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A REFEREED PAPER

EDIBLE COATINGS AND OTHER SURFACE TREATMENTS TO MAINTAIN COLOR OF LYCHEE FRUIT IN STORAGE

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Abstract. **The bright red pericarp of lychee (*Litchi chinensis* Sonn.) fruit quickly turns brown after harvest due to peel dehydration, anthocyanin degradation, and fungal growth on the fruit surface. Lychee fruit, cv. 'Brewster' and 'Mauritius' in Florida, and 'Juckapat' in Thailand, were dipped in acidic treatments (2-2.5% citric acid, 2% ascorbic acid, 2% acetic acid, 1% isoascorbic acid), antioxidants (0.5% acetylcysteine, 0.02% hexylresorcinol), antimicrobial treatments (peroxyacetic acid [Storox], 5 or 20% ethanol) and various coatings (carrageenan, hydroxypropylcellulose [HPC], sucrose fatty acid esters [Semperfresh], pectin oligomers, and a carnauba wax emulsion), alone or in combination. Combinations of acid solutions with antioxidants gave better results than acid solutions alone. In particular, the mixture of isoascorbic acid with acetylcysteine and hexylresorcinol gave higher chroma readings with the L*a*b* color measuring system, indicating higher color intensity. This treatment also had better decay control and reduced browning. Ascorbic acid, isoascorbic acid, and acetylcysteine alone resulted in higher chroma in one experiment. Visual quality was higher for these treatments after 15 and 21 days storage at 5°C, as well as for the sucrose fatty acid ester. HPC performed well on the Thai fruit, but not on the Floridian fruit. Finally, among the antimicrobial treatments, ethanol at 5% had lower browning and better decay control, and resulted in higher visual quality of 'Mauritius' lychee after 2 weeks. Future efforts will also aim at reducing pathogen pressure in the field, as well as after harvest.**

The lychee (*Litchi chinensis* Sonn.) fruit is a small (3-5 cm diameter) non-climacteric tropical fruit. At maturity, the bright attractive red pericarp is peeled and reveals the juicy white-fleshed endocarp with a delicate flavor. However, the pericarp quickly loses its bright red color within 24 to 28 h after harvest (Holcroft and Mitcham, 1996). While this does not affect eating quality, the fruit is less attractive for marketing.

Causes of browning of the lychee pericarp have been attributed to anthocyanin breakdown, polyphenol oxidase (PPO), and peroxidase (PO) activities (Jiang et al., 2004; Underhill, 1992). PPO is involved in anthocyanin degradation in the presence of phenolic compounds, naturally high in the lychee pericarp (Jiang, 2000; Jiang et al., 2004; Underhill, 1992). Moreover, an anthocyanase cleaving the sugar moiety from the anthocyanin was recently found and resulted in a colorless anthocyanidin at pH above 3.0 (Zhang et al., 2001; 2003). The unstable anthocyanidin produces an *o*-phenol, which is also a good substrate for PPO, producing even more brown pigments (Zhang et al., 2001). PO activity is also involved in the formation of brown polymeric pigments (Jiang et al., 2004; Zhang et al., 2005); its activity increases after harvest (Underhill and Critchley, 1995). In addition to oxidative enzymatic activity, as pH increases closer to 5.0 in the cells, anthocyanins become colorless, thus revealing the oxidation-induced brown pigments (Jiang et al., 2004; Underhill and Critchley, 1994). Furthermore, membrane leakage naturally occurring during fruit senescence, reduces compartmentation between vacuoles and cell solutes, and contact between anthocyanin-degrading and oxidative enzymes is increased (Jiang et al., 2004). Micro-cracks were observed on the pericarp surface with increasing density after 12 h (Underhill and Critchley, 1993; Underhill and Simons, 1993). These microcracks potentially increase the oxidation processes. It is also hypothesized that fungal enzymes might contribute to the browning of lychee pericarp (Underhill and Simons, 1993).

Sulfur dioxide (SO_2) fumigation, followed by hydrochloric acid (HCl) dips have been used commercially to prolong lychee shelf-life and color (Holcroft and Mitcham, 1996). While SO_2 reduces fungal development, it appears to allow better penetration of HCl in the pericarp. However, alternative treatments have been sought, as there is increasing resistance from consumers to having residual SO_2 on foods (Holcroft and Mitcham, 1996). Storage in modified atmosphere packaging (MAP) to prevent dehydration improved some aspects of lychee storage but not color (Rattanapanone and Boonyakiat, 2005), while controlled atmosphere (CA) reduced browning up to 42 d in storage (Tian et al., 2005); but CA is not an affordable technique for small growers in many producing regions of the world. Acidifying treatments applied as dips, alone or in combination with surface coatings would present a more practical technique, but most research gave inconsistent results (Jiang et al., 2005; McGuire and Baldwin, 1998). Lack of reproducibility of anti-browning treatments could be due to different enzymatic systems in different cultivars, and also variations of PPO activity with cultivar and maturity (Jiang et al., 2004). This article reports on further testing of dip treatments with objectives of acidifying, adding antioxidant, and / or preventing dehydration of lychee pericarp with a surface coating.

Materials and Methods

Fruit material. Preliminary experiments were conducted with 'Brewster' and 'Juckapat' lychees. 'Brewster' was harvested in 2004 at the University of Florida experimental station in Home-

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Table 1. Coatings used for preliminary experiments on 'Brewster' lychee in Florida in 2004, and on 'Juckapat' lychee in Thailand in 2005.

Code	Coating	pH
	2004: 'Brewster'	
Citric	Citric acid 2.5%	1.96
CAAcet	Citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	2.00
IAH	Isoascorbate 0.8% + *N*-acetyl-L-cycteine 0.4% + 4-hexylresorcinol 0.02%	2.35
HPC-CAAcet	Hydroxypropylcellulose 2% + citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	1.94
HPC-pep	Hydroxypropylcellulose 2% + peptone 0.5% + citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	2.23
CMC-CAAcet	Carboxymethylcellulose 2% + citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	2.87
CMC-pep	Carboxymethylcellulose 2% + peptone 0.5% + citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	2.95
	2005: 'Juckapat'	
Water	Water	6.78
Citric	Citric acid 2%	2.14
CAAcet	Citric acid 2% + ascorbic acid 1% + *N*-acetyl-L-cycteine 0.5%	2.10
IAA	Isoascorbic acid 1%	2.73
IAH	Isoascorbate 0.8% + *N*-acetyl-L-cycteine 0.4% + 4-hexylresorcinol 0.02%	2.46
HPC	Hydroxypropylcellulose 2%	6.39
Citric + HPC	Citric acid 2%, then hydroxypropylcellulose 2%	—
CARR	Carrageenan 1%	7.82
Citric + CARR	Citric acid 2%, then carrageenan 1%	—

stead, Fla, and 'Juckapat' was obtained from the local market in Chiang Mai, Thailand, in early spring of 2004. In June 2005, 'Mauritius' lychees were obtained from a local grower in Homestead. All treatments were applied the day after harvest.

Procedure. Fruit were sorted for absence of defects, then dipped in the various antioxidant or coating solutions at room temperature for 30 s (Tables 1 and 2), air dried, and packed in 980 mL (1 qt) polystyrene clamshell containers (Deli container type) (CI18-1160 ClearView® SmartLock®, Pactiv Corp., Lake Forest, Ill.). After packing, 'Brewster' was stored at 5°C (41°F) for 3 weeks, 'Juckapat' was stored at 2°C for 2 weeks, and 'Mauritius' was stored at 5°C (41°F) for 2 ('Mauritius first experiment') or 3 weeks ('Mauritius second experiment'). For 'Brewster' and 'Mauritius', three replications of ten fruit were used per coating, while two replications of 8 fruit were used for 'Juckapat'.

Upon storage removal, fruit surface color was measured with a Minolta CR-300 Chroma Meter (Minolta, Tokyo, Japan) calibrated to a white plate using the CIE L*, a*, and b* system in Florida, and with a Hunter Color-meter (Color

Table 2. Coatings used on 'Mauritius' lychee in Florida in a replicated experiment in 2005.

Code	Coating	pH[a]
	2005: 'Mauritius'	
Water	DI-water	5.32-5.60
Citric	Citric acid 2%	1.99-2.00
Ascorbic	Ascorbic acid 2%	1.80-2.53
CA	Citric acid 2% + ascorbic acid 2%	1.96
Acet	*N*-acetyl-L-cycteine 0.5%	2.35
CAAcet	Citric acid 2% + ascorbic acid 2% + *N*-acetyl-L-cycteine 0.5%	1.75-1.95
IAA	Isoascorbic acid 1%	2.57-2.68
IAH	Isoascorbate 1% + *N*-acetyl-L-cycteine 0.5% + 4-hexylresorcinol 0.02%	2.16-2.32
Acetic	Acetic acid 2%	2.41-2.54
Storox	Peroxyacetic acid (PAA) 100-200 ppm[b]	2.78-3.77
5% etOH	Ethanol 5%	3.21
20% etOH	Ethanol 20%	4.64
HPC-CA	Hydroxypropylcellulose 2% + citric acid 2% + ascorbic acid 2% + ethanol 5%	1.73-1.98
CARR-CA	Carrageenan 0.5% + citric acid 2% + ascorbic acid 2% + ethanol 5%	1.62-1.81
PGA-CA	Polygalacturonic acid 0.2% + citric acid 2% + ascorbic acid 2%	1.85-2.09
Low-CA	PGA oligomers, low fragments 0.2% + citric acid 2% + ascorbic acid 2%	2.17-2.28
Medium-CA	PGA oligomers, medium fragments 0.2% + citric acid 2% + ascorbic acid 2%	2.08-2.25
LTP	Lychee treatment powder 5%	5.17-5.09
LTP-CA	Lychee treatment powder 5% + citric acid 2% + ascorbic acid 2%	2.26-2.40
Semperf.	Semperfresh low pH formula	7.0
CA + Semperf	Citric acid 2% + ascorbic acid 2%, then Semperfresh low pH	NV
Carnaub	Carnaub solution at 20%	8.5
CA + Carnaub	Citric acid 2% + ascorbic acid 2%, then Carnaub	NV

[a]pH values given for the first and second experiment in 2005, except for ethanol, Semperfresh and Carnaub, which were only measured in the second experiment. CA and Acet were only applied in the second experiment. NV means "no value".
[b]PAA was 200 ppm in the first experiment, 100 ppm in the second experiment.

Table 3. 'Brewster' color and decay measurements after 3 weeks in storage at 5°C in year 2004.

	Hue	Chroma	% Browning	% Decay
	Initial			
	23.7	34.19		
Treatment	After 3 wks at 5°C			
Control	24.53 bc	30.63 b	55.10 abc	46.30 b
Citric	26.09 a	31.07 b	51.40 c	44.43 b
CAAcet	25.46 abc	29.80 b	54.17 bc	70.37 a
IAH	25.69 ab	32.89 a	46.30 c	22.23 c
HPC-CAAcet	24.48 bc	29.73 b	53.23 bc	64.83 ab
HPC-pep	25.54 abc	27.83 c	63.40 ab	72.23 a
CMC-CAAcet	24.42 bc	27.76 c	56.47 abc	64.83 ab
CMC-pep	24.22 c	25.33 d	65.73 a	77.80 a

Means followed by a different letter within a column are significantly different by the Duncan's multiple range test ($\alpha = 0.05$).

Quest XE, Hunter Lab, USA) in Thailand. Florida fruit ('Brewster' and 'Mauritius') were visually evaluated for percent browning and mold. Percent browning was determined by visually assessing the surface area of the fruit that was brown: 0% brown (peel color was all or mostly red): 25% brown (at least 75% of the peel was red): 50% brown (half of the peel was brown): 75% brown (only 25% of the peel had red color); and 100% brown (none of the peel had red color). Percent decay was determined by numbers of fruit per group with mycelial growth on the surface of the peel. Weight loss was recorded in 2005. 'Juckapat' fruit were analyzed for sugars, acids, and vitamin C. Soluble solid content (SSC) was measured with a digital refractometer (Model PR-101, Atago, Japan). Juice was titrated for TA to pH 8.1 endpoint. Ascorbic acid content was determined using the 2,6-Dichloroindophenol titrimetric method (Ranganna, 1977, 1986).

Coating materials. The coatings formulations are listed in Tables 1 and 2. The following reagents were from Sigma-Ald-

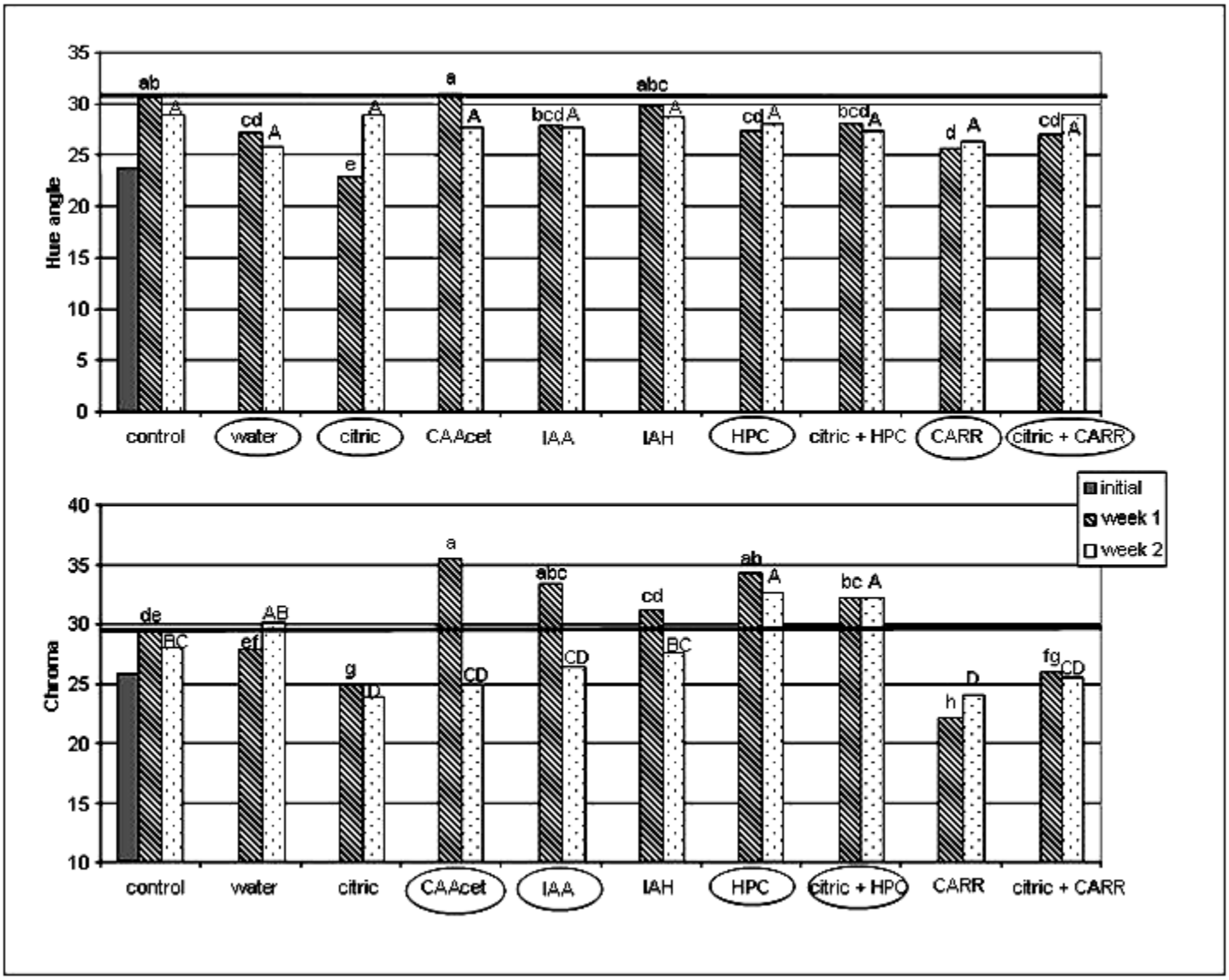

Fig. 1. 'Juckapat' color changes per treatment and storage. Bars with different letters indicate significant differences between treatments by the Duncan's multiple range test ($\alpha = 0.05$). Lower and upper cases are differences between treatments within one and two weeks, respectively. The horizontal lines indicate the level of control after 2 weeks storage. Circles around treatment names are to point out lower hue or higher chroma.

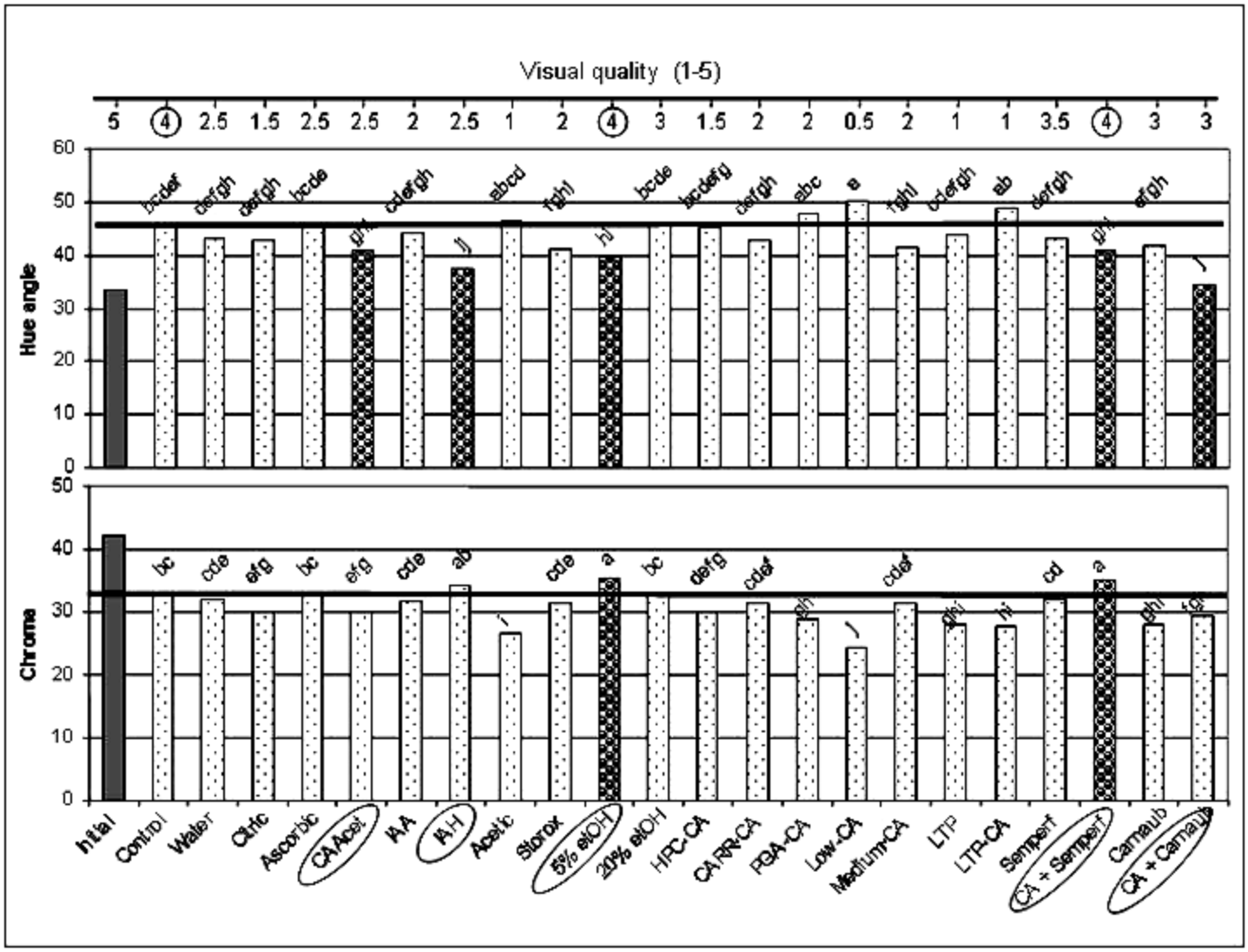

Fig. 2. 'Mauritius' visual quality (1 = low; 5 = good), hue angle, and chroma, after 2 weeks in storage (first experiment, year 2005). Bars with different letters indicate significant differences between treatments by the Duncan's multiple range test ($\alpha = 0.05$). Initial value, measured right before treatments, is only for indication, and is not included in the ANOVAs for means separation. The horizontal lines indicate the level of control after 2 weeks storage. Circles around treatment names and bars with darker fills are to point out lower hue or higher chroma.

rich, St. Louis, Mo., USA: citric acid, 99.5% FCC; ascorbic acid, 99%; *N*-acetyl-L-cycteine, reagent grade; D-isoascorbic acid; 4-hexylresorcinol; carrageenan, from Irish Moss, Type I, commercial grade; peptone, N-Z-soy peptone; polygalacturonic acid (PGA) sodium salt; carboxymethylcellulose (CMC) sodium salt, low viscosity. Hydroxypropylcellulose (HPC), Klucel, LF, was from Aqualon, Wilmington, Del. Acetic acid, glacial, was from Fisher, Fair Lawn, N.J. Peroxyacetic acid (Storox®) was from BioSave Systems, Glastonbury, Conn. Ethanol was ethyl alcohol USP grade, 200 Proof. Carnaub, a carnauba-based fruit coating was from Pace International, Yakima, Wash. Lychee treatment powder treatment (LTP) and Semperfresh Formulation II modification I (sucrose fatty acid ester with low pH formula) coatings were from Agricoat Industries, Berkshire, UK. Polygalacturonic acid oligomers were obtained from pectin digestion with endo-polygalacturonase and fractioned into low- and medium-class fragments right before the experiment (Cameron et al., 2005).

Results

Color. In these experiments, color was judged according to the hue angle and chroma values: lower hue indicates a redder fruit, while higher chroma indicates higher color intensity (McGuire and Baldwin, 1998). Preliminary experiments with 'Mauritius' showed that treatments with citric at 2.5%, ascorbic acid at 2.5%, and a solution of isoascorbate with acetylcysteine and hexylresorcinol (IAH) had higher chroma (higher intensity) values than control (data not shown). Therefore, these acidifying and antioxidant substances were maintained in all further experiments, alone or in combination with each other, or added to polysaccharide coatings.

In 2004, for 'Brewster' cultivar, all treatments resulted in fruit with redness similar to control, or less red than control, with hue values similar to or higher than that of control (Table 3). However, fruit treated with IAH had higher chroma (Table 3) and was visually brighter (data not shown). Citric

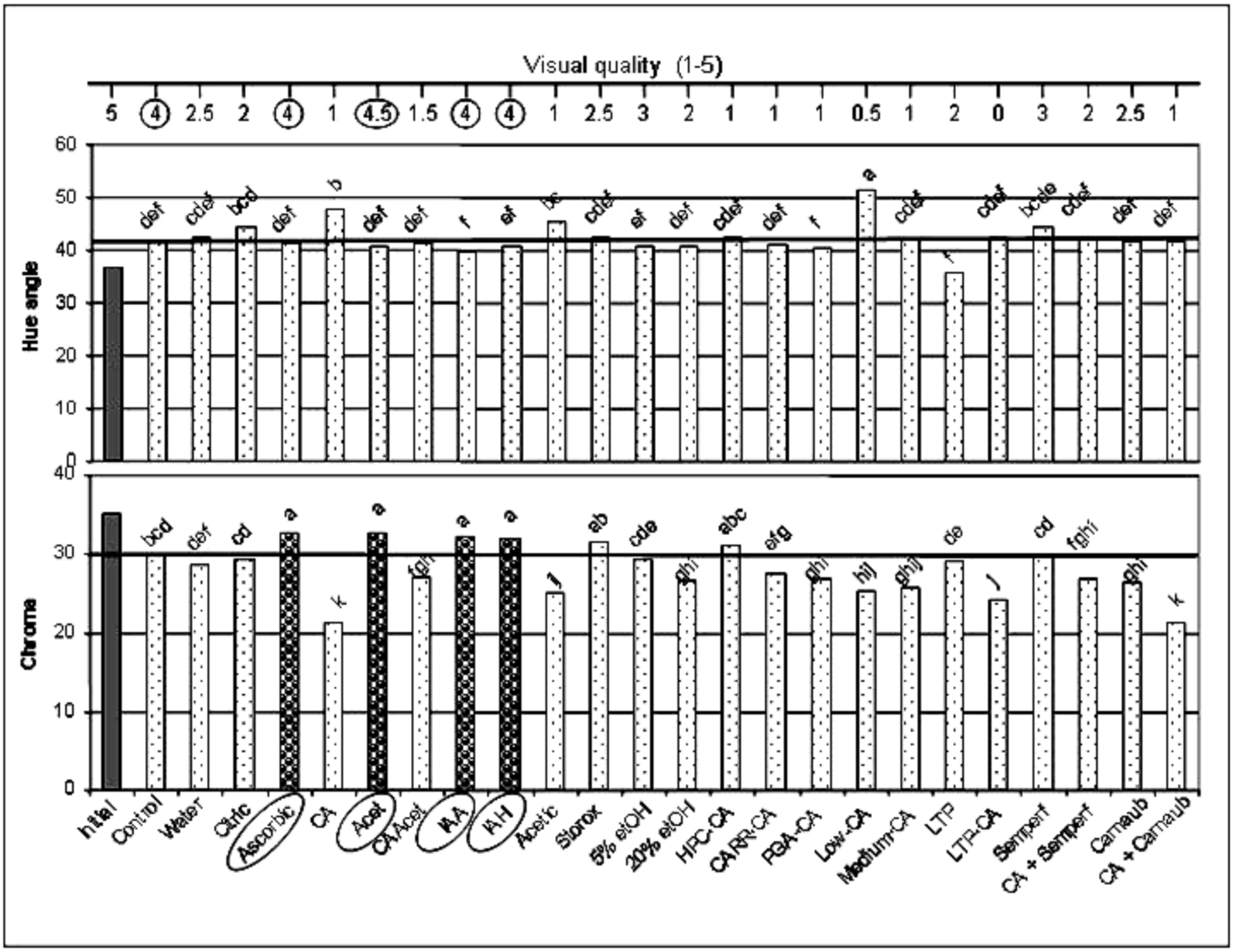

Fig. 3. 'Mauritius' visual quality (1 = low; 5 = good), hue angle and chroma, after 3 weeks in storage (second experiment, year 2005). Bars with different letters indicate significant differences between treatments by the Duncan's multiple range test ($\alpha = 0.05$). Initial value, measured right before treatments, is only for indication, and is not included in the ANOVAs for means separation. The horizontal lines indicate the level of control after 3 weeks storage. Circles around treatment names and bars with darker fills are to point out lower hue or higher chroma.

acid treated fruit also appeared brighter, although chroma was not different from control.

'Juckapat' treated with water, citric acid, HPC, CARR, and citric + CARR had lower hue angle than control after 1 week, but no differences between treatments were maintained after 2 weeks (Fig. 1, top). Chroma was higher (brighter fruit) than control for fruit treated with the solutions of CAAcet, IAA, HPC, and citric + HPC (Fig. 1, bottom). Fruit treated with HPC, and citric + HPC, maintained higher chroma after 2 weeks. For this cultivar, visual evaluation was best for the treatments with a higher chroma. Fruit treated with CARR were dull due to a thick coating residue, even though they were redder. This treatment could be improved with a more diluted formulation of carrageenan.

In 2005, color of 'Mauritius' after 2 weeks storage was best maintained by 5% etOH, and by Semperfresh low pH preceded by an acid dip (CA + Semperf), according to chromameter hue angle and chroma color data (Fig. 2). Visual quality was highest amongst coated fruit for these two treatments, but not higher than control. Treatments with CAAcet, IAH, and CA + Carnaub also had a lower hue angle than control, indicating redder fruit (Fig. 2). 'Mauritius' color after 3 weeks in storage (different fruit, repeated experiment) was best when treated with ascorbic acid, Acet, IAA, and IAH as indicated by chroma and visual evaluation (Fig. 3). Visual evaluation was still acceptable for the 5% etOH treatment and Semperfresh alone.

Browning and decay. For 'Brewster' in 2004, fruit treated with the mixture of IAH had significantly less decay than control and all other treatments. Polysaccharide-based coatings were used with the intention to prevent fruit dehydration. However, these coatings also favored decay development, which was further increased with the addition of peptone (Table 3).

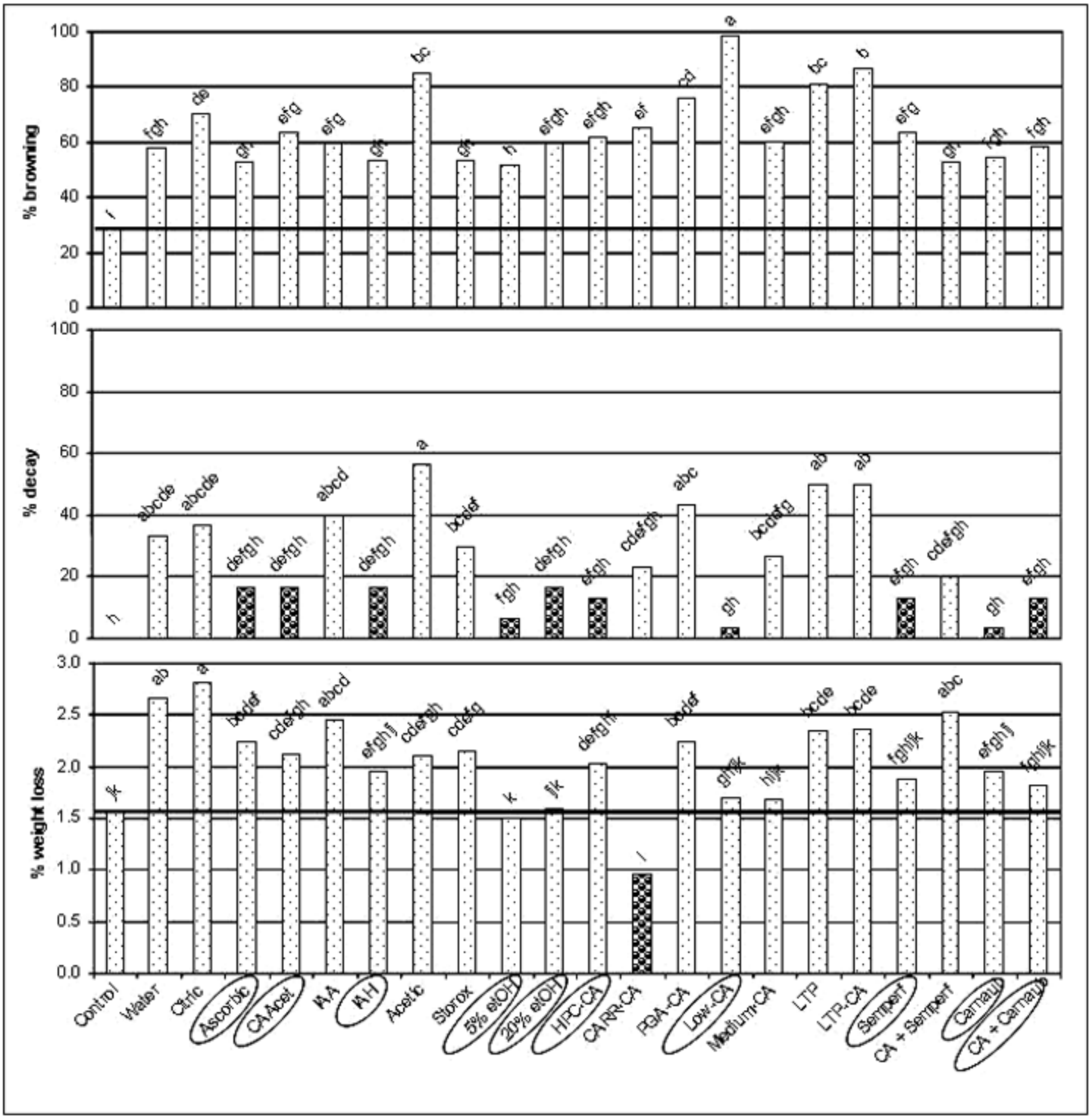

Fig. 4. 'Mauritius' percent browning, percent decay, and fruit weight loss after 2 weeks in storage (first experiment, year 2005). Bars with different letters indicate significant differences between treatments by the Duncan's multiple range test ($\alpha = 0.05$). The horizontal lines indicate the level of control after 2 weeks storage. Circles around treatment names and bars with darker fills are to point out lower decay (but not lower than control), or lower weight loss.

In 2005, no treatment reduced browning or decay of 'Mauritius' lychees when compared to control (Figs. 4 and 5). The primary fungus isolated from the affected peel was *Colletotrichum gloeosporioides* (anthracnose). In the first experiment (2 weeks storage), fruit treated with 5% etOH had lower browning rate, as well as fruit treated with ascorbic acid, IAH, Storox, and CA + Semperf (Fig. 4). Treatments with 5% etOH, low-CA, and Carnaub had the lowest fruit decay, followed by ascorbic acid, CAAcet and IAH solutions, 20% etOH, HPC-CA, Semperfresh alone, and CA + Carnaub (Fig. 4). In the second experiment (3 weeks storage), IAA, low-CA, Carnaub, and CA + Carnaub had the best decay control, but only ascorbic acid had the lowest browning (Fig. 5). It is to be noted that low-CA (low PGA with citric and ascorbic acid) had

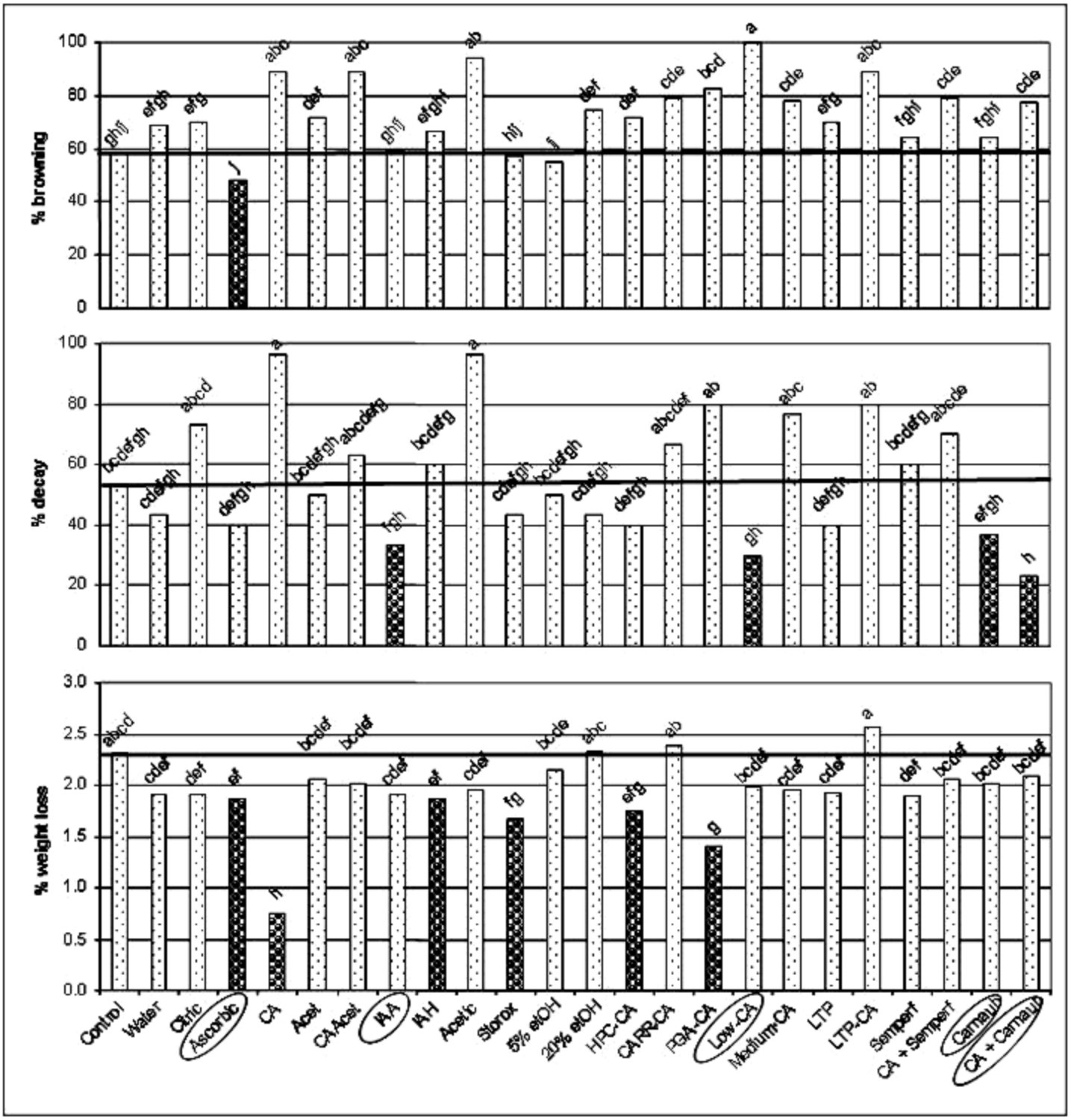

Fig. 5. 'Mauritius' percent browning, percent decay, and fruit weight loss after 3 weeks in storage (second experiment, year 2005). Bars with different letters indicate significant differences between treatments by the Duncan's multiple range test ($\alpha = 0.05$). The horizontal lines indicate the level of control after 3 weeks storage. Circles around treatment names and bars with darker fills are to point out lower browning, decay, or weight loss.

the best decay control in this replicated experiment, but the fruit was uniformly brown. The different fractions of PGA were tested because the medium-fragments seemed to induce some natural plant defense against decay in strawberries (Cameron et al., 2005). In this experiment, none of the PGA fractions had a beneficial effect on lychees; low PGA had a good decay control but it induced a browning response.

Weight loss. Fruit weight loss was reduced by the CARR-CA coating after 2 weeks (Fig. 4), and by ascorbic acid, CA, IAH, Storox, HPC-CA, and PGA-CA after 3 weeks (Fig. 5). There-

fore, none of the coating had a consistent control over dehydration, and some water-soluble solutions had as much weight loss control as the coatings. Most of the coatings were polysaccharide-based. In spite of their hydrophilic nature, they can act like a "buffer" as they absorb moisture and hold it, delaying its release to the atmosphere. Carnaub, which is wax-based, should theoretically prevent moisture loss, but it was not the case in this experiment.

Fruit composition. Quality parameters were only measured for 'Juckapat'. For this cultivar and in this experiment, SSC ranged from 15.95 to 16.67 °Brix and TA from 0.180 to 0.203% citric acid after one week in storage, and from 16.25 to 17.10 °Brix and from 0.154 to 0.200% citric acid after 2 weeks, without differences between treatments. On the other hand, vitamin C was improved by a coating application: treatments with IAH, HPC, and CARR, alone or with citric acid, reduced loss of vitamin C in the fruit. Initial value was 1.36 $mg \cdot g^{-1}$ (fresh weight); after one week in storage, vitamin C content of control fruit was 0.478 $mg \cdot g^{-1}$, while it was 0.628, 0.600, and 0.672 $mg \cdot g^{-1}$ for IAH, HPC, and CARR, respectively. Vitamin C content was still higher for the IAH treatment after 2 weeks (0.528 $mg \cdot g^{-1}$ versus 0.375 $mg \cdot g^{-1}$ for control). Therefore, there may be a beneficial effect for applying coating and antioxidant treatments to maintain lychee quality.

Discussion

Acidifying and antioxidant treatments. A summary of treatments with positive results is presented in Table 4. No one single treatment was superior to the other treatments in all 4 experiments, with three cultivars. Citric acid alone only maintained low hue angle in 'Juckapat', and had a positive result on browning for 'Brewster' (Table 4). Earlier research showed effectiveness of citric acid treatments at much higher concentrations: 1 $mol \cdot L^{-1}$ (~20%) (Terdbaramee et al., 2003). In the current experiments, an effort was made to maintain pH at around 2.0, as fruit tended to lose anthocyanins (bleeding), indicating loss of membrane integrity, when dipped in solutions at lower pH in earlier trials (unpublished). Ascorbic acid alone had a positive effect in reducing browning in both 'Mauritius' experiments, a positive effect on color in the second 'Mauritius' experiment, and a positive effect in reducing decay in the first 'Mauritius' experiment (Table 4). In spite of contradictory discussions about the effect of ascorbic acid on preventing anthocyanin degradation reviewed by Holcroft and Mitcham (1996), recent research showed that ascorbic acid could prevent lychee anthocyanins degradation in vitro (Jiang, 2000). In fact, complementing the citric acid solution with an antioxidant would be beneficial by both preventing anthocyanin decoloration by lowering the pH, and by reducing PPO and PO activities with the antioxidants. Jiang and Fu (1998) had successful results with a solution of 100 $mmol \cdot L^{-1}$ citric acid (~2%) and 10 $mmol \cdot L^{-1}$ glutathione (~0.3%). In the present experiments, the combination of citric acid with ascorbic acid and acetylcysteine (CAAcet) had a positive effect on chroma of 'Juckapat' and on hue angle and decay control of 'Mauritius' in the first experiment (Table 4). The solution containing isoascorbate, acetylcysteine and 4-hexylresorcinol (IAH) had even better results for color measurements, browning evaluation and decay control in more than one experiment (Table 4). That formulation combined with an ultra-low (0.8-1.3) pH solution such as in Joas et al. (2005) might give more consistent results over time.

Table 4. Summary of treatments with some positive results (B = 'Brewster', 3 weeks storage; J = 'Juckapat', 2 weeks storage; M1 = 'Mauritius' first experiment, 2 weeks storage; M2 = 'Mauritius' second experiment, 3 weeks storage).[z]

	Hue angle				Chroma			Browning				Decay				Weight loss		
Treatment	B	J	M1	M2[y]	B	J	M1	M2	B[y]	J	M1[y]	M2[y]	B	J	M1[y]	M2[y]	B	J	M1	M2
Citric	0	+	0	0	0	0	0	0	+	–	0	0	0	–	0	0	–	0	0	0
Ascorbic	–	–	0	0	–	–	0	+	–	–	+	+	–	–	+	0	–	–	0	+
Acet	–	–	–	0	–	–	–	+	–	–	–	0	–	–	–	0	–	–	–	0
CAAcet	0	0	+	0	0	+	0	0	0	–	0	0	0	–	+	0	–	0	0	0
IAA	–	0	0	0	–	+	0	+	–	–	0	0	–	–	0	+	–	0	0	0
IAH	0	0	+	0	+	0	0	+	+	–	+	0	+	–	+	0	–	0	0	+
Storox	–	–	0	0	–	–	0	0	–	–	+	0	–	–	0	0	–	–	0	+
5% etOH	–	–	+	0	–	–	+	0	–	–	+	0	–	–	+	0	–	–	0	0
HPC-CA	0	0	0	0	0	+	0	0	0	–	0	0	0	–	+	0	–	0	0	+
CARR-CA	–	+	0	0	–	0	0	0	–	–	0	0	–	–	0	0	–	0	+	0
Semperf	–	–	0	0	–	–	0	0	–	–	0	0	–	–	+	0	–	–	0	0
Carnaub	–	–	0	0	–	–	0	0	–	–	0	0	–	–	+	+	–	–	0	0
CA + Semperf	–	–	+	0	–	–	+	0	–	–	+	0	–	–	0	0	–	–	0	0
CA + Carnaub	–	–	+	0	–	–	0	0	–	–	0	0	–	–	+	+	–	–	0	0

[z]"+" indicates better than control, "0" indicates no positive result, "–" indicates treatment not performed in that experiment.
[y]When no treatment was better than control, "+" indicates better than other treatments.

Sanitizers and decay control. Although fungal growth on the fruit pericarp has been mentioned as another cause of browning (from enzymes generated by the pathogen) (Underhill and Simons, 1993), the effort of controlling browning by controlling fungal growth has been less investigated than the control of anthocyanin degradation. There was a high anthracnose (*Colletotrichum* spp.) pressure for the Florida fruit harvested in 2004, and in 2005, *Colletotrichum* and *Alternaria* were isolated from the fruit surface. Peroxyacetic acid (Storox) and ethanol were tested to see whether they could control decay without damaging fruit surface. Ethanol at 5% improved color, and had a positive effect on browning and decay control in the first 'Mauritius' experiment (Table 4). Storox had only a positive effect on browning in the first 'Mauritius' trial, and a positive effect on weight loss control (Table 4).

Fruit coatings. Finally, coatings formulated with an acid and antioxidant solution were used to prevent fruit dehydration and maintain an acid environment around the pericarp. In the present trials, the combination of citric acid with ascorbic acid was not sufficient to prevent browning, and therefore, the effect of additional coating was not beneficial. Nevertheless, HPC, alone or with citric acid added, improved chroma of 'Juckapat' fruit (Fig. 1 and Table 4). Acidified HPC also had a positive effect on decay control in the first 'Mauritius' experiments. The sucrose fatty acid ester formulation Semperfresh preceded by an acid dip, had a positive effect on hue, chroma, and browning control of 'Mauritius' in the first experiment (Table 4). Carnaub, a carnauba-based coating formulation, had a beneficial effect on decay control on 'Mauritius', with or without dipping lychee in acid prior to coating. That specific formulation of carnauba left a white residue coating on the fruit, but nevertheless, the application of a film to protect the fruit from pathogen development may be pursued in the future.

Future research will focus more attention to fruit decay prevention before harvest, and will continue testing treatments combining acidifying and antioxidant treatments with protective coatings.

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