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VISCOSITY AND PARTICLE SIZE DISTRIBUTION IN COMMERCIAL FLORIDA FROZEN CONCENTRATED ORANGE JUICE

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Abstract. **Seventy-nine random samples from 22 commercial Florida frozen concentrated orange juice (FCOJ) processing plants were analyzed for viscosity by the Brookfield method and analyzed for particle size distribution and particle population using a Coulter Model T particle counter. Viscosity of the samples was compared statistically with the vol of particles in 31 particle size ranges from 0.79 μm to 1024 μm diam.**

Multiple regression analysis indicated the combined vol of particles of 4 diam ranges between 1.58 and 101.63 μm correlated better (R = 0.473) with the viscosities of the FCOJ samples than vol of other size range combinations.

Viscosity is recognized as an important factor in the production of frozen concentrated orange juice (FCOJ). Kelly (7) showed a mathematical relationship between viscosity and the heat transfer coefficient of a citrus juice evaporator where a decrease in viscosity was associated with an increase in the coefficient. Riley (8) noted the limitations of tank farm pumping caused by viscosity of FCOJ. Ezell (6) related viscosity to the physical stability and quality of the product. Rouse et al (9) presented viscosity studies and reviewed earlier correlations of viscosity with the content of various constituents as pectins and pulp.

The relationship of pulp particle size with viscosity of FCOJ has not been studied although particle size distribution in orange juice has been studied by Buslig and Carter (4). Because of interest from the industry, the authors designed this experiment to determine if certain particle size ranges in FCOJ have higher correlations with viscosity than others.

Materials and Methods

It was decided to use commercial samples from as many plants as possible during a single season so that the study could easily be related to industry production. Seventy-nine FCOJ samples packed in 22 Florida processing plants during the 1974-75 season were randomly selected from duplicates of samples collected by USDA-AMS inspectors and used in another study (1). Samples were 45°Brix (± 0.50), packed in 6, 12, or 16 fluid oz containers with various commercial labels and were stored at −8°F until analysis.

A Coulter Model T counter was used utilizing 50, 400, and 2000 μm diam aperture counting tubes. The counting range of these tubes overlap and a total range of 0.79 to 1024 μm was achieved by classifying the particles into 31 size ranges related to each other by a ratio of $\sqrt[3]{2}$ in diam (5) as shown in Table 1.

Table 1. Minimum diameters for various size ranges of FCOJ particles.

Size range number	Minimum particle diam (μm)	Size range number	Minimum particle diam (μm)
1	0.79	17	32.01
2	1.00	18	40.33
3	1.26	19	50.81
4	1.58	20	64.02
5	2.00	21	80.66
6	2.52	22	101.63
7	3.17	23	128.04
8	4.00	24	161.33
9	5.04	25	203.26
10	6.35	26	256.09
11	8.00	27	322.66
12	10.08	28	406.52
13	12.70	29	512.19
14	16.00	30	645.32
15	20.16	31	813.05
16	25.40		

Samples were reconstituted to 12.8°Brix with distilled water and prepared for counting by dilution of 0.1 to 10 ml reconstituted (recon) juice made to 1000 ml with 1% sodium chloride solution containing 5% propylene glycol[1] as a preservative. In the case of large aperture counting, the diluting salt solution was made to 30% v/v in glycerine. Both solutions were filtered through a 0.35 μm filter before using. To avoid aperture clogging, the juice dilutions were passed through a 325 (45 μm) and a 42 (355 μm) mesh stainless steel screen before counting with the 50 and 400 μm apertures, respectively.

Results over the entire range were calculated with a Wang 720 C calculator including background correction (3). The gross particle populations/ml juice were then converted to μm^3 volumetric units and the results plotted as μm^3 of vol of the 31 individual size ranges within the 0.79 to 1024 μm range.

Samples for viscosity analyses were thawed without agitation in the unopened container for 2 hrs in 79°F tap water. Cans were opened and the viscosity was measured in the container using a Brookfield LVT viscometer with a #2 spindle at 12 rpm (2). Sample temp was 79°F ± 1°F.

Statistical analyses of particle and viscosity data were performed on a General Automation SPC 16/65 SPC minicomputer. Plotting of the data was performed with a Tektronic 4051 Graphic System as shown in Figures 1, 2, and 3.

[1]Laboratory safety dictated replacement of 0.1% sodium azide, used as a preservative in earlier studies.

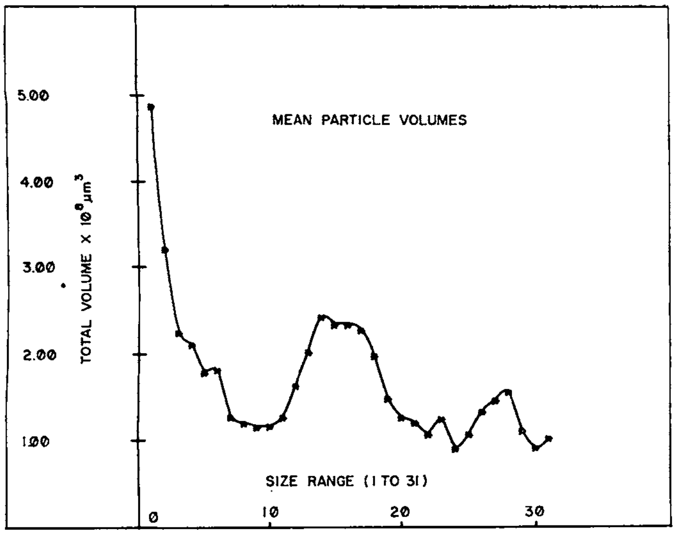

Fig. 1. Mean total particle volume x 10^8 μm^3 per ml recon juice vs. size range.

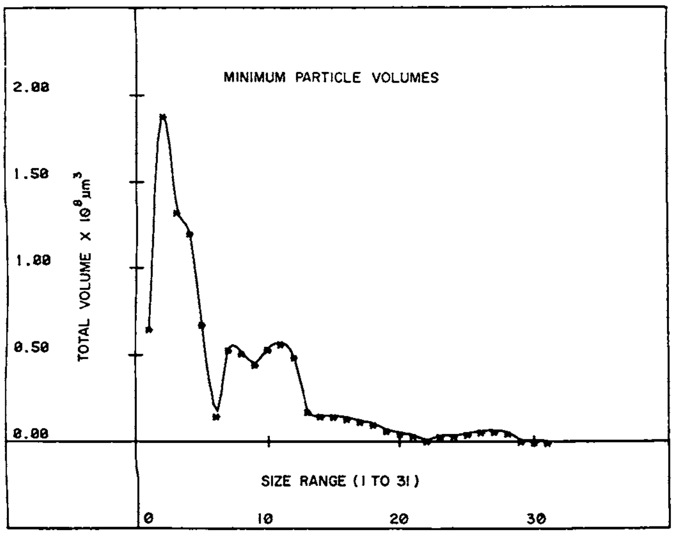

Fig. 2. Minimum total particle volume x 10^8 μm^3 per ml recon juice vs. size range.

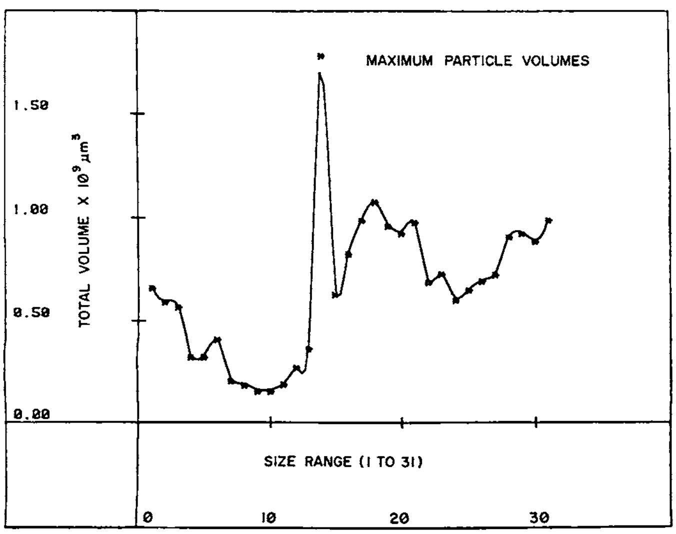

Fig. 3. Maximum total particle volume x 10^9 μm^3 per ml recon juice vs. size range.

Results and Discussion

Viscosities ranged from 485 to 2013 cps with a mean of 1140 cps. Particle vol ranged from 2.208 to 16.742 x 10^9 μm^3 per ml recon juice with a mean of 5.429 x 10^9 μm^3 per ml.

Figures 1, 2, and 3 show curves for mean, min, and max values respectively for particle vols for each size range. These curves illustrate the wide variation in particle size diam among the samples. The mean curve shows that the average sample had a high vol of very small size particles with a lower vol of large particles. The min curve shows the min value measured in each size range and that almost no particle vol was detected for the upper half of the size range. This was also typical of curves calculated by the Wang 720 C for several individual samples. The data and the max curve show that a high vol of particles did occur in the upper half of the range of some samples.

A multiple regression analysis was made using viscosity as the dependent variable and the vol of particles in each of the 31 size ranges as the independent variables. The vols of a combination of 4 size ranges were selected by the analysis as showing a correlation ($R = 0.473$) to sample viscosities, significant at the 95% level. This means that the combined vol of particles in diam size ranges, 1.58 to 2.00 μm; 10.8 to 12.79 μm, 20.16 to 25.40 μm, and 80.66 to 101.63 μm in the samples explained 22.33% (R^2 x 100%) of the variation in viscosity among the samples.

Further examination of the data indicated that when some other size ranges were combined into groups, improvement was sometimes shown over the single size ranges in the multiple regression equation. As an approach, sums of vol data from 1 to 2, 2 to 8, 8 to 128, 256 to 512, and 512 to 1024 μm diam were combined and used as variables in a multiple regression analysis with viscosity as the dependent variable. This approach did not improve the correlation. Similarly, combinations of the above mentioned sums and ratios of these in all combinations failed to give any higher correlation than the original single range combinations. The highest value in these attempts was obtained ($R = 0.319$) when the sum of the vols between 8 to 128 μm diam size ranges and the ratio of sums between 8 to 128 and 512 to 1024 μm size ranges entered into the regression equation. Nevertheless, these results show that viscosity may be significantly influenced at the 95% level by certain combinations of particle sizes. Further investigation of these results may help to clarify more specifically the effect of particles on viscosity values.

Analysis of the single size range multiple regression shows that vol of particles from the 1.58 to 101.63 μm diam size may correlate better with sample viscosities than vol of particles of smaller or larger diam. Also, in the single size range multiple regression the correlation coefficients of the 3 larger size ranges were positive while the coefficient for the smallest size range was negative showing that an increase in vol of particles in the 1.58 to 2.00 μm range may show a tendency to reduce viscosity in FCOJ. Conversely, an increase in the vol of particles in the other 3 size ranges may show a tendency to increase the viscosity.

Conclusions

A possible practical application of these observations is in the area of viscosity reduction in FCOJ. The results show that if diam of particles in the 10 to 100 μm range are reduced to below 2 μm, a reduction of viscosity may be produced. This study can lead to simplified viscosity reduction through isolating the 10 to 100 μm particles by centrifuging or screening and reducing particle size in a narrow size range rather than treating the total orange juice vol.

Several methods of treatment for particle size reduction such as homogenization, screening, pulverization, sonication, and enzymatic might find application here. The need for additional studies in this area is indicated.

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FLESH TEXTURE AND RESPIRATION OF WAXED PEACHES[1]

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Abstract. **Respiration of fresh peaches waxed after harvest with a paraffin-base emulsion was significantly lower than that of unwaxed fruit as determined by gas-liquid chromatography. Waxed peaches evolved 12.80 ml of CO_2 per Kg of fruit per hour at 21°C, compared to 14.56 ml for unwaxed fruit. The decrease in respiration correlated with a significant increase in texture breakdown of the flesh of waxed peaches held for 3 weeks at 1°C compared to unwaxed checks. Flesh texture breakdown is one of the limiting factors in maintaining the market quality of peaches during storage. Although waxing peaches after harvest is an effective treatment to preserve fresh appearance and market quality, its effect on respiration may lead to a significant decrease in internal quality after prolonged refrigerated storage.**

Peaches (*Prunus persica* [L.] Batsch) are a perishable commodity that are often shipped long distances to market and retailed under unfavorable storage and display conditions. Many growers wax their peaches in combination with a fungicide for decay control. Postharvest waxing extends the marketing life of the fruit by reducing moisture loss and shrivel, and by enhancing general appearance (5). Peaches of most cultivars are held in refrigerated storage for 2 weeks without significant quality deterioration (3). Fresh market quality, however, deteriorates after 2 to 3 weeks in storage. Although the external appearance of the fruit may be acceptable, flavor is lost and flesh texture becomes dry and mealy—a condition known as "wooliness." Wooliness, or internal texture breakdown, occurs most noticeably in fruit stored in advanced stages of maturity and increases as a function of time in storage (2).

Little is known of the effect of postharvest waxing treatments on the physiology, flavor, and texture of peaches in storage. Vines et al (4) reported that waxing did not affect the organoleptic qualities of citrus fruits in storage but did reduce the internal concn of oxygen and raise that of carbon dioxide (CO_2). Wells (unpublished results) observed that peaches coated with an excessive amount of wax developed off-flavors after 5 days at room temp. Peaches waxed under commercial conditions, however, were unaffected. This report describes experiments conducted at the U. S. Department of Agriculture's Southeastern Fruit and Tree Nut Laboratory in Byron, Ga. to study the effects of commercial waxing treatments on the respiration and market quality of peaches during prolonged storage periods.

Materials and Methods

Peaches were selected for uniformity of size and freedom from bruises from local packing sheds in Houston County, Ga. Fruit were color-sorted into 3 maturity grades, green, firm-ripe, and ripe with a Spectrosort (FMC, Lakeland, Fla.), and brush defuzzed and waxed with a commercial peach waxer. Wax was applied as a 10x dilution of a water soluble, paraffin-base emulsion sprayed against rotating brushes under conditions simulating those of commercial practice. Fungicides were incorporated into the wax to control postharvest decays (5). Some fruit were waxed without brush defuzzing, and unbrushed and unwaxed fruit served as checks. A total of 120 fruit per treatment were packed in trays in cardboard peach containers and held at 1°C. Sixty fruit per treatment were removed after one day for respiration studies at room temp, and the remainder removed after 3 weeks for quality tests.

Flesh texture was first evaluated subjectively by rating 30 peaches per treatment according to the pressure required to break the skin with the thumb. A rating of 1 = firm texture, or not breakdown, and 2 through 4 = slight, moderate, and severe texture breakdown, respectively. A rating of 2 or above was considered unacceptable market quality.

Objective texture evaluations were based on pressure tests on 30 fruit per treatment measured with an Instrom TM (Amer. Instrom, Silver Spring, Md.). A patch of skin was peeled from each side of the peach suture and the pressure required to puncture the flesh recorded as kg force.

[1]The authors wish to acknowledge the assistance of Bethany LeDuc.