Candelilla-shellac: An Alternative Formulation for Coating Apples

Victorine Alleyne and Robert D. Hagenmaier
U.S. Department of Agriculture, Agricultural Research Service, Citrus and Subtropical Products Laboratory, 600 Avenue SNW, Winter Haven, FL 33881

Abstract. An experimental candelilla-shellac formulation for coating apples (Malus ×domestica Borkh.) was developed and compared with commercial shellac-based and carnauba-shellac-based coatings on 'Gala' and 'Delicious' apples by determining effects on quality attributes, respiration, and internal atmospheres. Fruit were stored at 5 °C for 7 days followed by storage at 21 °C for 14 days. Gloss of 'Delicious' apples coated with candelilla-shellac formulations containing 7% to 34% shellac increased with increasing shellac concentrations. 'Gala' and 'Delicious' apples coated with a candelilla formulation containing 34% shellac maintained quality similar to those coated with commercial carnauba-shellac-based coatings, as indicated by gloss, firmness, internal CO2, O2, and ethanol levels, steady-state respiration rate, weight loss, and flavor. By comparison, shellac-coated fruit maintained the highest gloss throughout the experimental period. Shellac-coated apples were also firmer, contained more ethanol, and received higher flavor scores than did apples receiving other coating treatments. Gloss of all coated fruit decreased with time, although shellac-coated fruit lost less gloss over the 21-day storage period. Analysis of gloss, firmness, fruit respiration, ethanol, weight loss, and flavor demonstrated that the candelilla formulation containing 34% shellac is competitive with current commercial carnauba-based apple-coating products.

Apples usually are coated before market distribution, primarily to improve their appearance. Other benefits of wax coatings include a shelf-life extension, reduction of weight loss and respiration rate, ripening retardation, and quality maintenance (Saftner et al., 1998). Commercial apple coatings are either shellac or carnauba-shellac based. These materials are associated with nonfood uses such as floor and car waxes. Alternative ingredients for shellac and carnauba-shellac must be found in the event that consumers become uncomfortable about their use on apples.

Candelilla wax, an extract from the plant Euphorbia antisyphilitica Zucc., is a generally recognized as safe (GRAS) substance that is permitted for use in certain foods with no limitations except good manufacturing practices (21 CFR, Code of Federal Regulations, 184.1976). Candelilla has extended the storage life of bananas (Musa sp.) (Siade and Pedraza, 1977), tomato (Lycopersicon esculentum), muskmelons (Cucumis melo L., Cantalupensis Group) (Siade et al., 1977), limes [Citrus aurantifolia (Christm.) Swingle] (Paredes-Lopez et al., 1974), and other citrus fruits (Lakshminarayana et al., 1974). Candelilla has a similar low-oxygen permeability but a 50% lower water-vapor permeability, than does the commonly used ingredient in apple coatings, carnauba wax (Donhowe and Fennema, 1993). Hence, candelilla is the more effective water-vapor barrier. Carnauba wax is an exudate of leaves of a Brazilian palm, Copernicia cerifera (Arr. Cam.) Mart. It is also considered a GRAS substance and is permitted for use in coatings for a range of food products, including fruits and vegetables. Shellac resin, a secretion from the insect Laccifer lacca Kerr, also used in apple coating formulations, is a versatile compound that dissolves in alcohols and alkaline solutions. Because of its compatibility with most waxes, shellac can be incorporated into wax formulations and contributes higher gloss (Baldwin et al., 1995; Hernandez, 1994) to the coated products. The objective of this study was to develop and evaluate coating formulations containing candelilla that could substitute for carnauba coatings.

Materials and Methods

'Gala' and 'Delicious' apples were obtained from a commercial packinghouse in Wenatchee, Wash., in 1998, after 6 months of controlled atmosphere (2% CO2 and 1.1% O2 at 0 °C) storage. 'Gala' fruit weight ranged from 200 to 245 g (size 88) while 'Delicious' ranged from 250 to 287 g (size 80). Fruit were shipped via 2-d Federal Express to Winter Haven, Fla. 'Gala' apples arrived on 5 Mar. and were placed at 5 °C prior to coating on 10 and 17 Mar. 'Delicious' apples arrived on 5 May, and treatments were applied on 6 May without prior on-site cold storage and on 13 May after removal from 5 °C storage. Before coating treatments were applied, the apples were removed from cold storage and allowed to stand at room temperature (25 °C) for 24 h. Coatings were applied manually, using 0.5 ml fruit spread evenly over the surface using gloved hands. A pilot-plant scale conveyor dryer (Central Florida Sales and Service, Auburndale) dried fruits at 50 °C for 5 min. Fruits were then stored for 7 d at 5 °C, then 14 d at 21 °C and 45% relative humidity (RH) in temperature-controlled rooms, to simulate marketing conditions. Coatings were evaluated in duplicate experiments, using 'Gala' apples in Expts. 1 and 2 and 'Delicious' apples in Expts. 3 and 4.

The experimental candelilla-shellac formulation was made by mixing a candelilla wax microemulsion with a shellac solution. The microemulsion was made in a pressure cell loaded with 300 g candelilla wax (No. 75; Stratf and Petsch, W. Babylon, N.Y.), 30 g oleic acid (Emersol; Henkel Chemicals Group, Cincinnati), 15 g myristic acid (Emery 655; Henke Chemicals Group and Hystrene 9014; Wito Corp., Newark, N.J.), 41 g 30% NH3, and 145 g water. This mixture was heated to 100 °C, 900 g additional water was added, and the emulsion was mixed 5 min, rapidly cooled in a water bath at 50 °C, and adjusted to 20% total solids and 0.7% gelatin (Rousselot 75 A; Bio-Industries, Waukesha, Wis.) with addition of water and gelatin solution. The shellac solution contained 20% shellac (RS2; Mantrose Haueser, Atteboro, Mass.), 0.7% gelatin, and 0.3% NH3, and the pH was adjusted to 9.3 with additional NH4 OH. The shellac solution was added to the stirred candelilla wax emulsion to make formulations with shellac as 20% or 34% of the coating solids (CANDS20 and CANDS34, respectively). For example, CANDS20 consisted of 80% candelilla emulsion and 20% shellac solution. For the preliminary experiments, formulations with other percentages of shellac were also used. Experimental formulations were compared with two shellac coatings: AP-40 (Shield-Brite Corp., Kirkland, Wash.) (SH1) and Vector 7 (Solutec Corp., Yakima, Wash.) (SH2); and two carnauba-shellac coatings: Apple Lustr 231 (Decco, Monrovia, Calif.) (CARS1) and Primafresh HS (Johnson’s Wax, Racine, Wis.) (CARS2).

External quality (gloss), internal quality (firmness and sensory flavor), and physiological indicators (internal CO2 and O2, weight loss) were evaluated using 10 individual fruit replicates per treatment. Steady-state respiration rate was measured using two replicates of five fruit each. Composite samples from three fruits were used to evaluate ethanol content and sensory flavor.

Average gloss units (GU) at an angle of 60° to a fine normal with the fruit surface were measured using a micro-TRI-gloss reflectometer (BYK-Gardner, Silver Spring, Md.) equipped with a shield having a circular 19-mm-diameter aperture (Hagenmaier and Baker, 1994). Gloss of apples ranged from ≈3.0 GU for noncoated fruit to 13.0 GU for shellac-coated fruit.

Apple firmness was assessed with a fruit pressure tester (model FT 327; McCormick, Facchini, Alfonzio, Italy), equipped with an 8-mm-diameter, flat cylinder plunger. Two

Received for publication 29 Mar. 1999. Accepted for publication 14 July 1999. Mention of a trademark or proprietary product is for identification only and does not imply a guarantee or warranty of the product by the U.S. Dept. of Agriculture. The U.S. Dept. of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status.

To whom reprint requests should be addressed. E-mail address: hagenmaier@ithink.com.
measures of penetration force at 90° angles were taken at opposite sides, in the equatorial plane of each fruit, after removing a 12-mm-diameter disc of peel.

Gas samples for internal gas measurements were obtained by submerging fruits under water, then inserting a syringe needle through the stylar end into the core cavity and withdrawing a 5–10-mL sample. Before sampling, the syringe was flushed with water to remove trapped air. The CO$_2$ and O$_2$ concentrations in the syringe were obtained by submerging fruits under water for 1 h. The diameter disc of peel.

A continuous flow-through system was used to measure fruit steady-state respiration rate at 21 °C. Sealed glass jars (3.8 L) each containing 1 kg fruit were attached to a source of air. Humidity inside the jars was controlled at 43% by passing the flow-through air into a saturated solution of K$_2$CO$_3$/2H$_2$O. Respiration rate was estimated from CO$_2$ exhaust, air flow rate, and weight of the sample. A GC equipped with a 30 m × 0.53 mm GSQ column ID (J&W Scientific, Folsom, Calif.) and a thermal conductivity detector was used for CO$_2$ analysis. Conditions for chromatography were identical to those indicated above.

Coated ‘Gala’ fruit contained higher CO$_2$ and lower internal O$_2$ levels than did noncoated fruit, but no difference between coatings was detected (Table 2). Coating treatments did not affect ‘Gala’ firmness values ranging from 31 to 33 N. Steady-state respiration rate of ‘Gala’ apples was not affected by treatment, but rates ranged from 22.7 mg·kg$^{-1}$·h$^{-1}$ in noncoated fruit to 16.0 in CAR$S_2$-coated fruit, suggesting a trend toward reduction in respiration rate because of coating. Ethanol content of ‘Gala’ fruit was not affected by treatment, and was generally low. Sensory flavor score was also unaffected by treatment. No specific trend was evident in terms of ethanol content and flavor.

Results and Discussion

Gloss of ‘Delicious’ apples increased with increasing concentrations of shellac added to candellila wax formulations. Average gloss ranged from 8.7 GU at 0% shellac to 10.1 GU at 34% shellac. The commercial carnauba-shellac coating (CARS$2_2$) had mean gloss of 10.0 GU, about the same as the candellila-shellac formulations containing 34% shellac.

The initial and final gloss of ‘Gala’ apples coated with CANDS$2_0$ was virtually the same as that of apples with the CARS$2_2$ coating (Fig. 1). Initial gloss of apples with CANDS$2_0$ was somewhat less than that of apples with the CARS$2_2$ coating. In general, coated apples had markedly higher initial gloss than noncoated fruit (Fig. 1). Gloss is a surface phenomenon associated with texture (Bennet, 1975), but the exact mechanism for gloss decay is unknown.

Coated ‘Delicious’ apples had higher initial gloss than noncoated fruit throughout the experimental period (Table 1). Apples coated with formulations containing only shellac had the highest gloss during the 21-d storage period. Of the two commercial carnauba-shellac coatings, one was superior to the candellila-shellac coating both initially and after cold storage. Gloss of all fruit, coated and noncoated, decreased during storage; CARS$2_2$-coated fruit exhibited the greatest decrease while SI$2_2$ exhibited the least.

These results indicate that shellac-coated fruit had high initial gloss and maintained higher gloss than the wax-based formulations during cold storage and at room temperature. These findings differ from those reported for citrus by Hagenmaier and Baker (1994), where gloss of shellac coatings decreased more than that of wax coatings. This difference may be attributed to commodity differences in natural wax coatings, fruit surface topography, firmness and rigidity, and/or storage temperature regimen. Apples are very firm fruit with smooth surfaces, whereas citrus is a resilient fruit with many small surface indentations, and thus may be more prone to coating fractures due to handling. Gloss levels of fruit coated with candellila-shellac generally were similar to those of fruit coated with carnauba-shellac throughout the experimental period. These results confirm that experimental candellila-shellac coating can confer gloss characteristics to apples comparable to commercially used coating products.

Coated ‘Gala’ fruit contained higher CO$_2$ and lower internal O$_2$ levels than did noncoated fruit, but no difference between coatings was detected (Table 2). Coating treatments did not affect ‘Gala’ firmness values ranging from 31 to 33 N. Steady-state respiration rate of ‘Gala’ apples was not affected by treatment, but rates ranged from 22.7 mg·kg$^{-1}$·h$^{-1}$ in noncoated fruit to 16.0 in CAR$S_2$-coated fruit, suggesting a trend toward reduction in respiration rate because of coating. Ethanol content of ‘Gala’ fruit was not affected by treatment, and was generally low. Sensory flavor score was also unaffected by treatment. No specific trend was evident in terms of ethanol content and flavor.

‘Delicious’ apples coated with commercial shellac formulations were firmer than fruit treated with the other coatings or noncoated fruit (Table 3), but firmness of apples coated with candellila-shellac and carnauba-shellac coatings was similar. In previous studies, commercial shellac coatings reduced softening and other evidence of ripening in ‘Delicious’ and ‘Golden Delicious’ apples (Drake and Nelson, 1990; Saffner et al., 1998).

All coatings increased internal CO$_2$, and reduced internal O$_2$ of ‘Delicious’ apples, with only small differences between the coatings (Table 3). These results agree fairly well with those of Drake and Nelson (1990), who found no differences among shellac, carnauba, and
In summary, an experimental candelilla formulation with 34% shellac conferred gloss characteristics comparable to those of commercial carnauba-shellac coatings on ‘Delicious’ and ‘Gala’ apples. Firmness, ethanol content, and flavor of apples coated with candelilla-shellack were similar to those of carnauba-shellack-coated fruit. In general, quality of the former was similar to that of apples coated with commercial carnauba products.

Shellack-coated ‘Delicious’ apples had higher gloss, firmness, and ethanol content than wax-coated fruit. Shellack and wax-shellack coatings on ‘Delicious’ and ‘Gala’ apples reduced internal \(\text{O}_2\), increased internal \(\text{CO}_2\), and reduced steady-state respiration rate and weight loss of ‘Delicious’ apples. Flavor tended to be better in coated than noncoated apples. ‘Delicious’ apples were more responsive to coating treatments than were ‘Gala’ apples.

**Literature Cited**


Hagenmaier, R.D. and R.A. Baker. 1994. Metabolic differences between citrus and apples: Comparison of internal \(\text{CO}_2\) and \(\text{O}_2\) levels and 
shifted 
respiration rate.

Shellack-coated ‘Delicious’ apples contained much more ethanol than did the other treatments (Table 3). The trend towards higher \(\text{CO}_2\) and lower \(\text{O}_2\) that characterized shellack-coated apples correlates with observed lower respiration rates, and emphasizes the influence of the coating-mediated modified internal atmosphere on fruit respiration rate.

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