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EFFECTS OF FILM PACKAGING, IN-CARTON AIR FILTERS, AND STORAGE TEMPERATURES ON THE KEEPING QUALITY OF FLORIDA GRAPEFRUIT[1]

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Abstract. **The keeping quality of grapefruit wrapped individually in a polyethylene (PE) bag or with a polyvinyl chloride (PVC) film, or packed in PVC film-lined fiberboard cartons was investigated in actual and simulated export experiments. Effects of in-carton air filters, and storage temperatures were also tested. PE bags were superior in terms of restricting weight loss, undesirable changes in peel color and gloss, and stem-end rot. Weight loss was linearly correlated with susceptibility to deformation. Effects of in-carton air filters were not significant. Quality was better in fruit stored for 3 weeks at 0°C plus 1 week each at 5° and 10°C followed by 3 weeks at 21°C, rather than 5 weeks continuously at 10°C followed by 3 weeks at 21°C.**

Weight loss due to transpiration is a serious factor limiting the economic postharvest life of grapefruit as well as the more generally recognized factors of decay, physiological disorders such as chilling injury (CI), ethylene dibromide (EDB) burn, senescence, seed germination, and physical damage. The obvious effects of excessive weight loss for much of the Florida grapefruit sold in Japan indicates that commercial waxing is not necessarily adequate (8). Multiple waxing, however, may cause an ethanol buildup in juice as reported by Davis and Hofmann (2). Very high relative humidity (RH) would be beneficial in reducing, not only weight loss (9), but also CI (6) and deformation (10). Excessive humidity leads to carton collapse, thus RH higher than 85 to 90% cannot be maintained unless waterproof cartons or bulk bins are used. Alternatively, film packaging might be used to restrict weight loss (7). Films can be used without any regulation by food additive laws which limit the use of many synthetic waxes and antitranspirants. As early as 1936 Stahl and Fifield (12) reported beneficial effects of film wrapping on preservation of cold stored Florida citrus fruits. Grierson (4) reviewed consumer packaging of citrus fruits, noting increased decay due to condensation in PE bags. Hassaku (*Citrus hassaku* Hort. ex Tanaka), the morphology of which is similar to grapefruit, is successfully stored in film-lined field boxes or by wrapping individually, so called "uni-pack", with low density PE bags in Japan (H. Kitagawa, unpublished). Ben-Yehoshua in Israel reported that deterioration of citrus fruits is delayed by individual "seal-packaging" in a high density PE film, and equipment has been developed to wrap fruit mechanically (1). Farooqi et al. (3) observed beneficial effects of PE film-liners on extending the shelf-life of Pakistan citrus fruits.

A storage test at Lake Alfred in 1978-79 showed that in-carton air filters decreased the undesirable peel color change from pale yellow to orange of 'Marsh' grapefruit (W. Grierson, unpublished). Use of temperatures lower than about 10°C is restricted due to susceptibility to CI of grapefruit (5). Film wrapping (12) and proper prestorage delay-treatments (5, W. Grierson and K. Kawada unpublished) are known to minimize this CI problem. PVC films were investigated to control CI of grapefruit by modifying in-package atmosphere (13, 14). In this simulated export tests, effects of some combinations of film packaging, in-carton air filters, and storage temperatures on the keeping quality of Florida grapefruit were studied.

Materials and Methods

Mid-season 'Marsh' grapefruit were obtained from an Indian River packinghouse on February 23, 1979. Fruit were washed, treated with 1000 ppm thiabendazole (TBZ) and FS #93 solvent wax, then packed in export fiberboard cartons in Lake Alfred the next day. Treatments were with or without film liners using a non-fogging type PVC film (REYNOLON®-GSP, 15 μ Reynolds Metals Co.), combined with or without 5 in-carton air filters (EXTEN-O-LIFE®, Stay-Fresh Co.) per carton. Filters were inserted after EDB fumigation for the actual export trial, or on the corresponding date for the simulated test. A total of 18 cartons for an actual shipping trial to Tokyo was brought back to Vero Beach for unitization on Feb. 26, thence to EDB fumigation where the film-lined cartons were opened for fumigation. Samples reached the Tampa dock in the early morning of Feb. 27, and were kept in the dock storage at about 16°C until March 2. These cartons arrived in Tokyo 4 weeks later. Another 12 cartons, 3 per treatment, were held at Lake Alfred for 1 week at room temperature, plus 4 weeks at 10°C followed by 3 weeks at 21°C to simulate shipping and marketing conditions.

Late-season 'Ruby Red' grapefruit were picked by the authors from a commercial Indian River grove on April 24, 1979 a rainy day after a dry period. Fruit were washed, treated with 1000 ppm TBZ and FS #93 solvent wax, packed and stored the next day. *Expt. 1.* Fruit were unipacked, i.e., individually wrapped, tightly in a low density PE bag (BAGGIES®, sandwich size, 15 μ, Colgate-Palmolive Co.) or with the previously used PVC film, or left unwrapped as the control. Bottom corners of the PE bags were cut off to avoid modified atmosphere effects. Three cartons per treatment were stored for 5 weeks at 10°C, followed by 3 weeks at 21°C. *Expt. 2.* Three cartons each of PE uni-packed and control fruit were stored immediately, while another 3 cartons each were packed and stored after a 3-day delay treatment at 29°C and 80% RH, for 3 weeks at 0°C plus 1 week each at 5° and 10°C, followed by 3 weeks at 21°C.

Peel color of the mid-season fruit was read with a Hunter D25D color and color-difference meter. Peel color and gloss of the late-season fruit were scored as the following subjective ratings by the senior author. *Peel color:* 1-greenish yellow, 2-pale yellow, 3-deep yellow, 4-orange yellow, 5-light orange. *Peel gloss:* 1-dull, 3-moderate, 5-bright. Fruit firmness was measured by the Grierson Creep Tester (10), a static load tester. In-fruit gas drawn from the core cavity with a hypodermic syringe under water, and in-carton gas

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samples were analyzed by gas chromatography for O_2, CO_2 and ethylene concentration. CI was scored on the previously reported 1-100 scale (5). Seven to 10 fruit per carton were used for color and gloss, 10 to 12 for firmness, 3 for gas analyses, and 7 for weight loss evaluations.

Results and Discussion

Results of mid- and late-season experiments are shown in Tables 1 and 2, respectively. Data from the actual trial to Tokyo is not included in the Table 1, for the trend was similar to the simulated test otherwise mentioned below.

Weight loss

Weight loss was significantly reduced by film packaging. Reduction in weight loss over control was 41% by PVC film-liners (Table 1), 58% by PVC uni-pack, and 84% by PE uni-pack (Table 2, Fig. 1). Considering weight loss only, the potential economic life of grapefruit was doubled by PVC and as much as sextupled by PE uni-pack, as more than about 5% weight loss makes fruit unsalable (6). Weight loss during the initial delay period was high (Table 1). A considerable amount of grapefruit has been held in non-

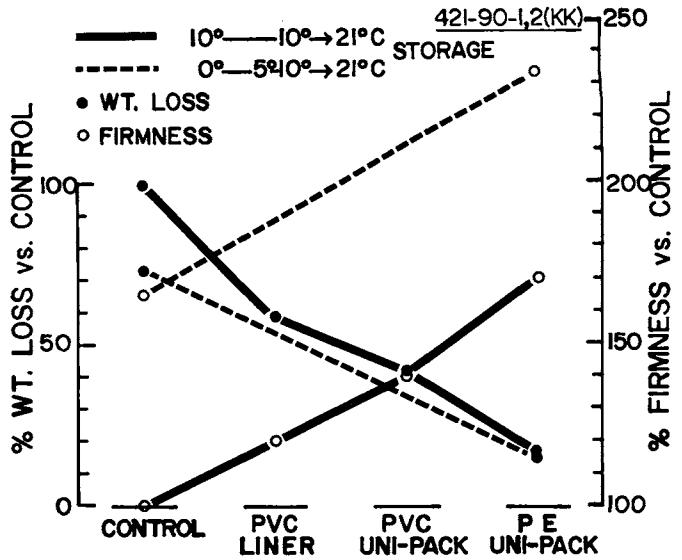

Fig. Effects of film packaging and storage temperatures on weight loss and firmness of Florida grapefruit. (Data are from Tables 1 and 2. Lines are used just for convenience, not to show continuance.)

Table 1. Effects of film liners and in-carton air filters on the keeping quality of Florida mid-season 'Marsh' grapefruit.[z]

Treatments		Wt. loss			Decay	Peel color[y]		421-90-1 Firmness[x]
Film liner	Air filter	Delay	Arrival (%)	Final	Final (%)	Arrival (a/b ratio)	Final (a/b ratio)	Final (%)
No	No	1.8	3.1	6.8	1.7	0.08	0.08	100
	Yes	1.7	3.0	6.0	8.3	0.08	0.07	93
Yes	No	0.9	1.7	3.5	5.0	0.09	0.08	124
	Yes	1.0	1.8	4.0	0	0.08	0.07	116
Film liner[w]		**	**	**	ns	ns	ns	**

[z]Delay: room temp, 1 wk. Arrival: delay + 10°C, 4 wk. Final: arrival + 21°C, 3 wk. Data based on 3 cartons per treatment.
[y]Hunter D25D color and color-difference meter.

[x]Fruit firmness = $\frac{\text{Permanent deformation of the no-film, no-filter control}}{\text{Permanent deformation of the treatment}} \times 100$ (%).

Permanent deformation measured by the Grierson Creep Tester (10).
[w]Significant at 1% level (**) or non-significant (ns). Air filter and film x filter were ns for all measurements.

Table 2. Effects of film uni-packaging and storage temperatures on the keeping quality of Florida late-season 'Ruby Red' grapefruit.[z]

421-90-2

Treatments	Wt. loss			Decay	Peel[y] color	Peel[x] gloss	CI[w] score	Firmness[v]	In-fruit gas concn		
	Delay	Arrival (%)	Final	(%)				(%)	O_2 (%)	CO_2 (%)	C_2H_4 (ppm)
Expt. 1	No delay + 10°C, 5 wk + 21°C, 3 wk										
Control	—	3.6a[u]	5.5a	23.3a	3.8a	3.4d	1.3abc	100d	16.2a	4.2a	.15a
PE uni-pack	—	0.5d	0.9d	3.3b	3.4b	4.1bc	1.7abc	172bc	17.5a	3.5a	.03b
PVC uni-pack	—	1.2c	2.2c	10.0b	3.8a	3.9c	1.0bc	140c	15.4a	4.0a	.17a
Expt. 2	No delay or 3-day delay at 29°C, 80% RH + 0°C, 3 wk + 5°C, 1 wk + 10°C, 1 wk + 21°C, 3 wk										
Control											
Immediate	—	2.1b	4.0b	18.3a	2.9c	4.5a	3.7a	165bc	—	—	—
Delayed	1.8	3.2a	4.6b	8.3b	2.6cd	4.3ab	1.0bc	152c	—	—	—
PE uni-pack											
Immediate	—	0.4d	0.8d	6.7b	2.6d	4.6a	3.3ab	233a	—	—	—
Delayed	1.7	1.9b	2.1c	3.3b	2.6cd	4.5a	0.7c	202ab	—	—	—

[z]*At the final examination* except weight loss. Data based on 3 cartons per treatment.
[y]Peel color: 1—greenish yellow, 2—pale yellow, 3—deep yellow, 4—orange yellow, 5—light orange.
[x]Peel gloss: 1—dull, 3—moderate, 5—bright.
[w]Chilling injury scored on a 1-100 scale, CI = 10 is onset of CI (5).
[v]Fruit firmness = $\frac{\text{Permanent deformation of the Expt. 1 control}}{\text{Permanent deformation of the treatment}} \times 100$ (%).
Permanent deformation measured by the Grierson Creep Tester (10).
[u]Mean separation within columns by Duncan's multiple range test at 5% level.

refrigerated rooms at the dock as simulated in this test. If fruit are shipped at chilling temperatures, however, this amount of weight loss stress might be beneficial to increase resistance to CI of grapefruit (W. Grierson and K. Kawada, unpublished). Weight loss in the simulated marketing period was as high as in transit (Tables 1 and 2). Even covering unitized cartons with PE sheets would restrict this weight loss. In the late-season test, the beneficial effect of lower storage temperatures on weight loss was evident (Table 2, Fig. 1), as has been shown before (9).

Decay

Total decay in the late-season test was higher than in the mid-season test, probably due to advanced maturity and weather conditions at harvest. Nevertheless, percentage decay varied irrationally within duplicated cartons of the mid-season test, but was more uniform in the late-season test (data not shown). This could be due to the commonly observed effect of carelessness in commercial harvesting. Once a fruit in a film-lined carton decayed, ethylene and liquid from the diseased fruit accumulated, and then such condition tended to lead further decay. Condensation in film-lined cartons did not occur during simulated transit at Lake Alfred, but seemed to occur in some cartons exported to Tokyo even though a highly permeable, non-fogging type PVC was used. At these occasions, in-carton air filters were helpful to absorb some water. The difference between actual and simulated tests indicates the importance of actual shipping trials besides simulated experiments. In contrast to film liners, uni-pack, especially PE uni-pack reduced decay, virtually all of which was stem-end rot (Table 2). Analysis of internal gas samples of individual fruit indicated minor modification by wrapping with perforated PE bags or the PVC shrink film. There were, however, surprisingly high concentrations of ethylene in perfectly sound fruit of the control and the PVC uni-pack after the simulated marketing period (Table 2). There were more fruit with green calyces in PE uni-pack than in the control (data not shown). It may be that PE uni-pack maintained the resistance of grapefruit to stem-end rot by minimizing senescence as indicated by the lower ethylene concentration in fruit. Schiffmann-Nadel et al. (11) reported that the increase in stem-end rots, as the result of frost or chilling conditions, may be related to a decrease in the resistance of grapefruit to rots due to its chilling susceptibility. Uni-pack would also be beneficial in resolving problems due to contact with diseased fruit such as "soilage", and disposal of decayed fruit. Condensation occurred only outside but not inside of the tightly wrapped films.

Peel color and gloss

PE uni-pack reduced peel senescence in terms of peel color and gloss, but the PVC uni-pack was only effective in maintaining peel gloss (Table 2). There were no significant effects of PVC film liners nor in-carton air filters (Table 1). The effect of low temperatures on retention of peel greenness and gloss was far better than that of the PE uni-pack (Table 2).

Chilling injury

No significant CI occurred even on the fruit stored immediately at 0°C for 3 weeks plus 1 week each at 5° and 10°C, followed by 3 weeks at 21°C in the late-season test (Table 2, Expt 2). TBZ, a fungicide used for this test is known to restrict CI of grapefruit (13). Although the 3-day delay treatment significantly reduced CI (Table 2, Expt. 2), this was at levels well below the CI score 10 which is considered to indicate the onset of commercially significant CI (5).

Fruit firmness

The beneficial effects of film packaging are reinforced by our findings that weight loss is linearly correlated with percentage permanent deformation (Fig. 2). Rivero et al. (10) reported that grapefruit kept under humid conditions until packaging were more resistant to deformation than

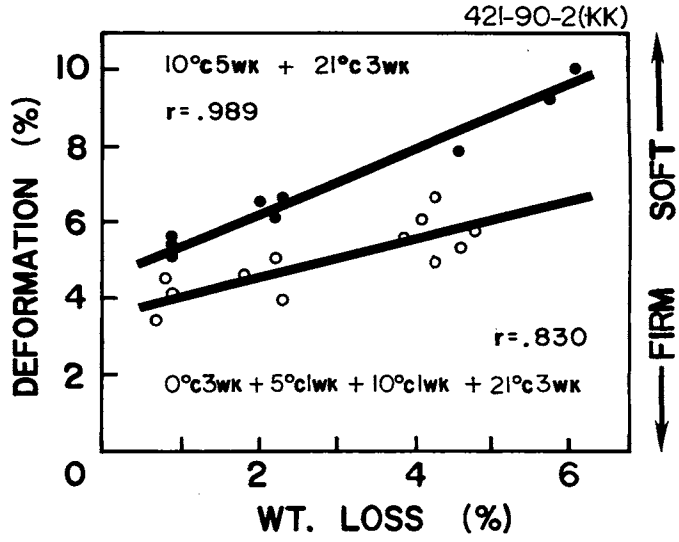

Fig. 2. Linear regressions between weight loss in storage and permanent deformation (fruit firmness) at the end of storage under 2 temperature systems. Both correlations are significant at 1% level. Deformation measured by the Grierson Creep Tester (10).

were those exposed to the sun and wind. Our data indicate that fruit stored at lower temperatures were firmer than those held at higher temperatures even at the same weight loss levels (Fig. 2). This may be related to the degree of fruit senescence, as more mature fruit are less resistant to deformation (10). Thus, fruit uni-packed in PE bags and stored at lower temperatures was firmest (Table 2, Fig. 1).

Effects of film packaging on internal quality, modified atmosphere effects of sealed uni-pack on controlling CI, and combined effects with growth regulators are being investigated further.

Literature Cited

1. Ben-Yehoshua, S. 1978. Delaying deterioration of individual citrus fruit by seal-packaging in film of high density polyethylene. I. General effects. *Proc. Int. Soc. Citriculture.* (in press).
2. Davis, P. L. and R. C. Hofmann. 1973. Effects of coatings on weight loss and ethanol buildup in juice of oranges. *J. Agr. Food. Chem.* 21:455-458.
3. Farrooqi, W. A., M. Ahmad, and Z. M. Khalid. 1979. Effects of polyethylene and some lining materials on the shelf-life extension of citrus fruits. *The Citrus Industry* May:14, 16, 17, 20.
4. Grierson, W. 1969. Consumer packaging of citrus fruit. *Proc. Ist Int. Citrus Symp.* (Univ. of Calif.) III:1389-1401.
5. ————. 1974. Chilling injury of tropical and subtropical fruits. V. Effect of harvest date, degreening, delayed storage and peel color on chilling injury of grapefruit. *Proc. Trop. Reg., Amer. Soc. Hort. Sci.* 18:66-73.
6. ————. and W. F. Wardowski. 1978. Relative humidity effects on the postharvest life of fruits and vegetables. *HortScience* 13: 570-574.
7. Hardenburg, R. E. 1971. Effect of in-package environment on keeping quality of fruits and vegetables. *HortScience* 6:198-201.
8. Kitagawa, H. and K. Kawada. 1979. Marketing of Florida grapefruit in Japan. *Proc. Fla. State Hort. Soc.* 92: (in press).
9. McCornack, A. A. 1975. Postharvest weight loss of Florida citrus fruits. *Proc. Fla. State Hort. Soc.* 88:333-335.

10. Rivero, L. G., W. Grierson, and J. Soule. 1979. Resistance of 'Marsh' grapefruit to deformation as affected by picking and handling methods. *J. Amer. Soc. Hort. Sci.* 104:551-554.
11. Schiffmann-Nadel, M., J. Waks, and E. Chalutz. 1975. Frost injury predisposes grapefruit to storage rots. *Phytopathology* 65:630.
12. Stahl, A. L. and W. M. Fifield. 1936. Cold storage studies of Florida citrus fruits. II. Effect of various wrappings and temperatures on the preservation of citrus fruits in storage. *Fla. Agr. Expt. Sta. Bul.* 304.
13. Wardowski, W. F., L. G. Albrigo, W. Grierson, C. R. Barmore, and T. A. Wheaton. 1975. Chilling injury and decay of grapefruit as affected by thiabendazole, benomyl and CO_2. *HortScience* 10:381-383.
14. ————, W. Grierson, and G. J. Edward. 1973. Chilling injury of stored limes and grapefruit as affected by differentially permeable packaging films. *HortScience* 8:173-175.