JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Edible Coatings Influence Fruit Ripening, Quality, and Aroma Biosynthesis in Mango Fruit

KHUYEN T. H. DANG,[†] ZORA SINGH,*[,†] AND EWALD E. SWINNY[§]

Curtin Horticulture Research Laboratory, Muresk Institute, Faculty of Science and Engineering, Curtin University of Technology, G.P.O. Box U1987, Perth, Western Australia 6845, Australia, and Food and Biological Chemistry Laboratory, Chemistry Centre, 125 Hay Street, East Perth, Western Australia 6004, Australia

The effects of different edible coatings on mango fruit ripening and ripe fruit quality parameters including color, firmness, soluble solids concentrations, total acidity, ascorbic acid, total carotenoids, fatty acids, and aroma volatiles were investigated. Hard mature green mango (*Mangifera indica* L. cv. Kensigton Pride) fruits were coated with aqueous mango carnauba (1:1 v/v), Semperfresh (0.6%), *Aloe vera* gel (1:1, v/v), or *A. vera* gel (100%). Untreated fruit served as the control. Following the coating, fruits were allowed to dry at room temperature and packed in soft-board trays to ripen at 21 ± 1 °C and 55.2 ± 11.1% relative humidity until the eating soft stage. Mango carnauba was effective in retarding fruit ripening, retaining fruit firmness, and improving fruit quality attributes including levels of fatty acids and aroma volatiles. Semperfresh and *A. vera* gel (1:1 or 100%) slightly delayed fruit ripening but reduced fruit aroma volatile development. *A. vera* gel coating did not exceed the commercial mango carnauba and Semperfresh in retarding fruit ripening and improving aroma volatile biosynthesis.

KEYWORDS: *Mangifera indica* L.; Carnauba; *Aloe vera*; Semperfresh; fatty acids; carotenoids; aroma volatiles

INTRODUCTION

Application of an edible coating on the fruit surface imparts a glossy appearance and better color, reduces fruit weight loss, extends storage life, and prevents microbial spoilage, which is extremely important to perishable fruit (*1–4*). Edible coatings create a modified atmosphere around the fruit by providing a semipermeable barrier to water vapor and gases (*5*), and their use offers an attractive alternative to film packaging due to their environmentally friendly characteristic (*5*). The performance of different types of edible coatings is dependent on their composition. The application of various edible coatings has been reported to affect fruit appearance, ripening, and quality in different mango cultivars (*1, 6–15*). The outcomes of edible coatings on fruit ripening and quality are a function of various factors such as coating type, formulation concentration, fruit nature, cultivar, fruit maturity, storage conditions, and thickness of the coating layer. If properly used, edible coatings could delay mango fruit ripening (*12*), retard chlorophyll breakdown (*7, 15*), retain fruit firmness (*13*), reduce weight loss (*12*), decrease fungal decay or fruit fly infestation (*15, 16*), retain fruit ascorbic acid (*7*), alleviate chilling injury (*10, 15*), and/or improve fruit appearance.

Information on the influences of edible coatings on fruit aroma is scant, especially on mango fruit. Baldwin et al. (*1*) reported that Natural Seal, a cellulose-based polysaccharide coating, improved aroma volatiles in mango fruit, whereas carnauba wax did not affect aroma volatile concentrations. However, two off-flavor compounds, ethanol and acetaldehyde, were also significantly higher in the mango fruit coated with Natural Seal (*1*). Application of various types of biopolymers as edible coatings on guava and apricot fruits showed that dextran and carboxymethylcellulose were more effective than polyethylene in retaining water and aroma compound (2-pentanone) of the fruit (*17*). Similarly, starch- and pectin-based coatings were also reported to improve the shelf life and aroma of Mexican guava (*18*). 'Valencia' oranges coated with commercial polysaccharide-based or shellac-based coatings exhibited higher concentrations of several aroma volatiles such as ethanol, ethyl butanoate, ethyl acetate, and α-pinene as compared to the untreated fruit (*19*). Likewise, increased concentrations of volatile compounds responsible for fresh orange flavor such as acetaldehyde, ethyl acetate, ethyl butyrate, and methyl butyrate have been reported in 'Pineapple' orange coated with beeswax or TAL Pro-long (*20*).

Aloe vera gel is a novel edible coating for organic fruit storage technology. Beneficial effects of this gel to human health have also been reported such as reduction of cholesterol and glyceride levels, reversion of extant atheromatous cardiovascular problem, and stimulation of cell regeneration (*21*). Recently, application

* Corresponding author (e-mail Z.Singh@curtin.edu.au; telephone +61 8 9266 3138; fax +61 8 9266 3063).
[†] Curtin University of Technology.
[§] Chemistry Centre.

10.1021/jf072208a CCC: $40.75
Published on Web 02/02/2008

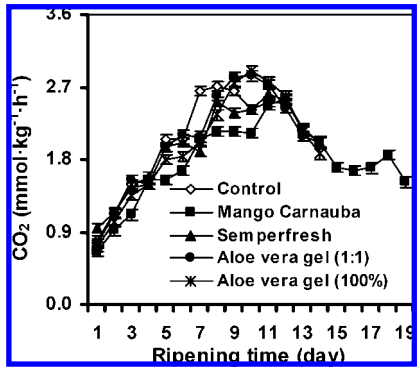

Figure 1. Effects of various edible coatings (T) and ripening time (RT) on the respiration rate of the mango fruit during ripening at ambient temperature. $n = 9$ (3 fruit × 3 replications). Vertical bars represent standard error of means. LSD ($P \leq 0.05$): T = 0.10, RT = 0.15, T × RT = 0.34.

of *A. vera* gel coating has been reported to extend shelf life by delaying postharvest loss of quality in sweet cherries and table grapes (*22, 23*). *A. vera* gel-coated cherries showed delayed color change and fruit softening as well as reduced physiological weight loss (*22*). Similarly, *A. vera* gel-coated table grapes retained higher ascorbic acid and total phenolic compounds as compared to the uncoated fruit (*23*). No research has been reported on the effects of *A. vera* gel on shelf life, fruit quality, and aroma volatiles in mango or any other tropical fruit.

Various factors affecting the biosynthesis of aroma volatiles in mango and other fruits have been reported such as cultivar (*24–27*), growing conditions (*28*), fruit maturity at harvest (*29, 30*), fruit senescence (*31*), fruit parts (*42*), storage and fruit-ripening temperature (*33, 34*), controlled atmosphere storage (*35–37*), and other postharvest treatments (*38, 39*). As a prelude, the effects of these coatings on mango fruit ripening, quality, and chilling injury have been reported (*7, 10, 11, 14, 15*), whereas no research has been reported on their effects on aroma volatile production in 'Kensington Pride'. Moreover, no information is available on whether *A. vera* gel coating exceeds current commercial coatings in extending shelf life while maintaining fruit quality and aroma. These observations prompted the present study associated with the influences of mango carnauba, Semperfresh, and *A. vera* gel coatings on fruit ripening, quality, and aroma production in 'Kensington Pride' mango.

MATERIALS AND METHODS

Fruit and Experimental Design. Hard mature green mango fruits (respiration rate = 0.91 ± 0.12 mmol of CO_2 kg^{-1} h^{-1}, firmness = 129.03 ± 0.05 N) as described by Lalel et al. (*30*) were harvested from a commercial orchard located at Chittering, Western Australia (latitude 31° 25′ S, longitude 116° 5′ E). Fruits were desapped, fungicide-treated (Sportak 0.55 mL L^{-1} with Prochloraz as an active ingredient), air-dried, packed in soft-board trays, and transported by a refrigerated truck (13 °C) to Perth, Western Australia. Fruits of uniform size and free from any blemish and visual symptoms of diseases were manually coated with aqueous mango carnauba (1:1 v/v), Semperfresh (0.6%), *A. vera* gel (1:1 v/v), or *A. vera* gel (100%). Following the coating, the fruits were dried with a fan at room temperature, packed in soft-board trays, and allowed to ripen at 21 ± 1 °C and 55.2 ± 11.1% relative humidity until the eating soft stage. Uncoated fruits were used as the control. The experiment was laid out by following a completely randomized design. Ten fruits were used as an experimental unit and replicated three times.

Coatings and Chemicals. Mango carnauba was a food-grade carnauba emulsion obtained from Castle Chemicals Pty. Ltd. (Sandgate, Newcastle, Australia). Semperfresh was obtained as a gift sample from

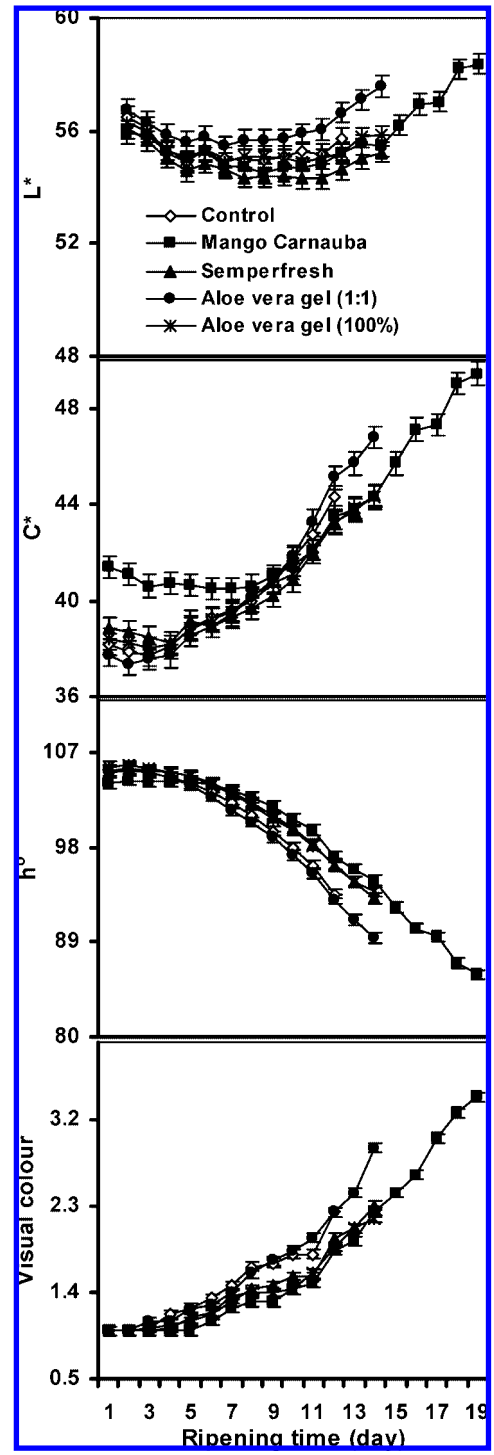

Figure 2. Effects of various edible coatings (T) and ripening time (RT) on color development of the mango fruit during ripening at ambient temperature. $n = 30$ (10 fruit × 3 replications). Vertical bars represent standard error of means. LSD ($P \leq 0.05$): (top panel) L^*, T = 0.29, RT = 0.46, T × RT = ns (0.51); (panel second from top) C^*, T = 0.38, RT = 0.59, T × RT = 1.32; (panel second from bottom) $h°$, T = 0.38, RT = 0.58, T × RT = 1.30; (bottom panel) visual color, T = 0.07, RT = 0.11, T × RT = ns (0.12). ns = not significant at $P \leq 0.05$. Values within parentheses represent SED.

Agricoat Industries Ltd. (Great Shefford, Bershire, U.K.) through Colin Campbell (Chemicals) Pty. Ltd. (Wetherill Park, NSW, Australia). *A. vera* gel was obtained as freeze-dried powder from Yunnan Yuanjiang Evergreen Biological Industry (Group) Co., Ltd. (Northern Section of Kunming High-Tech Industrial Development Zone, Kunming, China). Standards of fatty acid methyl esters (C6:0, C8:0, C10:0, C12:0, C14:0,

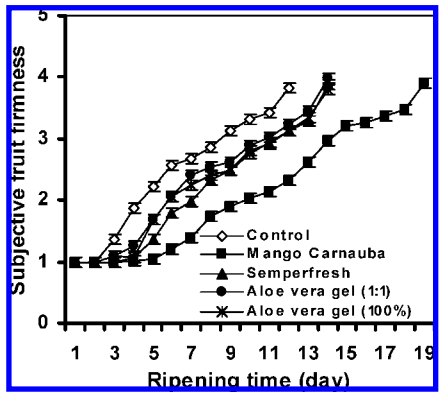

Figure 3. Effects of various edible coatings (T) and ripening time (RT) on the subjective fruit firmness during ripening at ambient temperature (1, hard; 2, sprung; 3, slightly soft; 4, eating soft; 5, overly soft). $n = 30$ (10 fruit × 3 replications). Vertical bars represent standard error of means. LSD ($P \leq 0.05$): T = 0.07, RT = 0.10, T × RT = 0.23.

C16:0, C16:1, C18:0, C18:1, C18:2, and C18:3 methyl esters), heptadecanoic acid, and boron trifluoride (14% in methanol) were purchased from Sigma-Aldrich (Castle Hill, NSW, Australia). Aroma volatile standards, including α-pinene, β-pinene, myrcene, car-2-ene, α-phellandrene, car-3-ene, α-terpinene, *p*-cymene, limonene, γ-terpinene, α-terpinolene, linalool, α-terpineol, decanal, benzothiazole, decanol, decanoic acid, α-copaene, tetradecanal, α-gurjunene, *trans*-caryophyllene, aromadendrene, α-humulene, alloaromadendrene, γ-gurjunene, β-ionone, ledene, ethyl dodecanoate, methyl tetradecanoate, tetradecanoic acid, acetic acid, isobutyl acetate, ethyl butyrate, ethyl hexanoate, ethyl *n*-heptanoate, methyl octanoate, ethyl-2-octenoate, and ethyl octanoate, were obtained from Sigma-Aldrich, whereas γ-dodecalactone was purchased from Bronson and Jacobs (Homebush Bay, NSW, Australia).

Respiration Rate. Three fruits from each replication were randomly chosen for daily respiration rate measurement during the ripening period. Fruits were incubated separately in 1 L airtight jars for 1 h. Two 2-mL gas samples from the headspace of each jar were taken and injected into an infrared gas analyzer [Servomex Gas Analyzer, Analyzer series 1450 Food Package Analyzer, Servomex (U.K.) Ltd., East Sussex, U.K.]. Respiration rate was calculated on the basis of the peak areas of the samples and CO_2 standard (BOC Gases, Australia Ltd.) and expressed as millimoles of CO_2 kilogram per hour.

Fruit Color Development. The skin color of individual fruits from each replication was measured daily during ripening period using both visual assessment (score 1–5, 1 = 100% green, 2 = 75% green, 3 = 50 green/yellow, 4 = 75% yellow, and 5 = 100% yellow) as described by Shorter and Joyce (*40*) and objective color measurement by a ColorFlex 45°/0° spectrophotometer (HunterLab ColorFlex, Hunter Associates Inc., Reston, VA) and expressed as L^*, chroma (C^*), and hue angle ($h°$). L represents the lightness of the fruit color, which ranges from 0 (black) to 100 (white), whereas $h°$ represents red-purple at an angle of 0°, yellow at 90°, bluish green at 180°, and blue at 270°.

Subjective Fruit Firmness. Subjective firmness of individual fruits was evaluated daily by hand (nondestructive) during the ripening period using the rating scale from 1 to 5 (hard to oversoft) described by Shorter and Joyce (*40*): 1 = hard, 2 = sprung, 3 = slightly soft, 4 = eating soft, and 5 = oversoft.

Ripening Time, Physiological Weight Loss (PWL), and PWL Rate. Ripening time was recorded as the number of days from coating application until fruit reached the eating soft stage such as subjective firmness rating 4 and/or >75% yellow skin color development as described by Shorter and Joyce (*40*). PWL was calculated at the eating soft stage as percent of weight loss compared to the initial weight. PWL rate was calculated as percent weight loss per day during the ripening period.

Soluble Solids Concentration (SSC), Titratable Acidity (TA), and Ascorbic Acid. Fresh juice was extracted from ripe fruit, and SCC was determined using an infrared digital refractometer (Atago-Palette PR 101, Atago Co. Ltd., Itabashi-Ku, Tokyo, Japan) and expressed as percent. TA was determined by titrating fruit juice against 0.1 N NaOH and expressed as percent malic acid. Ascorbic acid was estimated by following the method of Malik et al. (*41*). Mango pulp (5 g) was homogenized with 25 mL (6%) of metaphosphoric acid solution containing 0.18% (w/v) disodium salt of ethylenediaminetetraacetic acid in a glass pestle and mortar using 300 mg of white quartz sand (−50 + 70 mesh, Sigma Aldrich). The homogenate was centrifuged at 3000 rpm for 15 min. The supernatant was used for estimation of ascorbic acid using Folin's reagent. Two milliliter disposable cuvettes were used to record the absorbance of mixed sample after 10 min at 760 nm with a UV−vis spectrophotometer (model 6405, Jenway Ltd. Felsted, Dunmow, Essex, U.K.). Ascorbic acid level was calculated against 100% L-ascorbic acid standard curve and was expressed as milligrams per 100 grams of fresh weight (FW) of pulp.

Total Carotenoids. Total carotenoids from the pulp of the ripe fruit were estimated by following the method of Lalel et al. (*30*) using a UV–vis spectrophotometer (Jenway 6405, Dunmow, Essex, U.K.) and expressed as milligrams per kilogram of β-carotene equivalent.

Fatty Acid Analysis. Fatty acids from the ripe mango pulp were estimated by following the method of Lalel et al. (*30*). Each sample was tested twice. Fatty acids were extracted using anhydrous diethyl ethyl and methylated using 14% BF_3 in methanol. The analysis of fatty acids was conducted by using a gas chromatograph (GC) (Agilent Technologies, 6890N Network GC system, Palo Alto, CA) fitted with a flame ionization detector (FID) and a split injector (1/10). The separation was achieved on a capillary column (AT-WAX, 30 m × 0.32 mm i.d. × 1 μm film thickness, Alltech Associates Pty. Ltd., NSW, Australia). Hydrogen was used as a carrier gas (1.2 mL min^{-1}). The oven temperatures were maintained at 110 °C for 1 min and then increased to 180 °C at a rate of 15 °C min^{-1} followed by a second ramp of 2 °C min^{-1} to 240 °C and maintained at this final temperature for 10 min. The detector and injector temperatures were 250 and 240 °C, respectively. Fatty acids were identified by comparing their retention time (RT) with the RT of authentic fatty acid methyl esters C6:0 to C18:3 (Sigma Aldrich, Castle Hill, NSW, Australia) and by co-injections. The concentrations of individual fatty acids were calculated using the internal standard (ISTD) and expressed as micrograms per gram of pulp.

Aroma Volatile Analysis. Aroma volatiles were analyzed by following the method of Lalel et al. (*30*) with some modifications. HS-SPME was used for extracting free aroma volatile compounds from pulp. Frozen mango pulp (10 g) was thawed and homogenized with 35 mL of saturated NaCl solution. The homogenate (7 mL) was then transferred into an airtight 15 mL vial together with 1 μL of the ISTD mixture (methyl hexanoate, tridecane, and hexadecane at a concentration of 20, 20, and 10 μg mL^{-1}, respectively) for aroma volatile extraction. The extraction temperature and duration were 50 °C and 30 min, respectively. Volatile compounds already adsorbed onto the SPME fiber were then thermally desorbed in a splitless injector of a GC-FID or GC−mass spectrometer (MS) for 30 min. Each sample was tested twice.

A GC-FID (Agilent Technologies, 6890N Network GC system) was used for identification and quantification of aroma compounds from pulp of mango fruit. Oven temperature was maintained at 40 °C for 5 min and then ramped at 3 °C min^{-1} to 220 °C followed by 2 °C min^{-1} to 240 °C and kept for 10 min. Separation was achieved on a capillary column (HP-5MS, 50 m × 0.2 mm i.d. × 0.33 μm, Agilent Technologies). Detector and injector temperatures were 290 and 240 °C, respectively. Hydrogen was used as a carrier gas (1 mL min^{-1}). Aroma volatile compounds were identified by comparing their retention index (RI) with those of authentic compounds and from the literature. The RI was calculated using the formula of Van Den Dool (*42*).

The confirmation of known compounds or the identification of unknown volatiles was conducted on a GC-MS. A MS (MS, Hewlett-Packard 5890 series II) was interfaced with an Agilent 6890 GC, which was equipped with a capillary ZB-1 100% methyl polysiloxane (60 m × 0.25 mm i.d. × 0.25 μm, Phenomenex, NSW, Australia). Helium was carrier gas at 1.1 mL min^{-1}. Injector temperature was 240 °C. Oven temperature was maintained at 40 °C for 5 min and then increased to 240 at 5 °C min^{-1} and held for 10 min. Mass spectra were scanned

Table 1. Effects of Various Edible Coatings on Ripening Time, Fruit Color, and Quality at Eating Ripe Stage[a]

parameter	edible coatings					LSD ($P \leq 0.05$)
	control	mango carnauba	Semperfresh	*A. vera* gel (1:1)	*A. vera* gel (100%)	
ripening time (days)	12.20 a	19.80 c	14.40 b	14.07 b	14.50 b	0.53
L^*	55.72 a	58.37 b	55.23 a	57.57 b	55.84 a	1.47
C^*	44.29 a	49.42 c	44.38 a	46.78 b	44.27 a	2.35
$h°$	93.58 c	85.92 a	93.21 c	89.38 b	93.78 c	2.86
firmness (N)	19.90	18.93	19.27	19.40	19.50	ns (0.68)
SSC (%)	13.70	12.11	13.26	13.25	13.07	ns (0.46)
TA (%)	0.29 bc	0.17 a	0.30 c	0.21 a	0.23 ab	0.06
SSC/TA	48.64 a	70.68 b	45.64 a	65.17 b	57.87 ab	13.20
ascorbic acid (mg 100 g^{-1})	10.30 a	10.45 a	13.41 b	10.63 a	10.08 a	2.24
total carotenoids (mg kg^{-1})	65.49	71.41	69.80	66.05	70.13	ns (4.04)

[a] $n = 30$ for L^*, C^*, and $h°$; $n = 15$ for firmness; and $n = 3$ for the remaining parameters. ns = not significant at $P \leq 0.05$. Values within parentheses represent SED. Any two means in the same row followed by the same letter are not significantly different.

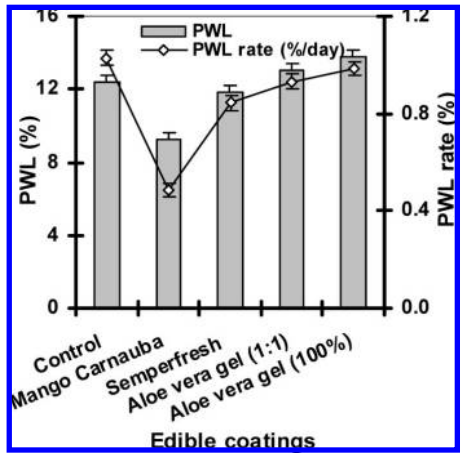

Figure 4. Effects of different edible coatings on physiological weight loss and physiological weight loss rate during fruit ripening. $n = 3$. Vertical bars represent standard error of means. LSD ($P \leq 0.05$): PWL = 1.21, PWL rate = 0.09.

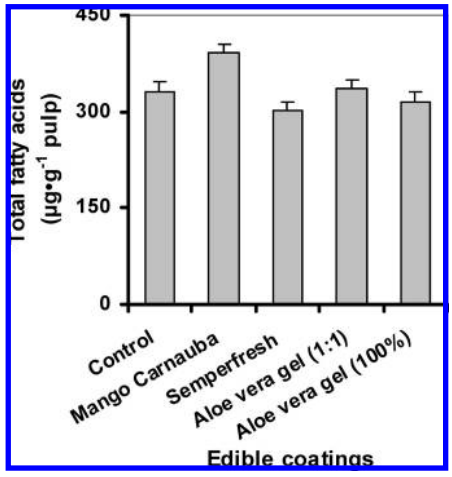

Figure 5. Effects of various edible coatings on concentrations of total fatty acids in the pulp of the ripe mango fruit. $n = 6$ (3 replications, each replication tested twice). Vertical bars represent standard error of means. LSD ($P \leq 0.05$) = 44.08.

at 70 eV and matched with the standards in an electronic WILEY275.L library (http://wwww.wiley.com/WileyCDA/WileyTitle/productCD-0471440973.html) for the identification.

Statistical Analysis. Effects of different edible coatings on various fruit ripening and quality parameters were assessed within the ANOVA using Genstat 9, release 9.1.0.147 (Lawes Agricultural Trust, Rothamsted Experimental Station, Rothamsted, U.K.). Least significant difference (Fisher's protected LSD) was calculated at $P \leq 0.05$ following a significant F test. Statistical analysis for data of daily observation was conducted as two-way ANOVA (edible coatings and ripening time) for the first 12 days because some treatments finished their ripening period. The validity of analysis was ensured by checking all of the assumptions of analysis.

RESULTS

Respiration Rate. Mango carnauba-coated fruit exhibited significantly lower respiration rate as compared to the control and all other treatments (**Figure 1**). The fruit coated with Semperfresh, *A. vera* gel (1:1), and *A. vera* gel (100%) did not show any significant difference in the respiration rate as compared to the uncoated fruit. However, the application of all edible coatings, especially mango carnauba, delayed the climacteric peak in the coated fruit as compared to the control. The interaction between various edible coatings and ripening time significantly affected the respiration rate during the fruit-ripening period.

Fruit Color Development. *A. vera* gel (1:1) resulted in increased lightness (L^*), whereas Semperfresh and mango carnauba reduced skin lightness of the coated fruit as compared to the control (**Figure 2**). Interaction between edible coatings and ripening time significantly affected C^* and $h°$. Mango carnauba-coated fruit showed higher C^* values as compared to the fruit from the control and all other coatings. The fruit coated with mango carnauba, Semperfresh, and *A. vera* gel (100%) exhibited delayed color development (higher $h°$) as compared to the uncoated fruit, which was more prominent from day 9 of the ripening period. Similar observations were recorded for visual color, in which all coatings delayed fruit color development as compared to the control except *A. vera* gel (1:1).

Subjective Fruit Firmness. All edible coatings delayed the loss of fruit firmness as compared to the control (**Figure 3**). The fruit coated with mango carnauba remained firmer than the fruit coated with any other coating. The interaction effect between edible coatings and ripening time on subjective fruit firmness was found to be significant.

Ripening Time and PWL. All edible coatings delayed fruit ripening as compared to the control. Mango carnauba was the most effective in delaying fruit ripening (**Table 1**). Different concentrations of *A. vera* gel coatings did not show any significant difference in retardation of the fruit ripening. Mango carnauba reduced total PWL as compared to the control (**Figure 4**). All edible coatings reduced PWL rate as compared to the control except *A. vera* gel (100%). Mango carnauba-coated fruit exhibited the lowest PWL rate (0.49%/day) as compared to the fruit from the control (1.03%/day) and all other coatings.

Fruit Color, Firmness, SSC, TA, SSC/TA, Ascorbic Acid, and Total Carotenoids at the Eating Soft Stage. Mango

Table 2. Effects of Various Edible Coatings on the Concentrations (Micrograms per Gram of Pulp) of Individual Fatty Acids in the Pulp of the Ripe Mango Fruit[a]

	edible coatings					
fatty acid	control	mango carnauba	Semperfresh	*A. vera* gel (1:1)	*A. vera* gel (100%)	LSD ($P \leq 0.05$)
caproic acid	0.56 a	0.76 b	0.47 a	0.51 a	0.46 a	0.17
caprylic acid	0.40 a	0.67 b	0.34 a	0.40 a	0.36 a	0.14
capric acid	0.25 c	0.28 c	0.19 ab	0.20 b	0.16 a	0.04
lauric acid	1.17ab	1.46 b	0.88 a	1.03 a	0.85 a	0.33
myristic acid	11.94	13.18	9.79	11.44	11.17	ns (1.13)
palmitic acid	94.40 a	115.08 b	87.61 a	96.05 a	89.60 a	13.54
palmitoleic acid	64.27 a	96.73 b	55.77 a	71.55 a	73.54 a	19.15
stearic acid	0.97 b	0.93 b	0.83 ab	0.84 b	0.68 a	0.16
oleic acid	64.13	71.43	64.66	72.60	62.30	ns (5.18)
linoleic acid	28.73	33.41	28.03	26.61	25.40	ns (4.00)
linolenic acid	64.87	58.13	52.67	53.73	51.08	ns (5.00)

[a] $n = 6$ (3 replications, each replication tested twice). ns = not significant at $P \leq 0.05$. Values within parentheses represent SED. Any two means in the same row followed by the same letter are not significantly different.

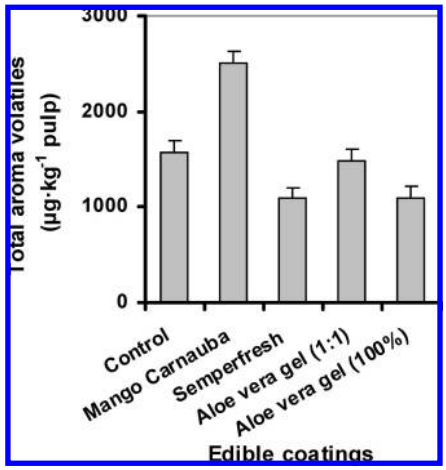

Figure 6. Effects of various edible coatings on concentrations of total aroma volatiles in the pulp of the ripe mango fruit. $n = 6$ (3 replications, each replication tested twice). Vertical bars represent standard error of means. LSD ($P \leq 0.05$) = 377.8.

carnauba- and *A. vera* gel (1:1)-coated fruit exhibited better color development as compared to the fruit from the control and all other coatings (**Table 1**). Various edible coatings tested did not significantly affect fruit firmness, SSC, and total carotenoids in the fruit as compared to the control (**Table 1**). The fruit coated with mango carnauba or *A. vera* gel (1:1) showed lower TA and higher SSC/TA than the uncoated fruit (**Table 1**). Semperfresh-coated fruit showed reduction in the loss of ascorbic acid as compared to the untreated fruit (**Table 1**).

Fatty Acids. Mango carnauba-coated fruit showed significant ($P \leq 0.05$) increases in the concentrations of total fatty acids (17–30%) in the pulp of the ripe mango as compared to the fruit from the control and all other coatings (**Figure 5**). The other edible coatings did not affect the concentrations of total fatty acids in the pulp of the ripe fruit as compared to the uncoated fruit. Influences of various edible coatings on individual fatty acids were more pronounced in saturated than in unsaturated fatty acids (**Table 2**). Among saturated fatty acids, the concentration of myristic acid in the ripe mango pulp was not affected by any of the coatings as compared to the uncoated fruit. The pulp of mango carnauba-coated fruit showed higher concentrations of caproic, caprylic, and palmitic acids than the pulp of the ripe fruit from the control. Semperfresh and *A. vera* gel at both concentrations did not affect the concentrations of caproic, caprylic, lauric, and palmitic acids but did reduce the concentrations of capric acid in the pulp of the ripe fruit

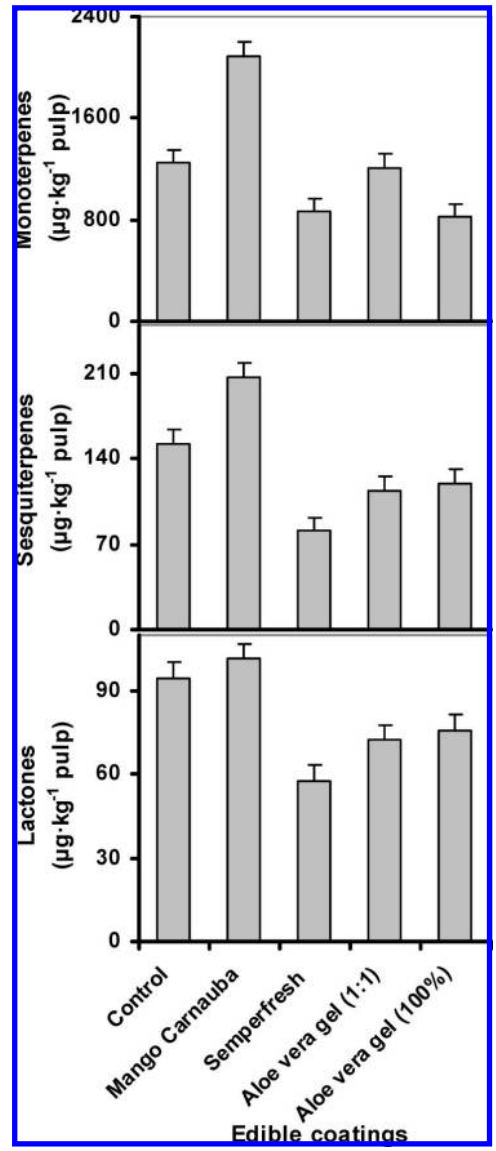

Figure 7. Effects of various edible coatings on the concentrations of total monoterpenes, sesquiterpenes, and lactones in the pulp of the ripe mango fruit. $n = 6$ (3 replications, each replication tested twice). Vertical bars represent standard error of means. LSD ($P \leq 0.05$): monoterpenes = 347.40; sesquiterpenes = 36.70; lactones = 17.13.

compared to the uncoated fruit. Fruit coated with *A. vera* gel (100%) also resulted in a reduced concentration of stearic acid

Table 3. Effects of Various Edible Coatings on the Concentrations (Micrograms per Kilogram of Pulp) of Different Monoterpenes in the Pulp of the Ripe Mango Fruit[a]

compound	retention index	identification mode	edible coatings					LSD ($P \leq 0.05$)
			control	mango carnauba	Semperfresh	*A. vera* gel (1:1)	*A. vera* gel (100%)	
α-pinene	935	RI, CO, MS	27.48 b	41.18 c	18.43 a	23.38 ab	18.44 a	6.95
α-fenchene	949	MS	0.12 b	0.19 c	0.08 a	0.11 ab	0.08 a	0.03
camphene	951	MS	0.08 a	0.13 c	0.06 a	0.08 a	0.06 a	0.03
β-pinene	979	RI, CO, MS	1.51 a	1.99 b	1.27 a	1.47 a	1.25 a	0.36
myrcene	991	RI, CO, MS	32.42 b	47.70 c	22.93 a	30.33 ab	22.05 a	8.74
car-2-ene	1002	RI, CO, MS	6.31 b	9.51 c	4.42 a	5.85 ab	4.33 a	1.59
α-phellandrene	1006	RI, CO, MS	11.41 c	15.64 d	8.21 ab	9.46 bc	6.73 a	2.56
δ-car-3-ene	1013	RI, CO, MS	106.97 b	155.78 c	78.26 ab	99.82 ab	77.89 a	28.96
α-terpinene	1019	RI, CO, MS	47.35 b	74.83 c	32.23 a	45.54 b	30.90 a	11.73
limonene	1031	RI, CO, MS	23.26 b	38.41 c	15.66 a	22.25 b	14.87 a	6.33
β-phellandrene	1032	RI, MS	7.08 c	11.68 d	4.90 ab	6.78 bc	4.49 a	1.98
cis-ocimene	1039	RI, CO, MS	2.46 b	2.57 c	1.85 ab	2.29 ab	1.17 a	0.61
trans-β-ocimene	1049	RI, MS	0.97 b	1.52 c	0.62 a	0.82 ab	0.62 a	0.25
γ-terpinene	1061	RI, CO, MS	4.46 b	7.17 c	3.17ab	4.28 ab	3.00 a	1.39
α-terpinolene	1095	RI, CO, MS	966.68 b	1676.96 c	662.75 a	952.14 b	628.87 a	277.20
p-mentha-1,5,8-triene	1115	RI, MS	1.27 a	2.51 b	1.39 a	1.29 a	1.10 a	0.46
(2-methylprop-1-enyl)cyclohexa-1,5-diene	1140	RI, MS	1.16 a	2.36 b	1.27 a	1.21 a	1.03 a	0.40
1,8-menthadien-4-ol	1181	MS	1.52 c	1.94 d	1.33 bc	1.02 ab	0.89 a	0.40
feranylacetone	1453	RI, CO, MS	0.86	0.96	0.77	0.82	0.84	ns (0.07)

[a] $n = 6$ (3 replications, each replication tested twice). ns = not significant at $P \leq 0.05$. Values within parentheses represent SED. Any two means in the same row followed by the same letter are not significantly different. RI, retention index on HP-5MS; CO, co-injection; MS, mass spectrometry.

Table 4. Effects of Various Edible Coatings on the Concentrations (Micrograms per Kilogram of Pulp) of Different Sesquiterpenes in the Pulp of the Ripe Mango Fruit[a]

compound	retention index	identification mode	edible coatings					LSD ($P \leq 0.05$)
			control	mango carnauba	Semperfresh	*A. vera* gel (1:1)	*A. vera* gel (100%)	
α-copaene	1386	RI, CO, MS	3.19 a	4.85 b	2.89 a	3.07 a	2.62 a	0.91
β-elemene	1401	MS	2.62 c	1.96 b	0.62 a	1.05 a	0.76 a	0.45
α-gurjunene	1423	RI, CO, MS	42.52 b	57.10 c	23.41 a	32.33 ab	38.96 b	10.81
trans-caryophyllene	1434	RI, CO, MS	47.85 c	67.23 d	23.40 a	35.94 bc	33.62 ab	12.30
aromadendrene	1455	RI, CO, MS	2.31 c	2.12 bc	1.59 a	1.66 ab	1.76 ab	0.49
α-humulene	1468	RI, CO, MS	30.95 b	40.84 c	17.36 a	23.80 ab	22.74 a	7.88
allo-aromadendrene	1475	RI, CO, MS	3.57 b	4.87 c	2.32 a	2.83 ab	3.28 ab	0.98
γ-gurjunene	1485	RI, CO, MS	4.47 b	6.26 c	2.83 a	3.46 ab	4.17 b	1.23
ledene	1508	RI, CO, MS	10.85 c	17.40 d	4.77 a	7.22 ab	9.10 bc	3.25
δ-cadinene	1534	MS	3.70 c	5.14 d	1.45 a	2.36 ab	2.94 bc	0.96

[a] $n = 6$ (3 replications, each replication tested twice). Any two means in the same row followed by the same letter are not significantly different. RI, retention index on HP-5MS; CO, co-injection; MS, mass spectrometry.

in the pulp of the ripe fruit as compared to the uncoated fruit. Among unsaturated fatty acids, the concentration of palmitoleic acid in the pulp of the ripe fruit coated with mango carnauba was 31–73% higher than in the pulp of the ripe fruit from the control or from any other coating. None of the edible coatings significantly affected the concentrations of the other unsaturated fatty acids such as oleic, linoleic, and linolenic acids in the pulp of the ripe mango as compared to the control fruit.

Total Aroma Volatiles. The pulp of the mango fruit coated with mango carnauba exhibited significantly increased levels of aroma volatiles in the pulp of the ripe fruit (almost 60% higher than the control) as compared to the control and all other coatings (**Figure 6**). *A. vera* gel (1:1) did not affect total aroma volatile levels as compared to the uncoated fruit. However, the pulp of the ripe fruit coated with Semperfresh or *A. vera* gel (100%) exhibited lower concentrations (about 40%) of total aroma volatiles than the control fruit.

Monoterpenes. The pulp of the ripe fruits coated with mango carnauba resulted in 68% increased concentration of total monoterpenes as compared to the control fruit. *A. vera* gel (1:1) did not affect the total monoterpene concentration in the coated fruit, whereas Semperfresh or *A. vera* gel (100%) significantly reduced the concentrations of total monoterpenes as compared to the control (**Figure 7**). The pulp of the fruit coated with mango carnauba showed higher concentrations of all monoterpenes than the control fruit except geranylacetone (**Table 3**). *A. vera* gel (1:1) did not significantly affect the concentrations of all individual monoterpenes compared to the uncoated fruit except 1,8-menthadien-4-ol. Semperfresh substantially reduced the concentrations of most of the individual monoterpenes in the pulp of the ripe fruit as compared to the uncoated fruit except camphene, β-pinene, δ-car-3-ene, *cis*-ocimene, γ-terpinene, *p*-mentha-1,5,8-triene, (2-methylprop-1-enyl)cyclo-hexa-1,5-diene, and 1,8-menthadien-4-ol. Similarly, the pulp of *A. vera* gel (100%)-coated fruit exhibited lower concentrations of most of the individual monoterpenes as compared to the uncoated control except camphene, β-pinene, *p*-mentha-1,5,8-triene, and (2-methylprop-1-enyl)cyclohexa-1,5-diene. α-Terpinolene, the most abundant volatile compound in 'Kensington Pride' mango, increased up to 73% in mango carnauba-coated fruit and decreased approximately 45–53% in Semperfresh and *A. vera* gel (100%)-coated fruit as compared to the control fruit. Mango carnauba also resulted in about 45% higher concentrations of δ-car-3-ene, the second most abundant aroma volatile, in the pulp of the ripe fruit as compared to the control.

Sesquiterpenes. Total sesquiterpenes in the pulp of the Semperfresh- and *A. vera* gel (1:1)-coated fruit were signifi-

Table 5. Effects of Various Edible Coatings on the Concentrations (Micrograms per Kilogram of Pulp) of Lactones, Aromatics, Alcohols, Aldehydes, and Norisoprenoid in the Pulp of the Ripe Mango Fruit[a]

			edible coatings					
compound	retention index	identification mode	control	mango carnauba	Semperfresh	*A. vera* gel (1:1)	*A. vera* gel (100%)	LSD ($P \leq 0.05$)
lactones								
γ-octalactone	1261	RI, CO, MS	67.22 c	58.18 bc	38.31 a	47.25 ab	47.70 ab	13.20
γ-decalactone	1473	MS	15.51 a	21.28 b	13.46 a	16.37 a	17.46 ab	4.51
δ-decalactone	1503	RI, MS	10.56 c	18.56 d	4.73 a	7.32 ab	9.35 bc	2.96
γ-dodecalactone	1685	RI, MS	1.50 a	3.27 b	1.27 a	1.40 a	1.44 a	0.49
aromatics								
p-cymene	*1027*	RI, MS, MS	2.62 c	1.96 b	0.62 a	1.05 a	0.76 a	0.44
p-cymen-8-ol	*1188*	MS	1.95 b	3.22 c	1.92 b	1.22 a	1.36 a	0.50
alcohols								
ethanol	3.25[b]	RT, CO	7.61 a	4.84 a	15.88 b	15.50 b	14.23 b	3.50
cis-3-hexenol	*855*	MS	10.45 b	5.89 a	9.39 b	6.57 a	6.63 a	1.50
1-hexenol	868	MS	2.28 a	2.06 a	3.65 b	4.45 b	2.48 a	1.03
aldehydes								
hexanal	797	RI, MS	5.99 a	9.59 b	7.01 a	6.64 a	7.43 a	2.07
trans-2-hexenal	*852*	MS	9.01 a	14.65 c	11.72 abc	12.20 bc	11.14 ab	3.15
trans-2-nonenal	*1161*	RI, MS	5.70 a	6.95 ab	8.29 bc	9.01 c	6.21 a	1.63
hexadecanal	1818	MS	36.60 a	57.75 b	27.07 a	35.39 a	34.90 a	11.44
norisoprenoid								
β-ionone	1494	RI, CO, MS	1.07 b	1.35 c	0.90 ab	0.85 a	0.93 ab	0.22

[a] n = 6 (3 replications, each replication tested twice). Any two means in the same row followed by the same letter are not significantly different. RI, retention index on HP-5MS; CO, co-injection; MS, mass spectrometry. [b] Retention time on HP-5MS.

cantly lower than that in the control fruit (**Figure 7**). Mango carnauba coating resulted in about 36% increased concentration of total sesquiterpenes in the pulp of the ripe fruit as compared to the control. The concentrations of all individual sesquiterpenes in the pulp of the mango carnauba-coated fruit, except β-elemene and aromadendrene, were significantly higher than in the control fruit (**Table 4**). *A. vera* gel (1:1) coating did not affect the concentrations of most of the individual sesquiterpenes in the pulp of the ripe fruit as compared to the control, except β-elemene, aromadendrene, ledene, and δ-cadinene. Although the concentrations of some sesquiterpenes in the pulp of the fruit coated with Semperfresh or *A. vera* gel were not significantly different from the control, these coatings generally reduced sesquiterpenes in the pulp of the ripe fruit.

Lactones. Mango Carnauba did not affect the concentration of total lactones, whereas Semperfresh and *A. vera* gel at both concentrations resulted in lower total lactones in the pulp of the ripe fruit as compared to the untreated fruit (**Figure 7**). The ripe pulp of mango carnauba-coated fruit exhibited significantly higher concentrations of γ-decalactone, δ-decalactone, and γ-dodecalactone than the pulp of the uncoated fruit (**Table 5**). Semperfresh, *A. vera* gel (1:1), and *A. vera* gel (100%) resulted in a lower concentration of γ-octalactone in the pulp of the ripe fruit as compared to the control. The concentrations of γ-decalactone and γ-dodecalactone in the pulp of the ripe fruit coated with Semperfresh or *A. vera* gel at both concentrations were not significantly different from those in the control fruit. However, the pulp of the ripe fruit coated with Semperfresh and *A. vera* gel (1:1) exhibited lower concentrations of δ-decalactone than the pulp of the uncoated fruit.

Aromatics and Alcohols. Semperfresh and *A. vera* gel coatings at both concentrations significantly reduced the concentrations of total aromatic compounds, whereas mango carnauba did not affect total aromatics in the pulp of the ripe fruit as compared to the control (**Figure 8**). Although influences of the edible coatings on individual aromatic compounds were inconsistent, the pulp of the ripe fruit coated with *A. vera* gel always showed lower concentrations of *p*-cymene and *p*-cymen-8-ol than the pulp of the control fruit (**Table 5**). Mango carnauba significantly reduced the concentration of total alcohols in the pulp of the ripe fruit as compared to the uncoated fruit (**Figure 8**). The concentrations of ethanol in the pulp of the ripe fruit coated with Semperfresh and *A. vera* gel at both concentrations were higher as compared to the pulp of the control fruit (**Table 5**). The pulp of the ripe fruit coated with mango carnauba, *A. vera* gel (1:1), and *A. vera* gel (100%) exhibited lower concentrations of *cis*-3-hexenol compared to the control fruit. 1-Hexenol concentration in the pulp of the ripe Semperfresh- and *A. vera* gel (1:1)-coated fruit was higher than that in the control fruit.

Aldehydes and Norisoprenoids. Total aldehyde concentration was significantly higher in the pulp of mango carnauba-coated fruit as compared to the control fruit (**Figure 8**). The other coatings did not significantly affect the concentration of total aldehydes in the pulp of the ripe fruit as compared to the uncoated control. Fruits coated with mango carnauba resulted in significantly higher concentrations of hexanal, *trans*-2-hexenal, and hexadecanal in the pulp of the ripe fruit as compared to the control (**Table 5**). *A. vera* gel (1:1) resulted in higher concentrations of *trans*-2-hexenal and *trans*-2-nonenal in the pulp of the ripe fruit compared to the untreated fruit. β-Ionone belongs to the norisoprenoid group. The pulp of the fruit coated with mango carnauba exhibited a higher ($P \leq 0.05$) concentration of β-ionone than the uncoated fruit, whereas Semperfresh or *A. vera* gel (100%) did not affect the concentration of β-ionone (**Table 5**). *A. vera* gel (1:1) resulted in a lower concentration of β-ionone in the pulp of the ripe fruit as compared to the control.

DISCUSSION

All edible coatings tested delayed fruit ripening. This was characterized by suppressed respiration and/or delayed climacteric peak, delayed fruit color development, and higher fruit

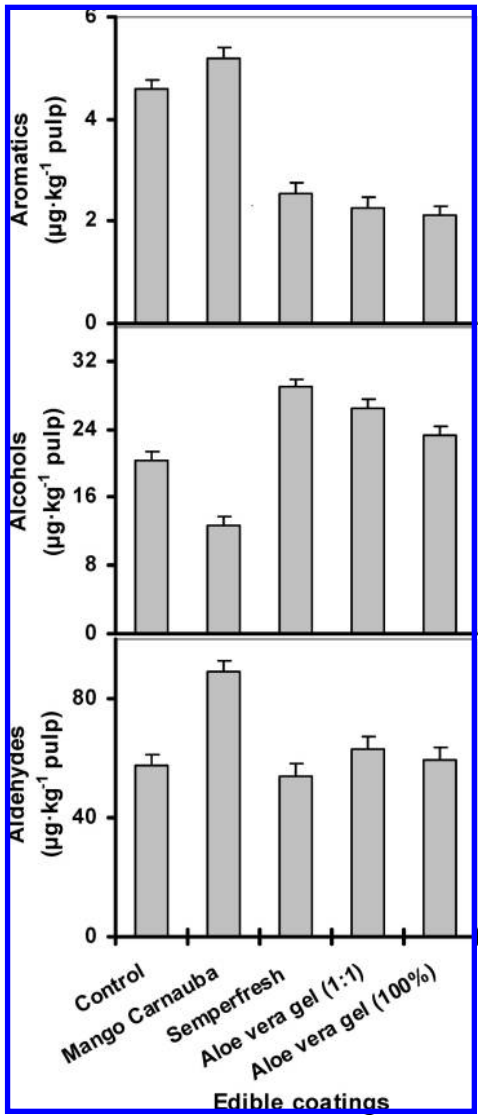

Figure 8. Effects of various edible coatings on the concentrations of total alcohols, aldehydes, and aromatics in the pulp of the ripe mango fruit. $n = 6$ (3 replications, each replication tested twice). Vertical bars represent standard error of means. LSD ($P \leq 0.05$): aromatics = 0.62, alcohols = 3.18; aldehydes = 12.70.

firmness in the coated fruit as compared to the uncoated controls. Similar effects of edible coatings have been reported in various fruits such as mango (*7, 11, 14*), grapes (*43*), and sweet cherries (*22*). The delay in the ripening of the coated fruit may be due to the modified internal atmosphere in the coated fruit, which decreases the activities of softening enzymes (*13*) and reduces the degradation of chlorophyll and/or the biosynthesis of carotenoids (*7, 11*) or due to the better turgidity in the coated fruit due to the lower dehydration (*8*). Mango carnauba surpassed all other coatings in retardation of fruit ripening, which may be attributed to coating formulation, concentration applied, and interaction between the fruit and the coatings.

The reduced PWL in the coated fruit may be ascribed to the ability of the coating film to block all lenticels and stem-end scar in the coated fruit, which may have resulted in reduced transpiration (*14*). Mango carnauba was more effective as a water vapor barrier as compared to all other coatings, which may be attributed to the hydrophobic nature of wax coatings. Polysaccharides are the main components of *A. vera* gel (*43*), which may explain the lower effectiveness of this coating in delaying PWL compared to mango carnauba. Fruit quality at the eating soft stage was improved in mango carnauba-coated fruit including better skin color, lower TA, and higher SSC/TA. In addition, a shiny and turgid appearance was also observed in the mango carnauba-coated fruit as compared to the control and all other coatings. Similarly, 'Lirfa' mango fruit coated with carnauba wax gained highest organoleptic score including color, texture, acidity, sweetness, and aroma as compared to the other coatings (*11*). Semperfresh-coated fruit showed higher concentration of ascorbic acid in the fruit pulp compared to the control. Similarly, 'Haden' mango coated with Semperfresh exhibited a reduced ascorbic acid loss as compared to the uncoated fruit (*7*).

Edible coatings altered the fatty acid profiles of the coated fruit as compared to the control. The concentrations of saturated fatty acids were more affected by the edible coatings tested than unsaturated ones. The fruit coated with mango carnauba exhibited improved concentrations of total fatty acids and some individual fatty acids such as caproic, caprylic, and palmitic acids in the pulp of the ripe fruit compared to the control fruit. The concentration of palmitoleic acid in mango carnauba-coated fruit was 1.3–1.7-fold higher than that in the fruit from the control or any other coating. To the best of our knowledge, no research has been reported on influences of edible coatings on fatty acids in the fruit pulp. The mechanism by which mango carnauba increased the biosynthesis of individual and additive total fatty acids in the coated fruit is yet unknown and warrants further investigations.

The fruit coated with mango carnauba exhibited significantly improved fruit aroma volatiles including total aroma volatiles, monoterpenes, sesquiterpenes, and aldehydes while maintaining comparative aromatic and lactone concentrations and reducing total alcohol levels compared to the control fruit. The increased concentrations of aroma volatiles in the pulp of the fruit coated with mango carnauba may be due to the increased concentrations of aroma precursors such as fatty acids in the pulp of the fruit from this coating as discussed above. Fatty acids have been reported to be precursors of various mango aroma volatiles such as esters, aldehydes, alcohols, ketones, acids, and terpenes (*37*). A low concentration of ethanol in the pulp of mango carnauba-coated fruit revealed that anaerobic conditions were not created in the fruit internal atmosphere, and therefore no off-flavors developed. Similarly, carnauba wax did not cause any accumulation of ethanol when applied to 'Tommy Atkins' (*1*) and 'Lirfa' mango (*11*) due to the low water vapor and high gas permeability of this lipid coating group (*1, 11*). The increased aroma volatiles in the pulp of mango carnauba-coated fruit in the present experiment were different from the results reported by Baldwin et al. (*1*), who claimed that carnauba wax under the trade name Tropical Fruit Coating did not improve the aroma volatiles of 'Tommy Atkins' mango. However, Hoa et al. (*11*) reported that carnauba wax-coated 'Lirfa' mango exhibited higher overall organoleptic scores including aroma than did the control fruit. This may be ascribed to variable responses of different mango cultivars to carnauba wax.

Semperfresh coating reduced the concentrations of total aroma volatiles, monoterpenes, sesquiterpenes, lactones, and aromatics as compared to the uncoated fruit. Ethanol, an anaerobic metabolite, in Semperfresh-coated fruit was >2-fold higher than in the control fruit, which led to higher total alcohols in the fruit from this coating as compared to the control fruit. Possibly, it may be due to the modified atmosphere conditions created in the Semperfresh-coated fruit (*14*), which may have resulted in reduced biosynthesis of other volatile groups mentioned above. 'Julie' mango coated with 1% Prolong, a product similar to

Semperfresh, has been reported to exhibit higher ethanol accumulation in the fruit pulp (*9*). Likewise, Semperfresh at 2 and 3% caused off-flavors in 'Nang Klangwan' mango within 6 days of its application (*14*). Our experimental data showed that Semperfresh at lower concentration (0.6%) resulted in higher concentrations of off-flavor compounds in 'Kensington Pride' mango, which may be ascribed to cultivar response.

A. vera gel coatings generally reduced aroma volatile biosynthesis in the fruit pulp, although the levels of significance varied with volatile compounds and concentrations of *A. vera* gel applied. Higher concentrations of *A. vera* gel (100%) seemed to have detrimental effects on the formation of monoterpenes, lactones, aromatics, and additive total aroma volatiles, whereas *A. vera* gel (1:1) adversely affected the biosynthesis of sesquiterpenes, lactones, and aromatic compounds. Both concentrations of *A. vera* gel tested in the experiment seemed to be high as indicated by the accumulation of ethanol in the pulp of the coated fruit. Polysaccharides are the main constituents of *A. vera* gel (*43*). Possibly, this may lead to an accumulation of CO_2 and a reduction of O_2 and create fermentative conditions similar to those of modified atmosphere packaging. The changes in the internal atmosphere of the coated fruit might reduce the metabolic rate and alter the metabolic pathways, leading to the alteration of the aroma profiles (*20*).

All of the coatings tested except mango carnauba significantly reduced the concentrations of total lactones as well as γ-octalactone in the coated fruit as compared to the control fruit.

In conclusion, all edible coatings tested significantly delayed fruit ripening in the coated fruit. Mango carnauba was the most effective in retarding fruit ripening while improving fruit appearance and quality including fatty acids and aroma volatiles.

ACKNOWLEDGMENT

We gratefully acknowledge Geoff Chidlow, School of Applied Chemistry, for his help in GC-MS analysis. We also thank Brendon Greirson, Agilent Technologies Perth, Western Australia, and Alicia Pasznicki from Horticulture Lab, Muresk Institute, for their help.

LITERATURE CITED

(1) Baldwin, E. A.; Burns, J. K.; Kazokas, W.; Brecht, J. K.; Hagenmaier, R. D.; Bender, R. J.; Pesis, E. Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. *Postharvest Biol. Technol.* **1999**, *17* (3), 215–226.

(2) Garcia, M. A.; Martino, M. N.; Zaritzky, N. E. Composite starch-based coatings applied to strawberries (*Fragaria ananassa*). *Nahrung/Food* **2001**, *45*, 267–272.

(3) Xu, S.; Xu, L. D.; Chen, X. Determining optimum edible films for kiwi fruits using an analytical hierarchy process. *Comp. Oper. Res.* **2003**, *30*, 877–886.

(4) Salvador, M. L.; Jaime, P.; Oria, R. Use of edible coatings to reduce water loss and maintain quality of Reinette apple. *Acta Hortic.* **2003**, *600*, 701–705.

(5) Rojas-Argudo, C.; Perez-Gago, M. B.; del Rio, M. A. Postharvest quality of coated cherries cv. 'Burlat' as affected by coating composition and solids content. *Food Sci. Technol. Int.* **2005**, *11* (6), 417–424.

(6) Kittur, F. S.; Saroja, N.; Habibunnisa; Tharanathan, R. N. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. *Eur. Food Res. Technol.* **2001**, *213*, 306–311.

(7) Carrillo-Lopez, A.; Ramirez-Bustamante, F.; Valdez-Torres, J. B.; Rojas-Villegas, R.; Yahia, E. M. Ripening and quality changes in mango fruit as affected by coating with an edible film. *J. Food Qual.* **2000**, *23* (5), 479–486.

(8) Fonseca, M. J. O.; Salomao, L. C. C.; Cecon, P. R.; Puschmann, R. Fungicides and wax in postharvest preservation of mango 'Haden'. *Acta Hortic.* **2004**, *645*, 557–563.

(9) Dhalla, R.; Hanson, S. W. Effect of permeable coatings on the storage life of fruits. II. Pro-long treatment of mangoes (*Mangifera indica* L. cv. Julie). *Int. J. Food Sci. Technol.* **1988**, *23*, 107–112.

(10) Nair, S. Biochemical aspects and control of chilling injury in mango fruit. Ph.D. thesis, Curtin University of Technolgy, 2002.

(11) Hoa, T. T.; Ducamp, M.-N.; Lebrun, M.; Baldwin, E. A. Effect of different coating treatments on the quality of mango fruit. *J. Food Qual.* **2002**, *25* (6), 471–486.

(12) Diaz-Sobac, R.; Luna, A. V.; Beristain, C. I.; De La Cruz, J.; Garcia, H. S. Emulsion coating to extend postharvest life of mango (*Mangifera indica* cv. Manila). *J. Food Process. Preserv.* **1996**, *20* (3), 191–202.

(13) Diaz-Sobac, R.; de la Cruz, J.; Vazquez Luna, A.; Beristain, C. I.; Garcia, H. S. Evaluation of softening and associated enzyme activities during the ripening of coated 'Manila' mangoes. *J. Hortic. Sci.* **1997**, *72* (5), 749–753.

(14) Ketsa, S.; Prabhasavat, T. Effect of skin coating on shelf life and quality of 'Nang Klanwan' mangoes. *Acta Hortic.* **1992**, *321*, 764–770.

(15) Feygenberg, O.; Hershkovitz, V.; Ben-Arie, R.; Jacob, S.; Pesis, E.; Nikitenko, T. Postharvest use of organic coating for maintaining bio-organic avocado and mango. *Acta Hortic.* **2005**, *682*, 507–512.

(16) Diaz-Sobac, R.; Perez-Flores, L.; Vernon-Carter, E. J. Emulsion coatings control fruit fly and anthracnose in mango (*Mangifera indica* cv. Manila). *J. Hortic. Sci. Biotechnol.* **2000**, *75* (1), 126–128.

(17) Quezada-Gallo, J. A.; Gramin, A.; Pattyn, C.; Diaz Amaro, M. R.; Debeaufort, F.; Voilley, A. Biopolymers used as edible coatings to limit water transfer, colour degradation and aroma compound 2-pentanone loss in Mexican fruits. *Acta Hortic.* **2005**, *682*, 1709–1716.

(18) Quezada-Gallo, J. A.; Diaz Amaro, M. R.; Gutierrez Cabrera, D. M. B.; Castaneda Alvarez, M. A.; Debeaufort, F.; Voilley, A. Application of edible coatings to improve shelf life of Mexican guava. *Acta Hortic.* **2003**, *599*, 589–594.

(19) Baldwin, E. A.; Nisperos-Carriedo, M.; Shaw, P. E.; Burns, J. K. Effect of coatings and prolonged storage conditions on fresh orange flavour volatiles, degrees Brix, and ascorbic acid levels. *J. Agric. Food Chem.* **1995**, *43*, 1321–1331.

(20) Nisperos-Carriedo, M. O.; Shaw, P. E.; Baldwin, E. A. Changes in volatile flavor components of Pineapple orange juice as influenced by the application of lipid and composite films. *J. Agric. Food Chem.* **1990**, *38*, 1382–1387.

(21) He, Q.; Changhong, L.; Kojo, E.; Tian, Z. Quality and safety assurance in the processing of *Aloe vera* gel juice. *Food Control* **2005**, *16* (2), 95–104.

(22) Martinez-Romero, D.; Alburquerque, N.; Valverde, J. M.; Guillen, F.; Castillo, S.; Valero, D.; Serrano, M. Postharvest sweet cherry quality and safety maintenance by *Aloe vera* treatment: a new edible coating. *Postharvest Biol. Technol.* **2006**, *39* (1), 93–100.

(23) Serrano, M.; Valverde, J. M.; Guillen, F.; Castillo, S.; Martinez-Romero, D.; Valero, D. Use of *Aloe vera* gel coating preserves the functional properties of table grapes. *J. Agric. Food Chem.* **2006**, *54*, 3882–3886.

(24) Engel, K. H.; Tressl, R. Studies on the volatile components of two mango varieties. *J. Agric. Food Chem.* **1983**, *31*, 796–801.

(25) MacLeod, A. J.; Pieris, N. M. Comparison of the volatile components of some mango cultivars. *Phytochemistry* **1984**, *23* (2), 361–366.

(26) MacLeod, A. J.; Snyder, C. H. Volatile components of two cultivars of mango from Florida. *J. Agric. Food Chem.* **1985**, *33*, 380–384.

(27) Pino, J. A.; Mesa, J.; Muñoz, Y.; Martí, M. P.; Mabbot, R. Volatile components from mango (*Mangifera indica* L.) cultivars. *J. Agric. Food Chem.* **2005**, *53*, 2213–2223.

(28) Fellman, J. K.; Miller, T. W.; Mattinson, D. S.; Mattheis, J. P. Factors that influence biosynthesis of volatile flavour compounds in apple fruit. *HortScience* **2000**, *35* (6), 1026–1034.
(29) Watson, R.; Wright, C. J.; McBurney, T.; Taylor, A. J.; Linforth, R. S. T. Influence of harvest date and light integral on the development of strawberry flavour compounds. *J. Exp. Bot.* **2002**, *53* (377), 2121–2129.
(30) Lalel, H. J. D.; Singh, Z.; Tan, S. C. Maturity stage at harvest affects fruit ripening, quality and biosynthesis of aroma volatile compounds in 'Kensington Pride' mango. *J. Hortic. Sci. Biotechnol.* **2003**, *78* (2), 225–233.
(31) Lalel, H. J. D.; Singh, Z.; Tan, S. C. Aroma volatiles production during fruit ripening of 'Kensington Pride' mango. *Postharvest Biol. Technol.* **2003**, *27* (3), 323–336.
(32) Lalel, H. J. D.; Singh, Z.; Tan, S. C. Distribution of aroma volatile compounds in different parts of mango fruit. *J. Hortic. Sci. Biotechnol.* **2003**, *78* (2), 131–138.
(33) Lalel, H. J. D.; Singh, Z.; Tan, S. C. Ripening temperatures influence biosynthesis of aroma volatile compounds in 'Kensington Pride' mango fruit. *J. Hortic. Sci. Biotechnol.* **2004**, *79* (1), 146–157.
(34) Nair, S.; Singh, Z.; Tan, S. C. Chilling injury adversely affects aroma volatile production in mango during fruit ripening. *Acta Hortic.* **2004**, *645*, 529–535.
(35) Bender, R. J.; Brecht, J. K. Aroma volatiles of mature-green and tree-ripe 'Tommy Atkins' mangoes after controlled atmosphere vs. air storage. *HortScience* **2000**, *35* (4), 684–686.
(36) Lalel, H. J. D.; Singh, Z. Controlled atmosphere storage of 'Delta R2E2' mango fruit affects production of aroma volatile compounds. *J. Hortic. Sci. Biotechnol.* **2006**, *81* (3), 449–457.
(37) Singh, Z.; Lalel, H. J. D.; Nair, S. A review of mango fruit aroma volatile compounds − state of the art research. *Acta Hortic.* **2004**, *645*, 519–527.
(38) Lalel, H. J. D.; Singh, Z.; Tan, S. C. The role of methyl jasmonate in mango ripening and biosynthesis of aroma volatile compounds. *J. Hortic. Sci. Biotechnol.* **2003**, *78* (4), 470–484.
(39) Lalel, H. J. D.; Singh, Z.; Tan, S. C. The role of ethylene in mango fruit aroma volatiles biosynthesis. *J. Hortic. Sci. Biotechnol.* **2003**, *78* (4), 485–496.
(40) Shorter, A. J.; Joyce, D. C. Effect of partial pressure infiltration of calcium into 'Kensington' mango fruit. *Aust. J. Exp. Agric.* **1998**, *38*, 287–294.
(41) Malik, A. U.; Singh, Z. Pre-storage application of polyamines improves shelf-life and fruit quality of mango. *J. Hortic. Sci. Biotechnol.* **2005**, *80* (3), 363–369.
(42) Van Den Dool, H.; Dec Kratz, P. A generalisation of the retention index system including linear temperature programmed gas−liquid partition chromatography. *J. Chromatogr., A* **1963**, *11*, 463–471.
(43) Valverde, J. M.; Valero, D.; Martinez-Romero, D.; Guillen, F.; Castillo, S.; Serrano, M. Novel edible coating based on *Aloe vera* gel to maintain table grape quality and safety. *J. Agric. Food Chem.* **2005**, *53*, 7807–7813.

Received for review July 24, 2007. Revised manuscript received November 5, 2007. Accepted November 17, 2007. K.T.H.D. is thankful to Nong Lam University, Ho Chi Minh City, Vietnam, and the Ministry of Education and Training, Vietnam, for providing a scholarship during her Ph.D. degree.

JF072208A