to the system are that the cells are exposed to low concn. of the *chemical* abscission agents for a longer period of time. Such a binding and slower uptake would account for the sustained ethylene production observed by Holm and Wilson (14) when a similar 3-way combination that differed in concn. was applied to 'Valencia' oranges.

Uptake of ^{14}C-Release with Sweep was not any greater than the control in April and May, thus the use of other adjuvants in the 3-way combinations might have been just as effective. However, 3-way combinations with the others were not investigated.

This and earlier work indicates that a minimum of 4 to 8 hours without rain is required for good absorption of abscission chemicals for fruit loosening in the field. Rainless absorption time for Release for good efficacy is longer than for Acti-Aid (4, 15). High temperatures (33°C) and medium relative humidity levels (50 to 65%) result in the best uptake of Release during the months of harvest in April and May (13). Lower efficacy would be expected from spraying in the evening when temperatures drop and RH tends to increase, often resulting in dew which may collect and drip from the orange, thus removing the active chemical agent with it. Optimal times for spraying in April and May will probably fall between 10 a.m. and 3 p.m. during the day.

Literature Cited

1. Albrigo, L. G. 1972. Distribution of stomata and epicuticular wax on oranges as related to stem end rind breakdown and water loss. *J. Amer. Soc. Hort. Sci.* 97:220-223.
2. ———. 1972. Ultrastructure of cuticular surfaces and stomata of developing leaves and fruit of the 'Valencia' orange. *J. Amer. Soc. Hort. Sci.* 97:761-765.
3. ———. 1972. Variation in surface wax on oranges from selected groves in relation to fruit moisture loss. *Proc. Fla. State Hort. Soc.* 85:262-263.
4. ———. 1975. Chemical control of fruit abscission. *In: Shedding of Plant Parts.* T. T. Koxlowski, ed. Chapter 12. p. 482.
5. ———. 1977. Some parameters influencing development of surface wax in citrus fruits. *First Int. Citrus Congr.* (Spain). Vol. II. p. 107-115.
6. ———, S. K. Murphy and R. H. Biggs. 1977. Influence of temperature and humidity on *Citrus sinensis* Osbeck cv. Valencia epidermal cells. *HortScience.* 12:418.
7. Biggs, R. H. 1971. Citrus abscission. *HortScience.* 6:388-392.
8. Cooper, W. C. and W. H. Henry. 1968. Field trials with potential abscission chemicals as an aid to mechanical harvesting of citrus in Florida. *Proc. Fla. State Hort. Soc.* 81:62-68.
9. ———, W. H. Henry, G. K. Rasmussen, P. C. Reece and B. J. Robers. 1968. Control of abscission in agricultural crops and its physiological basis. *Plant Physiol.* 43:1560-1576.
10. ———, G. K. Rasmussen and D. J. Hutchinson. 1969. Promotion of abscission of orange fruits by cycloheximide as related to site of treatments. *Biosci.* 19:443-444.
11. ——— and W. H. Henry. 1972. Effect of growth regulators on the response of citrus fruit to cycloheximide-induced abscission. *Proc. Fla. State Hort. Sci.* 85:29-32.
12. Kossuth, S. V. 1978. Uptake of ^{14}C-Release in 'Valencia' oranges as affected by its location on the fruit, temperature humidity, treatment duration and fruit position on the tree. *J. Amer. Soc. Hort. Sci.* 103:561-564.
13. ———, R. H. Biggs and V. W. Winkler. 1978. Uptake and distribution of ^{14}C-labeled 5-chloro-3-methyl-4-nitro-1H-pyrazole in 'Valencia' and 'Hamlin' oranges. *J. Amer. Soc. Hort. Sci.* 103:20-22.
14. Holm, R. E. and W. C. Wilson. 1977. Ethylene and fruit loosening from combinations of citrus abscission chemicals. *J. Amer. Soc. Hort. Sci.* 102:576-579.
15. Murphy, S. K., R. H. Biggs and V. W. Winkler. 1976. Uptake and distribution of "Release" in 'Valencia' and 'Hamlin' oranges. *Proc. Fla. State Hort. Soc.* 89:43-45.
16. Wardowski, W. F. and W. C. Wilson. 1971. Observations on early and mid-season orange abscission demonstrations using cycloheximide. *Proc. Fla. State Hort. Soc.* 84:81-83.
17. Wheaton, R. A., W. C. Wilson and R. E. Holm. 1977. Abscission response and color changes of 'Valencia' oranges. *J. Amer. Soc. Hort. Sci.* 102:580-583.
18. Wilson, W. C. 1971. Field testing of cycloheximide for abscission of oranges in the Indian River area. *Proc. Fla. State Hort. Soc.* 84:67-70.
19. ———. 1973a. A comparison of cycloheximide with a new abscission chemical. *Proc. Fla. State Hort. Soc.* 86:56-60.
20. ———. 1973b. Problems encountered using cycloheximide to produce abscission of oranges. *HortScience.* 8:323-324.
21. ——— and G. E. Coppock. 1968. Chemical abscission studies and trials with mechanical harvesters. *Proc. Fla. State Hort. Soc.* 81: 39-43.

Proc. Fla. State Hort. Soc. 91:106-109. 1978.

SOME MOISTURE PROPERTIES OF DRIED CITRUS PEEL[1]

R. J. Braddock and W. M. Miller
Institute of Food and Agricultural Sciences,
Agricultural Research and Education Center,
P. O. Box 1088, Lake Alfred, FL 33850

Additional index words. cattle feed, moisture equilibrium.

Abstract. **Equilibrium moisture content of dried citrus pulp cattle feed was measured for different relative humidity (RH) levels at 25°C. Storage of dried pulp and pellets at 8.8% moisture in atmospheres between 30 and 100% RH resulted in re-equilibration of moisture contents from 6 to 29%. In a constant 52% RH atmosphere at 25°C, both loose pulp and pellets reached an equilibrium moisture content of 9 to 10% within 2 to 5 days. Drying rate curves at 100°, 130°, and 155°C were obtained for feed mill press cake and showed constant drying rates between 73 and 25% moisture. A falling rate was apparent from 25% down to about 3% moisture. Particle size distributions of press cake, fines, and dried pulp are also included. Particle size distributions were similar when comparing the press cake with the whole dried pulp. Both fractions had a significant proportion of particles distributed between 2.2 to 6 mm with a small proportion in the 1.5 mm range.**

Data from a Florida statistical report (10) indicated that over one million tons of dried citrus pulp and pellets were produced during the 1977 season. This important by-product is vital to the function of the Florida citrus processing industry and to many livestock producers worldwide.

Citrus peel residue, in its wet state, contains 80 to 85% water and is readily fermentable. The difficulty of handling this material necessitates dehydration to a low (10%) moisture content. But if proper precautions are taken to maintain dry conditions, the product may be handled, stored, and shipped in a manner similar to other dry feedstuffs.

Some physical properties of dried citrus pulp have been studied. Ross and Kiker (9) and Ross and Boots (8) measured bulk density, void space, moisture equilibrium, compressibility, and other properties in studies which reported design data for citrus pulp handling and storage facilities. An earlier study by Bissett and Veldhuis (1) reported the effect on citrus pulp moisture equilibrium caused by mixing different amounts of citrus molasses with the pulp.

[1]Florida Agricultural Experiment Stations Journal Series No. 1522.

The present investigation was conducted to provide information concerning drying rates, particle size distribution and citrus peel residue, and some basic physical properties of dried citrus pellets. Moisture equilibrium data for dried loose pulp and pellets are also provided. This data should be useful to processors and engineers concerned with citrus pulp quality and energy conservation during manufacturing and handling.

Experimental

Drying rate. Drying rate curves were obtained using a laboratory oven operated at dry bulb air temperatures of 100°, 130°, and 155°C under natural convective conditions. Approximately 25 to 35 g samples of feed mill press cake were placed in open aluminum moisture dishes and weighed on an electronic balance each 10 min until no further weight loss was apparent.

Particle size. U. S. Standard screens No. 1, 4, 6, 8, 10, 14, 20, 30, 40, 50, and 70 were used to sieve commercial samples of press cake, dry peel, meal, and dust. Results are presented as wt % of sample retained on a particular screen vs. size of the opening.

Equilibrium moisture. Commercially dried citrus pulp and pellets, 0.635 cm (1/4 inch) and 0.953 cm (3/8 inch) diameter were weighed in glass petri dishes and placed in desiccators containing appropriate saturated salt solutions to control the relative humidity of the atmosphere, then placed in an environmental chamber at 25°C. Sample sizes 20 to 25 g were used so that the sample surface area did not exceed the surface area of the liquid in the desiccator. Salt solutions in the desiccators and the corresponding relative humidities were taken as follows from solutions suggested by Rockland (7): magnesium bromide (31%), magnesium nitrate (52%), sodium chloride (75%), barium chloride (90%), and distilled water (100%). Once each day (or interval), the desiccators were opened, the glass top placed on the petri dish; the sample was weighed quickly and returned to the chamber. The initial moisture contents of the samples were determined by vacuum oven (12 hr, 60°C).

Results and Discussion

Particle size. Uniform particle size is important during dehydration. If large pieces are present, drying conditions must be altered to include longer drying times; while, fines and dust which dry rapidly may contribute to product losses and air pollution problems. Fig. 1 illustrates a typical particle size distribution of some feed mill pulp fractions.

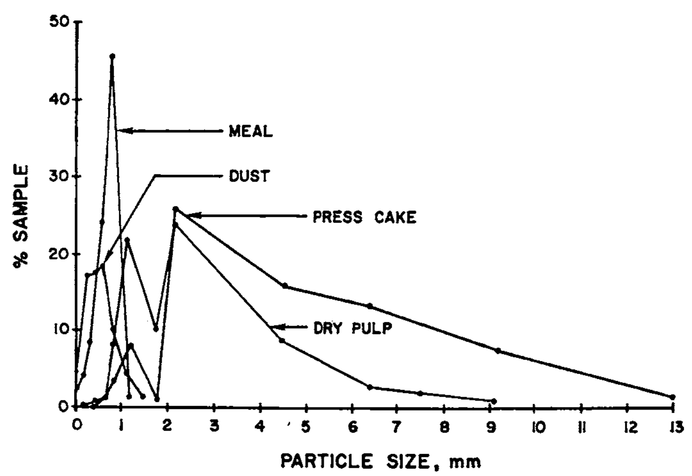

Fig. 1. Particle size distribution of citrus press cake, dried pulp, meal, and dust.

The distribution of the wet press cake and the dried pulp were similar, in that a fraction of the particles were about 1 mm with another fraction distributed in the 2 to 5 mm range. The major particle distributions of the meal and dust portions of the fines were below 1 mm.

Drying rate. Drying rate curves (Fig. 2) at 100°, 130°,

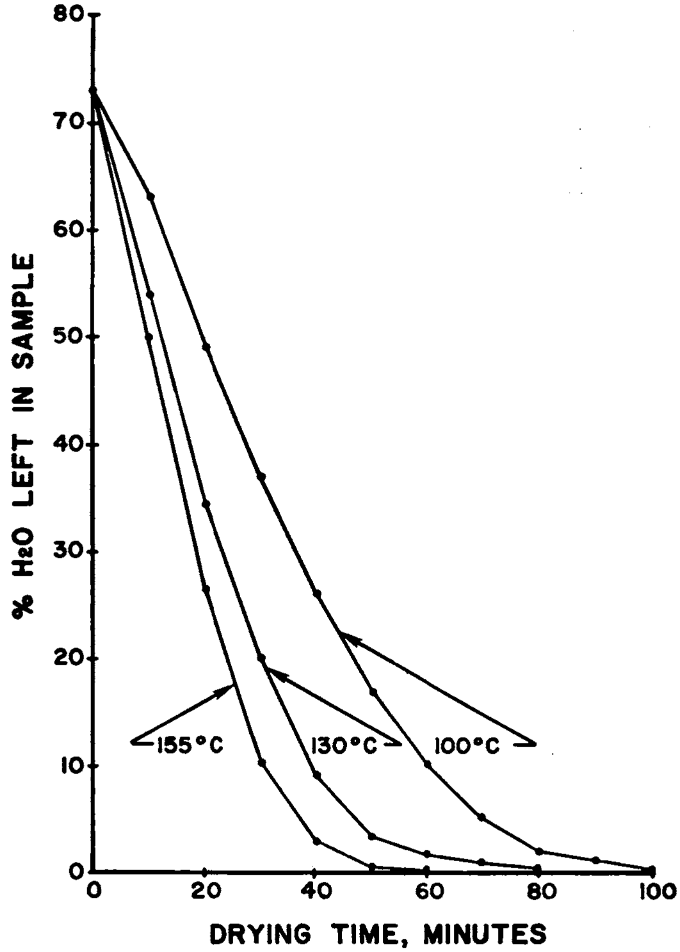

Fig. 2. Drying rates at 100°, 130°, and 155°C for citrus press cake.

and 155°C for press cake indicate constant drying rates at the 3 temperatures from 73% down to about 25% moisture. Below 25% moisture, a falling rate was observed. These results can be interpreted to mean that pulp water removal below 25% is more difficult. In general, an analogous relationship has been shown to exist between the falling-rate moisture periods and Newton's heating and cooling equations (2, 3). The moisture (M) relationship is expressed as

$$\frac{M-M_e}{M_i-M_e} = e^{-k\theta}$$

with θ, time, and subscripts e and i representing equilibrium and initial states. Using the data from Fig. 2 less than 25% moisture content, 2 distinct falling rate periods were noted on a semi-log plot, Fig. 3. A breakpoint occurred between 0.1 and 0.2 moisture ratios for the 3 dryer temperatures. The k value, represented by the slope of the semi-log plots inincreased with high temperatures. Also, the drying rate constant was less for the 2nd falling rate period. A proper modification of the drying process might be to perform dehydration in 2 stages, a processing procedure which at one time was practiced in the citrus industry and had yield and quality advantages over single stage drying, as stated by Kesterson and Braddock (6). As applied, 2-stage drying

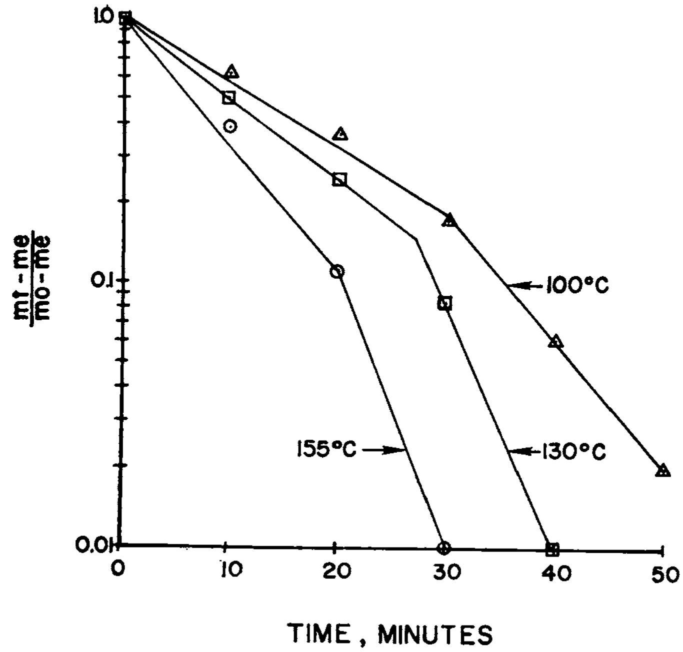

Fig. 3. Moisture ratio vs. drying time of falling rate drying of press cake below 25% moisture.

could be accomplished by having one stage for the constant rate and a second during the falling rate period. The second falling rate is not encountered in commercial practice.

Equilibrium moisture. Moisture equilibrium of loose dried citrus pulp at 60% RH, 26°C has been shown to occur at about 11 to 12% moisture (9). Other research has shown this equilibrium to take about 2 to 3 weeks (1). For a sample of loose commercial pulp, it can be determined from Fig. 4 that above 75% RH at 25°C, moisture equilibrium does,

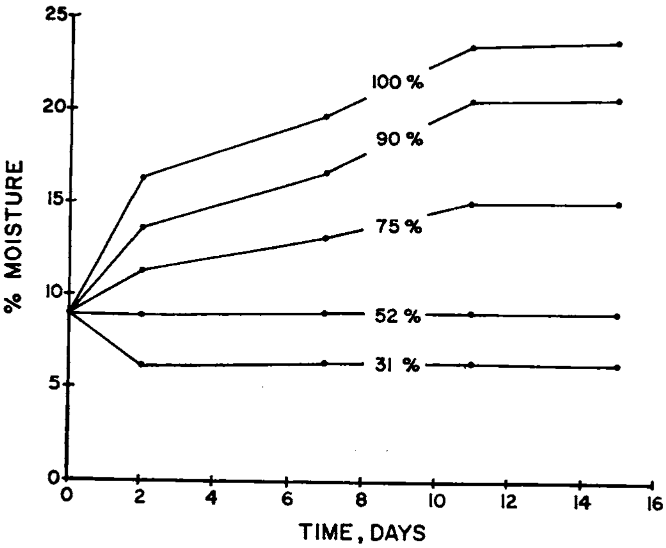

Fig. 4. Moisture equilibrium of citrus pulp at 25°C and 31, 52, 75, 90, and 100% RH atmospheres.

indeed, occur in approx 2 weeks. However, less time was required at lower relative humidities (31 and 52%) and equilibrium moistures near the initial moisture content of the product (8.8%). This time difference is expected because the driving force would be lower with lower RH in the storage atmosphere.

The equilibrium moisture content was fitted to the general relationship developed by Henderson (4).

$$1\text{-RH} = \exp^{-AT_{abs}M^B}$$

with T in °R and M expressed as decimal. A and B are experimentally determined constants. At 25°C, these values were A, 4.4 x 10^{-5}; B, 1.789 for dried peel and A, 4.4 x 10^{-5}; B, 1.702 for pellets. These were in the range Henderson and Perry (5) found for other biological materials: *A* range of 0.6 x 10^{-4} to 3.1 x 10^{-7} and *B* from 1.0 to 3.0. Using the above values for A and B, one can predict the equilibrium moisture (M) of pellets given absolute temperature (T_{abs}) and relative humidity (RH) of the storage conditions. Equilibrium moisture content for storage at extreme temperatures should be checked, since the equation was developed for 25°C.

Our results (Fig. 5) indicate that above 75% RH at 25°C, equilibrium had not occurred within 28 days. Mold growth in the pellets at 90 and 100% atmospheres commenced after 28 and 25 days, respectively. No mold growth occurred within 28 days in the other samples. The samples at 31 and 52% RH appeared stable within 1 week.

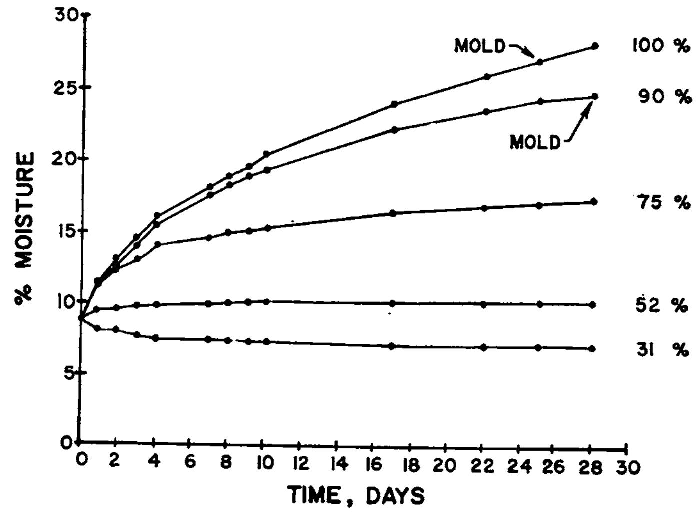

Fig. 5. Moisture equilibrium of citrus pellets at 25°C and 31, 52, 75, 90, and 100% RH atmospheres.

Interpreting the results presented in Figs. 4 and 5, it could be said that in order to maintain the moisture content of dried citrus pulp as pellets in the range of 10 to 12%, contact with air of greater than 50 to 60% RH at 25°C (77°F) should be minimized.

Other properties. Because of the lack of published information on citrus pellets, we have included some data related to 2 different sized pellets (Table 1). The bulk density of pellets is approximately twice the value for loose

Table 1. Some properties of citrus pellets relating weight, area, and volume.

Property	Pellet diam	
	0.64 cm	0.95 cm
Pellets/kg	1500	1400
Area (cm^2/pellet)	4.5	4.6
Area (cm^2/kg)	7000	6500
Pellet vol (cm^3/kg)	1010	1070
Bulk density (kg/m^3)	625.8	577.6
% void space[z]	63.3	60.4

[z]% void space determined by the method described by (9).

pulp described by Ross and Kiker (9). The % void space reflects the compaction effect occurring as a result of pelletizing. Savings in energy cost for handling and shipping occur as a result of manufacturing pellets because of a large decrease in volume. There is also some space advantage to making pellets with greater bulk density.

Literature Cited

1. Bissett, O. W., and M. K. Veldhuis. 1951. Hygroscopic characteristics of dried citrus pulps containing citrus molasses. *Feedstuffs* 23 (Sept. 8):26.
2. Brooker, D. B., F. W. Bakker-Arkema, and C. W. Hall. 1974. Drying cereal grains. AVI Publishing, Westport, Conn.
3. Hall, C. W. 1971. Drying farm crops. AVI Publishing, Westport, Conn.
4. Henderson, S. M. 1952. A basic concept of equilibrium moisture. *Agr. Eng.* 33:29-32.
5. ———, and R. L. Perry. 1966. Agricultural process engineering. AVI Publishing, Westport, Conn.
6. Kesterson, J. W., and R. J. Braddock. 1976. By-products and specialty products of Florida citrus. *Agr. Exp. Sta. Tech. Bul.* 784. pp. 15, 16.
7. Rockland, L. B. 1960. Saturated salt solutions for static control of relative humidity between 5 and 40°C. *Anal. Chem.* 32:1375.
8. Ross, I. J., and W. S. Boots. 1967. Storage and handling of dried citrus pulp. *Trans. Citrus Eng. Conf.*, ASME, Lakeland, Fla. p. 68.
9. ———, and C. F. Kiker. 1967. Some physical properties of dried citrus pulp. *Trans. ASAE* p. 483.
10. Statistical Summary. 1976-77 Season. Florida Canners Association, Winter Haven, Fla.

Proc. Fla. State Hort. Soc. 91:109-111. 1978.

DETERMINING THE YIELD AND QUALITY OF PECTIN FROM FRESH PEEL AND PECTIN POMACE[1]

P. G. CRANDALL, R. J. BRADDOCK, AND A. H. ROUSE
University of Florida,
Institute of Food and Agricultural Sciences,
Agricultural Research and Education Center,
P. O. Box 1088, Lake Alfred, FL 33850

Additional index words. citrus, specialty products, by-products, orange, grapefruit, lemon, lime.

Abstract. **A method for determining the yield and jelly grade of pectin in freshly extracted citrus peel and dry pomace is outlined. A flow diagram shows the necessary steps. The importance of the steps as well as critical control points are discussed. This method may be used to determine the amount of pectin in citrus peel so that the citrus processor can decide either how much peel to make into pectin pomace or how much to make into cattle feed.**

The estimated annual worldwide production of pectin is approximately 7,250 metric tons, approximately 60% of which is produced from citrus. California produces approximately 30% of the world's supply.[2] The citrus processing industry in Florida annually produces over 779,000 metric tons of dried citrus peel, mainly orange and grapefruit, for use as cattle feed (7). Currently, none of this peel is being made into a more valuable product, pectin pomace, which would yield 20-30% pectin (4). However, some of Florida's lemon and lime peel is being leached and dried into pectin pomace which is then transported to Europe for manufacture into pectin. This is an expensive way to make pectin because of the high cost of transportation and handling.

A pectin plant operating in Florida, extracting pectin from fresh rather than dried pomace, could be expected to produce approximately 13% more 150 grade pectin (2). Today, there is not sufficient demand for *all* of Florida's citrus peel to be made into pectin but a significant amount could be profitably made into pectin, and there are prospects for an increasing demand for pectin. Researchers are investigating the physiological benefits of consuming larger amounts of pectin in the diet (8). If additional research substantiates that pectin significantly lowers serum cholesterol in humans, then there may be a large increase in the demand for citrus pectin.

In addition, there were many people in the citrus industry who felt cattle feed would have no market if Florida ever produced more than a million short tons. However, we have exceeded that figure and cattle feed is selling at a higher price than ever. The point being that demand predictions are based to an extent on increases in current supplies and are difficult to make.

This paper was written to provide citrus processors and other interested persons with a method of evaluating the potential economic value of the pectin found in fresh citrus peel and pomace.

Experimental Method

Materials. Fresh citrus peel from the juice extraction process, taken as quickly as possible, or leached and dried peel (called pectin pomace) were used for the experimental analyses. Chemicals were reagent grade and the isopropanol was checked for metal contamination. Tap water was used in the leaching step and distilled water in the extraction step. The apparatus used to test the jellies is described (5).

The word 'peel' collectively refers to both the fresh peel and pectin pomace.

Method. The procedure for evaluating the yield and quality of pectin from citrus peel is outlined in Fig. 1. This figure shows an overview of the steps involved and the approximate amounts of peel needed for each step. A detailed description of this method including the necessary apparatus, reagents, and step by step instructions, as well as example calculations and typical data sheets is available from the authors (3).

Discussion

Total solids in fresh peel. It is important to start the analysis with a known quantity of fresh peel because this will be used in calculating the yield of 150 grade pectin on a fresh peel basis. The percentage of total solids found in the fresh peel indicates how much soluble solids, pectin, and 'other' components besides water are in the peel (Fig. 1). After the fresh peel has been leached, pressed, and total solids determined, then the amount of soluble solids removed by leaching can be calculated as a difference.

The more soluble solids that are leached from the peel, the greater will be the yield of pectin from a given weight of peel. However, the larger amounts of soluble solids leached from the peel will place a greater load on the waste treatment facility. See reference (1) for a more complete discussion of leaching and utilization of the leach water.

In evaluating pectin pomace, the leaching step has already been done during manufacture, so it is necessary only to determine the percentage of total solids in the dry pomace.

---

[1]Florida Agricultural Experiment Stations Journal Series No. 1578.
[2]Sunkist Growers, Inc. 1977. Private communication.