any storage condition or wax treatment, but the bulge of the surface coated and dipped boxes was less than that of the unwaxed boxes. The average bulge was 2 inches for the unwaxed boxes, 1.5 inches for the surface coated boxes and 1.4 inches for the dipped boxes. This indicates that the surface coated and dipped boxes retained more of their rigidity during the storage period than did the unwaxed boxes.

Literature Cited

1. Bennett, A. H., J. M. Wells, and R. L. Wilson, Jr. 1979. The effect of precooling, waxing, and storage humidity on the postharvest quality and weight loss of peaches. XV Intern. Congress of Refrigeration, Paper No. C2-70, 7 p.
2. Benson, R. E. 1971. Effects of humidity and temperature on tensile stress-strain properties of kraft linerboard. Tappi 54(5):699-703.
3. Fibre Box Handbook. 1979. Fibre Box Assoc. 104 p.
4. Garrett, R. E. J. J. Mehlschau, and L. R. Brickner. 1979. Carton performance specifications for iceburg lettuce. Amer. Soc. Agr. Eng. Paper No. 79-6513. 36 p.
5. Henry, F. E. 1979. Wax treatment of corrugated shipping container samples while under vacuum. Amer. Soc. Agr. Eng. Paper No. 79-6517. 15 p.
6. Henry, F. E. 1980. Wax treatment of corrugated fiberboard shipping containers. Amer. Soc. Agr. Eng. Paper No. 80-4527. 15 p.
7. Moody, R. C. 1965. Edgewise compression strength of corrugated fiberboard as determined by local instability. U.S. Forest Serv. Res. Paper FPL-46. 8 p.
8. Peleg, K. and P. Smolinski. 1979. Performance standards of shipping containers for Michigan apples. Michigan State Univ. 30 p.

Proc. Fla. State Hort. Soc. 96: 327-329. 1983.

MOISTURE LOSS AND JUICE QUALITY FROM WAXED AND INDIVIDUALLY SEAL-PACKAGED CITRUS FRUITS[1]

Albert C. Purvis
University of Florida,
Institute of Food and Agricultural Sciences,
Citrus Research and Education Center,
700 Experiment Station Road,
Lake Alfred, FL 33850

Additional index words. Citrus paradisi, Citrus sinensis, °Brix, acidity, polyethylene films, waxing.

Abstract. **Seal-packaging of individual fruit was effective in reducing moisture loss from oranges and grapefruit stored at 21°C and 5°C. During storage, the major change in internal quality observed for oranges and grapefruit was a reduction in acidity with the consequent increase in Brix:acid ratio. Acidity reduction was greater at 21°C than at 5°C and seal-packaging did not alter acidity reduction when compared to waxing. Although seal-packaging in polyethylene maintains the fresh appearance of citrus fruits during long-term storage at room temperature, it does not alter the rate at which internal acidity decreases. Thus, a problem with long-term storage of seal-packaged low acid citrus fruits may be the development of insipid flavors resulting from acidity reduction. The problem of acidity reduction may not be as apparent with waxed fruit because of the generally shorter shelf life.**

Transpiration (moisture loss) and respiration are processes which contribute most to the physiological deterioration of citrus fruits after harvest. Because moisture loss results in a rapid deterioration in the appearance of the fruit, more attention has been given to controlling transpiration than respiration. Waxes, along with high humidity and refrigeration, have traditionally been used to reduce moisture loss from fresh citrus fruits during transit and storage. Additional benefits are derived from refrigeration, such as reduced respiratory activity of the fruit as well as reduced invasion and growth of fungal pathogens. Sealing fruit individually in polyethylene film has been shown to be more effective than waxes in reducing moisture loss, especially under conditions of low humidity and nonrefrigerated temperatures (2, 3, 5, 7, 10). Thus, with longer storage periods at nonrefrigerated temperatures, respiration may contribute more than transpiration to the deterioration of seal-packaged fresh citrus fruits. In previous studies, sealing fruit in polyethylene film had no apparent effect on juice quality of 'Marsh' grapefruit (2, 10) and 'Shamouti' oranges (2) compared to waxed fruit stored at 20 to 21°C. The study reported here compares to effects of waxing and sealing in polyethylene film on moisture loss and juice quality of 'Marsh' grapefruit and 'Hamlin' oranges stored at 5°C and 21°C.

Materials and Methods

'Hamlin' oranges and 'Marsh' grapefruit were harvested from the groves of the Citrus Research and Education Center at Lake Alfred. The fruit were prepared for storage within 2 to 4 hr after harvest. All fruit were washed, dipped in a 600 ppm benomyl [methyl 1-(butylcarbomoyl)-2-benzimidazole-carbamate] suspension to minimize decay during storage and air dried. The fruit were randomized into lots and half were waxed with a solvent-type wax (Flavorseal, FMC). The remaining fruit were individually seal-packaged in 21.1 μm polyethylene film (Cryovac D-925) with a Cryovac Magna-Lok Edgeseal Machine (Cryovac Division, W. R. Grace & Co., Duncan, SC 29334) and the film was shrunk in a Cryovac Shrink Tunnel. Ten fruit from each treatment and storage temperature were numbered with a felt-tip pen and weighed at the start of each experiment and at predetermined intervals during the storage period. Storage room temperatures were maintained at 5°C $\pm$ 1°C and 21°C $\pm$ 1°C for the entire time. Relative humidity of the storage rooms ranged from 85 to 95%. All weighings were completed within 0.5 hr after the fruit were removed from storage and the fruit were returned to the storage rooms immediately after weighings. Weight loss is presented on a surface area and weight basis. Since most of the weight loss from fruit during storage can be accounted for by water loss (2), weight loss and transpiration here were considered synonymous. Surface area was calculated from polar and equatorial diameters.

At the end of the storage experiment, the juice was extracted from individual fruit of each treatment, weighed, and analyzed for °Brix with an Abbe refractometer (American Optical Corp., Buffalo, NY 14215) and for total acids by titration with standard NaOH using phenolphthalein indicator.

[1]Florida Agricultural Experiment Stations Journal Series No. 5173.

Results and Discussion

Waxed and seal-packaged 'Hamlin' oranges and 'Marsh' grapefruit lost moisture faster at 21°C than at 5°C (Fig. 1). This is due to the larger driving force for evaporation at 21°C than at 5°C. At a relative humidity of 85%, the vapor pressure deficit (driving force for evaporation) is 1.31 mbars at 5°C and 3.73 mbars at 21°C. However, the difference between moisture loss at 21°C and at 5°C was less for grapefruit than for oranges. Moisture loss from seal-packaged oranges and grapefruit was small compared to that from waxed fruit. Waxed oranges and grapefruit lost moisture faster during the first 2 to 3 wk of storage than subsequently.

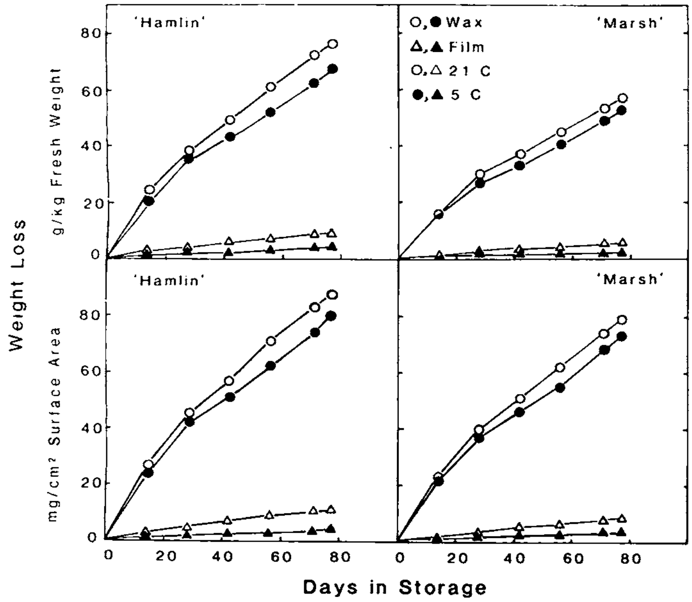

Fig. 1. Weight loss of waxed and seal-packaged 'Hamlin' oranges and 'Marsh' grapefruit during storage at 5°C and 21°C. The vapor pressure deficit (driving force for evaporation) at 85% relative humidity is 1.31 mbars at 5°C and 3.74 mbars at 21°C.

Waxed 'Hamlin' oranges lost moisture more rapidly than did waxed 'Marsh' grapefruit. McCornack (9) suggested the greater moisture loss by oranges and mandarin-type fruit compared to grapefruit was related more to the nature of the fruit than to the larger surface:mass ratio. However, when expressed on a weight basis, moisture loss from oranges was 30% greater than from grapefruit, whereas, when expressed on a surface area basis, moisture loss was only 10% greater for oranges than for grapefruit (Fig. 1). While the amount of epicuticular wax (1) as well as wax composition (4) influences moisture loss from plant tissues, the differences in moisture loss due to fruit wax characteristics may be reduced by the application of additional wax to the fruit.

After 11 wk of storage at 5°C or 21°C, seal-packaged oranges still had lost less than 1% of their weight whereas waxed oranges had lost 6 to 7%. During the same period seal-packaged grapefruit lost less than 0.5% weight compared to about 5% for waxed grapefruit.

Since most of the water is lost from peel tissue, moisture loss primarily affects the appearance of the fruit. The consequences of peel moisture loss are shrinkage, softening, shrivelling, and deformation of the fruit. However, increases in the percentage of juice were observed for waxed and seal-packaged grapefruit during storage for 82 days at 21°C, but not at 5°C (Table 1). No change in percentage juice was observed in 'Hamlin' orange during storage for the same period at 21°C or 5°C (Table 2). Martin et al. (8) attributed the increase in percentage juice of grapefruit stored at 15°C to rind shrinkage plus some change in the nature of juice sacs which resulted in the percentage pulp after extraction being less than in freshly harvested fruit.

Table 1. Juice quality of waxed and seal-packaged 'Marsh' grapefruit stored for 82 days at 5°C or 21°C.

Treatment	Storage temperature	Juice (%)	°Brix	Acid (%)	Ratio
Initial	—	49.8a[z]	9.7a	1.42a	6.9a
Waxed	5°C	49.9a	9.8a	1.25 b	7.9 b
	21°C	59.7 b	9.9a	1.30 b	7.6ab
Seal-packaged	5°C	49.8a	9.4a	1.25 b	7.6ab
	21°C	59.3 b	9.4a	1.21 b	7.8 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Juice quality of waxed and seal-packaged 'Hamlin' oranges stored for 82 days at 5°C or 21°C.

Treatment	Storage temperature	Juice (%)	°Brix	Acid (%)	Ratio
Initial	—	49.8a[z]	10.7ab	0.90a	12.0a
Waxed	5°C	47.2a	11.4ab	0.71ab	16.3 b
	21°C	43.6a	10.6ab	0.63 b	17.3 b
Seal-packaged	5°C	47.8a	11.8 b	0.82ab	14.6ab
	21°C	48.7a	10.4a	0.60 b	17.5 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Acid concentration of the juice decreased in 'Marsh' grapefruit and 'Hamlin' oranges stored at 21°C and 5°C (Tables 1 and 2). No significant changes occurred in °Brix of 'Marsh' grapefruit or 'Hamlin' oranges stored at 21°C and 5°C. The decrease in acid concentration with little or no change in °Brix resulted in increases in the Brix:acid ratios of oranges and grapefruit during storage. The decrease in acid concentration in the juice of 'Hamlin' oranges was greater in fruit stored at 21°C than at 5°C. No differences in acid concentrations were observed between waxed and seal-packaged oranges or grapefruit stored at 21°C or 5°C. Similar observations were made by Ben-Yehoshua et al. (2) with 'Shamouti' oranges and 'Marsh' grapefruit stored at 20°C.

Although peel tissue has higher respiratory activity than the juice sacs (6), respiratory activity of the juice sacs would result in internal quality changes of the fruit during storage. Presumably, the decrease in acid concentration was a consequence of respiratory activity. Sugars and organic acids can be utilized as respiratory substrates, but the substrate normally respired by stored citrus fruits has not been determined. The larger decrease in acidity of oranges compared to grapefruit stored at 21°C may be due to the higher respiratory activity of the orange fruit (12). Respiratory activity is highly dependent on temperature, thus greater decreases in acidity might be expected as storage temperature is increased. Tugwell (11) in Australia reported that early harvests of mandarins and grapefruit wrapped in film and held at room temperature rapidly lost acidity and became more palatable during storage. Since acidity decreases fairly rapidly in fruit still hanging on the tree, the feasibility of harvesting high acidity fruit and storing it wrapped to reduce the acidity is not readily apparent.

Citrus fruits do not respond favorably to low oxygen atmospheres; therefore, long-term storage at nonrefrigerated temperatures can result in ethanol and acetaldehyde accumulating in the juice. Ethanol accumulation was not determined in the present study, but in previous studies (5), ethanol accumulated less in seal-packaged fruit than in waxed fruit. Ethanol and other anaerobic metabolites accumulate as a consequence of high respiratory activity and restricted oxygen diffusion to the juice sacs. Apparently waxes are more restrictive than polyethylene films to the diffusion of oxygen. Interestingly, the permeability of the polyethylene film used in this study increases almost linearly with increasing temperatures between 6°C and 38°C (Cryovac, personal communication). At 30°C, the permeability of the film is still more than 3 times greater than the rate of oxygen consumption (unpublished data). It is unlikely, therefore, that the film restricted oxygen diffusion into the fruit.

Thus, the primary effect of polyethylene films on citrus fruits appears to be the reduction of moisture loss. There is no evidence that the film used in this study had any effect on the respiration of oranges or grapefruit which resulted in internal quality changes different from those of waxed fruit stored under the same conditions.

Acknowledgments

The author gratefully acknowledges Cryovac Division, W. R. Grace & Co., Duncan, SC 29334 for supplying the film used in this study and for the use of an L-sealer and shrink tunnel. The technical help of J. D. Rice is greatly appreciated.

Literature Cited

1. Albrigo, L. G. 1972. Distribution of stomata and epicuticular wax on oranges as related to stem end rind breakdown and water loss. J. Amer. Soc. Hort. Sci. 97:220-223.
2. Ben-Yehoshua, S., I. Kobiler, and B. Shapiro. 1979. Some physiological effects of delaying deterioration of citrus fruits by individual seal packaging in high density polyethylene film. J. Amer. Soc. Hort. Sci. 104:868-872.
3. Ben-Yehoshua, S., I. Kobiler, and B. Shapiro. 1981. Effects of cooling versus seal-packaging with high-density polyethylene on keeping qualities of various citrus cultivars. J. Amer. Soc. Hort. Sci. 106: 536-540.
4. Grncarevic, M. and F. Radler. 1967. The effect of wax components on cuticular transpiration—model experiments. Planta 75:23-27.
5. Hale, P. W., P. L. Davis, F. J. Marousky, and A. J. Bongers. 1982. Evaluation of a heat-shrinkable polymer film to maintain quality of Florida grapefruit during export. Citrus and Vegetable Magazine. October 1982, pp. 39-43, 45-46, 48.
6. Hussein, A. A. 1944. Respiration in the orange. A study of systems responsible for oxygen uptake. J. Biol. Chem. 155:201-211.
7. Kawada, K. and L. G. Albrigo. 1979. Effects of film packaging, in-carton air filters, and storage temperatures on the keeping quality of Florida grapefruit. Proc. Fla. State Hort. Soc. 92:209-212.
8. Martin, W. E., R. H. Hilgeman, and J. G. Smith. 1939. Grapefruit storage studies in Arizona. Proc. Amer. Soc. Hort. Sci. 37:529-534.
9. McCornack, A. A. 1975. Postharvest weight loss of Florida citrus fruits. Proc. Fla. State Hort. Soc. 88:333-335.
10. Purvis, A. C. 1983. Effects of film thickness and storage temperature on water loss and internal quality of seal-packaged grapefruit. J. Amer. Soc. Hort. Sci. 108:562-566.
11. Tugwell, B. 1981. Results of storage trials with citrus wrapped in polyethylene film. Packingshed Newsletter No. 8. October 26, 1981. Waikerie, S. Australia.
12. Vines, H. M., W. Grierson, and G. J. Edwards. 1968. Respiration, internal atmosphere, and ethylene evolution of citrus fruits. Proc. Amer. Soc. Hort. Sci. 92:227-234.

Proc. Fla. State Hort. Soc. 96: 329-332. 1983.

POTENTIAL AND PROBLEMS OF FILM-WRAPPING CITRUS IN FLORIDA[1]

L. Gene Albrigo
University of Florida,
Institute of Food and Agricultural Sciences,
Agricultural Research and Education Center,
700 Experiment Station Road,
Lake Alfred, FL 33850

M. A. Ismail
Florida Department of Citrus,
Agricultural Research and Education Center,
700 Experiment Station Road,
Lake Alfred, FL 33850

Additional index words. polyethylene film, decay, weight loss, ethylene dibromide, machinery.

Abstract. **Experimental and commercial storage and shipping tests of film-wrapped citrus fruit were conducted the past 5 seasons. Fruit wrapped in film lost less water than waxed fruit, creating the potential for better arrival condition of export fruit and for extended storage of fruit to prolong the domestic marketing season. Film wrapping may allow 1 to 2 month holding periods with little quality loss at moderate temperatures (21°C) and longer storage at lower temperatures. Unwaxed fruit should be used for film wrapping since the 2 barriers of film plus wax can lead to excessive off-flavor, particularly at temperatures higher than 21°C. Promising prototypes of commercial wrapping machines have been tested in Florida packinghouses, but the integration of this machinery into a typical packinghouse line will require extensive or innovative packing line alterations since unwaxed fruit of specific sizes is required for wrapping. If adequately permeable films are used, cool coloring and fumigation can be accomplished in film-wraps. Handling and decay control methods have often been limiting factors in research and especially in commercial tests. Better handling and fungicide application are needed to insure adequate decay control if film wrapping is to become a commercial practice.**

Plastic film wrapping can extend the shelf life of citrus fruit with the primary effect of reducing weight (water) loss and thereby deformation (1, 2, 5, 9, 11, 12). This report summarizes some previous film wrap work on citrus, presents new data on color changes and fumigation in film wraps, and evaluates problems and potentials for commercial use of film wrapping.

Materials and Methods

Data on weight loss and decay from grapefruit tests (1, 2, 3, 9, 12) over several years were summarized. Commercially harvested fruit were used in most of these tests and were commercially treated with TBZ [2-(4′-thiazolyl) benzimidazole] fungicide or by us with benomyl [(1-butylcarbamoyl)-2-benzimidazole carbamic acid].

'Robinson' tangerines (*Citrus reticulata* Blanco) were

[1]Florida Agricultural Experiment Stations Journal Series No. 5197.