ditions. Pulp temperatures should be measured for a vegetable which will provide a representative temperature for the entire container, pallet or group of pallets, as the case may be. A portable electronic thermometer with an insertion type probe and digital read-out is a worthwhile investment for accurate temperature measurement. Thermocouples allow remote readout at a central location particularly for vacuum cooling, in which the product is sealed in the tube.

The procedure for vacuum cooling scheduling is slightly different, since the wet bulb temperature changes as the vacuum tube pressure falls and rises during cooling. For this situation, the wet bulb temperature in the vacuum tube and the pulp temperature should be measured to avoid the potential of freezing with absolute pressures below 0.18 inches mercury.

After determining the average cooling temperatures, the actual cooling curve can be plotted on a copy of the Precooling Schedule (Figure 2). This is done by placing points for each elapsed time and average temperature measurement and then drawing a line between the points. If the elapsed time was measured in hours, as in the case of room or forced-air cooling situations, the times must be converted to minutes for plotting on the Precooling Schedule. Notice that the Elapsed Cooling Time axis is on a logarithmic scale and begins at 10 minutes. This scale allows longer cooling times to be plotted. The cooling curve for vacuum cooling can be plotted more accurately by dividing the Elapsed Cooling Time axis by a factor of 10.

Finally, to determine the 1/2 and 7/8 cooling times, begin by drawing a line from the initial pulp temperature on the *left axis* to the cooling medium temperature on the *right axis* of the Precooling Schedule. An example for slush-ice precooling of sweet corn is included in Figure 3. Then, where this line intersects the vertical dashed line for 1/2 Cooling (point A on Figure 3), draw a horizontal line to the cooling curve (point B). At this point on the cooling curve, draw another line straight down to the Elapsed Cooling Time axis (point C). This is the 1/2 Cooling time (read 55 minutes for this example).

The recommended 7/8 Cooling Time is determined by repeating this procedure on the same Precooling Schedule beginning with the initial pulp temperature/cooling medium temperature line where it intersects with the vertical dashed line for 7/8 Cooling (Point D on Figure 3). Following the lines to points E and F, the 7/8 Cooling Time is determined (read approximately 225 minutes for this example).

Summary

An approach has been described for evaluating individual farm operations to determine the optimal type of precooler. By systematically reviewing each step in the farm operation one can understand the impact that a particular precooling method would have on the overall operation. Finally, once a precooler is selected and installed, precooling schedules for individual commodities and packaging methods can be determined using the enclosed worksheets.

Literature Cited

1. Florida Agricultural Statistics. Vegetable Summary. 1988. Florida Dept. of Agriculture and Consumer Services. Florida Agric. Statistics Serv. Orlando, Florida. April.
2. Gaffney, J. J. and C. D. Baird. 1977. Forced-air cooling of bell peppers in bulk. Trans. of ASAE 20(6):1174-1179.
3. Hardenburg, R. E., A. E. Watada, and C. Y. Wang. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. Agriculture Handbook No. 66. U.S. Dept. Agr. Washington, D.C.
4. Kader, A. A., R. F. Kasmire, F. G. Mitchell, M. S. Reid, N. F. Sommer, and J. F. Thompson. 1985. Postharvest technology of horticultural crops. Coop. Ext. Service. University of California. Special Pub. 3311. Agr. and Nat. Resources Pub., Berkeley, CA 94720. 192 pp.
5. McGregor, B. M. 1987. Tropical products transport handbook. U.S. Dept. Agr. Handbook No. 668. Washington, D.C. (Also available in Spanish).
6. Mitchell, F. G., R. Guillou, and R. A. Parsons. 1972. Commercial cooling of fruits and vegetables. Agr. Pub. Manual 43. University of California. Berkeley, CA 94720.
7. Ryall, A. L. and W. J. Lipton. 1979. Handling, transportation and storage of fruits and vegetables. Vol. 1. Vegetables and melons. 2nd. Edition. AVI Pub. Co., Inc. Westport, Conn. 587 pp.
8. Sherman, M. 1985. Produce handling for roadside markets. Vegetable Crops Fact Sheet VC-33. Florida Cooperative Extension Service, University of Florida, Inst. Food Agr. Sci. Gainesville.
9. Showalter, R. K. and W. Grierson. 1972. Precooling fruits and vegetables in the Southeast. ASHRAE Symposium Bulletin SF-4-70.
10. Stewart, J. K. and H. M. Couey. 1976. Hydrocooling vegetables. Mark Res. Rpt. 637. U.S. Dept. Agr., Washington, DC.

Proc. Fla. State Hort. Soc. 101:182-184. 1988.

FRICTIONAL PROPERTIES IN HANDLING CITRUS

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Abstract. **A series of tests were conducted to determine rolling and sliding coefficient of friction values for 'Marsh' grapefruit, 'Murcott' tangerines, and 'Valencia' oranges in untreated, washed, and washed/waxed conditions. Using a variable incline table, surfaces of unpainted plywood, UHMW-polyethylene, sheet metal, and Teflon were evaluated. The ranking of these surfaces from low to high coefficient of friction was Teflon, UHMV-polyethylene, plywood, and sheet metal. Using a controlled rotation roller conveyor with PVC rollers on 7.6 cm centers, the maximum incline angles for fruit conveying were established. For static roller conveying, the maximum angle was 15° for grapefruit and 22.5° for oranges and tangerines.**

Friction properties of citrus are important in materials handling for both packing and processing plants. Such properties also become important when determining fruit handling criteria to minimize damage. For example, trans-

Florida Agricultural Experiment Station Journal Series No. 9714.

fer sections between conveyors should be at an incline sufficient to allow fruit to roll. Inadequate incline angles can create bruising and pinching of citrus fruit.

General techniques for determining coefficient of friction (COF) and rolling resistance of agricultural products have been detailed by Mohsenin (3). Regarding citrus, Chen and Squire (1) reported COF values related to abrasive damage of oranges. Their results in relating higher friction forces to greater abrasive damage were inconclusive. COF values were determined for Florida citrus and reported by Miller (2). These tests were conducted using a non-rolling fruit on a flat surface with a horizontally mounted load cell to measure the frictional force. In this study, an elevated table was designed and built to test rolling versus sliding friction. Also, fruit stability on a roller conveyor was measured to establish elevation angles for conveying whole fruit.

Objectives of this study were to: 1) determine COF values of Florida citrus for either sliding or rolling motion and 2) establish roller conveyor angles for inclined transport of Florida citrus.

Materlals and Methods

COF tests. An elevated table was constructed where the base surface could be changed to accommodate various test surfaces. Individual fruit were placed in a stable position, typically the stem end, and the table angle was increased at a uniform rate with a pulley arrangement. The angle at which motion was observed was measured with an inclinometer. Three citrus varieties, 'Marsh' grapefruit, 'Murcott' tangerines, and 'Valencia' oranges, vere evaluated on 4 surfaces, unpainted plywood, UHMW-polyethylene, galvanized sheet metal, and Teflon. Fruit were tested in either an unwashed, washed, or washed and waxed condition. All fruit from a sample size of 50 were measured to obtain 3 principal axial limensions (a, b, c) and to calculate sphericity, $(abc)^{1/3}/a$ where a = longest intercept, b = longest intercept normal to a and c = longest intercept normal to a and b.

Stability tests. For stability tests, an inclined roller conveyor unit with 6.0 cm rollers on 7.6 cm centers of RC2060 chain was utilized. The rollers were powered separately by a urethane belt arrangement placed between the rollers and an underside slider support. This addition facilitated testing with forward, reverse, or null motion of the rollers. One end of the entire conveyor assembly was elevated by a forklift to achieve the desired test angles. Test conditions were bracketed around a marginal conveying angle established through preliminary tests. Incremental angle adjustments were 2.5°. The same fruit varieties listed previously were tested to establish conveyor elevation angles. Roller rotation speeds of 0.62, 0, and −0.61 Hz were tested. Translational velocity of the conveyor was 0.12 m/s. A sample of 35 fruit of average size was tested. In this discussion, negative rotational speeds represent reverse motion with respect to the translational motion.

Results and Disscussion

COF results. Test results comparing various frictional surfaces and fruit varieties have been compiled in Table 1. The 'Murcott' tangerines, which were least spherical (sphericity = 0.90), exhibited sliding motion for all surfaces tested. 'Marsh' grapefruit (sphericity = 0.95) displayed sliding motion on the Teflon surface only. 'Valencia' oranges rolled on all surfaces and had an average sphericity of 0.98.

The COF values for rolling motion were markedly lower than those reported by Miller (2) for fixed position sliding motion. However, sliding COF values for the elevated table method compared favorably with previous data (Table 2). In the design of packingline machinery, the low rolling COF values may or may not be applicable. En masse motion may be encountered where either sliding or rolling friction might predominate. For a worst-case situation, the

Table 2. Comparison of coefficient of friction values for elevated table technique with non-rolling flat surface tests (2).

	Surface			
Test method	Unpainted plywood	UHMW-polyethylene	Sheet metal	Teflon
Flat surface, non-rolling condition	0.41	0.37	0.46	0.21
Elevated table, sliding condition data	0.37	0.33	0.43	0.24

Table 1. Rolling or sliding coefficient of friction values ($\bar{x}$/s.d.) for three varieties of Florida citrus evaluated on different surfaces.

		Surface				
Variety	Treatment	Unpainted plywood	UHMW-polyethylene	Sheet metal	Teflon	Avg.
Murcott tangerine	U—unwashed	.391/.033(S)[z]	.332/.036(S)	.425/,040(S)	.271/.021(S)	.344c
	W—washed	.346/.021(S)	.310/.021(S)	.432/.016(S)	.236/.021(S)	
	W/W—wahed/waxed	.360/.046(S)	.343/.046(S)	.433/.045(S)	.249/.026(S)	
Marsh grapefruit	U	.320/.039(R)	.257/.030(R)	.305/.030(R)	.210/.016(S)	.276b
	W	.306/.053(R)	.307/.055(R)	.308/.045(R)	.233/.020(S)	
	W/W	.266/.038(R)	.270/.038(R)	.295/.043(R)	.213/.017(S)	
Valencia orange	U	.216/.027(R)	.208/.012(R)	.212/.031(R)	.202/.021(R)	.206a
	W	.202/.025(R)	.209/.026(R)	.212/.019(R)	.206/.027(R)	
	W/W	.200/.027(R)	.203/.029(R)	.198/.029(R)	.202/.023(R)	
Avg.		.290b[y]	.271b	.313b	.225a	

[z]S = sliding, R = rolling.
[y]F = 232.0 for varieties (1% significance), F = 51.4 for surfaces (5% significance). Means with same letter within column or row do not differ significantly at 5% level for Duncan's test.

elevated angle found from the relationship, tan θ = μ could be calculated using the higher sliding COF values.

As in the previous study (2), the Teflon surface produced the lowest COF values (overall $\bar{x}$ = 0.225). The other surfaces, unpainted plywood (overall $\bar{x}$ = 0.290), UHMW-PE (overall $\bar{x}$ = 0.271), and sheet metal (overall $\bar{x}$ = 0.313), were not signlficantly different. Treatment effects of no washing, washing or washing and waxing were not significant. Fruit variety was highly significant (1% level) and was related to fruit sphericity and the ease of inducing rolling motion. Note that for 'Vaiencia' orange where rolling motion was encountered, no differences were evident among the surfaces.

Stability results. The second part of this study dealt with elevation angles associated with whole fruit conveying. Three fruit rotational speeds were analyzed with percent of fruit successfully conveyed at various incline angles measured. Average abaxial diameters were 7.9 cm—'Valencia,' 11.7 cm—'Marsh' grapefruit, and 7.2 cm—'Murcott' tangerine. Successful conveying percentages are plotted in Fig. 1 as a function of the conveyor angle. Grapefruit could be conveyed at an incline of 15° with either stationary or forward roller rotation. The fruit varieties of a smaller size, 'Valencia' oranges and 'Murcott' tangerines, could be conveyed 100% successfully at 22.5°. The tangerines, although smallest, were limited to 22.5° due to their nonspherical shape. Roller rotation had the effect of creating fruit instability and resultant low success rates at the various conveyor angles.

In general, the reverse roller motion resulted in the lowest success rates in conveying the fruit. The effects of rotation were more pronounced for grapefruit and tangerine as their flattened ends created more unstable motion. The overall high to low ranking based on fruit rotation was stationary, forward roller rotation, and reverse roller rotation.

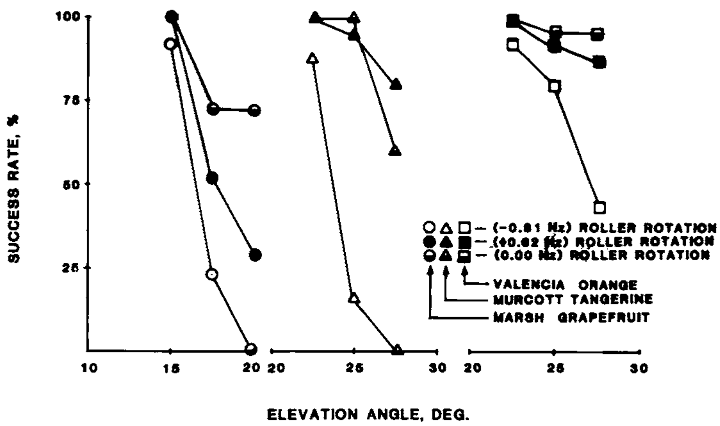

Fig. 1. Conveyance success rate as function of roller rotation and incline angle.

Summary

COF values were determined for 3 citrus varieties tested on 4 surfaces. By using an inclined table, initiation of either sliding or rolling motion could be observed. For all surfaces in testing 'Marsh' grapefruit and 'Valencia' oranges, rolling motion was observed except for 'Marsh' grapefruit on Teflon. For 'Murcott' tangerines, sliding motion was noted on all surfaces. There were highly significant differences between fruit varieties due to differences in their sphericity and resultant motion. Teflon had the lowest COF values, 0.225 for all varieties. The sliding COF values compared favorably with earlier results for fixed position fruit. On a roller conveyor with standard 6.0 cm rollers on 7.6 cm centers, the maximum angle for 100% success in conveying fruit was 15° for 'Marsh' grapefruit and 22.5° for both 'Valencia' orange and 'Murcott' tangerine. Both forward and reverse motion of the rollers reduced the conveyor success rate compared to the no rotation condition.

Literature Cited

1. Chen, P. and E. F. Squire. 1971. An evaluation of the coefficient of friction and abrasive damage of oranges on various surfaces. Trans. Amer. Soc. Agr. Eng. 14:1092-1094.
2. Miller, W. M. 1986. Mechanical and physical properties for postharvest handling of Florida citrus. Proc. Fla. State Hort. Soc. 99:122-127.
3. Mohsenin, N. N. 1970. Physical properties of plant and animal materials. Gordon and Breach. New York, NY.

Proc. Fla. State Hort. Soc. 101:184-187. 1988.

COMPARATIVE ACTIVITY OF SELECTED FOOD PRESERVATIVES AS CITRUS POSTHARVEST FUNGICIDES

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Additional index words. dowicide, *Penicillium digitatum,* potassium sorbate, sodium benzoate, sodium o-phenylphenate, sodium propionate, thiabendazole.

Abstract. **Recently the food preservative potassium sorbate (KSrb) has been proposed as a postharvest fungicide for control of green mold (*Penicillium digitatum* (Sacc.)) on citrus. Two other food preservatives, sodium benzoate (NaBz) and sodium propionate (NaPr), are also used for similar food preservative applications. Trials on Valencia oranges inoculated with green mold indicate that all 3 have similar fungicidal activity and are equivalent to the traditional Dow-Hex treatment as a postharvest fungicide for citrus. None of these 3 chemicals are currently approved by the U.S. Environmental Protection Agency for postharvest use on citrus.**

[1]Appreciation is expressed to Mr. E. Dane Nicole of Fresh Mark Corporation for supplying the Dow-Hex concentrate (Fresh Flood DX) used in these trials.