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Coating Guavas with Cellulose- or Carnauba-based Emulsions Interferes with Postharvest Ripening

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Abstract. **Harvested, mature-green guava *(Psidium guajava* L.) fruit were coated with cellulose- or carnauba-based emulsions to compare the effect on fruit ripening and quality of ripened fruit. Coatings containing 2% or 4% hydroxypropylcellulose significantly slowed softening an average of 35% or 45%, respectively, compared to uncoated fruit (a delay of 1 to 2 days in September and 4 to 5 days by January). A 5% carnauba formulation slowed softening by 10% to 30% and was most effective at reducing weight loss. Neither of the cellulose- nor the carnauba-based coatings affected the decay susceptibility of softened fruit, but coated fruit did not develop as much color, had a lower soluble solids concentration, and were more prone to surface blackening in storage than uncoated fruit.**

Guavas are tropical, climacteric fruit that are typically harvested while still green and firm then placed into storage between 7 and 12C for shipment to markets. Fruit removed from cold storage to ≥20C ripen within 3 to 10 days (Vazquez-Ochoa and Colinas-Leon, 1990). Soon after ripening begins, the decay fungus *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz., which can be latent but undetectable in unripe fruit (Jeffries et al, 1990), may make fruit unsalable. In combination with temperature control, a mechanism that delays ripening of guavas would allow the shipper and retailer a greater window of opportunity for maintaining fruit quality.

Coating formulations have been developed to enhance many fruit characteristics. These materials may reduce weight loss, promote color, or retard decay. To varying degrees, all coatings promote the selective exchange of gases between the storage atmosphere and fruit (Kester and Fennema, 1986). Nature Seal (EcoScience, Orlando, Fla.) coatings, based on cellulose derivatives, are specifically formulated to reduce O_2 diffusion into a fruit and stop CO_2 diffusion to the outside, thereby delaying fruit ripening (Nisperos-Carriedo et al., 1991). Our objectives were to ascertain changes in the ripening rate of guavas coated with two such cellulose emulsions or a commercial carnauba wax and to compare the market quality of ripe fruit.

Materials and Methods

Mature-green guavas [averaging 93 g (SD = 32.5)] were obtained from a local packinghouse in Dade County, Fla., within 3 h of harvest. Forty fruit washed in tap water were randomly sorted into each of three treatments and a control group then weighed individually. Surface coatings were applied by hand-wiping fruit with ≈6.4 $\mu l \cdot cm^{-2}$ of surface. These coatings included a commercial carnauba wax formulation, TFC 213 (American Machinery Corp., Orlando, Fla.), containing 5% carnauba wax and fatty acid soaps with a total solids content of 8%, and two Nature Seal formulations composed of hydroxypropylcellulose at either 2% or 4% plus preservative, acidulant, and emulsifiers with total solids of 3% and 5%, respectively (Nisperos-Carriedo and Baldwin, 1992). Fruit were allowed to air-dry for 90 min. Then, treated fruit and the uncoated controls were placed into storage at 12C. After 7 days, all fruit were weighed individually a second time and removed to 20C to ripen. This procedure was replicated five times for a total of six harvests throughout the season (three harvests in Sept. 1993, one each in Oct. and Nov. 1993, and one in Jan. 1994).

Fruit taken from cold storage were examined daily after their removal to 20C, and the date was noted when gentle finger pressure applied simultaneously from both sides could indent the fruit ≈0.5 cm. This subjective measurement of firmness corresponded to a resistance by the fruit of 10 to 20 N; at harvest, resistance averaged 96.8 N. When 50% of the control fruit had softened and were subjectively estimated to be ripe, the quality of all fruit was evaluated. Fruit were weighed a third time, and the percentages of surface decay and injury were estimated with a 12-point visual acuity scale (Horsfall and Barratt, 1945). Firmness of each fruit was measured with a universal testing instrument (model 1011; Instron Corp., Canton, Mass.) fitted with a compression anvil 12 mm in diameter. Resistance to pressure was recorded after a compression of 3 mm. The color at the equator of each fruit was determined with a chromameter (model CR-200; Minolta Corp., Ramsey, N.J.) recording in the L*, C*, and h° (lightness, chroma, and hue angle, respectively) color system that had been calibrated to a standard white reflective plate. Measurements were taken across an area of ≈50 mm^2 with diffuse illumination at a viewing angle of 0° under CIE illuminant C conditions (McGuire, 1992).

Twenty ripe control fruit and 10 randomly chosen treated fruit were peeled, and the pulp of individual fruit was forced through a 16-mesh sieve (pore size = 2.25 mm^2) to remove seeds. Pulp (21 g) was mixed with 5 ml of distilled water, and the pH was determined. One gram of this mixture was transferred to a centrifuge tube and spun at 5000× *g* for 15 min, and the refractive index (Abbe refractometer; Fisher Scientific Co., Pittsburgh) was determined on the supernatant for calculation of the soluble solids concentration (SSC). The remaining pulp was titrated with 0.1 M NaOH to a pH of 8.1 for calculation of titratable acidity expressed as the percentage of citric acid.

The same procedures were repeated a second time on 10 additional treated fruit when a subjective evaluation indicated that 50% of fruit in a particular treatment had softened. Thus, we were able to compare 1) the level of ripeness of treated fruit at the time controls were ripe and 2) the quality of softened and presumably ripe, treated fruit with ripe controls.

Table 1. Ripening retardation in guavas after postharvest application of cellulose- or carnauba-based emulsions and cold storage.

Coating	Days until softening at 20C[z]					Fruit not softening[y]
	September	October	November	January	Mean[y]	(%)
None	6.2	7.0	8.8	11.3	8.3 c	4.2 b
Hydroxypropyl cellulose						
2%	7.9	8.4	13.0	15.5	11.2 ab	9.2 ab
4%	9.0	9.0	14.7	16.2	12.2 a	15.8 a
Carnauba wax, 5%	6.7	8.6	11.6	14.7	10.4 b	4.4 b

[z]Fruit were held at 12C for 7 days then 20C to ripen (as judged subjectively by resistance to gentle finger pressure). Months represent experimental replications.
[y]Means of 240 fruit per treatment. Mean separation at $P \leq 0.05$ according to the Ryan–Einot–Gabriel–Welsh multiple F test in SAS.

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The data were tested by analysis of variance, and means were separated (Ryan–Einot–Gabriel–Welsch multiple F test) using the SAS statistical package (1985). After analysis, Horsfall–Barratt rating values were converted to percent surface area decayed or injured.

Results and Discussion

As the harvest progressed from late summer through early winter, the time required for uncoated, cold-stored, control fruit to ripen when moved to 20C increased from 6 to 11 days (Table 1). As harvest date was not a replicated variable, however, this factor was not included in the statistical analysis. Coated fruit consistently softened at a slower rate than uncoated control fruit. Applying 2% hydroxypropylcellulose delayed softening from 1 to 4 days; the same material at 4% did not significantly increase this delay. The commercial 5% carnauba formulation also delayed softening, though generally not to the same extent as the hydroxypropylcellulose coatings. Between 4% and 16% of the guavas did not soften within 2 to 3 weeks; this percentage increased with the hydroxypropylcellulose concentration but was not affected by the carnauba wax (Table 1). The 5% carnauba wax consistently retarded weight loss in storage more effectively than either formulation of hydroxypropylcellulose (Table 2).

When control fruit were ripe, coated fruit were firmer, their surface pigmentation was greener and generally less intense, and pulp SSC was lower (Table 3). For all coatings, decay and injury (a tendency for ridges on the peel to blacken) were below levels found in the controls.

When coated fruit softened and were more directly comparable to the equally soft, ripe controls, they continued to be somewhat greener, darker, and less vivid than uncoated fruit (Table 3). Although decay severity was similar among controls and coated fruit, injury was significantly more widespread on the latter. Titratable acidity in the pulp of softened, coated fruit was similar to that in the uncoated controls, but the SSC of most coated fruit remained lower.

Traditionally, fruit coatings have been applied to improve appearance and reduce moisture loss in storage (Kester and Fennema, 1986). All films also offer some resistance to gas exchange, depending on their composition and thickness. As commercially applied, however, carnauba waxes are less likely to affect the permeability of O_2, CO_2, or C_2H_4 (Hagenmaier and Shaw, 1992). Hydrophilic films, such as those incorporating starch, carrageenan, or cellulose, retard the movement of these gases but have less effect on water vapor (Kester and Fennema, 1986). Coatings, unintentionally in the case of the carnauba formulation or intentionally in the case of those based on a cellulose derivative, manipulate O_2 and CO_2 levels within fruit in a manner analogous to that of modified-atmosphere storage. Storage atmospheres rich in CO_2 successfully delay ripening in diverse fruit (Smith et al., 1987). Applying a cellulose-based film to papayas (*Carica papaya* L.) alters the internal gas concentrations, retards ripening, and extends shelf life (Baldwin et al., 1992). A similar alteration may explain the delayed softening and color development of coated guavas.

Coating guavas does not affect all aspects of ripeness at the same rate. Hydroxypropylcellulose or carnauba wax coatings allow softening to proceed, but full color development and SSC are not attained. Softening can develop as a result of the fruit producing polygalacturonase or from maceration by pectolytic enzymes produced in infections by *C. gloeosporioides* (Mason and Jeffries, 1993). Pectate lyase, one enzyme in the arsenal of this fungus, is more invasive under conditions of low O_2 (Maher and Kelman, 1983).

These coatings also make cold-stored guavas prone to a blackening of the peel after their removal to a ripening temperature. Cold-stored guavas may not be amenable to the modified atmospheres induced within fruit by these particular coatings. Oxygen may become too severely limited and CO_2 concentrations too high within fruit at a time when they not only must undergo metabolic changes induced by the onset of ripening but also adapt to cold temperatures. Coating cold-stored guavas with any film may not be advisable if quality is to be maintained.

Table 2. Weight loss during storage of guavas after postharvest application of cellulose- and carnauba-based emulsions.

	Wt loss (%)[z]		
Coating	On removal from 7 days at 12C	Control fruit ripe at 20C	Coated fruit ripe at 20C
None	5.6 a	17.3 a	NA
Hydroxypropyl cellulose			
2%	4.9 a	14.9 b	23.6 a
4%	4.9 a	14.2 b	22.5 a
Carnauba wax, 5%	3.2 b	10.9 c	15.8 b

[z]NA = not applicable. Means of 240 fruit per treatment. Mean separation at $P \leq 0.05$ according to the Ryan–Einot–Gabriel–Welsh multiple F test in SAS.

Table 3. Quality aspects of guavas after postharvest application of cellulose- and carnauba-based emulsions and cold storage.

					Surface			Pulp[z]	
	Firmness	Color[y]			Decay	Injury		TA	SSC
Coating	(N)	L*	C*	h°	(%)	(%)	pH	(%)	(%)
First comparison: Control fruit ripe at 20C[x]									
None	14.9 a	60.5 a	41.3 a	90.3 c	4.7 a	4.6 a	3.8 a	0.66 a	8.10 a
Hydroxypropyl cellulose									
2%	22.1 b	57.6 b	39.3 b	102.2 a	2.3 bc	2.3 b	3.8 a	0.63 a	7.16 b
4%	24.6 b	56.5 b	38.8 b	105.3 a	1.8 c	2.3 b	3.9 a	0.69 a	7.17 b
Carnauba wax, 5%	22.2 b	58.5 ab	39.1 b	97.9 b	3.3 ab	1.9 b	3.9 a	0.66 a	6.73 b
Second comparison: Coated fruit ripe at 20C[x]									
None	14.9 a	60.5 a	41.3 a	90.3 cd	4.7 a	4.6 b	3.8 a	0.66 a	8.10 a
Hydroxypropyl cellulose									
2%	15.7 a	55.2 b	36.2 b	95.9 ab	5.3 a	17.7 a	3.8 a	0.64 a	7.11 a–c
4%	17.0 a	53.6 b	35.2 b	99.8 a	6.8 a	19.2 a	3.9 a	0.64 a	6.74 c
Carnauba wax, 5%	16.1 a	56.9 b	36.9 b	94.0 bc	6.0 a	12.8 a	3.9 a	0.69 a	6.88 bc

[z]TA = titratable acidity; SSC = soluble solids concentration.
[y]Color in CIE; L* = lightness (0 = dark, 100 = light), C* = chroma (0 = dull, 100 = vivid), h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish green).
[x]Means of 240 fruit per treatment. Mean separation at $P \leq 0.05$ according to the Ryan–Einot–Gabriel–Welsh multiple F test in SAS.

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