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EFFECTS OF HARVEST DATE AND TYPE OF FILM WRAPPING ON KEEPING QUALITY OF FLORIDA GRAPEFRUIT

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Abstract. **'Marsh' grapefruit harvested from a Florida Indian River district grove from February through June were wrapped with 60 gauge (15 μm) polyvinylchloride (PVC) film, polyolefin (PO) film, perforated polyolefin film, or polybutadiene (PB) film and compared to a waxed control. The fruit were stored at 15.5, 21, and 29.5°C (60, 70, and 85°F, respectively). Weight and decay loss, section drying, and seed germination were tested at 0, 4, and 8 weeks after harvest; internal ethanol, O_2 and CO_2 were tested at 4 and 8 weeks; flavor evaluations were made after 8 weeks. Film wrapping significantly reduced weight loss. The PO film was the best treatment for controlling weight loss. Weight loss, section drying, and seed germination increased with date of harvest and storage time and increasing storage temperature. Storage at 29.5°C resulted in increased section drying, seed germination, and internal ethanol level and increased °Brix to percent acid ratio. Fruit in the waxed control group had lower internal O_2 and higher CO_2 levels than film-wrapped fruit; no significant difference was detected in internal ethanol. No significant flavor differences were noted between juices from film-wrapped fruit and that of the waxed control, nor between juices derived from fruit stored with different film wraps. Fruit harvested after May and held 2 months at any of the storage temperatures, with or without film wraps, resulted in (1) juice of marginal or unacceptable flavor and (2) a marked decrease in juice acidity (with an accompanying marked increase in °Brix to percent acid ratio).**

In order to expand markets and increase price for Florida grapefruit, high quality has to be maintained for both U.S. sales and export shipments (14). Plastic film wrapping has shown advantages of extending shelf-life by reducing weight loss, minimizing fruit deformation, reducing chilling injury, and limiting the spread of decay from fruit to fruit that are packed in the same container (2, 5, 9, 12, 16). In addition, film wraps keep fiberboard containers drier thus maintaining box strength (9, 13). One potential problem in commercial use of film wrapping during storage or shipping to market is development of off-flavors, (4, 13). Another problem with fruit harvested late in the season is development of severe section drying and seed germination (2, 14, 15).

The objective of this study was to determine if fruit harvest date and film permeability interact with storage temperature to significantly affect certain quality factors of Florida grapefruit.

Materials and Methods

'Marsh' grapefruit were carefully harvested from 6 trees at a Florida Indian River grove near Fellsmere, on 5 dates during 1987: 2 Feb., 9 Mar., 13 Apr., 18 May, and 22 June. Approximately 225 fruit were harvested from each of 3 sets of 2 trees (3 replications) each time. All fruit were washed, treated with fungicide (600 ppm Benomyl + 1000 ppm Imazalil) to prevent the fruit from decaying, and then divided into 5 equal lots. Fruit in 4 of the lots were individually sealed in (1) polyolefin film (PO) (Cryovac D950, gauge 60 (15 μm)), (2) perforated polyolefin film (perforated PO) (Cryovac PY07, gauge 60), (3) polyvinylchloride film (PVC) (Borden BW 51, gauge 60), or (4) polybutadiene film (PB) (JSR, gauge 60) then heat shrunk. The other lot was treated with Flavorseal™ solvent wax (FMC Corp.) as a control. Every treatment replication lot was divided into 3 groups, placed in cardboard cartons, and stored at 15.5, 21, and 29.5°C. Weight loss from original fresh weight, section drying, and seed germination were measured at 0, 4, and 8 weeks after harvest; internal ethanol, O_2 and CO_2 were determined at 4 and 8 weeks; flavor evaluations were made after 8 weeks.

For the section drying test, all the fruit were cut perpendicular to the core axis into 4 parts having the same thickness (stem and stylar ends plus 2 central parts). At each cut, the juice vesicles were classified into 1 of 5 grades to describe the degree of section drying: 0 = no section drying; 4 = severe section drying. Section drying grades per fruit could range from 0 to 12, i.e., for the sum of 3 cut surfaces graded 0 to 4.

For the O_2 and CO_2 tests, 3 fruit from each carton were individually placed under water under an inverted funnel with a sealed stem and internal air was extracted by vacuum. Two or three 1 ml samples of air from the head space were analyzed with a Fisher clinical gas partitioner chromatograph (Fisher Scientific Co., Model 99).

Ethanol was measured in triplicate. Three fruit from each carton were juiced. Ten ml samples of grapefruit juice from these fruit were placed into 25 ml test tubes; the test tubes were sealed and placed at 40°C in a water bath for more than 2 hr. Three 1 ml gas samples were taken and tested by gas chromatography (HP 5730A with 1.5 m x 2 mm Carbowax 20 M column, operating condition: oven 95°C, carrier N_2 at 60 ml/min, detector 200, inlet 100) (6).

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For flavor evaluation, the juice from 10 fruit obtained using an electric hand reamer was composited. Panels consisted of 13 to 16 experienced evaluators. A 9-point hedonic scale was used for rating juice flavor: 9 = like extremely; 1 = dislike extremely. Juice color, °Brix (corrected for temperature and acid), percent acid (as anhydrous citric acid) were measured in the juice from each lot of May and June harvested fruit after 8 weeks storage. °Brix to percent acid ratio was calculated.

A randomized block design was compared by analysis of variance and significant differences between treatments were determined by Duncan's multiple range test at the 5% level.

Results

The 3 kinds of film, PO, PVC, and PB, significantly reduced weight loss compared with the waxed control group during the storage period in this experiment (Table 1). Among these treatments, fruit with the PO film had the lowest weight loss. The fruit wrapped with the PO film had an average of only 0.5% weight loss after 4 weeks in storage and 0.8% weight loss after 8 weeks in storage while the control group had 2.2% weight loss in 4 weeks and 3.6% in 8 weeks. Perforated PO film gave the poorest weight loss control. It allowed 4.2% weight loss over 8 weeks in storage.

Weight loss of grapefruit increased with harvest date from Feb. to May (Table 2). Fruit harvested in early Feb. had only 1.2% weight loss after 4 weeks storage and 2.2% weight loss after 8 weeks storage while May-harvested fruit had 2.0% weight loss after 4 weeks storage and 2.8% weight loss after 8 weeks storage. Weight loss of the fruit harvested in June was 1.6% after 4 weeks and 2.4% after 8 weeks, and was significantly less than the fruit harvested in May.

Fruit in any of the film wraps in this experiment had significantly lower internal CO_2 levels and higher internal O_2 levels than that of waxed-control fruit. Waxed fruit had 5.7% internal CO_2 and 15.8% O_2, while the fruit in PO film had only 3.7% CO_2 and 18.5% O_2 after 8 weeks in storage. Fruit wrapped with PVC film had 4.5% CO_2 and 17.5% O_2 which were significantly higher than that of PO film and significantly lower than that of waxed control (Table 1). No significant differences among PO, PB, and perforated films were found after 8 weeks storage.

Table 1. The effects of film wrapping on Florida grapefruit quality factors.

Wk after harvest	Treatment	Quality factor			
		Weight loss	Internal CO_2 (%)	Internal O_2 (%)	Internal ethanol (%)
	Waxed control[z]	2.2[y]b	4.5 a	17.0 c	0.050 a
	PVC film	1.3 c	3.6 b	18.1 b	0.045 a
4	PO film	0.5 d	3.2 c	18.8 a	0.047 a
	PB film	1.3 c	2.9 cd	18.8 a	0.043 a
	Perf. PO film	2.6 a	2.7 d	19.1 a	0.041 a
	Waxed control	3.6 b	5.7 a	15.8 c	0.036 a
	PVC film	2.1 c	4.5 b	17.5 b	0.031 ab
8	PO film	0.8 d	3.7 c	18.5 a	0.026 ab
	PB film	2.1 c	3.3 c	18.4 a	0.026 ab
	Perf. PO film	4.2 a	3.7 c	18.6 a	0.023 b

[z]Tested films were PO film (D950), perforated PO film (PY07), PB film (JSR), and PVC film (BW 51).
[y]Mean separation in columns for 4 or 8 weeks after harvest by Duncan's multiple range test, 5% level.

Table 2. The effects of harvest date on grapefruit weight loss and internal gases.

Wk after harvest	Harvest date	Quality factor			
		Weight loss (%)	Internal CO_2 (%)	Internal O_2 (%)	Internal ethanol (%)
	2 Feb.	1.2[z]c	2.4 b	18.8 a	0.024 d
	9 Mar.	1.5 b	2.5 b	18.9 a	0.029 cd
4	13 Apr.	1.5 b	3.9 a	18.0 b	0.036 c
	18 May	2.0 a	3.9 a	18.1 b	0.058 b
	22 Jun.	1.6 b	4.1 a	18.0 b	0.063 a
	Avg.	1.6	3.4	18.4	0.045
	2 Feb.	2.2 c	3.3 c	19.1 a	0.012 d
	9 Mar.	2.6 ab	4.2 b	17.7 b	0.022 c
8	13 Apr.	2.7 a	4.5 ab	17.6 b	0.026 bc
	18 May	2.8 a	4.8 a	17.3 bc	0.034 b
	22 Jun.	2.4 bc	4.1 b	17.0 c	0.048 a
	Avg.	2.6	4.2	17.7	0.029

[z]Mean separation in columns for 4 or 8 weeks after harvest by Duncan's multiple range test, 5% level.

Storage temperature greatly affected internal CO_2 level. After 8 weeks storage, internal CO_2 at 15.5°C was 3.9% while that at 29.5°C was 4.3% (Table 3). Internal O_2 showed less differences due to storage temperature than CO_2 in this test. No significant differences in O_2 occurred after 8 weeks storage.

Fruit harvested in Feb. had significantly lower internal CO_2 (3.3%) and higher O_2 (19.1%) than fruit harvested in May (4.8% CO_2 and 17.3% O_2) (Table 2). When averaged over 5 harvest dates, internal CO_2 significantly increased from 3.4 to 4.2 with storage time from 4 to 8 weeks while internal O_2 decreased from 18.4 to 17.7% (Table 2).

There were no significant differences in internal ethanol among film treatments after 4 weeks of storage (Table 1), but the internal ethanol level (0.023%) in the fruit wrapped with perforated film was significantly lower than that in the fruit of the waxed control (0.036%) after 8 weeks of storage.

Averaged over all the harvest dates, fruit stored at 29.5°C developed significantly higher ethanol (0.066% at 4 weeks and 0.049% at 8 weeks) compared with the fruit stored at 21 or 15.5°C (0.033% or 0.037% at 4 weeks and 0.018 and 0.019%, respectively, in 8 weeks) (Table 3). There were no significant differences in internal ethanol between fruit stored at 21 and 15.5°C.

Table 3. The effects of temperature on grapefruit weight loss and internal gases.

Wk after harvest	Temperature (°C)	Quality factor			
		Weight loss (%)	Internal CO_2 (%)	Internal O_2 (%)	Internal ethanol (%)
	29.5	2.1[z]a	3.8 a	18.0 b	0.07 a
4	21.0	1.7 b	3.4 b	18.3 b	0.03 b
	15.5	1.0 c	3.0 c	18.8 a	0.04 b
	29.5	3.4 a	4.3 a	17.7 a	0.05 a
8	21.0	2.7 b	4.4 a	17.7 a	0.02 b
	15.5	1.6 c	3.9 b	17.8 a	0.02 b

[z]Mean separation in columns for 4 or 8 weeks after harvest by Duncan's multiple range test, 5% level.

The later in the season that the grapefruit were harvested, the higher the internal ethanol was for the same storage period (Table 2). Fruit harvested in Feb. had only 0.012% internal ethanol while fruit harvested in June had 0.048% ethanol after 8 weeks in storage. Internal ethanol significantly decreased with time in storage for fruit from all five test dates.

The grade of section drying and the percentage of seed germination of the fruit sharply increased after May, being significantly higher in June (Fig. 1). PO film resulted in the lowest section drying while perforated film gave the lowest seed germination in these tests (Fig. 2). PB film-wrapped fruit had the highest seed germination rate among all coating treatments. Section drying and seed germination (Fig. 3) were significantly higher at 29.5°C storage temperature than at 15.5°C.

Storage temperature also affected juice quality (Table 4). For all coating treatments, fruit harvested in May and June and stored at 29.5°C for 8 weeks had a lower percent acid and higher °Brix to percent acid ratio (hereinafter referred to as ratio) than fruit harvested on the same date and stored at 21 or 15.5°C (Table 4). Fruit harvested in June had a lower percent acid and higher ratio than fruit harvested in May and stored under the same temperature and with the same coating treatments. The average ratio of the fruit stored at 29.5°C and tested in July (fruit harvested in May) was 13.7 and in August (fruit harvested in June) was 17.4 while that of the fruit stored at 21°C and tested in July was 10.1; August was 13.6. According to the flavor grades by the panelists, fruit harvested in Feb. had a better flavor when stored at 29.5°C for 8 weeks than at 21°C (Table 5). However, June-harvested fruit stored at 15.5°C had better juice flavor than juice from fruit stored at 29.5°C. No significant flavor differences among coating treatments held at the same storage temperature were found. The juice of fruit harvested in June and stored at 29.5°C developed severe off-flavor and was unacceptable in flavor quality.

Discussion

Waxing can significantly reduce weight loss of fruit during storage (3, 10); however, individually wrapping fruit with certain kinds of film can show even more effect on weight-loss control than waxing (1, 2, 8). Plastic films in this experiment significantly reduced weight loss compared to the control except for perforated film. Use of film resulted in about one-fourth as much weight loss in fruit as did the waxed control. Although the perforated film controlled weight loss the least, the percent weight

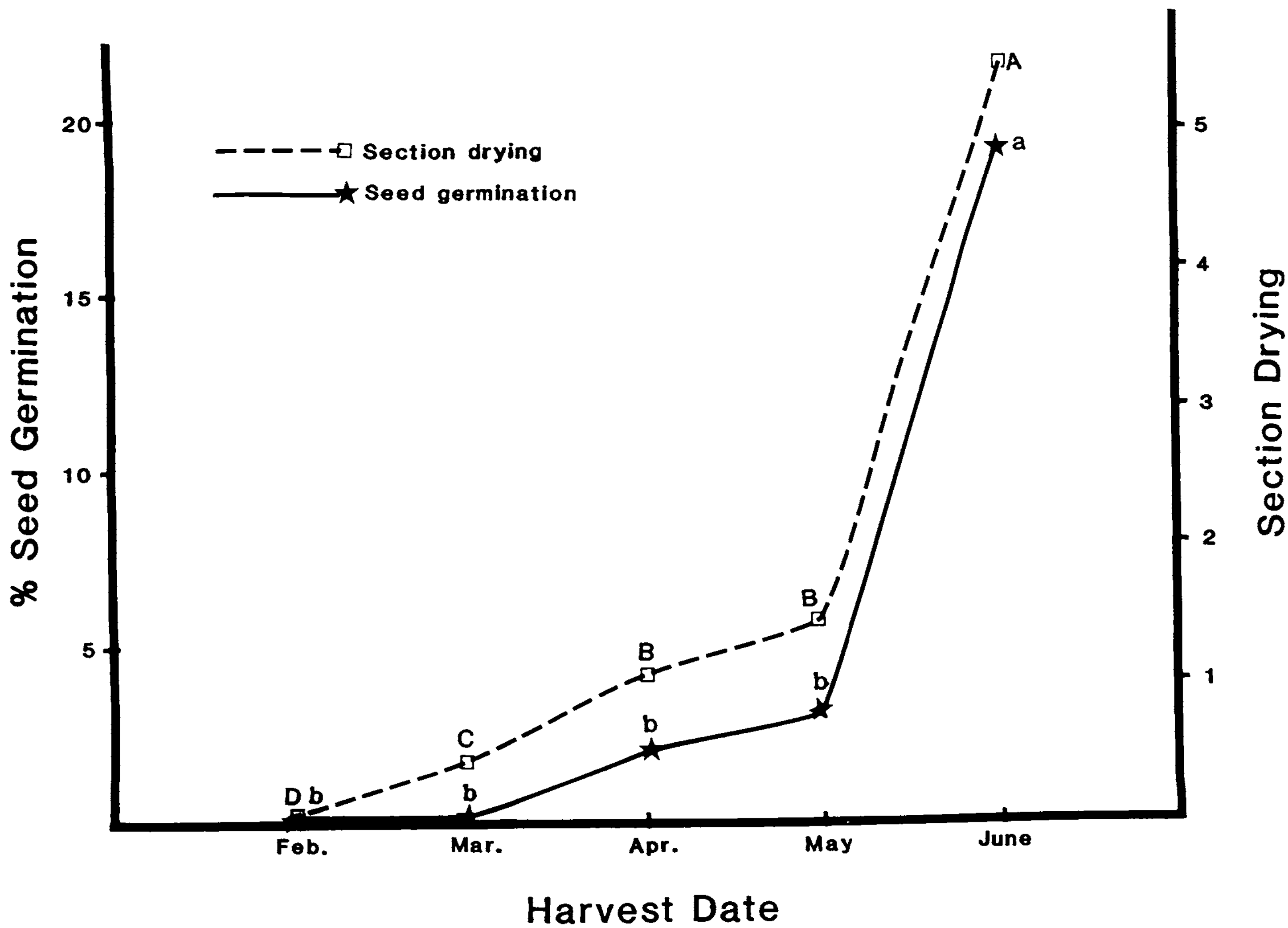

Fig. 1. Effect of harvest date on section drying and seed germination measured after 8 weeks storage. Points on the same line with different letters are significantly different at 5% level.

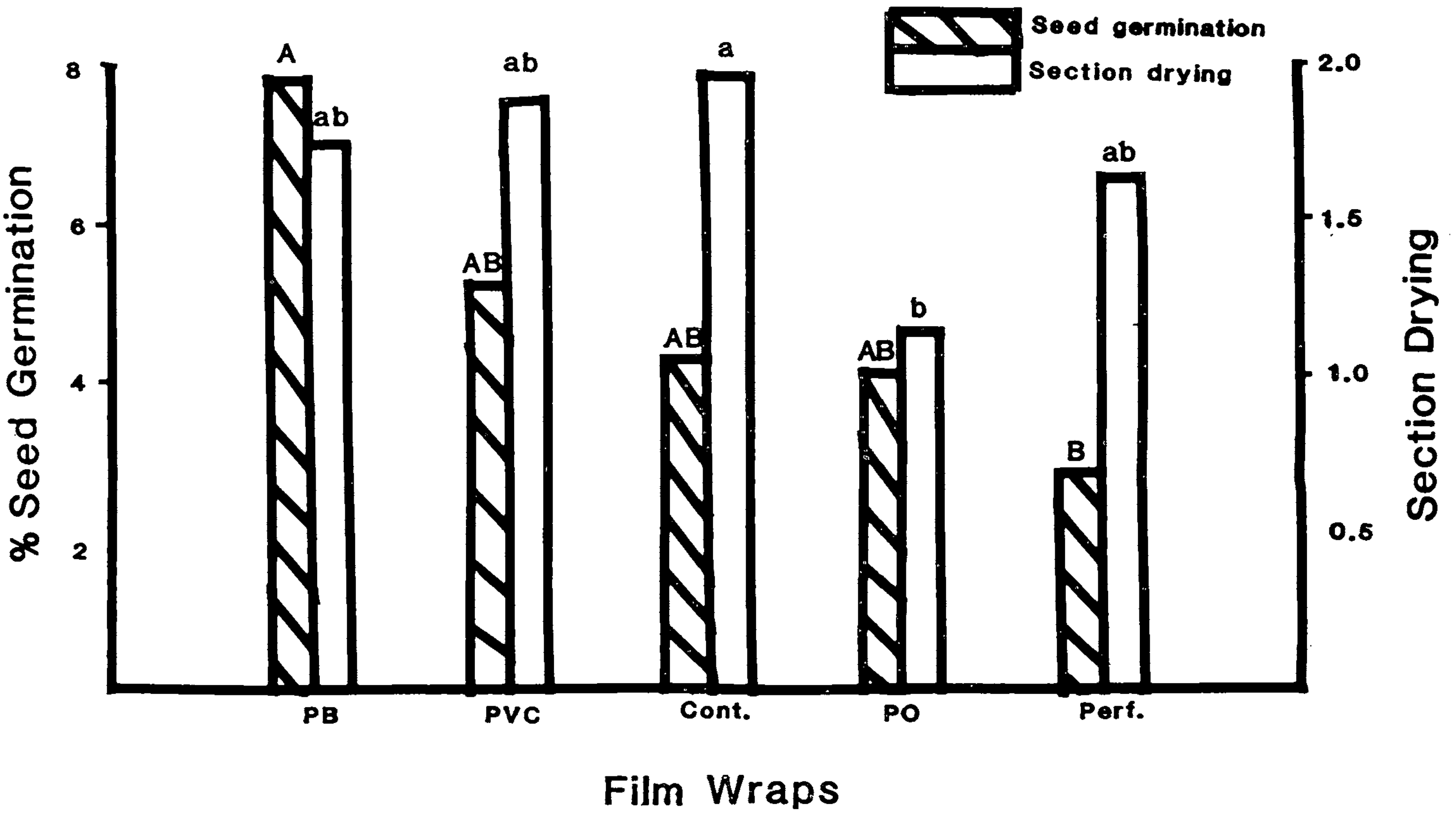

Fig. 2. Effects of film wrapping plus 8 weeks of storage on section drying and seed germination. Similarly marked bars with different letters are significantly different at 5% level.

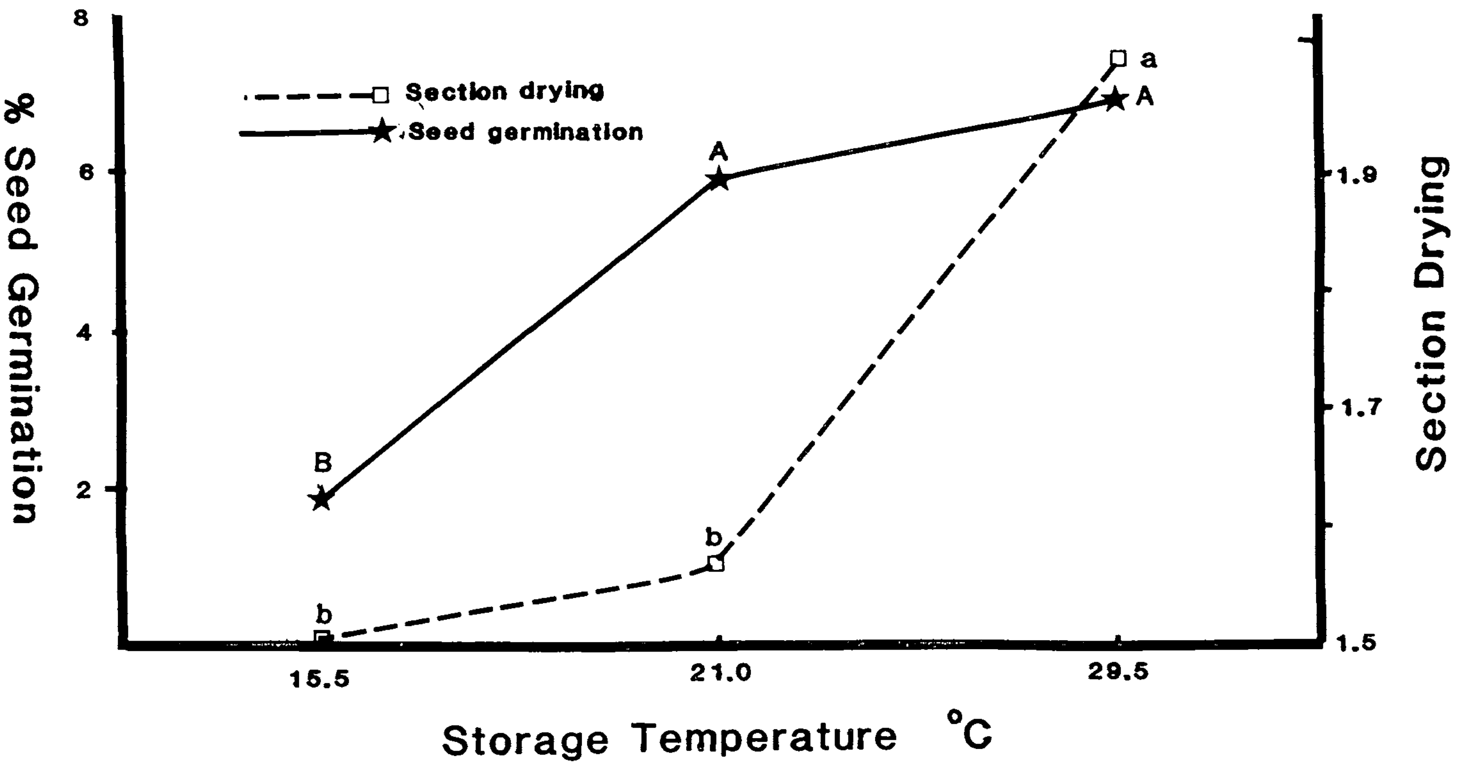

Fig. 3. Storage temperature effect on section drying and seed germination. The results were obtained from the fruit after 8 weeks storage. Points on the same line with different letters are significantly different at 5% level.

Table 4. °Brix (B), percent acid (A) and the °Brix to percent acid ratio (R) of the juices of grapefruit stored for 8 weeks at different temperatures and wrapped with different films.

Film-wrap	15.5°C			21°C			29.5°C		
	B	A	R	B	A	R	B	A	R
Harvested in May and tested in July									
Control	11.6[z]	1.1[y]	10.4[x]	11.3	1.2	9.8	11.2	0.8	13.3
PO	11.9	1.1	10.8	11.2	1.1	10.2	11.1	0.8	13.4
PB	11.7	1.1	10.6	11.3	1.1	10.1	10.7	0.8	14.0
Perf. PO	12.0	1.1	11.2	11.8	1.2	9.8	11.1	0.9	12.8
PVC	11.5	1.1	10.9	11.5	1.1	10.7	10.8	0.7	14.7
Avg.	11.5	1.1	10.6	11.4	1.1	10.1	11.0	0.8	13.7
Harvested in June and tested in August									
Control	11.2	0.9	12.7	—	—	—	11.2	0.7	17.2
PO	11.1	0.8	13.9	11.4	0.9	12.2	11.3	0.7	16.5
PB	11.3	0.8	14.9	11.9	0.9	13.6	11.0	0.6	19.0
Perf. PO	11.1	0.8	13.9	11.4	0.8	14.6	11.4	0.7	17.0
PVC	11.9	0.9	13.5	11.6	0.8	14.9	11.2	0.7	17.0
Avg.	11.3	0.8	13.8	11.6	0.8	14.1	11.2	0.7	17.4

[z]°Brix—corrected for temperature and acid.
[y]Percent acid (as anhydrous citric).
[x]°Brix to percent acid ratio (calculated).

loss after 8 weeks of storage was less than the generally acceptable 5% limit.

Higher weight loss occurred during storage in fruit harvested late in the season than in the fruit harvested early in the season. One explanation of the increasing weight loss from Feb. to May is that the cuticle and wax layer of the fruit cracked during senescence with the late harvest date allowing freer flow of moisture out of the fruit. Fruit harvested in June had less weight loss than in May, possibly because fruit harvested in June were held in storage at a higher humidity than earlier because the rainy season resulted in supplemental humidity. Unfortunately, storage humidity was not monitored.

Internal CO_2 and O_2 levels are an indication of the permeability of the coating when compared with the same harvest date and storage temperature. Film wrapping resulted in significantly lower CO_2 levels and higher O_2 levels than the waxed control indicating a favorable permeability to O_2 and CO_2 for the films. Although PO film resulted in remarkably lower weight loss than did perforated film, both films resulted in similar internal gas conditions which were superior to the control.

Harvest date and storage temperature were apparently major factors affecting fruit respiration, although respiration was not measured directly. The later the fruit were harvested and the higher the storage temperature, the higher was the internal CO_2 and the lower the internal O_2. Perhaps higher storage temperature increased anaerobic respiration intensity in the later harvested fruit. Ethanol levels were also significantly higher.

An increase of the internal CO_2 level in a fruit may inhibit respiration, thereby prolonging fruit storage life (17). However, citrus varieties have different responses to O_2 and CO_2 under controlled atmosphere storage (CA) conditions and Florida grapefruit do not respond well to CA (11). High CO_2 and low O_2 may also cause an increase in internal ethanol because of anaerobic respiration (7) rather than simply inhibiting respiration. This may lead to degenerative processes associated with senescence (17) and off-flavors will develop.

Table 5. Effect of harvest date, film wraps, and storage temperature on the mean hedonic flavor scores for grapefruit juice extracted after 8 weeks of storage.[z,y]

Harvest date	Film wrap and storage temperature			
	PVC(21°C)	PVC(15.5°C)	Perf.(15.5°C)	PB(15.5°C)
Feb.[x]	—	—	—	—
Mar.	5.7 a	7.2 b	6.9 b	7.1 b
Apr.	6.5 a	6.9 a	7.1 a	7.1 a
May	7.4 a	6.6 a	7.0 a	6.9 a
June	4.4 a	6.0 b	6.1 b	5.3 ab
	PVC(29.5°C)	PO(29.5°C)	Perf.(29.5°C)	PB(29.5°C)
Feb.[x]	7.1 a	6.9 a	7.0 a	6.7 a
Mar.	6.8 a	6.6 a	6.6 a	6.7 a
Apr.	6.6 a	6.7 a	6.4 a	6.8 a
May	6.6 a	7.0 a	6.5 a	7.1 a
June	5.3 b	5.8 b	5.4 b	4.1 a
	Cont.(21°C)	PO(21°C)	Perf.(21°C)	PB(21°C)
Feb.[x]	—	6.3 a	6.7 a	6.6 a
Mar.	6.9 a	6.9 a	5.5 bc	6.6 ab
Apr.	7.1 a	6.1 a	6.6 a	6.5 a
May	7.0 a	7.2 a	7.0 a	7.4 a
June	—	6.4 a	6.3 a	5.5 a
	Cont.(15.5°C)	PO(15.5°C)	Perf.(29.5°C)	PB(29.5°C)
Feb.[x]	5.8 a	6.3 ab	7.2 b	7.1 b
Mar.	6.6 a	6.8 a	6.9 a	6.9 a
Apr.	6.9 a	6.9 a	5.1 b	5.4 b
May	7.2 ac	7.6 bc	6.6 a	6.8 ac
June	5.4 a	5.0 a	3.8 b	3.8 b

[z]Means based on 13-16 evaluations by experienced panelists grading samples on a 9-point hedonic scale where 9 = like extremely; 1 = dislike extremely.
[y]Means in the same row sharing the same letter are not significantly different at the 95% level
[x]Only 4 samples could be evaluated at one time.

Some studies have shown that internal ethanol increases with storage time (7). Less internal ethanol appeared after 8 weeks than after 4 weeks in this experiment. At the same time, later harvested fruit had higher ethanol levels. Further studies are needed to determine the ethanol levels at harvest time and respiration rate of fruit harvested at different dates.

Chemical factors such as °Brix, percent acidity, and ratio were not affected by film wrapping. Harvest date and storage temperature also had no effect on °Brix, but both of these variables lowered percent acidity thus increasing the °Brix/acid ratio and affecting grapefruit juice flavor.

The flavor rating of grapefruit juice decreased with later harvest date, as indicated by flavor scores. Significant increases of internal ethanol and decrease of the ratio also occurred with later harvest date. This suggests that metabolism of late-harvested fruit is unfavorable and leads to poor flavor scores especially at higher storage temperature. Fruit harvested in June and stored at 21°C had moderately low flavor scores while fruit stored at 29.5°C developed a severe off-flavor after 8 weeks storage. It does not appear that off-flavor development is a serious problem in film-wrapped grapefruit even at temperatures as high as 29.5°C for 8 weeks if fruit are harvested before June. Presumably, at higher storage temperatures than studied, off-flavor will develop in both waxed and film-wrapped fruit harvested earlier than June.

As in a previous study (15), fruit harvested prior to May did not have severe section drying or seed germination problems as did fruit harvested after May. Also, in this study, fruit harvested after May and stored at lower temperatures had less section drying and seed germination than fruit stored at 29.5°C. Lower storage temperature appeared to suppress the development of these 2 defects as had been reported earlier (15).

In summary, film wrapping provided weight loss control without causing increased internal ethanol, section drying, seed germination, or off-flavor problems in excess of waxed control fruit. PO wrapping resulted in the best weight loss control and the lowest section drying. Harvesting fruit late in the season and storing at higher temperatures should be avoided because of increased weight loss, seed germination and section drying, and off-flavor development. Anaerobic respiration and seed germination were probably responsible for off-flavor development and reduced fruit quality in the late season fruit.

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BIOLOGICAL BASIS FOR POSTHARVEST USES OF FORMULATED QUATERNARY AMMONIUM COMPOUNDS (QUATS)

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Additional index words. control of plant pathogens on equipment, packinghouse sanitation, plant quarantine chemicals.

Abstract. **A formulation containing two quaternary ammonium compounds (dual quat) was particularly tested and observed to be effective against organisms causing decays such as bacterial soft rot in potatoes, blue and green mold rot and sour rot in citrus and brown rot and botrytis rot in stonefruits. At 200-1000 ppm, it was effective in sanitizing or reducing 99.99% miorobial load of selected organisms in 3 to 5 minutes. It was shown to be effective against certain Penicillium isolates that were tolerant to benzimidazole compounds commonly used as fungicides in citrus packinghouses.**

Many physical agents or activities can be used as sanitizers to reduce the microbial load or to kill most or all of the microbes around us, e.g. dry or wet heat; UV, IR or gamma radiation , mechanical washing or blowing, or even ultra sound waves. Over the past hundred years, chemical agents have also been used for killing or reducing the microbial load. The four major groups have been as follows e.g. halogens, oxidizers, phenolics and lastly quaternary ammonium compounds. Many other important groups of chemicals such as antibiotios, antimiorobials and preservatives or functional additives that inhibit microbial growth also have found important use in our lives.

During the early forties a group of chemicals known as quaternary ammonium compounds (quats) were synthesized and studied extensively. These chemical compounds were functionally active as cationic surface active agents and had exceptional antimicrobial effects. Since then these compounds have been very useful as sanitizers, antifoamers, antiseptic and antistatic agents in a variety of products useful in hospitals, laundries, dairies, meat and poultry plants, and fruit and vegetable processing plants. These chemicals have been used in many household products as well, and thus are truly classified and known as "the all purpose sanitizers".