Table 5. Correlations coefficients of various quality factors in WESOS (1979-80 season).

<table>
<thead>
<tr>
<th>Correlating factors</th>
<th>Early-mid season</th>
<th>Late season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum viscosity X Brix</td>
<td>-0.664*</td>
<td>-0.465*</td>
</tr>
<tr>
<td>Serum viscosity X conc. viscosity</td>
<td>0.237*</td>
<td>0.510*</td>
</tr>
<tr>
<td>Pulp X conc. viscosity</td>
<td>0.257*</td>
<td>0.419*</td>
</tr>
<tr>
<td>Pulp X color</td>
<td>0.440*</td>
<td>0.160</td>
</tr>
<tr>
<td>Total glycosides X absorbance</td>
<td>0.467*</td>
<td>0.374*</td>
</tr>
</tbody>
</table>

*Significant at 1% level.
**Significant at 5% level.

season samples. Total glycosides, however had significant correlations with the light absorbance.

Conclusion

The results of these studies indicated that the commercially produced WESOS in Florida had wide ranges in °Brix, Brix/acid, light absorbance (cloud), pulp content, serum viscosity, and concentrate viscosity. These characteristics can affect the value of WESOS as ingredients for beverage base. Manufacturers can improve the quality of this product and produce a more uniform WESOS by monitoring and controlling some of these parameters.

Additional index words. cattle feed, energy utilization.

**MICROWAVE DRYING OF CITRUS PEEL**

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**Abstract.** Laboratory tests were conducted to determine the drying characteristics of citrus peel subjected to microwave heating. A domestic 1.5 kW microwave oven was utilized for drying 25 to 100-g peel samples. Resultant drying curves displayed the characteristic falling-rate phenomena encountered with conventional heated air drying of biological materials. With 100-g samples, total drying time requirement was 42 min with a reduction from ca. 72 to 10% moisture content (wet-basis) achieved at 18 min. Maximum drying rates were observed during the 2 to 6 min interval after test initiation. During that period, combined efficiency for microwave conversion and water vaporization ranged from 6.2 to 14.5% with the larger sample sizes yielding higher efficiencies. Microwave drying has a potential application for quality control analyses of moisture content but required drying times were too extensive for feedforward or feedback dryer control.

Microwave energy has been applied recently to heating and drying food and agricultural products (15). Inter-molecular friction results in rapid heating with internal heat transfer augmented by conduction in solids and conduction plus convection in liquids. The friction is created by the oscillatory motion of polar water molecules excited at 915 or 2450 MHz. These frequencies are approved by the Federal Communications Commission. Radiofrequency dielectric heating at 99 MHz also has been studied by Stetson and Nelson (16).

In drying applications, the microwave heating creates a sufficient vapor pressure for a high rate of water vaporization. Under free water and atmospheric conditions, the product temperature would be ca. 100°C. In general, advantages to the microwave process are minimal thermal gradients in product heating, shortened drying times and a resultant reduction in product deterioration. To further
minimize thermal degradation of foods, research on combining microwave drying under vacuum has been reported
(1, 9).

This article reports on a study of the drying characteristic of citrus peel with microwave energy. Applications may be two-fold; large scale utilization in peel drying or as a rapid moisture determination method for laboratory analyses or dryer control. Considering the former application, electrical energy consumption was monitored in all drying tests.

The utilization of citrus peel for cattle feed is a standard practice of the Florida citrus industry (6, 11). A pressing operation is followed by rotary direct-fired drying. Flow and material balance for oranges and grapefruit have shown a wet-basis moisture content (Mwb) input to the dryer of 76% for 'Duncan' grapefruit and 72% for 'Valencia' orange press cake. A final moisture content of 8 to 10% Mwb is desired. In some plants, the dryer may be the restrictive process operation to increased plant throughput. In such cases, microwave drying may augment a conventional drying operation. Overdrying of citrus peel could be minimized in a second stage microwave process and moisture migration problems through case hardening would be reduced. Detrimental factors from overdrying include additional energy for water removal and a decline in the palatability and nutritional value of this fruit by-product (2, 7).

Researchers have also investigated microwave drying as an expedient technique for moisture content analysis. Lee and Latham (12) were able to dry 10-g meat samples in 3.5 min and found no significant difference in the moisture content between commercial microwave oven and conventional oven-dried samples at 135°C for 3 hr. For rice moisture determination, Noomhorm and Verma (14) compared microwave, air oven, various moisture meters against the standard AOAC method 14.058 (4). Their drying time was 14 min at 100% power level.

Farmer and Brusewitz (8) utilized a home microwave oven for moisture determination of wet alfalfa. Drying time for 25-g samples averaged 10 min while 150-g samples required 18 min. Both asbestos pads and water reservoirs were used for magnetron protection. An average error of 4% was reported between standard oven drying (3) and the microwave oven tests.

Materials and Methods

All microwave drying was performed with samples placed in 1 to 4 glass petri dishes placed in a domestic microwave unit (Sears 99651; 1.5 kW, 2450 MHz). Each petri dish sample consisted of 25 g feed mill press cake from 'Valencia' oranges. The press cake had been shredded and treated with 0.2% lime applied as a slurry (11). Samples were removed from the oven and weighed on an electronic balance every 2 min until no further weight loss was recorded. The sample dishes were positioned in specific locations within the oven as the microwave energy distribution may be non-uniform. Four replications were performed on 25, 50 and 75-g sample sizes while duplicate samples were analyzed for 100 g due to the extended drying time.

The oven was set at maximum power which constituted a 100% duty cycle. The duration of the duty cycle was 10 sec and could be adjusted from ca. 15 to 100%. An in-line volt and watt-meter (Robinar 12865; 0-260 V, 0 to 2.5 kW) was connected between the oven and 115 V outlet to monitor the electrical power input. Wattage levels were noted during each 2 min test interval.

Results and Discussion

To compare microwave drying characteristics with conventional heated air drying, a plot of percent water remaining versus time was generated (Fig. 1). Comparable studies in a natural convective oven indicated similar characteristic curves but total drying times were ca. 60, 80 and 100 min for temperature of 155, 130 and 100°C, respectively (5). Initial moisture content levels for the microwave-dried samples varied from 71.4 to 72.0% Mwb. Total drying time increased with the larger sample loads placed in the oven. However, the 50 and 75 g samples required approximately the same time. The similar drying patterns for these samples may have resulted from non-uniform energy distribution related to sample placement within the oven. Farmer and Brusewitz (8) reported a three-fold difference in free water vaporization dependent upon sample placement within a microwave unit.

Periodic mass measurements every 2 min increased the drying time over a continuous process. However, these time intervals should be representative of time requirements for laboratory moisture analyses. Each interval would consist of both sensible heating and evaporation. Also, in each interval, some space heating of the oven environ is encountered. Additionally, the first interval includes a greater sensible heating from room temperature to ca. 100°C. This phenomenon was observed as the maximum mass loss occurred between 2 to 4 min for 25, 50, and 75-g samples and between 4 to 6 min for a 100 g sample. The magnitude of this sensible heating would vary throughout the test as the specific heat for the peel changes from ca. 3.25 kJ/kg°C to 0.85 kJ/kg°C based on the Siebel equation (13).

Characteristics of falling-rate drying are derived from the non-dimensional ratio, [MR = (M-Mf)/(MrMf)], with respect to time (Fig. 2). M. represents moisture content, dry basis, at any time t, and subscript i and f denote initial and final conditions. A linear relationship was observed below a moisture ratio of 0.3. For the range 0.01<MR<0.3, the exponential equations, with t expressed in min, were:

- 25 g: \( MR = 9.01 e^{-0.381 t}, r^2 = 0.999 \)
- 50 g: \( MR = 5.68 e^{-0.311 t}, r^2 = 0.998 \)
- 75 g: \( MR = 8.89 e^{-0.311 t}, r^2 = 0.989 \)
- 100 g: \( MR = 2.84 e^{-0.211 t}, r^2 = 0.952 \)
Fig. 2. Moisture ratio vs. drying time of various sample loads subjected to microwave drying.

An initial lag, typically attributed to the sensible heat load in elevating both product and water to the vaporization temperature, was observed in these tests. Hence, predicted MR values from the exponential curve-fit were > 1.0 at t = 0.

Another part of this study was the analysis of the energy requirements for microwave drying. All tests were conducted without an additional water medium which would absorb a portion of the microwave energy. Note that in progressing from 25 to 100-g samples, the drying rate was reduced, i.e. reduced coefficient B in Ae⁻ⁿ curve-fit equations. For each sample size, the maximum moisture loss interval was found. Based on those levels, a peak efficiency [(m H/Ein)×100] was calculated (Fig. 3). Ein was measured as the electrical energy input into the oven and m is the moisture loss. H was taken as latent heat for water vaporization at 100°C. As the sample loading increased, the peak efficiency approached 15%.

Larger sample sizes resulted in higher peak efficiency but the rate of increase was less between the 75 to 100-g sample load. These low efficiencies can be somewhat attributed to the magnetron size involved. Forwalter (9) indicates that very large scale units may approach 70% efficiencies for AC-electric to microwave conversion and 95% microwave to product transfer. A net efficiency of 67% would result. Also, secondary heat recovery is achievable from the waste heat in cooling the magnetron.

At present, there would be no economic incentive to utilize electrical microwave energy as the price disparity between electricity and on-site natural gas is approximately 3.2:1 (17) and Holladay (10) reports gas-fired dryer efficiencies 19% for dryer stand-alone units and 38% for a dryer plus waste heat evaporator.

For moisture analyses of citrus peel, press cake or dried citrus pulp cattle feed, modifications of AOAC methods for fresh fruits and dried animal feeds are routinely used in citrus labs. The moisture content of fresh citrus peel or press cake may be determined by drying at 100°C for 2 hr, then to constant weight (6-8 hr) at 70°C under pressure ≤ 100 mm Hg (AOAC Method 22.018). Moisture of dried peel or citrus pulp cattle feed may also be determined by drying in vacuo (AOAC Method 7.003), by distillation with toluene for 1-2 hr (Method 7.004), or by drying 2-4 hr at 135°C in an air oven (Method 7.008). These methods all require several hours to complete. A rapid chemical titration method suitable for dried peel is the Karl Fischer method (AOAC Method 32.040). This method takes about 15 min per sample (1-5 g) of finely ground dried pulp. However, precision with wet peel or press cake is poor, due to difficulty in uniform sampling.

Microwave drying could be utilized to perform high moisture determinations for citrus peel. The cumulative time requirements with readings each 2 min varied from 20 to 42 min dependent upon sample load and placement in the oven. Periodic measurements are required to establish the condition of no further moisture loss. The total drying time although greatly reduced over convective heated-air drying are too extended for any control process.

Literature Cited
REPROCESSING AND REPACKING CITRUS CONCENTRATE IN NON-FLORIDA DAIRIES

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Abstract. In this study the results of a survey of over 300 out-of-state dairies are reported. The findings indicate that dairies of all sizes and in all parts of the country are reconstituting or repacking bulk citrus concentrate from Florida and elsewhere. The majority of these firms report increased profits and few problems with mixed dairy-citrus operations.

Citrus is Florida's most important agricultural industry, with annual F.O.B. sales in 1981 of approximately 2.4 billion dollars (3). The on-tree value of the fruit in that year was around the one billion dollar mark (2). As in excess of 95% of the orange and 55% of the grapefruit crops are processed, the 1.4 billion dollar differential between F.O.B. and on-tree values in large part results from the value added from processing.

The major forms into which citrus is processed are concentrate and single strength juice. Both forms can be shipped from Florida in bulk or in consumer-ready packages. Growth in frozen concentrated orange juice (FCOJ) movement from Florida has resulted in large part from growth in movement of FCOJ in the bulk form (Fig. 1). Information is current lacking regarding the location, citrus product types and volumes produced in reprocessing facilities outside Florida. Such information would be of value to the industry. In this paper the preliminary results of an ongoing study to determine the extent of out-of-state reprocessing is reported. In particular, the citrus reprocessing activities of facilities producing consumer-ready fluid dairy products are reported.

Dairies producing consumer-ready fluid products were chosen for study as a first step in assessing out-of-state citrus juice packaging activity. It was felt that these firms would be likely to be reconstituting citrus products. The reasons behind this supposition were that these firms possess:

1. bottling capacities which are compatible with reprocessing-packaging of certain citrus products (especially chilled single strength orange juice (COJ) and grapefruit juice (CGJ)),
2. distribution systems geared to delivering a chilled product to retail grocery outlets, and
3. the potential to use concentrate as a backhaul from Florida subsequent to delivering milk (Florida is a milk deficit state).

The hypothesis that dairies producing consumer-ready fluid products are more likely than other dairies to reprocess citrus products will be tested in a later phase of the study.

The Survey

Between March and October, 1982, an in-depth phone survey was conducted to determine the extent of citrus reprocessing among non-Florida dairies located in the 48 contiguous states. The U.S. Food and Drug Administration publication Sanitation Compliance and Enforcement Ratings of Interstate Milk Shippers (SCERIMS) (4) served as the source for names and locations of dairies throughout the country. This source is generally recognized as being exhaustive.

Two thousand seventy dairies are listed in the SCERIMS. Of this total, 697 or 34% have product codes indicating that consumer-ready fluid dairy products are produced.

The Results

Frequency of reprocessing and marketing. Of those dairies contacted, 307 or 45% stated that they reprocess...