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Effects of Waxing on Moisture Loss and Ripening of 'Fuerte' Avocado Fruit

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Abstract. **Internal atmosphere composition, respiration rate, ethylene production, weight loss, and firmness were monitored during the ripening of waxed and nonwaxed avocado fruit *(Persea americana* Mill.) during storage at** 5°C, **and ripening at 20°. Artificial waxing, which usually forms a uniform film over the closely packed platelet structure of the natural wax, was sometimes incomplete. Waxing caused a slight buildup of CO_2 and possible reduction in internal O_2 concentrations during the preclimacteric of stored fruit, and may have reduced ethylene synthesis during the climacteric. Waxing caused a 1-day delay in fruit softening under extended cold-storage conditions.**

Polyethylene wax emulsions have become important in the storage and marketing of avocado because they reduce moisture loss, delay softening, and improve appearance, especially of the 'Fuerte' cultivar (9). During the past 3 years, over 7000 MT of waxed avocado fruit were marketed yearly in Europe. Experience with citrus indicates that the application of a selected artificial wax does not produce off-flavors while reducing moisture loss (1, 8); waxing of apple fruit does not affect flavor or ripening adversely (11). Attention has been given to the internal atmospheres of waxed fruit (2, 6, 8) in investigations of extended storage of citrus.

In general, waxing increases the CO_2 and decreases the O_2 concentrations of the internal atmosphere during storage. Increased internal CO_2 concentration could not be correlated with the decreased moisture loss (3, 6). Zauberman et al. (15) found that waxing avocado fruit depressed respiration and ethylene production of 'Fuerte' avocado. It is conceded generally that endogenous ethylene triggers a respiratory rise in only the climacteric class of fruit during the ripening process (10). A threshold value of 2 ppm ethylene in the atmosphere of avocado fruit was postulated by Burg and Burg (5). An

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analysis of the internal atmosphere and scanning electron microscopy (SEM) of waxed and nonwaxed fruit is reported here to elucidate the effect of waxing on avocado fruit ripening.

‘Fuerte’ avocado were picked and randomizedized the following day into lots of *5* fruit each; each fruit served as a replicate. Half of the lots were treated with a 12% water emulsion, polyethylene-based wax applied with a 2.50 T-Jet nozzle at a pressure of 380 kPa. The remaining lot were not waxed. Individual lots of waxed and nonwaxed fruit were subjected to the following storage and temperature treatments: a) storage at constant 20°C and about 80% relative humidity until soft, or b) storage at constant 5° and about 90% relative humidity for 14 days and then transfer to 20° until soft. One lot of 5 fruit for every treatment combination was used to monitor CO_2 and ethylene productions according to procedures previously described (14). A separate lot from each treatment combination was assessed at regular intervals for composition of internal atmosphere, CO_2 and ethylene production rates, weight loss, and firmness. The internal atmosphere was sampled according to a vacuum-extraction method (12), modified by using an upside-down 10 cm^3 syringe body fitted to a screw-on top of the bottle. A vacuum of 66.7 kPa (500 mm Hg) was applied to individual fruit for 30 sec. Gas samples were analyzed for ethylene, CO_2 and O_2 by gas chromatography. Fruit firmness was determined with a mechanized Chatillon pressure tester, equipped with a 6.5-mm-diameter conical tip (13, 14).

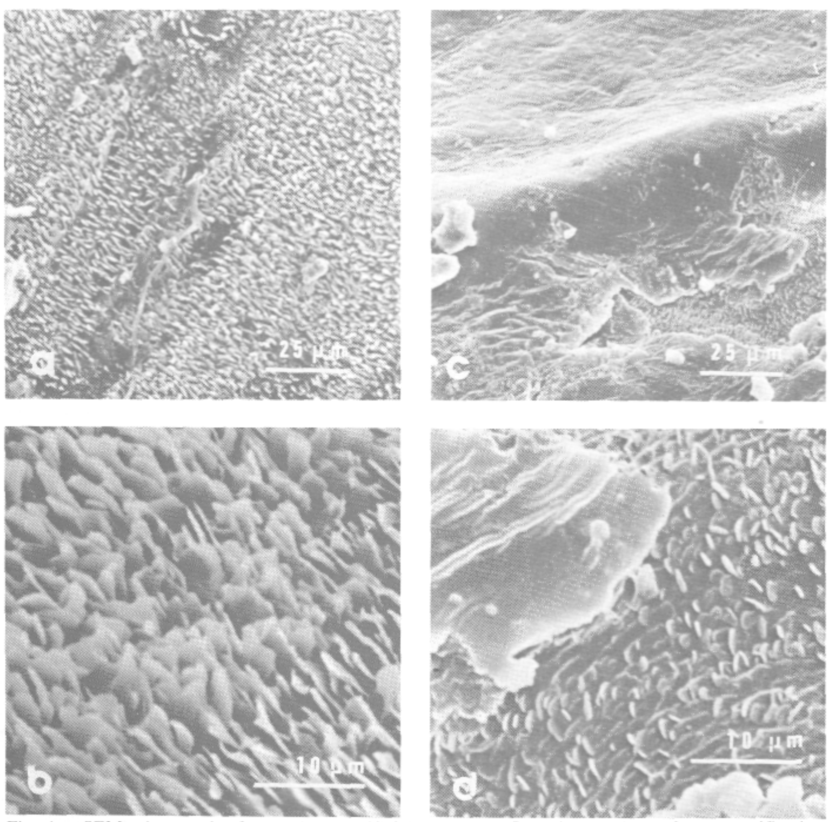

Fig. 1. SEM micrograph of natural and artificial waxes on ‘Fuerte’ avocado. **a**) Low magnification of natural wax structure, indicating some disorder in surface continuity (×450). **b**) Closely packed platelets in a well-oriented structure of the natural wax (×1500). **c**) Low magnification of artificial emulsion-wax film applied on avocado fruit peel (×450). **d**) Cracks in the artificial, emulsion-wax film (×1500).

Natural and waxed 'Fuerte" avocado cuticles were examined by SEM. Sections of the exocarp, 4-6 mm^2, were cut from selected fruit, freeze-dried, attached to aluminum stubs with silver paint, and coated with a thin layer of gold (20 nm) using the sputter technique. All specimens were examined with a Cambridge Stereoscan 180 SEM operated at 10-15 kV.

During 8 days at 20°C, waxed and nonwaxed avocado lost 5.1 % and 11.0% weight, respectively. After 14 days at 5° and then 4 days at 20° the difference was considerably less, with waxed avocado and nonwaxed losing 3.9% and 5.7% fresh weight, respectively. The same trends were reported by Zauberman et al. (15). SEM indicated that the natural cuticular wax, which appeared as well-oriented, closely packed platelet structure (Fig. 1a) exhibited some disorder in surface continuity (Fig. 1b). The commercial wax application, which usually forms a continuous and uniform film (Fig. 1c), was sometimes incomplete (Fig. 1d); therefore, the differences between waxed and unwaxed fruit also might vary according to the effective coverage of the surface area.

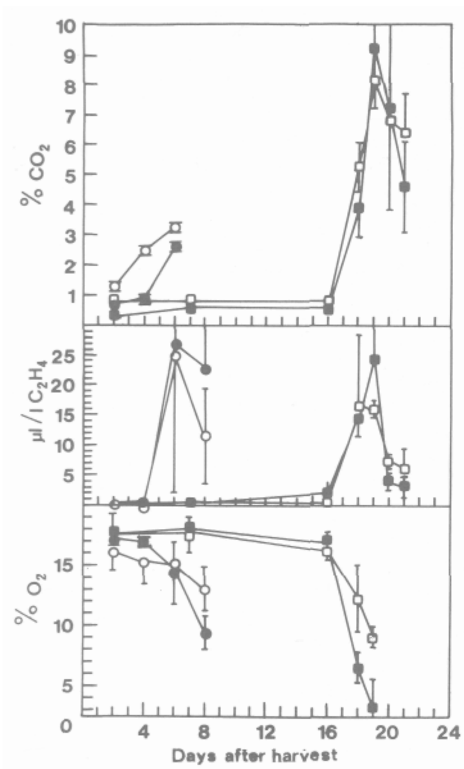

Fig. 2. Internal CO_2, C_2H_4, and O_2 concentrations of waxed (○) and nonwaxed (●) avocado fruit stored at 20°C, and for waxed (□) and nonwaxed (■) fruit stored for 14 days at 5° and additional 5 days at 20°. Data represent means and SD, 5 fruit per treatment.

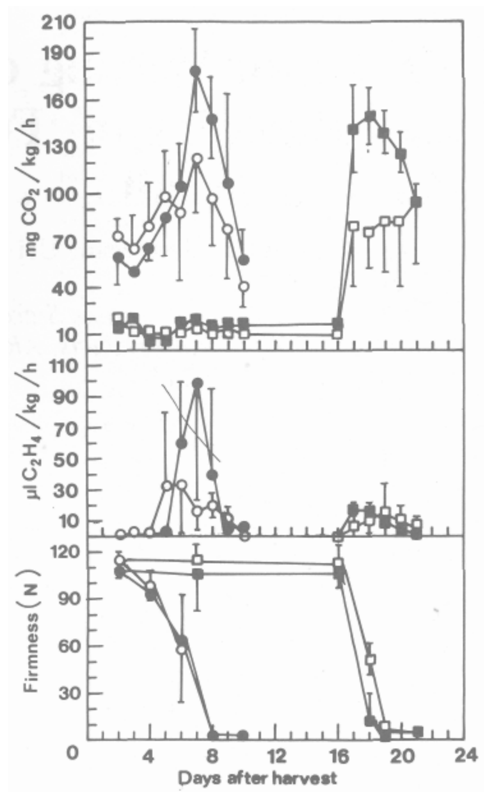

Fig. 3. Ethylene and CO_2 evolution rates and the softening rates of waxed (○) and nonwaxed (●) avocado fruit stored at 20°C, and for waxed (□) and nonwaxed (■) fruit stored for 14 days at 5° and additional 5 days at 20°. Data represent means and SD, 5 fruit per treatment.

Internal gas composition exhibited the typical CO_2 and ethylene production patterns characteristic for climacteric fruits (Fig. 2). Waxing caused an initial, but probably an insignificant, increase in the internal CO_2 level of fruit 2 days after waxing. Differences in CO_2 levels between waxed and unwaxed fruit decreased with time. Emanations of CO_2

and ethylene (Fig. 3) followed the same patterns of the internal atmosphere regimes. Control fruit at 20°C showed synchronization between respiration, and ethylene similar to that observed by Eaks (7).

Trends in the internal O_2 concentration (Fig. 2) support the observations (Fig. 3) for CO_2 production. As the climacteric gained momentum, however, O_2 was consumed and CO_2 was evolved (Fig. 3) at higher rates in the nonwaxed than in the waxed avocado. The reduction in respiration might be caused by a restriction in O_2 diffusion into the fruit by the wax application, and the naturally high internal CO_2 level. Biale (4) found that a reduction in O_2 concentration of the external atmosphere affected the climacteric peak deleteriously. The same might hold true when the inward diffusion of atmospheric O_2 is obstructed by an artificial wax layer on the fruit.

Almost no difference was found in the softening rate of waxed and nonwaxed fruit at 20°C without cold storage. After 14 days of cold storage, the nonwaxed fruit softened one day earlier, with the criterion for eating ripeness taken as 20-30 N firmness (Fig. 3). Studies by Zauberman et al. (15) showed that waxing delayed avocado fruit softening by 1 day, even when ripening (at 20°) was induced by a 24-hr application of exogenous ethylene, after 14 days of cold storage.

The presented data suggest that the artificial wax coating had relatively little effect on the fruit-softening processes following 2 weeks of cold storage. Internal CO_2, O_2, and C_2H_4 levels did not vary substantially between waxed and nonwaxed fruit; however, weight loss at 20° was reduced substantially by waxing.

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