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Cleaning Method Affects Shrinkage Rate of Citrus Fruit

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Abstract. **The shrinkage rate of 'Marsh' grapefruit *(Citrus paradisi* Macf.), 'Ambersweet' hybrid *[(C. reticulata* Blanco × *C. paradisi* Macf. × *C. reticulata)* × *C. sinensis* (L.) Osb.] and 'Valencia' oranges *[C. sinensis* (L.) Osb.] was increased 50 % to 150% by washing the fruit with rotary brushes, but was not changed by hand-washing the fruit with cellulose sponges. Internal CO_2 increased using both washing methods. Waxed fruit obtained from five Florida packinghouses and cleaned with rotary brushes and waxed had shrinkage rates the same as those of nonwashed controls. Thus, controlling the washing process is important to minimize shrinkage of fresh citrus fruit.**

For many years, citrus fruit have been prepared in packinghouses for the fresh-produce market by washing, treating with fungicide, and applying a coating (Kaplan, 1986; Smock, 1939). Currently, virtually all citrus fruit are coated, despite the flavor degradation that often results (Ahmad and Khan, 1987; Ben-Yehoshua, 1967; Cohen et al., 1990). Coated fruit commonly are said to be waxed, although many coatings contain no wax.

One reason for waxing citrus and other fruit is to reduce shrinkage due to water loss (Claypool, 1940; Hardenburg, 1967; Kaplan, 1986). However, before fruit are waxed they are washed, an operation that increases water loss. For example, washing navel oranges with brushes increased the shrinkage rate by 40% when measured after 1 week of storage at 24C (Millier and Brown, 1973). Waxing citrus fruit reportedly decreases the shrinkage rate to 70% of that of washed fruit (Hall, 1981). Washing and waxing together, according to these figures, would restore the shrinkage rate to that of nontreated, field-run fruit.

The present work-was undertaken to determine whether fruit washing could be controlled to minimize shrinkage, thus reducing dependence on wax for that purpose.

All fruit were freshly harvested Florida citrus. 'Marsh' grapefruit were harvested 21 Jan. 1992, 'Ambersweet' fruit were harvested 2 Nov. 1992, and 'Valencia' oranges were harvested in Apr. 1992. For laboratory and pilot-plant experiments, the fruit were divided randomly into treatment groups. 'Valencia' oranges from packinghouses were not randomized, although control and waxed fruit came from the same truckload. The packinghouses were located within 40 km of Winter Haven, Fla.

The fruit to be cleaned were soaked for= 1 min in an alkylbenzene sulfonate standard biodegradable cleanser that also contained methyl-naphthalene sulfonates, chelating agents and silicates; a sooty-mold cleaner that contained these ingredients plus a nonionic surfactant; or SOPP soap, which contains sodium *o* -phenylphenate and unspecified surfactants. All cleansers were diluted with water according to the manufacturer's recommendations (FMC Corp., Lakeland, Fla.).

Fruit were washed with standard packinghouse-type brushes or cellulose sponges. Polypropylene brushes have triangular-shaped bristles of medium stiffness, and polyethylene brushes (Industrial Brush Corp., Eaton Park, Fla.) have triangular bristles and are the softest ones used in the citrus industry. Brush diameter was 12 cm and rotation was 22 rpm. During sponge-washing, the fruit were hand-cleaned for 5 sec/fruit and, after 15 rein, cleaned once again the same way. After being washed, the fruit were rinsed for 1 sec under water running at 12 liters·min^{-1}.

Fruit cleanliness was determined visually. Fruit were rated clean if <25 mm^2 of the area appeared soiled.

Shrinkage was determined as weight loss over the specified period. The fruit were weighed at least three times after they had equilibrated to the 22C storage temperature. Shrinkage rates are reported in units of hourly weight loss as percent fruit weight.

Internal CO_2 was determined by a gas chromatography (model 5890a; Hewlett-Packard, Avondale, Pa.) fitted with a 30-m × 0.53-mm polystyrene column and thermal conductivity detector. Gas samples were withdrawn by syringe; the needle was inserted through the blossom end of the fruit into the core albedo.

Respiration rate was measured at 22C for 10 fruit held in 8-liter flow-through containers fitted with condensing coils to control relative humidity at 50%. Another set of coils controlled temperature. Air flowed into the chambers at 105 ml·min^{-1}. Respiration rate was determined after 4 h from steady-state CO, concentration. Reported respiration rates (in milligrams of CO_2 per kilogram per hour) are means of two determinations.

Air flux measures the tendency of a piece of fruit to allow air to pass through openings in its epidermis, a method recently developed (Hagenmaier and Baker, 1993). Briefly, a syringe needle is inserted 1 to 3 cm deep through the blossom end of the fruit into the albedo. After sealing the needle shaft against the fruit epidermis with 5-min epoxy glue, air flow into the needle is measured under applied hydrostatic pressure. Air flow and pressure are measured by movement and height of the meniscus in a manometer. Values are reported as flux at a hydrostatic pressure of 75 cm water (0.074 bar).

Statistical analyses are based on Student's t tests at $P \leq 0.05$; significant differences are reported at the computed level of significance.

Brush-washed fruit. Preliminary results indicated that brush-washed 'Valencia' oranges lost weight at 0.10% per h compared to 0.04% for nonwashed controls (1 to 2 min washing with polypropylene brushes, nine fruit per treatment).

Grapefruit washed the same way had a shrinkage rate ≈ 50% higher than that of the controls (Table 1). Internal CO_2 after storage for 7 days was higher for the washed fruit $(P \leq 0.001)$. The air flux was virtually unchanged, a result suggesting that washing did not markedly change the condition of the openings

Table 1. Shrinkage rates[z] and internal gases of 'Marsh' grapefruit[y] as effected by washing 1 to 2 min with polypropylene brushes and SOPP soap. Data were obtained after 1 week of storage at 22C and 50% relative humidity.

Treatment	Shrinkage rate (% per h)	Internal CO_2 (%)	Air flux (ml·min^{-1})
Control	**0.019**	**1.0**	**6.2**
Washed	0.029	1.6	4.6
SE	0.001	**0.07**	**0.9**

[z]All data are from individual measurements on 22 fruit. For difference in shrinkage rates and internal CO_2, $P \leq 0.0001$.
[y]Mean weight was 350 g/fruit; fruit were harvested 21 Jan. 1992 by clipping stems.

Table 2. Shrinkage rate[z] and internal CO_2 of 'Ambersweet' oranges cleaned for 30 sec with two types of brushes and SOPP soap and then stored at 20C and 75% relative humidity.

Brush type	Shrinkage rate (% **per h**)	Internal CO_2[y] (%) 2 days	7 days
None (control)	0.0087	1.4	1.0
Polyethylene	0.0120	1.8	1.4
Polypropylene	0.0141	2.0	1.7

[z]Rate of weight loss during third day of storage. Mean of four samples per treatment, five fruit per sample. LSD $(P \leq 0.05)$ is 0.001% per h.
[y]Means for five fruit per treatment; LSD = 0.05.

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(stomates, lenticels, and those caused by injuries) in the fruit surface.

Brush-washed 'Ambersweet' fruit had a shrinkage rate ≈ 60% higher than that of the controls when cleaned 30 sec with polypropylene bristles, but only ≈ 40% higher when cleaned with polyethylene bristles, which are softer (Table 2).

The shrinkage rate of 'Valencia' oranges brush-washed and waxed was not markedly different from that of the nonwashed controls (Table 3). Thus, applying coatings compensated for any increase in shrinkage rate caused by washing. The same result was found for 'Valencia' oranges coated with polyethylene wax in three Israeli packinghouses (Ben-Yehoshua, 1967).

Sponge-washed fruit. To determine the properties of fruit washed with minimum abrasion, fruit were sponge-washed. The shrinkage rate of 'Valencia' oranges was unchanged by washing in this manner (Table 4). Fruit cleanliness was highest with alkylbenzene sulfonate cleanser. Internal CO_2 was elevated by all cleansers tested (et< 0.01).

A similar effect on shrinkage was observed for 250 'Valencia' oranges washed with alkylbenzene sulfonate cleanser spiked with 250 ppm Cl_2 (from NaOCl) (Fig. 1). The sponge-washed fruit initially lost weight faster than the controls and, thus, had a shrinkage ratio >1.0. After storage for 7 days, however, the shrinkage rates were virtually the same.

The washed fruit had markedly higher internal CO_2 (Fig. 1; $\alpha \leq 0.001$). Internal CO_2 was elevated by all washing processes used in this study (Tables 1,2, and 4). Internal CO_2 is elevated further by waxing washed citrus fruit (Ben-Yehoshua, 1967; Cohen et al., 1990; Hagenmaier and Baker, 1993). Thus, washing and waxing hinder CO_2 exchange.

The respiration rate was slightly higher in sponge-washed fruit after 2 days of storage; but, when stored >2 days, respiration rate decreased (Fig. 1). Millier and Brown (1973) observed a temporarily higher respiration rate for brush-washed oranges, possibly caused by extra handling during washing (Vines et al., 1968).

Air flux through the peel decreased with storage time and was lower for the sponge-washed than the control fruit. The median values after 4.8. and 13 days of storage were 1.1,0.8, and 0.5 ml·min^{-1} for control&d 0.5, 0.3, and 0.2 ml·min^{-1} for sponge-washed fruit, respectively (10 samples per treatment).

Of the 250 sponge-washed fruit, 73% was acceptably clean, compared to an average of 93% of washed and waxed fruit. Thus, sponge-washing was not as effective as methods currently used in the citrus-processing industry. More thorough washing with sponges might have resulted in increased weight loss.

Shrinkage rate was virtually the same for nonwashed controls, fruit washed and waxed in packinghouses, and sponge-washed fruit. In contrast, brush-washed fruit had higher shrinkage rates. These results suggest that controlling abrasion during washing can yield citrus fruit with less shrinkage than that of fruit processed by present methods. Unfortunately, literature on postharvest citrus treatment generally does not mention cleansers, brush types, or brushing time; thus, it is of little value as an information base for controlling washing.

Whether it is possible to clean fruit to market conditions with minimal abrasion has not yet been demonstrated. However, results point to that possibility.

Table 3. Shrinkage rates of 'Valencia' oranges[z] from five packinghouses.

Packing-house	Fruit coating	Shrinkage rate (% per h)[y] Nonwashed, nonwaxed	Washed, waxed
A	Shellac–wood resin	0.044	0.043
B	Coumarone–indene	0.045	0.046
C	Coumarone–indene	0.047	0.034
D	Resin wax	0.037	0.032
E	Shellac	0.052	0.046
Means		0.045	0.040

[z]Harvested 15–16 Apr. 1992.
[y]Measured as rate of weight loss after 1 week of storage at 22C at 50% ± 10% relative humidity. Five samples per treatment, 800 to 1200 g fruit/sample. SE = 0.0016% per h.

Table 4. Shrinkage ratio, internal CO_2, and cleanliness of sponge-washed 'Valencia' oranges heavily contaminated with sooty mold.

Cleanser	Shrinkage ratio[y]	Internal[z] CO_2 (%)	Clean fruit[x] (%)
None (control)	1.00	3.6	1
SOPP Soap	0.98	7.0	62
Sooty mold	0.97	6.6	47
AS[w]	1.00	5.2	84
+ 250 ppm Cl_2	1.00	5.8	85

[z]Twenty-seven trials for control, 10 for washed fruit. SE = 0.04.
[y]Ratio of rate of weight loss at 20C to that of randomized controls from the same source. Ten samples per treatment, 800 to 1200 g fruit/sample. SE = 0.04.
[x]Mean of two trials (five trials for control), 25 fruit/trial. SE = 0.1.
[w]AS = alkylbenzene sulfonate.

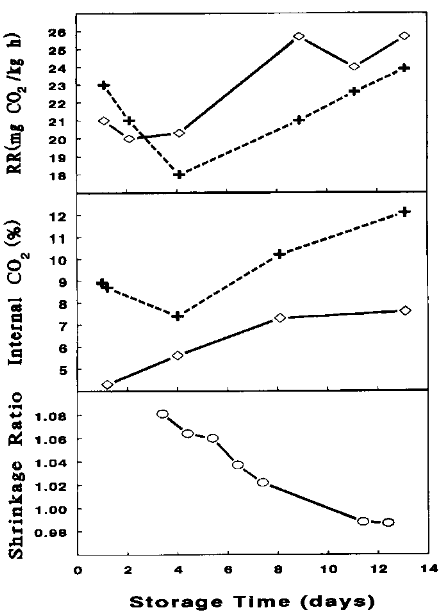

Fig. 1. Respiration rate (RR), internal CO_2, and shrinkage ratio of 'Valencia' oranges harvested 30 Apr. and stored at 22C. RR is based on two trials, 10 fruit/trial; internal CO_2 is the mean of 10 samples. (+) Washed, (◊) control. Shrinkage ratio (○) equals weight-loss rate of washed divided by that of control, based on 24 samples/treatment, 800 to 1200 g fruit/sample.

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