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Effect of Edible Coatings and Other Surface Treatments on Pericarp Color of Thai Lychee Cultivars

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Lychee fruit (*Litchi chinensis* Sonn.) have a brilliant red pericarp upon harvest that turns brown during shipping and storage. 'Hong Huay' and 'Juckapat' lychee fruit were harvested at the commercial stage (90% to 100% red pericarp) in Thailand. In five separate experiments, fruit with pedicels were dipped for 30 seconds in various treatment solutions, including no dip and water as controls, ascorbic acid, citric acid, acetic acid, chitosan, HCl, and two Semperfresh products, in an effort to retard browning of the percarp. Fruit were air-dried, and stored at 2 or 10 °C with 90% relative humidity for 1 to 3 weeks. Total soluble solids (TSS), titratable acidity (TA), weight loss, total ascorbic acid (TAA), and color (hue angle and chroma) were measured over the storage period. During storage, TSS generally increased while TA and TAA generally decreased (except for those treatments that were treated with ascorbate). Most treatments reduced weight loss compared to untreated fruit. Treatment of lychee fruit with acidified coatings including Semperfresh, acidified Semperfresh (with 2% citric acid), Semperfresh lychee treatment power (LTP) ± citric acid and chitosan + HCl sometimes resulted in brighter, redder color than control fruit, as evidenced by lower hue angle or higher chroma values.

Lychee (*Litchi chinensis* Sonn.) is a non-climacteric subtropical to tropical fruit of high commercial value on the international trade market. This fruit, however, are highly perishable due to rapid loss of bright red peel color which turns brown within 24 to 28 h after harvest (Holcroft and Mitcham, 1996). The quality of the edible portion, however, is not necessarily affected. This discoloration is thought to be due to dehydration and/or oxidation leading to microcracking of the cuticle (Underhill and Critchley, 1993). It also may be due to leaking of enzymes and substrates and subsequent degradation of the red pigments (anthocyanins) and phenols by polyphenol oxidase (PPO), peroxidase (POD) (Jiang, 2000; Jiang and Fu, 1998, 1999; Jiang et al., 2004; Underhill, 1992), and/or phenylalanine ammonia lyase ((PAL) (Kaewchana et al., 2006a) and anthocyanase (Zhang et al., 2001). Ultimately brown pigments are formed or revealed, especially as cellular pH increases to the 3.0 to 5.0 range due to increased PPO activity. This leads to conversion of anthocyanin structures that result in red color to those that are colorless (Jiang et al., 2004; Underhill and Critchley, 1995). One study showed that as fruit browned during storage, peroxides and ethylene production increased along with membrane permeability accompanied by a decrease in polyamines. Addition of polyamines, especially spermine, retarded browning and delayed the increase in ethylene production , peroxide levels and cell leakage (Jiang and Chen, 1995). Acidification of the peel surface and application of coatings can retard dehydration and discoloration. (Jaos et al., 2005; Kaewchana et al., 2006a) by decreasing PPO activity and maintaining anthocyanins in their red-colored form. Sulfur dioxide (SO_2) fumigation and hydrochloric acid (HCl) dips have been used commercially to maintain lychee color, however, use of SO_2 is discouraged due to related health issues (Holcroft and Mitchanm, 1966). Kaewchana et al. (2006b) and Jiang and Fu (1999) reported that that relative humidity (RH) during storage affected the rate of peel browning. Use of modified atmosphere packaging (MAP) (Rattanapanone and Boonyakiat, 2005) and controlled atmosphere (CA) (Tian et al., 2005) improved lychee overall quality and color, respectively, but are considered expensive. Acidifying treatments, alone or in combination with coatings, have produced varied results for color maintenance (Jiang et al., 2005; McGuire and Baldwin, 1998; Plotto et al., 2006). Semperfresh, a sucrose ester coating, was reported to retain color of 'Hong Huay' by reducing weight loss. Theoretically, acidified coatings can both lower the fruit surface pH, and thereby inhibit enzyme activity and formation of colorless anthocyanins, and reduce the dehydration that contributes to the browning of the peel. The object of this study was to further examine the effects of acidified edible coatings, powders, and aqueous treatments on the physical and chemical properties of Thai lychee cultivars.

Materials and Methods

FRUIT MATERIAL. Lychee fruit 'Hong Hauy' and 'Juckapat' were harvested from local farms at the commercially mature stage with 90% to 100% of the peel exhibiting red color.

TREATMENT. The fruit, with 0.5-cm pedicels, were dipped in treatment solutions or coatings for 30 s, air dried and packed in clamshells with 8–20 fruit per clamshell and 2–4 clamshells per treatment. The fruit were stored at 2 or 10 °C with 90% relative humidity for up to 3 weeks. Treatment solutions and coatings are listed in Table 1. The experiments were arranged in a completely

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Table 1. Lychee treatment solutions and coatings.

A.) Aqueous treatments	Concn
1. Citric acid	2.0–3.0%
2. Ascorbic acid	2.0%
3. Calcium ascorbate	2.0%
4. Acetic acid	2.0%
5. Hydrochloric acid	0.25–0.50 N
B.) Polysaccharide coatings	
1. 0.5% Chitosan in 2% acetic acid	
2. 1.0% Chitosan in 2% acetic acid	
3. 0.5% Chitsan in 2% citric acid	
4. 1.0% Chitosan in 2 % citric acid	
5. 0.5% Chitosan in 0.25 N HCl	
6. 1.0% Chitosan in 0.5 N HCl	
7. Sucrose fatty acid esters (Semperfresh ± 2% citric acid)	
8. Lychee treatment powder [Semperfresh LTP (acid formulation) ± 2% citric acid]	

randomized design with two to four replicates per treatment. Data were analyzed by analysis of variance (ANOVA) with the SAS statistical software (SAS System Software Version 9.1, SAS Institute, Cary, NC, 1999). Separation of means was performed with Duncan's multiple range test, with $\alpha = 0.05$.

Measurements. Peel color was measured by a color meter (Color Quest XE, HunterLab, Reston, VA). Measurement of pulp juice pH was done with a pH meter (Model C831, Consort, Turnhout, Belgium). Total titratable acidity (TA) of pulp juice, expressed as percent malic acid (Plotto et al., 2006), was determined using the 2,6-dicloroindophenol titrimetric method (Ranganna, 1977). Total soluble solids (TSS) content of the pulp juice was measured by means of a digital refractometer (Model PR-101, Atago, Tokyo, Japan). Weight loss was determined by weighing the fruit initially, then at various times during storage, and expressed as percentage of initial weight.

Results and Discussion

Two Thai lychee cultivars were treated with acidic aqueous solutions, polysaccharide coatings, and an acidified powder with or without further acidification (Table 1). Initially fruit treated

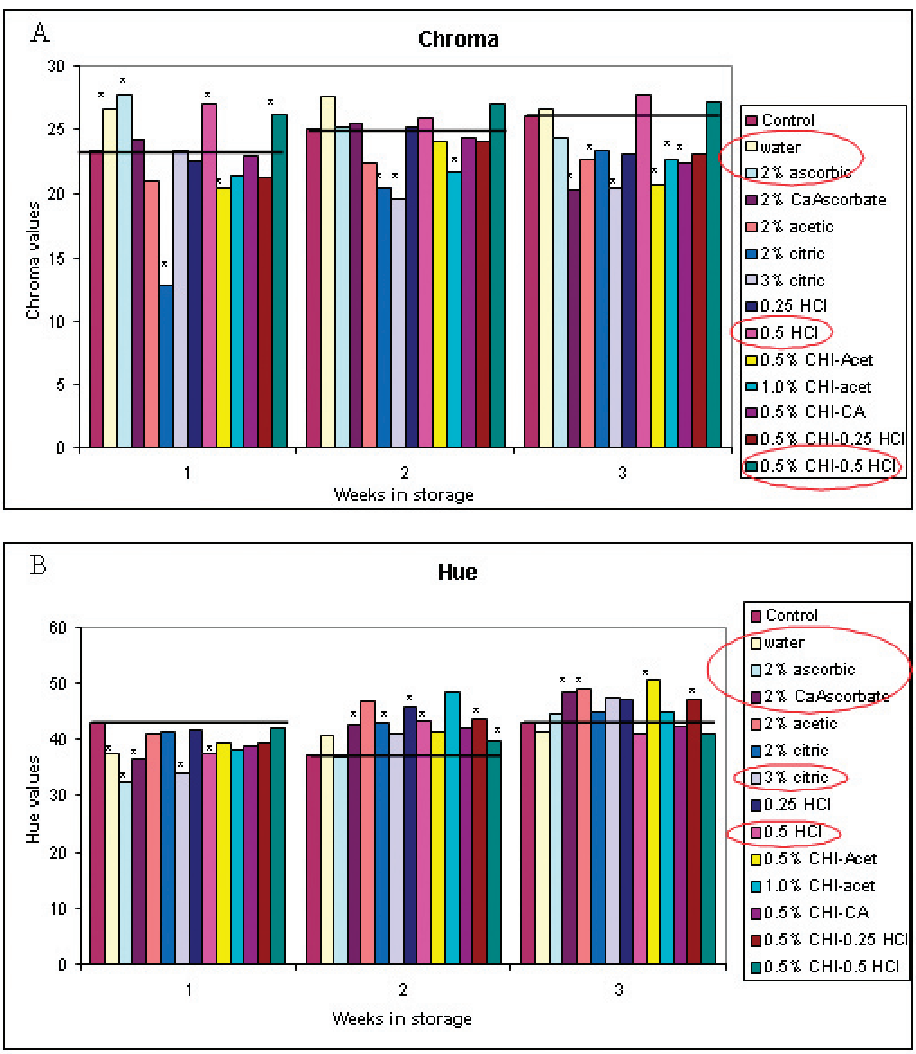

Fig. 1. Chroma (**A**) and hue (**B**) of 'Hong Huay' lychee fruit dipped in aqueous acidic treatments and acidified chitosan coatings, then stored at 2 °C with 90% relative humidity. CaAscorbate = calcium ascorbate; CHI = chitosan ± Acet = acetic acid; or CA = citric acid. A "*" denotes significant difference from control at ($\alpha = 0.05$).

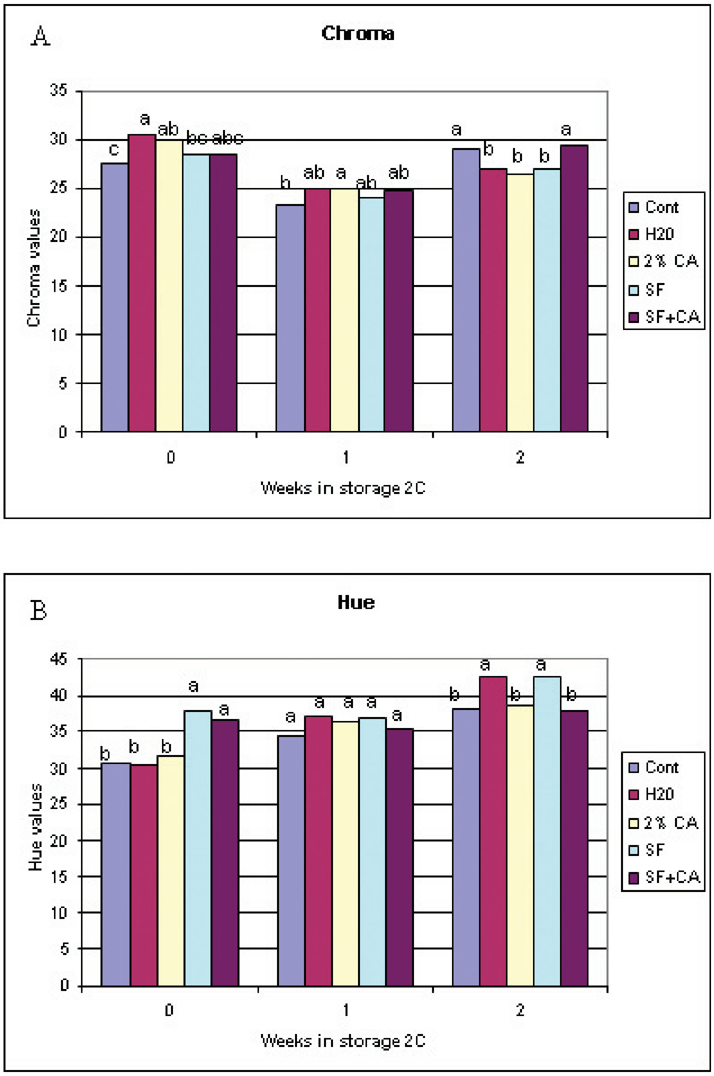

Fig. 2. Chroma (**A**) and hue (**B**) of 'Hong Huay' lychee fruit dipped in aqueous acidic treatments or an acidified (SF+CA) or non-acidfied (SF) sucrose ester coating, then stored at 2 °C with 90% relative humidity. Bars with the same letter are not significantly different at (α = 0.05). Cont = control.

with aqueous acidified solutions and chitosan coating exhibited some reduction of browning and so were brighter and had more red color in the first week of storage at 2 °C as exhibited by higher chroma and lower hue, respectively (Fig. 1 A and B). The most successful treatments were water, 2% ascorbic acid, 2% calcium ascorbate, 0.5 N HCl, and 0.5% chitosan coating further acidified with 0.5 N HCl (circled in Fig. 1). By 2 and 3 weeks of storage, however, all treated fruits exhibited less chroma and higher hue than untreated controls. Similar results were found for fruit treated with water, citric acid and acidified Semperfresh (a sucrose ester coating) in the first week for chroma and hue (Fig. 2 A and B), although none were significantly different from control for chroma or showed significantly lower hue. The coated fruit resulted in higher total ascorbic acid and those treated with citric acid showed higher titratable acidity (Table 2A). During storage, TSS generally increased while TA and TAA generally decreased (except for those treatments that were treated with ascorbate, data not shown).

When the fruit were stored at the abusive temperature of 10 °C for up to 1 week, those treated with acidified Semperfresh generally maintained higher chroma and lower hue (nonsignificant for hue) for 6 d (Fig. 3 A and B). Most treatments slightly reduced water loss, and acidified Semperfresh resulted in higher TSS and TAA (Table 2B).

For 'Juckapat' fruit stored at 2 °C, there was not much effect of treatments on chroma, but the lychee treatment powder (LTP) with or without further acidification was effective at maintaining the red color as evidenced by lower hue (Fig. 4 A and B), although only significantly different from control at time 0. Again, most treatments reduced water loss with the exception of Semperfresh. Control, water, and treatments with CA resulted in the highest TA, and Semperfresh and water treated fruit exhibited the highest and lowest TAA, respectively (Table 2C). The more successful treatments were repeated (citric acid, Semperfresh and LTP acidified with citric acid) and all treated fruit showed higher chroma (significant only at time 0, Fig. 5A), acidified LTP showed lower hue compared to control (treated with water) in the first week, although nonsignificant, but lost effectiveness by the second week of storage (Fig. 5B). The Semperfresh coating and powder (LTP) reduced water loss, CA and LTP+CA had lower TA, LTP+CA showed the highest TSS, and CA±LTP had higher TAA than Semperfresh+CA (Table 2D).

Table 2. Effect of treatments on lychee fruit weight loss (%WL), titratable acidity (TA), total soluble solids (TSS), and total ascorbic acid (TAA) stored at 2 °C for 2 weeks (Experiments A, C, and D) or 10 °C for 1 week (Experiment B). SF = Semperfresh; CA= citric acid; LTP = lychee treatment powder (Semperfresh product); FW = fresh weight.

Experiment	Treatment	WL (%)	TA (%)	TSS (%)	TAA (mg·g^{-1} FW)
A	Untreated	---	0.24 ab	19.30	0.22 b
	Water	---	0.20 b	19.35	0.25 b
	SF	---	0.22 ab	19.45	0.29 b
	2% CA	---	0.25 a	19.28	0.22 b
	SF+CA	---	0.23 ab	19.42	0.48 a
B	Untreated	1.8	0.25	19.73 b	0.40 bc
	Water	2.2	0.25	19.47 b	0.35 c
	2% Ca	1.4	0.25	19.63 b	0.53 ab
	SF+CA	1.7	0.25	20.27 a	0.64 a
C	Untreated	4.4 a	0.19 a	17.00	0.59 ab
	Water	3.4 bc	0.21 a	16.50	0.45 c
	2% CA	3.9 b	0.18 a	16.90	0.51 bc
	SF	4.6 a	0.17 ab	16.10	0.61 a
	SF+CA	3.2 cd	0.18 a	17.10	0.61 a
	LTP	2.4 c	0.14 b	16.40	0.53 abc
	LTP+CA	2.8 de	0.17 a	18.80	0.53 abc
D	Water	2.5	0.21 a	15.75 ab	---
	2% CA	2.8	0.15 b	15.45 b	0.46 a
	SF+CA	2.2	0.19 a	16.15 ab	0.38 b
	LTP+CA	1.6	0.16 b	17.50 a	0.49 a

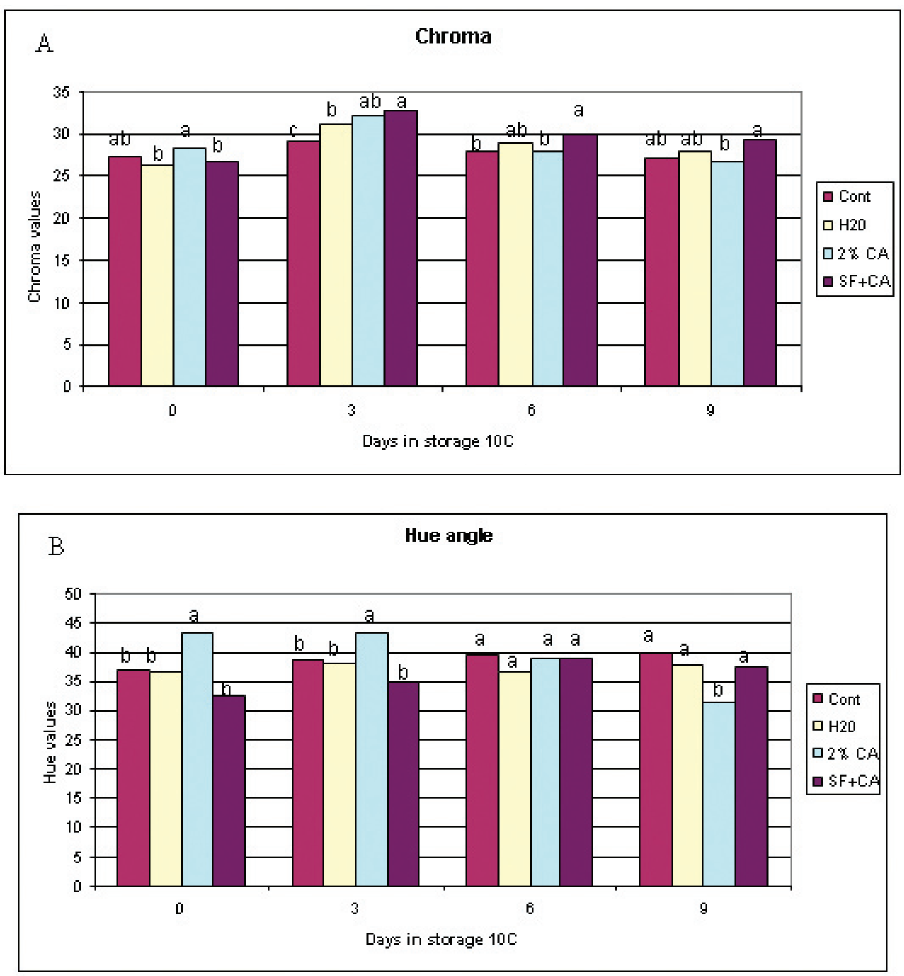

Fig. 3. Chroma (**A**) and hue (**B**) of 'Hong Huay' lychee fruit dipped in citric acid (CA) or Semperfresh + citric acid (SF+CA), a sucrose ester coating, then stored at 10 ºC with 90% relative humidity. Bars with the same letter are not significantly different at (α = 0.05). Cont = control.

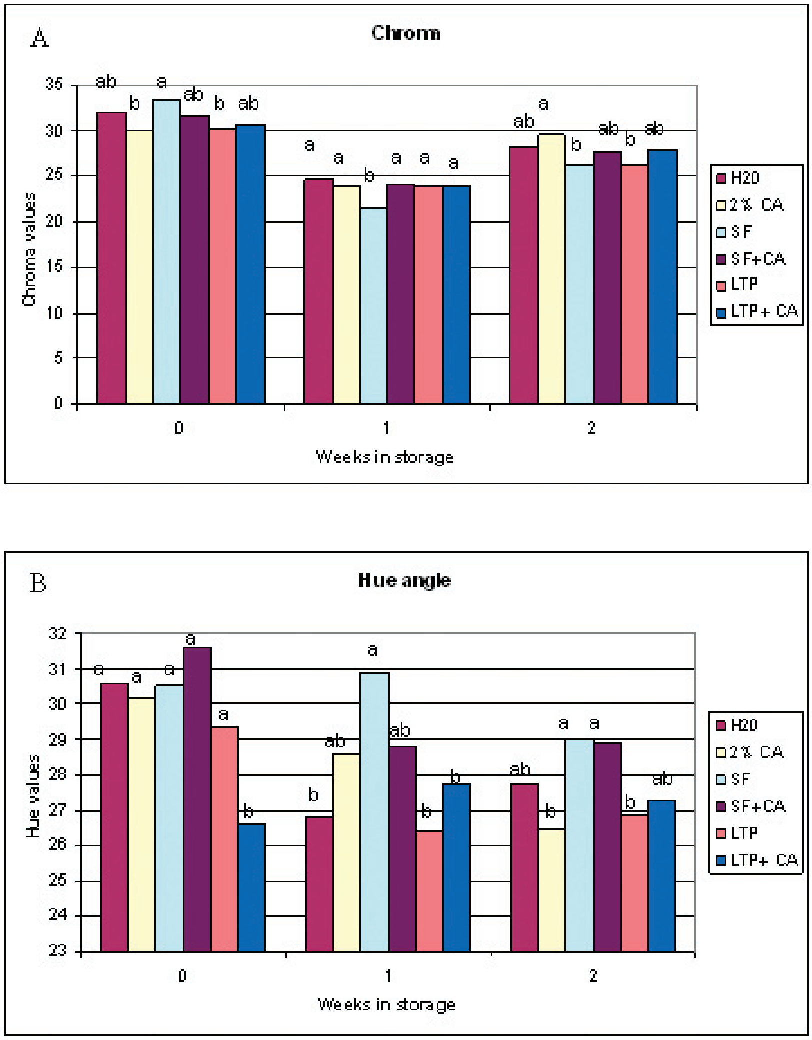

Fig. 4. Chroma (**A**) and hue (**B**) of 'Juckapat' lychee fruit dipped in citric acid (CA) or Semperfresh ± citric acid (SF, SF+CA), lychee treatment powder ± citric acid (LTP, LTP+CA), then stored at 2 °C with 90% relative humidity Bars with the same letter are not significantly different at ($\alpha = 0.05$). Cont = control.

In conclusion, there is some effect for acidified treatments, but only in first 1–2 weeks of storage at 2 °C, however the effect of acidification and coatings is greater when the fruit are stored at 10 °C. Often treatments were better than the untreated control, but not than fruit treated with water (which also helps delay dessication). Coatings generally resulted in higher TSS, TAA and sometimes TA as well as generally reducing weight loss. The acidified coatings and particularly the LTP seemed to be effective in maintaining color as Plotto et al., (2006) found for cellulose and carageenan coatings. These findings were similar for both varieties.

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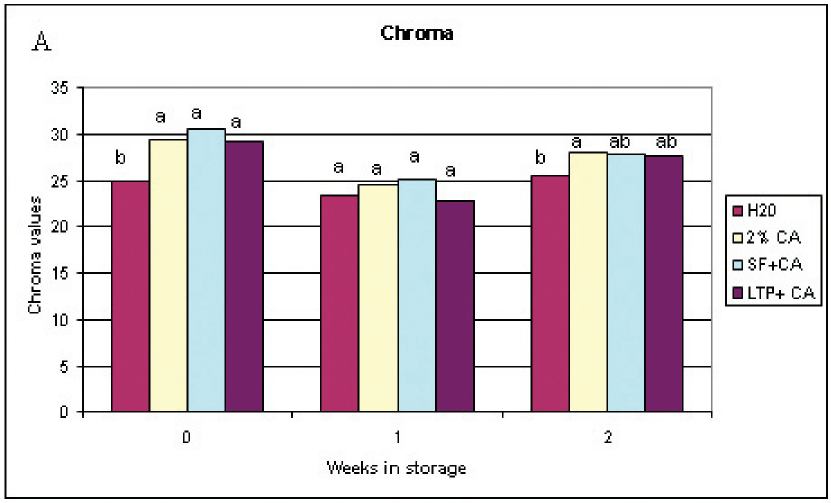

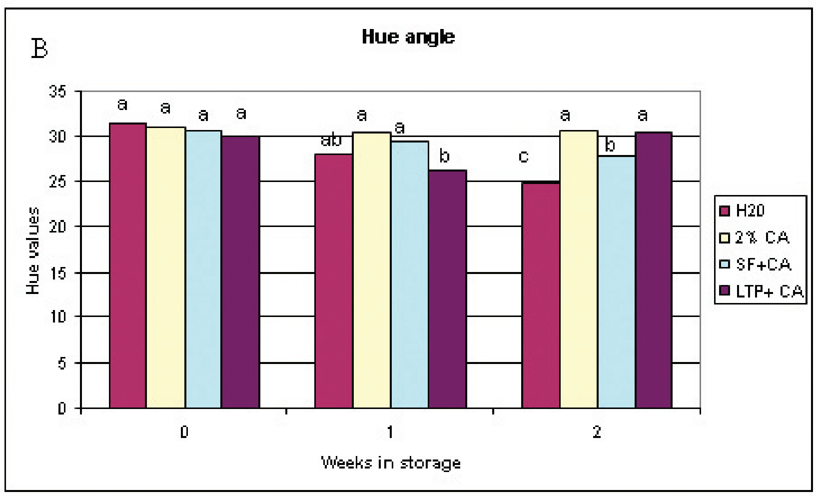

Fig. 5. Chroma (**A**) and hue (**B**) of 'Juckapat' lychee fruit dipped in citric acid (CA) or Semperfresh ± citric acid (SF, SF+CA), lychee treatment powder ± citric acid (LTP, LTP+CA), then stored at 2 °C with 90% relative humidity. Bars with the same letter are not significantly different at ($\alpha = 0.05$). Cont = control.

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