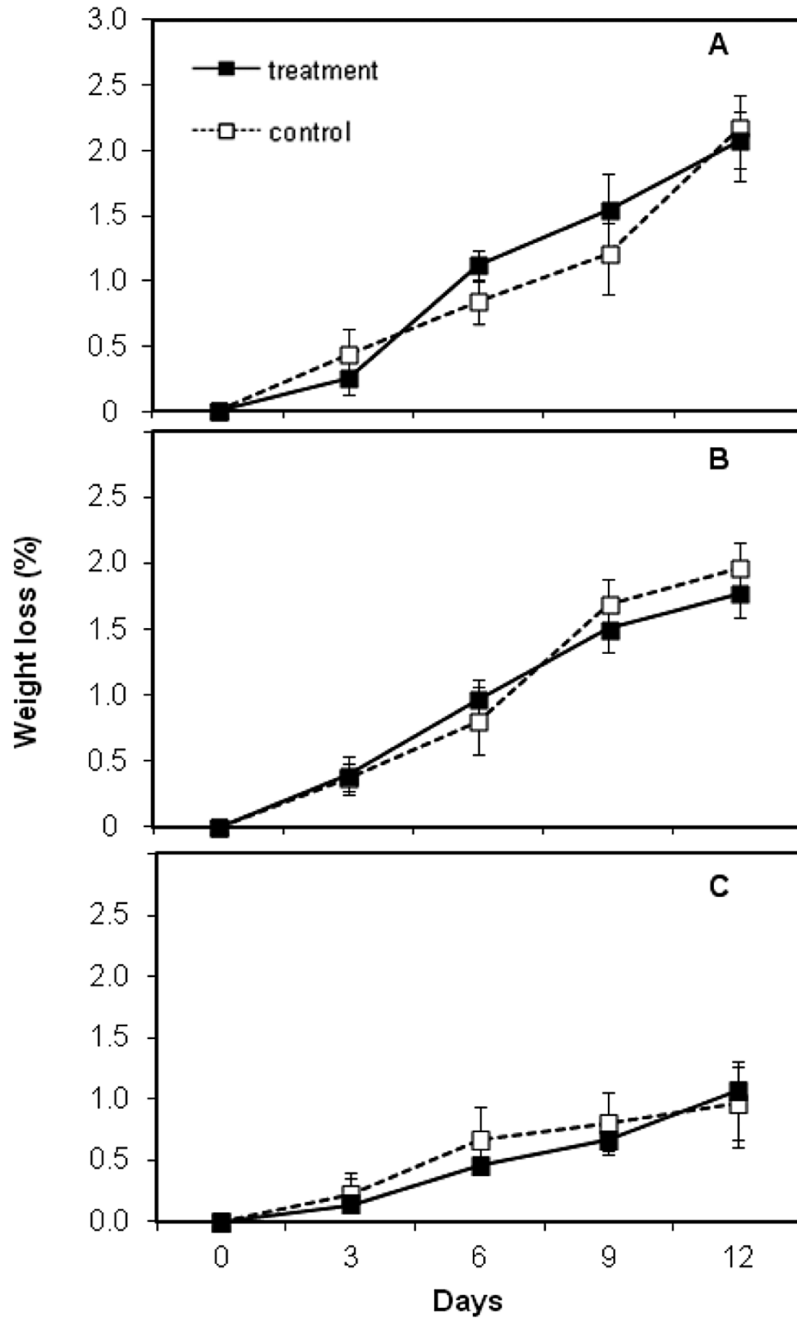


Figure 1. Changes in weight loss of minimally processed litchi *cv.* Honghuay (A), Gimjeng (B) and Jugkapat (C) during 12 days of storage at $4\pm 1^{\circ}\text{C}$. Bars represent the standard errors of mean resulting $p < 0.05$.

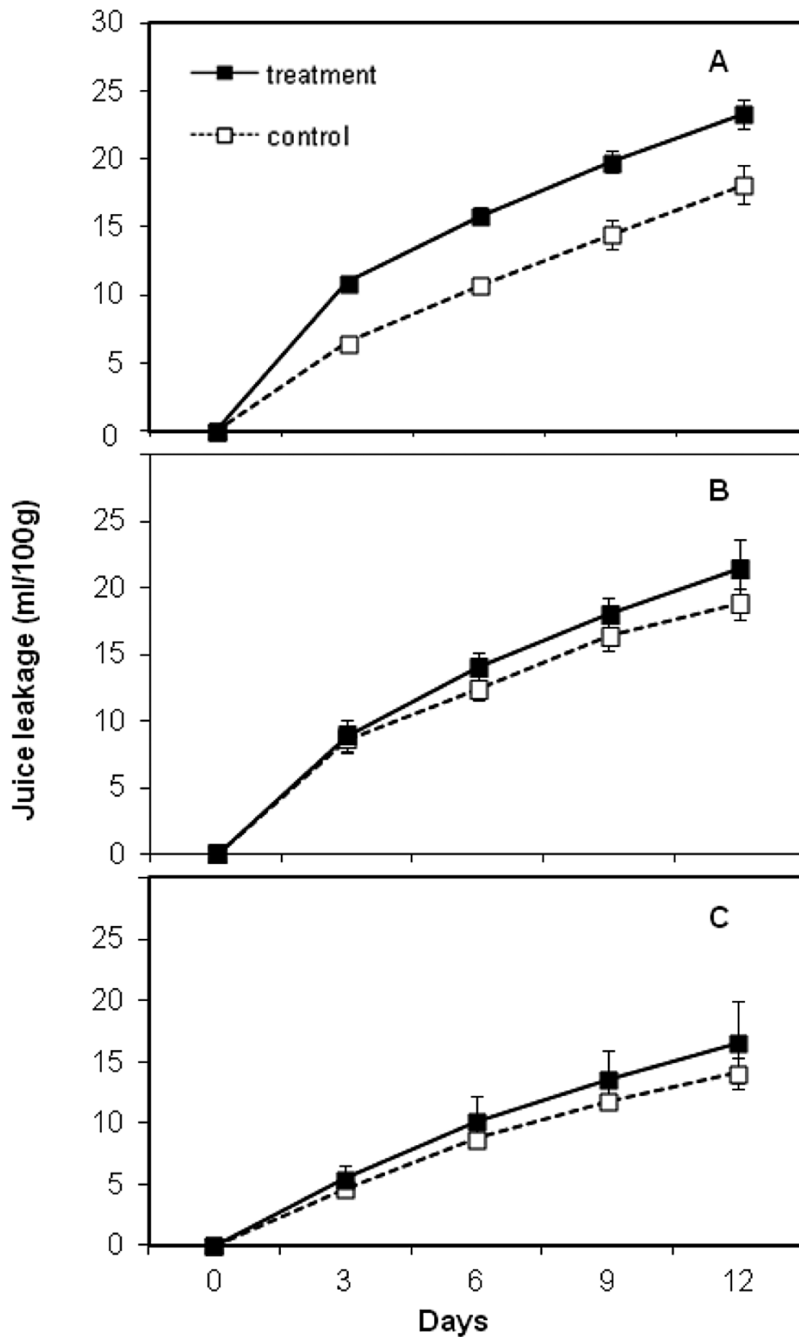


Figure 2. Changes in juice leakage of minimally processed litchi *cv.* Honghuay (A), Gimjeng (B) and Jugkapat (C) during 12 days of storage at $4 \pm 1^\circ\text{C}$. Bars represent the standard errors of mean resulting $p < 0.05$.

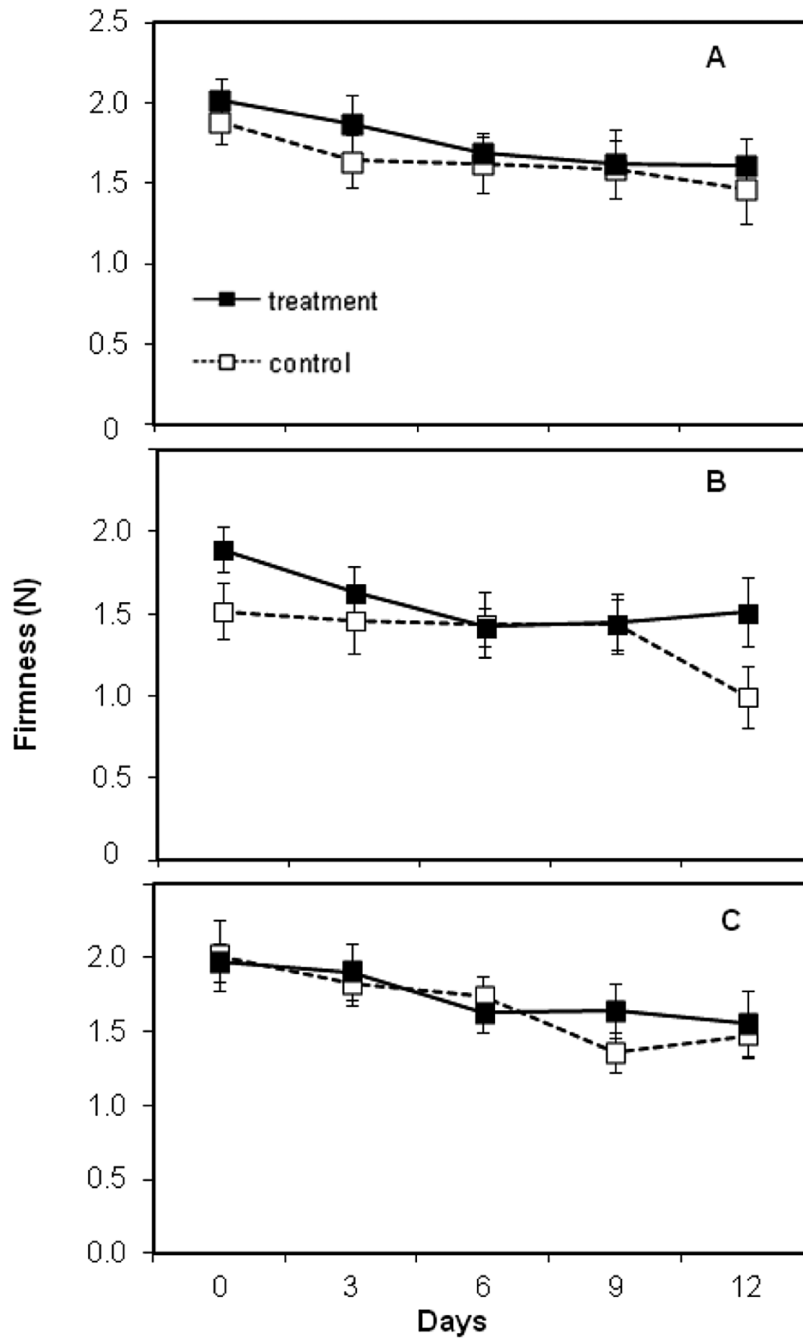


Figure 3. Changes in firmness of minimally processed litchi *cv.* Honghuay (A), Gimjeng (B) and Jugkapat (C) during 12 days of storage at $4\pm 1^\circ\text{C}$. Bars represent the standard errors of mean resulting $p < 0.05$.

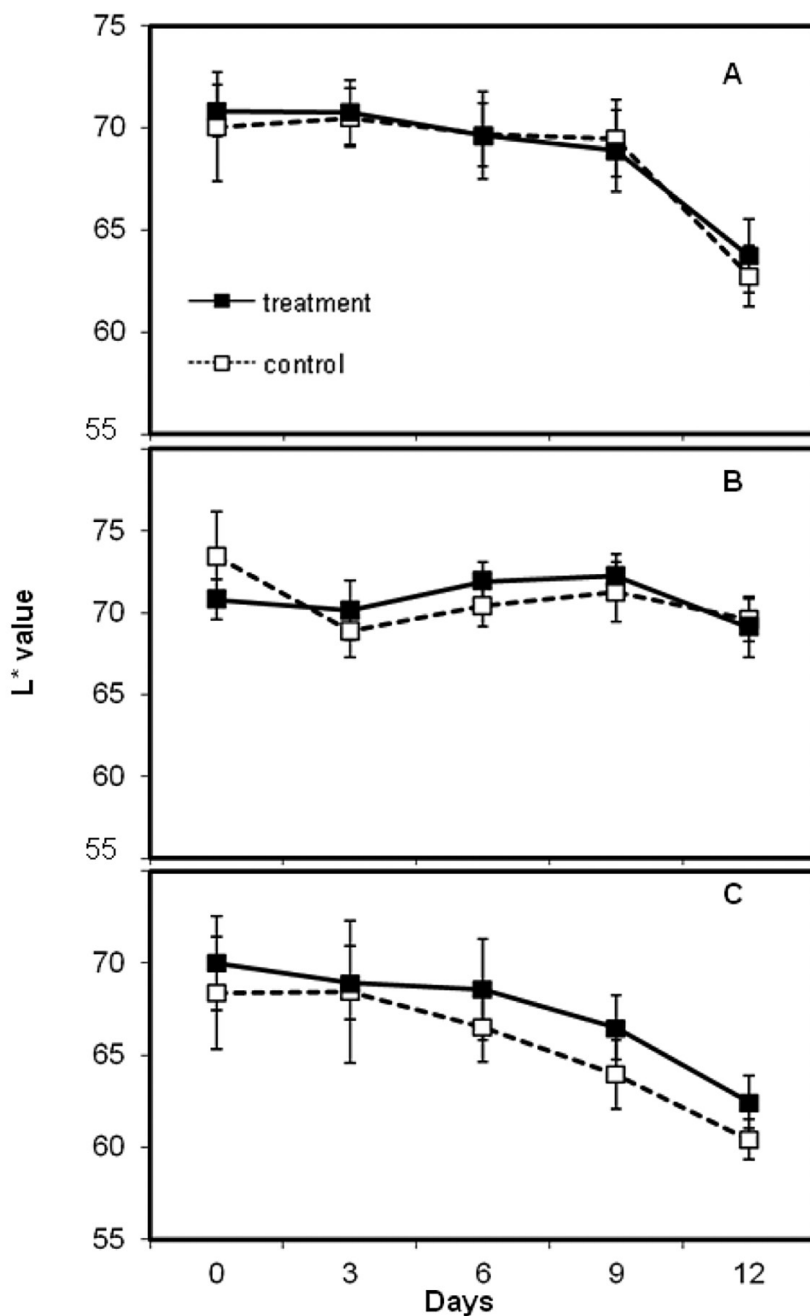


Figure 4. Changes in L* value of minimally processed litchi *cv.* Honghuay (A), Gimjeng (B) and Jugkapat (C) during 12 days of storage at 4±1°C. Bars represent the standard errors of mean resulting $p < 0.05$.

Chemical changes

The initial percent TSS of peeled arils was 14.7, 16.0 and 19.5% for ‘Jugkapat’, ‘Honghuay’ and ‘Gimjeng’, respectively (Table 1). TSS decreased after the dipping treatment in PAA solution and was significantly lower than the control throughout the storage periods. After 12 days of storage at 4±1°C, percent TSS of treated arils seems to have decreased slightly.

Table 1. Changes of total soluble solid (TSS,%) of minimally processed litchi treated with PAA during storage at 4±1°C.

Days	‘Honghuan’		‘Gimjeng’		‘Jugkapat’	
	control	treatment	control	treatment	control	treatment
0	17.56±0.39 Ba	16.03±0.30 ABb	20.10±0.16 Ba	19.52±0.58 Ab	15.23±0.12 Aa	14.67±0.15 Ab
3	17.81±0.34 Ba	16.44±0.30 Ab	21.18±0.88 Aa	19.10±0.21 Bb	15.10±0.10 ABa	13.93±0.06 Cb
6	18.34±0.64 Aa	16.30±0.55 Ab	19.28±0.16 Ca	18.38±0.37 Cb	15.03±0.20 ABa	14.33±0.12 Bb
9	17.67±0.09 Ba	15.50±0.63 Cc	19.76±0.13 Ba	18.84±0.05 Bb	14.87±0.21 Ba	14.43±0.06 Bb
12	17.81±0.15 Ba	15.81±0.33 BCb	21.00±0.26 Aa	19.01±0.24 Bb	15.10±0.17 ABa	14.10±0.10 Cb

Note: Data was expressed as mean of n=9. Means followed by values in each column (storage time) with distinct upper case letters represent the significantly different results ($p<0.05$). Values in each row (treatment) with distinct lower case letters represent the significantly different results ($p<0.05$).

The initial pH of ‘Gimjeng’, ‘Honghuay’ and ‘Jugkapat’ arils were 4.7, 4.4 and 4.1, respectively (Table 2). The pH of ‘Gimjeng’ and ‘Jugkapat’ showed no consistent changes during the 12 days of storage, while the pH of ‘Honghuay’ decreased significantly ($p<0.05$) from an initial value of 4.4 to 4.2 after the 12-day storage at 4±1°C. At each sampling date, the pH of the control was lower than the treatment and decreased rapidly throughout the storage period.

Table 2. Changes of pH of minimally processed litchi treated with PAA during storage at 4±1°C.

Days	‘Honghuan’		‘Gimjeng’		‘Jugkapat’	
	control	treatment	control	treatment	control	treatment
0	4.48±0.07 Aa	4.44±0.04 Aa	4.63±0.04 BCa	4.65±0.03 BCa	4.14±0.02 Aa	4.14±0.01 Ba
3	4.09±0.08 Bb	4.44±0.08 Aa	4.66±0.10 ABa	4.62±0.07 CDa	3.96±0.01 Db	4.11±0.01 Ca
6	3.47±0.07 Cb	4.30±0.06 Ba	4.72±0.04 Aa	4.71±0.02 Aa	4.08±0.01 Ba	4.01±0.01 Db
9	3.39±0.04 Db	4.33±0.01 Ba	4.58±0.06 CDa	4.58±0.02 Da	4.02±0.01 Ca	3.92±0.01 Eb
12	3.40±0.06 Db	3.94±0.21 Ca	4.54±0.09 Db	4.66±0.03 Ba	4.01±0.01 Cb	4.18±0.01 Aa

Note: Data was expressed as mean of n=9. Means followed by values in each column (storage time) with distinct upper case letters represent the significantly different results ($p<0.05$). Values in each row (treatment) with distinct lower case letters represent the significantly different results ($p<0.05$).

The initial TA of ‘Gimjeng’, ‘Honghuay’ and ‘Jugkapat’ arils was 0.5, 0.3 and 0.3 g malic acid/100g fresh weight, respectively (Table 3). TA of peeled arils of the three cultivars did not change consistently during storage and increased slightly to 0.5, 0.4 and 0.3g malic acid/100g fresh weight after 12 days of storage, respectively. TA of the control increased significantly ($p<0.05$) with increasing

storage time. The peeled arils of ‘Honghuay’ in both control and treatment had a higher percentage increase of TA than the other cultivars.

The initial TSS/TA of ‘Gimjeng’, ‘Honghuay’ and ‘Jugkat’ arils was 31.3, 62.1 and 48.7, respectively. The ratio showed the peeled arils of all cultivars had a sweet and acidic taste. After 12 days of storage, the TSS/TA ratio of peeled arils decreased to 28.9, 52.2 and 44.1 in ‘Gimjeng’, ‘Honghuay’ and ‘Jugkat’, respectively (Table 4). The results showed that all cultivars of peeled arils had a less sweet taste, especially in the control, with the increasing TA percentage.

Table 3. Changes of titratable acidity (TA, g malic acid/100g fresh weight) of minimally processed litchi treated with PAA during storage at 4±1°C.

Days	‘Honghuan’		‘Gimjeng’		‘Jugkat’	
	control	treatment	control	treatment	control	treatment
0	0.47±0.02 Cb	0.51±0.03 BCa	0.32±0.02 Ca	0.32±0.02 Ba	0.30±0.00 Ca	0.30±0.00 Ca
3	0.42±0.03 Da	0.47±0.03 Db	0.34±0.02 Ca	0.32±0.02 Ba	0.37±0.00 Aa	0.32±0.03 Bb
6	0.65±0.02 Ba	0.53±0.03 ABb	0.35±0.02 Ca	0.32±0.02 Bb	0.33±0.03 Ba	0.34±0.00 Aa
9	0.84±0.03 Aa	0.50±0.03 Cb	0.37±0.02 Ba	0.32±0.02 Bb	0.35±0.03 Aa	0.34±0.00 Aa
12	0.84±0.06 Aa	0.55±0.02 Ab	0.40±0.03 Aa	0.36±0.01 Ab	0.35±0.03 ABa	0.30±0.00 Cb

Note: Data was expressed as mean of n=9. Means followed by values in each column (storage time) with distinct upper case letters represent the significantly different results ($p<0.05$). Values in each row (treatment) with distinct lower case letters represent the significantly different results ($p<0.05$).

Table 4. Changes of the ratio of total soluble solid to titratable acidity (TSS/TA) of minimally processed litchi treated with PAA during storage at 4±1°C.

Days	‘Honghuan’		‘Gimjeng’		‘Jugkat’	
	control	treatment	control	treatment	control	treatment
0	37.51±1.34 Aa	31.28±1.44 Ab	62.21±3.20 Aa	62.08±5.95 Aa	50.53±0.38 Aa	48.65±0.51 Ab
3	46.24±7.08 Ba	35.45±2.20 Bb	63.38±3.14 Aa	59.88±3.83 ABb	40.98±0.27 Cb	44.13±2.49 Ba
6	28.38±1.91 Cb	30.71±2.16 BCa	55.80±2.66 Ba	57.17±3.65 Ba	45.39±1.11 Ba	42.79±0.46 Bb
9	21.12±0.95 Db	31.00±3.05 Ba	53.39±2.45 BCb	59.35±3.72 ABa	42.13±2.60 Ca	42.09±0.30 Ba
12	21.38±1.23 Db	28.91±0.87 Ca	52.35±3.45 Ca	52.17±2.02 Ca	43.22±2.08 ABb	47.87±0.38 Aa

Note: Data was expressed as mean of n=9. Means followed by values in each column (storage time) with distinct upper case letters represent the significantly different results ($p<0.05$). Values in each row (treatment) with distinct lower case letters represent the significantly different results ($p<0.05$).

The initial ascorbic acid content of peeled arils were 18.1, 19.8 and 47.8 mg/100g in ‘Honghuay’, ‘Gimjeng’ and ‘Jugkat’, respectively (Fig. 5 A-C). After 12 days of storage, peeled arils of ‘Honghuay’, ‘Gimjeng’ and ‘Jugkat’ lost 75.0, 86.1 and 35.1% ascorbic acid content, respectively.

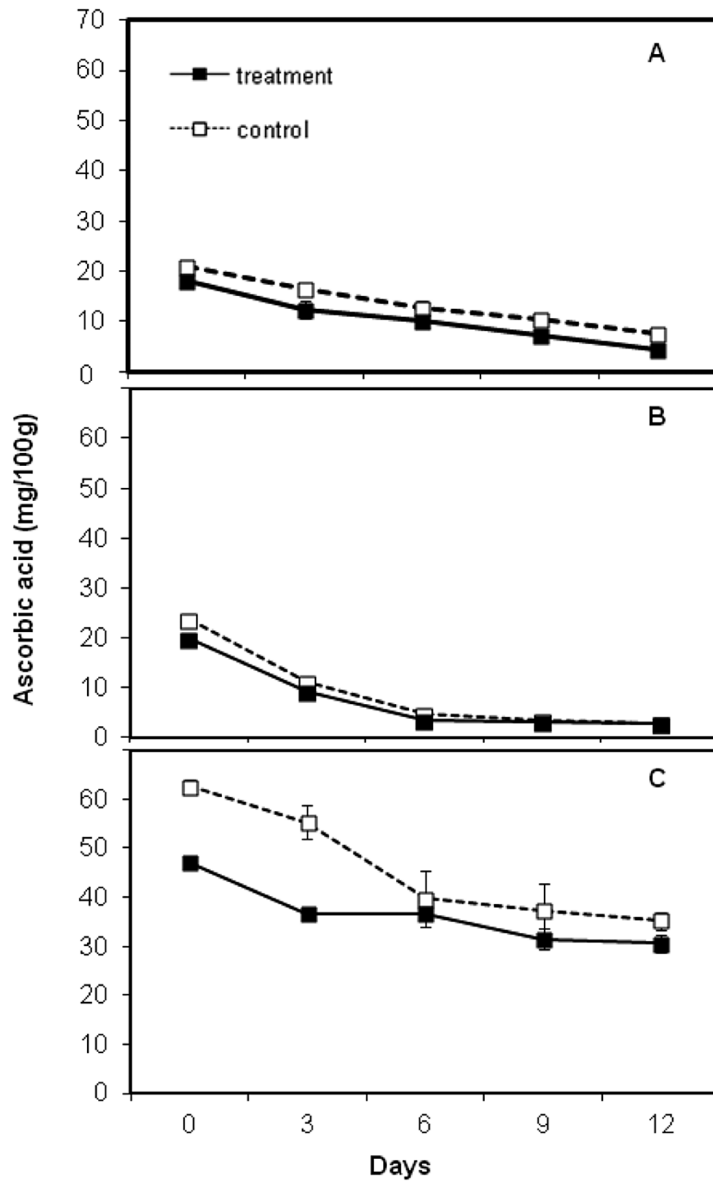


Figure 5. Changes in ascorbic acid (vitamin C) of minimally processed litchi cv. Honghuay (A), Gimjeng (B) and Jugkapat (C) during 12 days of storage at $4\pm 1^\circ\text{C}$. Bars represent the standard errors of mean resulting $p < 0.05$.

Microbial changes

The initial TBC of peeled arils of ‘Honghuay’, ‘Gimjeng’ and ‘Jugkatap’ were 1.3, 1.0 and 2.1 log CFU g⁻¹, respectively (Fig 6A-F). The sanitizing treatment with PAA solution reduced the initial TBC by 1.0-1.7 log cfu/g when compared with the control. During storage, the control showed a rapid increase in TBC from the initial day by 3.1, 3.8 and 4.3 log CFU g⁻¹ in ‘Honghuay’, ‘Gimjeng’ and ‘Jugkatap’, respectively, while TBC in treated arils increased by 1.8, 1.7 and 3.5 log CFU g⁻¹, respectively.

The initial yeast and mold counts in ‘Honghuay’, ‘Gimjeng’ and ‘Jugkatap’ were 0.6, 1.8 and 1.8 log CFU g⁻¹. The dipping in PAA solution reduced the initial yeast and mold counts in peeled arils by 0.8-2.3 log cfu/g when compared with the control. Yeast and mold counts in treated arils of ‘Honghuay’, ‘Gimjeng’ and ‘Jugkatap’ increased to 3.1, 2.9 and 4.7 log CFUg⁻¹ after 12 days of storage, respectively, while the yeast and mold counts of the control were 5.4-7.5 log CFU g⁻¹. ‘Jugkatap’ had a higher yeast and mold count than ‘Honghuay’ and ‘Gimjeng’, but no visual mold growth was observed on the surface of the arils.

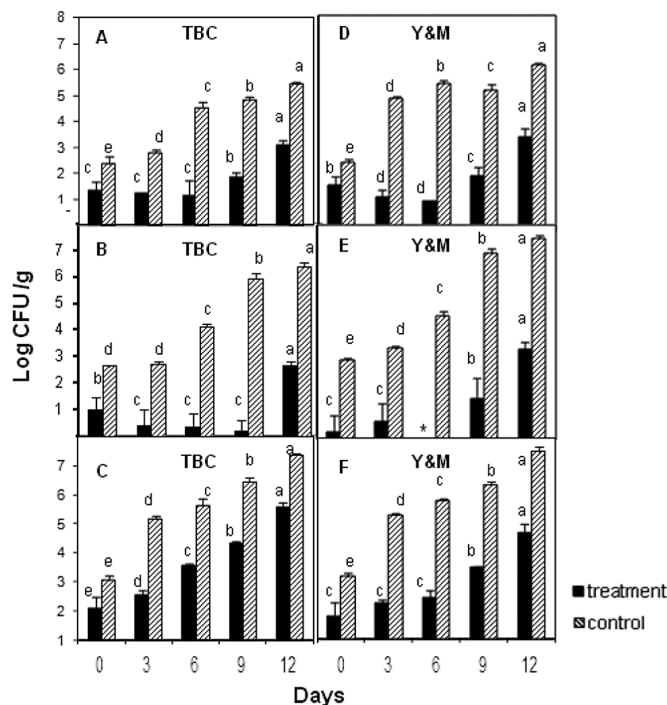


Figure 6. Changes in Total bacteria (TBC) and yeast and molds (Y&M) of minimally processed litchi cv. Honghuay (A,D), Gimjeng (B,E) and Jugkatap (C,F) during 12 days of storage at 4±1°C. Bars represent the standard errors of mean resulting $p < 0.05$. Bar with distinct lower case letters represent the significantly different results ($p < 0.05$). The asterisk symbol (*) in the graph represent the yeast-mold counts was lower than 1 colony per g sample.

Sensory quality and shelf life

The initial sensory quality scores for appearance, color, flavor, texture and overall acceptability of all three cultivars were very high (7.4-8.4). Color scores for 'Jugkatpat' arils (8.2) were higher than that of the other cultivars (7.8 and 8.0) on day 0, because there was no brown color on the internal surface of the arils (Fig. 7). During storage, color scores of all three cultivars decreased from an initial 7.8-8.2 to 5.0-5.4 after 6 days of storage. The change of color was indicated by the decrease in L* value. Appearance scores decreased from an initial 8.4-8.0 to 5.0-5.4 after 6 days of storage. 'Gimjeng' and 'Jugkatpat' arils were not translucent after 6 days of storage; however, softening around the cut area of the stem-end of all three cultivars was observed, as indicated by higher juice leakage and loss of firmness during storage. After five days of storage, firmness and aroma scores decreased sharply and the acceptability score dropped below the acceptable level in all three cultivars. These results indicated that the minimally-processed litchi becomes unacceptable to consumers after five days of storage, while the control became unacceptable after only three days.



Figure 7. Appearance of minimally-processed litchi fruit cv. 'Honghuay', 'Gimjeng' and 'Jugkatpat'.

DISCUSSION

The increased weight loss and juice leakage in minimally-processed litchi fruit during storage is due to the lack of protective pericarp and the wounding effect of deseeding, resulting in a delicate product easily susceptible to dehydration (Dong et al., 2004). Shah and Nath (2006, 2008) also reported juice leakage in minimally-processed litchi treated with an anti-browning agent, but this was reduced significantly by adding calcium lactate. They concluded that juice leakage was the result of loss of cellular sap due to loss in biochemical alterations. Juice can move from internal cell to outer cell, and the mixing of substrates and enzymes, such as α - and β -galactosidases, can enhance the reactions. In addition, the growth of pectolytic bacteria that can hydrolyze pectin in cell walls results in a loss of firmness (Toivonen and Brummell, 2008). Deseeding or the cutting process is the major factor that induced the release of juice from vacuoles of damaged cells. Part of the higher juice leakage in 'Honghuay' might be due to

the large damage to the arils caused by deseeding, since their arils are entangled with the seeds and do not separate as easily as the other two cultivars. Effect of cutting on juice leakage has also been reported in peeled citrus (Pao et al., 1997), fresh-cut watermelon (Fonseca and Rushing, 2006), melon (Ergun et al., 2007) and pineapple (Montero-Calderín et al., 2008). L^* value of litchi arils decreased continuously during storage due to the change into a yellowish color. This result agreed with the 15% decrease in the L^* value of peeled litchi arils dipped in the combination treatments of anti-browning agent, firming agent and osmo-vacuum dehydration after storage for 24 days in moderate vacuum packaging (Shah and Nart, 2008).

TA increased and pH decreased in all cultivars of minimally-processed litchi fruit during 12 days of storage, especially in the control. The TA and pH of 'Honghuay' changed more than the other two cultivars. This can be explained by the deterioration of tissues during deseeding, which induced a physiological response to injury, with longer storage times enhancing the biochemical alteration by microorganisms. This result disagreed with two other reports of whole litchi fruit that showed the percent TA decreased and pH increased (Chittavitti, 2006; Sawwa, 2003). However, our results are consistent with an earlier report in minimally-processed litchi fruit cv. Rose by Shah and Nart (2008), which showed the same trend in percentage changes of TA and pH during storage at $4\pm 1^\circ\text{C}$ in plastic trays sealed with polypropylene film under a moderate vacuum condition.

Percent TSS and ascorbic acid of treated arils decreased after dipping in PAA solution when compared with the control. This might be due to the dissolution of components in litchi arils into the PAA solution, or the water absorption into the tissue during dipping. A higher degradation of ascorbic acid in 'Honghuay' than 'Ginjeng' and 'Jugkat' is related to the high tissue damage and juice leakage. Moreover, a high reactivity to O_2 has been associated with degradation of ascorbic acid during storage (Shah and Nath, 2008). Dong et al. (2004) made similar observations; ascorbic acid decreased about 31% in arils dipped in 1-3% chitosan during 6 days storage. Ascorbic acid contents of peeled litchi arils treated with anti-browning and firming agents showed 80-90% loss after held for 24 days in moderated vacuum packaging at $4\pm 2^\circ\text{C}$ (Shah and Nath, 2008). The initial TSS/TA ratio of 'Honghuay', 'Ginjeng' and 'Jugkat' was in the range of 30-40, 50-60 and 40-50, respectively. The results showed that 'Ginjeng' had the highest sweet taste, followed by 'Jugkat', while 'Honghuay' had a sweet and acidic taste. However, the sweet taste decreased in all cultivars over the 12 days of storage. Thus, the optimal TSS/TA ratio for the production of minimally-processed litchi fruit should be in the range of 40-50. If the TSS/TA ratio is too high, litchi fruit over ripen, allowing spoilage bacteria to easily grow and resulting in a short shelf life.

PAA was an effective sanitizer for extending the shelf life of three cultivars of minimally-processed litchi fruit. The TBC and yeast and mold counts are the most important factors determining the shelf life of minimally-processed litchi fruit. They must not exceed standard set by the Department of Medical Sciences for ready-to-eat fruit and vegetables; $< 7 \log \text{cfu/g}$ for total bacteria count and < 4

log cfu/g for yeast and molds (Department of Medical Sciences, 2010). Arils in PAA treatment had TBC and yeast and mold counts lower than control throughout the storage period. After 12 days of storage, TBC in arils treated with PAA of ‘Honghuay’ (3.1 log cfu/g), ‘Gimjeng’ (2.6 log cfu/g) and ‘Jugkatpat’ (5.6 log cfu/g) cultivars were all within the acceptable standard. However, yeast and mold counts for the ‘Jugkatpat’ cultivar (4.7 log cfu/g) were higher than the standard after 9 days of storage.

Of the three cultivars, ‘Jugkatpat’ litchi is the most appropriate for processing to peeled litchi arils, given its high aril proportion and the absence of a brown color on the internal surface, resulting in good visual quality (Fig. 7). Moreover, ‘Jugkatpat’ arils had more ascorbic acid than the ‘Honghuay’ or ‘Gimjeng’ cultivars, making them more attractive to health conscious consumers. In addition, the ‘Jugkatpat’ cultivar is the most appropriate candidate for minimally-processed produce, because of its larger fruit size, ease of deseeding, the absence of brown color on the internal surface of the arils and the high ascorbic acid content.

The firmness and aroma scores decreased sharply and the overall acceptability score dropped below the acceptable level in all three cultivars after five days of storage, confirmed with firmness and juice leakage measurements. Thus, lower temperature storage for retarding a lag phase of microbial growth will be investigated in a further study. Firming agents will also be used to improve the firmness of litchi arils in a future study.

CONCLUSION

Minimally-processed litchi has a shelf life up to five days at $4\pm 1^\circ\text{C}$. Firmness and L^* values of the arils decreased and juice leakage increased during storage. Minimal changes were noted in the chemical properties of minimally-processed ‘Gimjeng’ and ‘Jugkatpat’ litchi cultivars. Ascorbic acid decreased significantly during storage. PAA reduced the total bacteria and yeast-mold counts of minimally-processed litchi fruit compared to control. ‘Jugkatpat’ cultivar was the most appropriate for processing to peeled litchi arils, given its high aril proportion, high ascorbic acid content and the absence of a brown color on the internal surface, which results in good visual quality.

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