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CONDITION OF WAXED OR FILM-WRAPPED 'MINNEOLA' TANGELOS AFTER STORAGE

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Abstract. **'Minneola' tangelo (*Citrus paradisi* Macf. x *Citrus reticulata* Blanco) is a relatively minor citrus variety commercially produced in Florida. High incidences of postharvest rind breakdown and decay limit the marketing potential of this specialty fruit from competing in the European export trade. During the 1989 season, 'Minneola' fruit from 3 different sources were washed with chlorine (200 pm), treated with imazalil (1,000 ppm) or not treated, and fruit were waxed or individually film wrapped. All fruit were evaluated after storage of 2 and 4 weeks at 4.5°C plus 1 additional week at 21°C. After 5 weeks' storage, the incidence of decay was 5% in imazalil-treated fruit compared to 10% in nontreated fruit. Imazalil was equally effective for decay control with either waxed or film wrapped fruit. During storage, rind breakdown (aging) and weight loss were less, and fruit softened at a slower rate in film-wrapped fruit compared to waxed fruit. Film wrapping enhanced the development of the red-orange color that is characteristic of 'Minneola' tangelo. Film-wrapped fruit consistently had a more acceptable flavor after storage than waxed fruit. Film wrapping of 'Minneola' tangelos reduces the rate of senescence, thus extending their shelf life for a longer marketing period. Film wrapping may be especially beneficial in increasing shelf life of 'Minneola' fruit in distribution and marketing of domestic gift fruit and in export sales.**

'Minneola' tangelo, one of the four main commercial tangelo hybrids, was developed and introduced to the Florida citrus industry in the early 1900's (5). Total bearing acreage of tangelos peaked at about 21,000 acres in the early 1970's, but has declined to about 9,500 acres where it has remained since 1984-85. Fifty-four percent of the fruit were marketed fresh in the early 1970's, compared to an average of 39% in the last 5 years (3). On-tree price of tangelos in the 1987-88 crop year was $5.35 per box, with a total crop value of $22.5 million. Although tangelos were originally considered a specialty fruit for gift fruit sales, a greater percentage of the crop is now utilized in processing. This is unfortunate, because 'Minneola' tangelos have a high consumer appeal, being high in juice content with a tart but aromatic flavor. They also have an attractive, deep reddish orange rind that peels easily, making the fruit easy to eat (5). Reports from market surveyors and receivers in the European market indicated that the risks of marketing losses for 'Minneolas' due to senescence and decay are excessive, thus preventing export sales (unpublished reports and personal communication).

With the exception of Harding et al. (5), little information on postharvest storage of 'Minneola' tangelos is available. 'Minneola' tangelos are very susceptible to senescence and decay, and consequently have a relatively short shelf life. Mandarin-type citrus and round oranges rapidly lose moisture during storage, which contributes to the development of stem-end rind breakdown (7). Purvis found that "Hamlin' oranges (*C. sinensis* (L.) Osbeck) lose moisture 10-30% more rapidly than grapefruit during storage, and that moisture loss was drastically reduced by wrapping fruit in permeable plastic film, without reduction in juice quality (9).

Recently, Ismail found that 'Minneola' tangelos harvested from trees previously treated with gibberellic acid (GA) had lower rates of postharvest senescence than fruit from untreated trees (6, personal communication). This work has important implications for fruit that is produced for the fresh market. Chun et al. (2), studying methods to reduce postharvest decay on 'Minneola' tangelos, found that film wrapping with or without fungicide reduced decay, and slowed the development of senescence. He also observed that peel color was enhanced by the microatmosphere in plastic film compared to that of waxed fruit. Previous studies show that wrapping of various citrus fruits in different types of plastic films reduces senescence, weight loss, spoilage and rots due to secondary infections, and improves general surface appearance (1, 8, 10).

The main purpose of this study was to confirm the advantages of film wrapping of 'Minneola' tangelos reported by Chun et al. (2), and determine the effect on peel color and flavor of wrapped and nonwrapped fruit during simulated domestic and export shipping time/temperature regimes.

Materials and Methods

Fruit, approximately size 80, was obtained either directly from field bins or from the packing line after chlorine wash. Three separate harvest lots (replications) were sampled from sources located in either Brevard or Polk County, Florida, during January 1989. Fruit not previously treated with chlorine at the packinghouse were dipped in an aqueous chlorine solution (200 ppm) for 2 min, washed with soap (Mold Strip 25®, Fresh Mark Corp., Ocoee, Fla.), and half of each fruit lot was treated with imazalil (IM) (1,000 ppm). IM-treated and untreated fruit were either waxed (Flavor Seal®, FMC Corp., Lakeland, Fla.) or individually sealed in plastic film (Clysar EHC-50®, DuPont De Nemours & Co., Wilmington, Del.) as previously described (4).Thirty fruit, from each treatment, were placed in 2/5-bushel, full-telescoping fiberboard citrus boxes. For each of the 3 lots tested, there were 3-box subsamples of fruit for each of the 4 treatments. The treatments for this 2 x 2 factorial experiment (fungicide x fruit coating) were:

Treatment	Imazalil	Wax	Film
1	−	+	−
2	−	−	+
3	+	+	−
4	+	−	+

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Fruit were held in refrigerated storage at 4.5°C, 90 ± 5% relative humidity (RH), and all fruit were inspected after 2 and 4 weeks and after 1 additional week at 21°C. Each fruit was rated for visible symptoms of aging, pitting, scald (rind discoloration), freshness of rind and stem scar, firmness, and decay as previously described by Chun et al. (2). In addition, 15 fruit each from treatments 3 and 4 were prepared for objective measurements of color and firmness. Color measurements were made initially and at each inspection with a colorimeter (Model D 25-9, with D-25 sensor, Hunter Associates Laboratory, Reston, Va.) using a 5-cm aperture. Forty-five fruit (15 per 3-box subsample) from each treatment replication were numbered and weighed, initially and after each inspection, for determining weight loss. Objective fruit firmness was measured with a Food Texture System® (Instron Corp., Canton, Mass.) calibrated (10 N, full scale) to read peak Newtons during 5-mm compression with a 5-cm, cylinder-shaped, flat-faced anvil on 15 random fruit from each box after 5 weeks' storage. After the final inspection, 2 random fruit from each box in treatments 3 and 4 were sectioned for sensory evaluation (flavor and texture) and scored by at least 6 participants based on a hedonic scale ranging from 1 (undesirable) to 9 (highly desirable).

Values for all data were averaged over the 3 tests and means were subjected to Duncan's multiple range or factorial analysis of variance procedures.

Results and Discussion

Waxed fruit lost about 3 times more weight than film-wrapped fruit during 4 weeks of storage; and after 1 additional week at 21°C, weight loss was 1.0% for wrapped and 2.4% for waxed fruit (Table 1). Objective measurement of firmness showed film-wrapped fruit tended to be firmer after the last inspection, but not significantly more than waxed fruit. Measured subjectively, film-wrapped fruit were consistently firmer than waxed fruit after 2, 4 and 5 weeks of storage.

Hunter color measurements indicated little or no change in 'L' (lightness-darkness), or 'a' (green-red) values during storage for either film wrapped or waxed fruit (Table 1). The 'b' (blue-yellow) value of wrapped fruit continued to decrease after 2 weeks of storage, but remained generally unchanged for waxed fruit. The decrease in 'b' value coupled with the relatively constant 'a' value for wrapped fruit compared with the static 'a' and 'b' values for waxed fruit probably explains the darker reddish orange hue of wrapped fruit after the total storage regime. The subjective color index values showed that external peel color of film-wrapped fruit was generally more acceptable than peel color of waxed fruit. Although objective peel color was measured on the same fruit at each inspection, the 3 measurements per fruit were taken at random areas on the peel surface. Therefore, Hunter color values may not be as precise as they might have been if 3 predetermined areas on the peel surface were marked initially, assuring that the same areas on the surface would be remeasured after each storage period.

Aging is an important indicator of citrus fruit freshness and is correlated with moisture loss. This is especially true for 'Minneola' tangelo where aging symptoms consist of brown necrotic areas of tissue on the peel surface, usually at the stem end of the fruit. These symptoms develop rapidly on 'Minneola' tangelos. Film wrapping significantly delayed early development of aging; and, after 4 weeks of storage, aging was reduced 60% compared with that observed on waxed fruit (Table 2). Little or no pitting was observed during storage, indicating no injury due to the storage temperature or duration.

Green mold rot was the predominant type of decay, accounting for about 65% of total decay at the final inspection. Imazalil reduced green mold rot; therefore, total decay was about half that observed for fruit not treated with IM. Stem-end rot did not develop until fruit were moved to 21°C storage, where after 1 week less than 2% of fruit were affected. Fruit coating had no effect on the incidence of decay. Subjective overall appearance rating indicates that peel of film-wrapped fruit were fresher than waxed fruit.

At the final evaluation, film-wrapped fruit had a more acceptable taste (mean index value 6.9) than waxed fruit (mean index value of 5.1). Mean total soluble solids (TSS 12.3 and 12.7, respectively), and mean pH values (3.3, 3.4,

Table 1. Percentage of weight loss, objective and subjective fruit firmness, Hunter color 'L', 'a', 'b', and 'a/b' values and subjective color index values for 'Minneola' fruit by storage duration and fruit coatings of plastic film (IW) or wax.

Storage/ treatment	Weight loss[z] (%)	Objective firm (N)	Subjective firm index[y]	Objective color value				Subjective color index[x]
				'L'	'a'	'b'	a/b	
Initial								
IW	—	2.8 a[w]	—	52.3 a	33.0 b	30.7 b	1.1 a	—
Wax	—	2.8 a	—	52.3 a	32.1 a	29.7 a	1.1 a	—
2 wk at 4.4°C								
IW	0.3 a	—	1.1 a	52.0 a	34.0 b	31.1 b	1.1 a	1.2 a
Wax	1.1 b	—	1.3 b	51.7 a	33.5 a	30.2 a	1.1 a	1.5 b
4 wk at 4.4°C								
IW	0.6 a	—	1.1 a	52.1 a	34.0 a	30.6 a	1.1 a	1.2 a
Wax	1.8 b	—	1.5 b	51.9 a	33.2 a	30.1 a	1.1 a	1.5 b
4 wk at 4.4°C + 1 wk at 21°C								
IW	1.0 a	2.9 b	1.4 a	51.4 a	33.4 b	29.9 a	1.1 a	1.3 a
Wax	2.4 b	2.6 b	1.8 b	52.8 b	31.4 a	30.0 a	1.1 a	1.6 b

[z]Cumulative decrease in weight (percent).
[y]*Index value*, 1 = firm, 2 = fairly firm, 3 = soft.
[x]Index value, 1 = good, 2 = fair, 3 = poor.
[w]Means in columns for each storage duration followed by the same letter are not significantly different at $P = 0.05$ by Duncan's multiple range test.

Table 2. Percentage[z] of 'Minneola' fruit rated sound and for aging, pitting, green mold (PEN), stem end rot (SER), and total decay, and subjective *index values for* external appearance and stem scar condition as influenced by individual wrapping (IW) and waxing, with and without imazalil (IM).

Storage duration/ treatment	Sound (%)	Age (%)	Pit (%)	PEN (%)	SER & Misc (%)	Total decay	Appear-ance[y] index	Stem[x] scar index
2 wk at 4.4°C								
IW	98.0	0.4	0.0	1.4	0.2	1.6	1.2	1.9
Wax	95.0	4.3	0.0	0.7	0.0	0.7	1.5	2.0
IM (–)	95.9	2.6	0.0	1.3	0.2	1.5	1.4	1.9
IM (+)	97.1	2.0	0.0	0.9	0.0	0.9	1.4	1.9
Coat	NS	*	—	NS	NS	NS	NS	NS
IM	NS	NS	—	NS	NS	NS	NS	NS
4 wk at 4.4°C								
IW	94.1	1.3	0.9	3.3	0.4	3.7	1.4	2.1
Wax	91.7	6.3	0.0	2.0	0.0	2.0	1.6	2.2
IM (–)	92.1	4.4	0.0	3.3	0.2	3.5	1.4	2.2
IM (+)	93.7	3.2	0.9	2.0	0.2	2.2	1.6	2.2
Coat	NS	*	NS	NS	*	NS	NS	NS
IM	NS	NS	NS	NS	NS	NS	NS	NS
wk at 4.4°C + 1 wk at 21°C								
IW	86.3	4.8	1.1	4.9	0.9	7.8	1.8	2.4
Wax	82.5	11.4	0.0	4.3	0.6	6.1	2.3	2.6
IM (–)	83.9	6.7	0.0	6.1	1.1	9.4	2.0	2.5
IM (+)	85.1	9.2	1.1	3.0	0.4	4.6	2.1	2.5
Coat	NS	*	NS	NS	NS	NS	*	*
IM	NS	NS	NS	*	NS	*	NS	NS

[z]Means of 3, 30-fruit subsamples for 3 replications per treatment and are cumulative over storage.
[y]Index value, 1 = fresh; 2 = fairly fresh; 3 = old.
[x]Index value, 1 = green fresh; 2 = green/brown, fairly fresh; 3 = brown, old.
[w]NS, * not significant or significant at $P = 0.05$ by factorial analysis; coat x IM interaction, NS for all condition or quality categories.

respectively) were not significantly different for wrapped or waxed fruit after 5 weeks of storage. In previous sensory evaluations of 'Minneola' tangelos by the authors (unpublished), juice from stored fruit had an off-flavor after relatively short storage periods of 6 weeks.

Although the main objective of this study was to determine differences in peel color relative to coating treatments, the most important effect of film-wrapping fruit was the reduction of aging symptoms. Eleven percent of waxed fruit showed aging symptoms even though weight loss was only 2.5% after 5 weeks of storage. Film wrapping extended or maintained the shelf-life of 'Minneola' without adversely affecting favor. As a potential gift fruit item, film-wrapped fruit may be a feasible alternative to waxed 'Minneola' tangelos.

In this study, microatmospheres (CO_2, O_2) were not taken from within the film-wrapped fruit because the film seals, made with a hot wire sealer, were not airtight. Internal atmospheres of film-wrapped fruit may have differed from those of waxed fruit during storage due to permeability differences between the 2 fruit coatings. Sensory evaluations showed no differences between wrapping and waxing, however. Additional studies on the effects of coating treatments of 'Minneola' fruit treated preharvest with GA should be conducted. Preharvest treatment with GA combined with postharvest film wrapping may dramatically reduce or delay senescence during storage and merchandizing. Increasing the potential for successfully marketing 'Minneolas' as fresh fruit could reverse the trend towards processing them for juice.

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