Wang (ed.) Chilling injury of Horticultural crops. CRC Press, Inc. Boca Raton, Fla.
Gould, W. P. and J. L. Sharp. 1990. Cold-storage quarantine treatment for carambolas infested with the Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 83:458-460.
Gould, G. W. and D. L. von Windeguth. 1991. Gamma irradiation as a quarantine treatment for carambolas infested with Caribbean fruit flies. Fla. Entomol. 74:297-300.
Hallman, G. J. 1989. Quality of carambolas subjected to hot-water immersion quarantine treatment. Proc. Fla. State Hort. Soc. 102:155-156.
Hallman, G. J. 1990. Vapor-heat treatment of carambolas infested with Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 83:2340-2342.
Hallman, G. J. 1991. Quality of carambolas subjected to postharvest hot water immersion and vapor heat treatments. HortScience 26:286-287.
Hallman, G. J. and J. R. King. 1992. Methyl bromide fumigation quarantine treatment for carambolas infested with Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 85:1231-1234.
Hallman, G. J. and J. L. Sharp. 1990. Hot-water immersion quarantine treatment for carambolas infested with Caribbean fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 83:1471-1474.
Hatton, T. T. 1990. Reduction of chilling injury with temperature manipulation. p. 269-280. In: C. Y. Wang (ed.) Chilling injury of Horticultural crops. CRC Press, Inc. Boca Raton, Fla.
Kenny, P. 1986. Effects of storage condition on carambola quality. Proc. Fla. State Hort. Soc. 99:222-224.
Miller, W. R., R. E. McDonald, and M. Nisperos-Carriedo. 1991. Quality of 'Arkin' carambolas with or without conditioning followed by low-temperature quarantine treatment. Proc. Fla. State Hort. Soc. 104:118-122.
Miller, W. R., R. E. McDonald, and J. L. Sharp. 1990. Condition of Florida carambolas after hot-air treatment and storage. Proc. Fla. State Hort. Soc. 103:238-241.
Morris, L. L. and H. Platenious. 1938. Low temperature injury to certain vegetables after harvest. Proc. Amer. Soc. Hort. Sci. 36:609-613.
Paull, R. E. 1992. Evaluation of possible carambola fruit fly disinfestation methods. Acta Hort. 296:181-184.
Purvis, A. C. 1985. Relationship between chilling injury of grapefruit and moisture loss during storage: amelioration by polyethylene shrink film. J. Amer. Soc. Hort. Sci. 110:385-388.
SAS Institute. 1982. SAS User's Guide: Statistics. SAS Institute. Cary, NC.
Sharp, J. L. and G. J. Hallman. 1992. Hot-air quarantine treatment for carambolas infested with the Caribbean fruit fly (Diptera:Tephritidae). J. Econ. Entomol. 85:167-172.
Schiffman-Nadel, M., E. Chalutz, E. Waks, and M. Dagan. 1975. Reduction of chilling injury in grapefruit by thiabendazole and benomyl during long-term storage. J. Amer. Soc. Hort. Sci. 100:270-272.
Wang, C.Y. 1990. Alleviation of chilling injury of horticultural crops. p. 281-302. In: C.Y. Wang (ed.) Chilling injury of horticultural crops. CRC Press, Boca Raton, Fla.

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CITRUS FRUIT WITH SINGLE OR LAYERED COATINGS COMPARED WITH PACKINGHOUSE-COATED FRUIT

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Additional index words. Oranges, grapefruit, microemulsion, shrinkage rate, ethanol, internal gases.

Abstract. **Oranges, grapefruit and tangerines that were coated with hydrocarbon-containing wax microemulsions had weight loss and internal CO_2 values less than half those coated commercially in Florida packinghouses. Valencia oranges coated in layers with two wax microemulsions had weight loss only 20-30% of washed control. High levels of gloss were not imparted by the microemulsions, but could be attained by application of a high-gloss coating as second coating. The high-gloss coatings, whether applied alone or as second coating, tended to inhibit gas exchange and elevate ethanol content.**

Fresh citrus fruit is coated primarily to give gloss to the surface, thus improving market appeal, with weight loss reduction a secondary goal (Kaplan, 1986; Hall, 1981). Our work has shown that weight loss and gloss are related: low weight loss helps to preserve gloss, and both can be achieved with layered coatings, the first of which is a wax microemulsion (Hagenmaier and Baker, 1993b; 1993c). The second coating can either be a wax selected for gloss (rather than shrinkage control) or a high-gloss shellac or resin coating. The present work shows how commercially coated Florida citrus fruit compares with fruit having single or layered coatings.

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Materials and Methods

Fruit. The fruit coated in our laboratory were from groves near Winter Haven, Fla., maintained by the Florida Department of Agriculture. The Hamlin and Navel oranges, the Ruby Red grapefruit and the Murcott tangerines were harvested Jan 25, 1993. The Valencia oranges were harvested May 11-June 1, 1993. The commercially coated fruit were from packinghouses located within 25 miles of Winter Haven, Florida. For comparisons of laboratory-coated fruit with packinghouse-coated fruit, the fruit was all harvested and coated within a two-day period. Fruit coated in our laboratory were washed with rotating polyethylene brushes (type PSE, made by Industrial Brush Corp., Lakeland, Fla.) with a citrus cleaner containing sodium o-phenylphenate (Freshgard 5, FMC Corp., Lakeland, Fla.).

Coatings. Wax microemulsions AC3 and PE4 were supplied by Allied Signal (Morristown, N.J.). Formulation

AC3 contained 17% AC316, 3.0% oleic acid, 2.1% morpholine and 0.4% ammonia; formulation PE4 contained 10.2% AC680, 6.8% Be Square 195 (Petrolite, Tulsa, Okla.), 3% oleic acid and 2.1% morpholine. AC316 and AC680 are grades of oxidized polyethylene made by Allied Signal. Microemulsion K123B, made in our laboratory, contained 8.5% oxidized polyethylene, 8.5% petroleum wax, 3.0% oleic acid, 2.6% morpholine and 50 ppm dimethylpolysiloxane (Hagenmaier and Baker, 1993b). The oxidized polyethylene was grade E20 from Eastman Chemicals; the petroleum wax was P161 (Exxon, Houston, Texas). Formulation RS, not a microemulsion, contains 9.5% shellac, 9.3% wood resin, 4.7% morpholine, 1.3% oleic acid and 50 ppm dimethylpolysiloxane. The shellac was Mantrolac R-49 (Mantrose Haeuser Co., Westport, CT). The wood resin was 807A (Resinall Corp., Hattiesburg, Miss.). Coatings on the fruit from 10 central Florida packinghouses (purchased control) were coumarone-indene resin in solvent (SOL) or wood resin/shellac based water waxes herein designated R1 to R5. All coatings were applied within 1 day after harvest.

Some coatings were applied in two layers, the objective being to control weight loss with the first coating and increase gloss with the second (Hagenmaier and Baker, 1993c). When two coatings were applied, the first coating was dried before application of the second.

Weight loss. Weight (to 0.1 g accuracy) was measured during storage of fruit at 4°C and 90% RH, or at 14°C and 90% RH, or at 20°C and 55-75% RH. Samples of 5 fruit each (minimum 4 samples per trial) were weighed 4 times over a one week period.

Internal gases. CO_2 and O_2 values were determined after 1 week at the indicated storage temperature, a minimum of 5 samples per trial. The gas was withdrawn by syringe from the blossom end of the fruit submerged in water. The CO_2 concentration was determined with a gas chromatograph (Model 5890A, Hewlett-Packard, Avondale, Pa.) fitted with a 30 m × 0.53 mm i.d. polystryrene column (type GSQ, J&W Scientific, Folsom, Calif.) and a thermal conductivity detector. Column and detector temperatures were 35° and 120°C, respectively; Helium carrier gas flow was 7 ml/min. The O_2 concentration of internal gas was measured by passing 4 ml of the gas through an InPack Model 507 O_2 Analyzer (Wilmington, Mass.) modified to function as a flow-through cell by removal of the sampling syringe.

Ethanol. Juice was extracted from fruit stored for 1 week at 20°C. For each treatment there were a minimum of 2 samples, each consisting of the pooled juice from 7 fruit. Juice was extracted and distilled to obtain 20 ml condensate per 100 ml juice. Ethanol content of condensate was determined with the gas chromatograph, using 50 m × 0.32 mm FFAP column (Hewlett Packard) and flame ionization detector. Column temperature was 60°C, detector and injector were both 250°C, and He column flow rate was 3 ml/min. Blush was visually determined from appearance of fruit submerged overnight (15-20 hrs) in water, then air-dried 2-4 hours.

Gloss. Gloss was determined with a reflectometer (Model micro-TRI-gloss, BYK Gardner, Silver Spring, Md.). This unit, which is designed to measure gloss of flat surfaces, was calibrated on the standard surface supplied with the instrument, after which the lens opening was restricted to 18 mm length, to block out stray light. Gloss Units (G.U.) were measured at 60° to the vertical at 10 different locations and the mean value taken for a minimum of 6 fruit per treatment.

Statistics. Data were analyzed using linear models with Statistix software (Analytical Software, St. Paul, Minn.). Values of LSD were calculated as 5% level of significance.

Results and Discussion

Four different varieties of citrus fruit coated in two stages with wax microemulsions—the first layer of which was a hydrocarbon-wax-containing formulation—had weight loss at 20°C of 0.18-0.34%/day (Table 1). These fruit (marked 2W in Table 1) had markedly lower rate of weight loss than commercially coated fruit from Florida packinghouses. Moreover, internal CO_2 was 3-6% for the 2W fruit. The relatively high values of CO_2 for the Ruby Red, Hamlin, Navel and Murcott fruit coated in Florida packinghouses indicate that the commercial coatings inhibited exchange of CO_2 and O_2. In addition, except for the Navel oranges, ethanol content of the packinghouse fruit was also higher, indicating that fruit to be more likely to have off flavor.

The higher rate of weight loss for the fruit from commercial packinghouses could have been at least partly caused by the washing operation. Our previous work indicates that more gentle washing gives fruit with lower rate of weight loss (Hagenmaier and Baker, 1993a). It was for this reason that the fruit processed in our laboratory was washed only with polyethylene brushes.

Table 1. Shrinkage rate, internal CO_2 and ethanol content of citrus fruit[z] from 5 central Florida packinghouses and for fruit with two layers of wax microemulsion, after 1 week storage.

Storage[y] T (°C)	Type fruit	Coat[x]	P.H.[w]	Shrinkage rate (%/d)	Internal CO_2(%)	Ethanol (ppm)
20	Ruby Red	2W	ARS	0.18	3.4	288
20	Ruby Red	R5	H	0.76	7.4	422
20	Hamlin	2W	ARS	0.29	4.8	372
20	Hamlin	R5	H	0.83	11.1	837
20	Hamlin	R2	G	0.46	10.5	1121
20	Navel	2W	ARS	0.25	5.9	655
20	Navel	R1	I	0.73	9.7	467
20	Murcott	2W	ARS	0.34	5.7	643
20	Murcott	R1	J	0.73	13.3	1666
20	Murcott	SOL	E	0.92	10.7	1248
14	Ruby Red	2W	ARS	0.043	2.4	—
14	Ruby Red	R5	H	0.17	3.7	—
4	Hamlin	2W	ARS	0.019	—	—
4	Hamlin	R5	H	0.054	—	—
4	Hamlin	R2	G	0.026	—	—
4	Navel	2W	ARS	0.014	—	—
4	Navel	R1	I	0.023	—	—
4	Murcott	2W	ARS	0.016	—	—
4	Murcott	R1	J	0.028	—	—
4	Murcott	SOL	E	0.043	—	—
$LSD_{0.05}$ at 20°C				0.04	2.7	160
$LSD_{0.05}$ at 14°C				0.02	1.0	
$LSD_{0.05}$ at 4°C				0.003		

[z]Mean fruit weight was 160 g, 260 g, 170 g, 420 g for Hamlin, Navel, Murcott and Ruby Red, respectively.
[y]R.H. was 55% at 20°C, 90% at 14°C, 99% at 4°C.
[x]2W was a layered coating: first coat was microemulsion PE4 and second was AC3. Application rate for each was 0.4 ml/fruit. The R coatings were aqueous, resin-based citrus coatings. SOL was solvent wax.
[w]The single letters are packinghouses. ARS is our laboratory.

It is noteworthy that the wax-coated grapefruit stored at 20°C, 55% R.H., had shrinkage and internal CO_2 similar to packinghouse fruit in cold storage (14°C, 90% RH). This suggests that grapefruit with wax-based coatings has less need of refrigeration than the same fruit with shellac or resin coatings.

Valencia oranges from packinghouses had rate of weight loss about four times that of fruit coated with wax microemulsion K123B, and three times that of fruit with one layer of K123B and a second layer of high-gloss shellac-resin coating (Table 3). The wax microemulsion used in this case contained petroleum wax as the hydrocarbon wax, whereas microcrystalline wax was the hydrocarbon source in the water-vapor barrier used for the data of Table 1.

Application of coatings did increase light reflectance of the fruit surface (Table 2). Highest values of reflectance were obtained when the second coating contained shellac and resin. However, such coatings elevated internal interior CO_2 and reduced O_2 values - whether the shellac and resin coatings were the only coating applied (see values for packinghouse fruit in Tables 1 and 2) or applied as second layer (Table 2). In both cases, the ratio of CO_2 to O_2 is markedly higher than for fruit not coated or coated only with wax microemulsion.

The ethanol content of juice from fruit with the high-gloss coating was virtually the same (2,000 ppm) as packinghouse fruit, which was much higher than fruit not coated or coated only with wax microemulsion (Table 2). Ethanol content as high as 2000 ppm should indicate that some flavor deterioration may have occurred, although flavor analysis was not included in this study. Ke and Kader (1990) found a significant decrease in flavor of Valencia oranges when ethanol had risen to 2000 ppm; Ahmad and Khan (1987), working with mandarin, found the same result.

Thus, layered coatings with a shellac outer coating did solve one of the problems associated with high-gloss coatings, that is, relatively high weight loss of the coated fruit. Such a coating did not, however, solve the flavor problems associated with inhibition of gas exchange by these coatings, because gas exchange was inhibited about the same whether the high-gloss coating was applied as only coating (as in the packinghouses) or as second coating in our laboratory. By contrast, coatings consisting of two wax layers kept weight loss low with much less inhibition of gas exchange.

Table 2. Properties of Valencia oranges with wax or layered coatings compared with packinghouse fruit coated with resin waxes. Fruit was stored one week at 20°C, 75% Relative Humidity.

Treatment		Shrinkage	Internal Gas		Ethanol	Gloss[z]
Coating	P.H.	(%/day)	O_2(%)	CO_2(%)	(ppm)	(G.U.)
None (unwashed)	ARS	0.56	19.3	2.1	573	—
None (washed)	ARS	0.73	17.7	3.1	656	4.6
K123B	ARS	0.18	12.3	6.3	910	5.8
K123B-RS[y]	ARS	0.22	4.4	13.3	1990	7.9
R1[w]	A	0.57	6.1	13.4	2975	5.0
R1	B	0.55	2.8	11.5	1556	5.7
R1	C	0.74	2.4	10.5	1757	5.0
R4	D	0.70	5.8	11.3	2127	5.1
SOL	E	0.88	4.6	11.0	1610	5.5
SOL	F	0.51	7.9	6.6	2512	5.7
R2	G	0.59	5.6	11.0	2093	4.2
R5	H	0.59	6.7	9.9	1556	5.7
$LSD_{0.05}$		0.04	5.2	2.7	250	0.9

[z]Measured within 2 days after acquisition or coating of the fruit.
[y]First coating was microemulsion K123B; second was high-gloss coating RS; application rate for each was 0.5 ml/fruit.
[w]See Table 1.

Literature Cited

Ahmad, M. and I. Khan. 1987. Effect of waxing and cellophane lining on chemical quality indices of citrus fruit. Plant Foods for Human Nutrition 37:47-57.

Hagenmaier, R. D. and R. A. Baker. 1993a. Cleaning method affects shrinkage rate of citrus fruit. HortScience 28(8):824-825.

Hagenmaier, R. D. and R. A. Baker. 1993b. Wax microemulsions as citrus coatings. Manuscript submitted to J. Agric. Food Chem.

Hagenmaier, R. D. and R. A. Baker. 1993c. Layered coatings to control weight loss and preserve gloss of citrus fruit. Manuscript submitted to HortScience.

Hall, D. J. 1981. Innovations in citrus waxing-an overview. Proc. Fla. State Hort. Soc. 94:258-263.

Kaplan, J. J. 1986. Washing, waxing and color-adding, p. 379-395. In W. F. Wardowski, S. Nagy and W. Grierson (eds). Fresh citrus fruits. AVI Publishing Co., Westport, Conn.

Ke, D. and A. A. Kader. 1990. Tolerance of 'Valencia' oranges to controlled atmospheres as determined by physiological responses and quality attributes. J. Amer. Soc. Hort. Sci. 115(5):779-783.

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POSSIBLE QUARANTINE TREATMENTS FOR FLORIDA AGRICULTURAL FOOD COMMODITIES

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Abstract. **The availability and need for quarantine treatments for agricultural commodities produced in Florida were examined. The most important quarantine pest in Florida is the Caribbean fruit fly, *Anastrepha suspensa* (Loew), and quarantine treatments exist for grapefruit, orange, tangerine, mango, carambola, and guava infested with this fly. Other treatments could potentially be used for other fruits. Some fruits presently have no potential quarantine treatments for Caribbean fruit fly. Quarantine treatments are also available for**

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