Table 1. Projected Processing Costs For FreshNote® Process.

| Operating Costs | $/Gallon of Feed |
|---|---|
| Utilities | |
| Electricity | 0.018 |
| Refrigeration | 0.007 |
| Water | — |
| Supplies | |
| Chemicals | 0.007 |
| Miscellaneous | 0.002 |
| Labor $20/hr | |
| Operator @ 4 hrs/day | 0.001 |
| Subtotal | 0.035 |
| Lease & Royalty (5 yr. service/membrane replacement) | 0.070 |
| Total | $0.105/gal. |
| Capital Depreciation | $0.05-0.08/gal. |
| Total Cost | $0.15-0.18/gal. |

Table 2. Projected Cost Assumptions.

- 20,000 lbs/hr water removal rate
- 2,000 operating hours per year
- 8,900,000 gallons feed per year
- Electricity @ 10.06/KWH
- Refrigeration @ $2/ton/day
- Water @ $1/1,000 gallons
- Labor @ $20/hr

Cost assumptions are shown in Table 2. As one can see, the total cost is now projected to 15¢ to 18¢/gallon of raw juice feed. Operating costs for utilities, supplies and labor are 3.5¢/gallon. The balance of the cost is capital depreciation for the equipment and lease and royalty costs for service and membrane replacement.

Assessing the value of a new technology requires that one not only consider the cost, but also the benefit. Figure

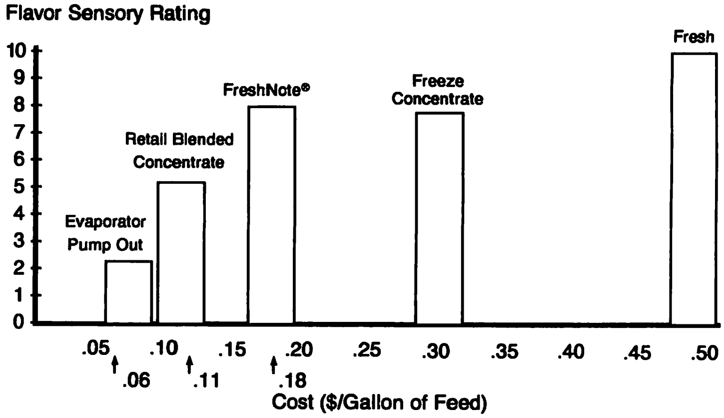


Fig. 15. Flavor/Cost Comparison for Various Concentration Technologies.

15 shows a ranking of thermal, membrane, and freeze concentrators for cost and product quality. Fresh juice is included as a flavor reference only. The FreshNote™ process offers significant flavor improvement at a reasonable cost increment.

*Development programs.* The membrane concentration process is now available for commercial use. Systems up to 20,000 lbs/hr, concentrating to a minimum 42° Brix are being discussed in the Mediterranean and Florida markets where there is strong customer interest. Our goal, however, is to improve the process so it can be adopted by a large percentage of the citrus industry. With this in mind we have set our R&D objectives to raise the final product concentration level to the point that the product can be stored in existing tank farms (58° B) and reduce the cost to the processor to 12¢/gallon of feed. We feel that opportunities exist for significant advances in the UF and RO segments which bring our objectives within reach.

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# EFFECTS OF TEMPERATURE ON PULP REMOVAL FROM ORANGE JUICE BY CENTRIFUGATION

S. M. BARROS
*Florida Department of Citrus*
*Scientific Research Department*
*Citrus Research and Education Center*
*700 Experiment Station Road*
*Lake Alfred, Florida 33850*

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*Abstract.* **During the 1985-86 and 1986-87 Florida citrus seasons, several harvests of Hamlin, Pineapple, and Valencia oranges were made. The juice from these varieties was subjected to centrifuging at ambient and 195°F temperature using a Westfalia separator. Statistical evaluations showed significant differences in pulp removal between the two temperatures in the Valencia juice for both seasons and from Pineapple juice during the 1985-86 season. In both cases, the juice centrifuged hot yielded the highest pulp removal. No significant difference was found in the pulp removal from Hamlin juice samples. However, in both seasons the percentage of pulp removed from the Hamlin juice was highest from the juice centrifuged at the higher temperature.**

The centrifuge has played an important role in the citrus industry as an aid to manufacturing. Its role in the manufacture of byproducts has been reported by various investigators (2, 5, 6). Peleg and Mannheim (8) evaluated a process for the production of orange concentrate based on centrifugal separation of the juice into pulp and serum.

Murdock (7) reported on the use of centrifuges in some citrus plants for the removal of pulp solids from orange juice.

The purpose of this study was to determine the effect of centrifuging juice at ambient and approximately 195°F on pulp removal.

## Methods and Materials

During the 1985-86 and 1986-87 seasons, a total of six harvests each of Hamlin and Valencia oranges were made, along with five harvests of Pineapple oranges. The 20 field box samples were harvested from the Citrus Research and Education center's (CREC) Davenport groves. The fruit were transported and delivered to the CREC packinghouse in 10 field box pallets. The fruit were then washed and sized, with fruit 2-3 1/4" in diameter selected for the study. The fruit from each harvest were randomized into two samples, placed in 10-box pallets and weighed. The samples weighed between 550 and 1100 lbs., and were extracted one at a time on a commercial FMC Model 291B-100 citrus juice extractor using typical commercial settings (1) previously reported. The extracted juice and pulp slurry was then finished using an FMC Model 35 juice finisher modified for pneumatic control of pulp discharge. The discharge pressure was set to yield quick fiber (4) readings in the range of 150-170 for the finished pulp. The finished juice, which ranged from 30-80 gallons, was then held in a cold-walled tank until centrifuging.

The juice was centrifuged using a Westfalia Separator type SA7-06-076 with a self-cleaning bowl, using settings presented in Table 1. The settings used were selected to remove approximately 50% of the available pulp from the control (ambient temperature) juice. Once determined, the settings were used for both the ambient and hot juice runs. The settings in Table 1 varied somewhat between harvests due to juice yield and pulp content of the control juice. The centrifuged juice was held in a second cold-walled tank, and mixed using a hand stirrer in order to avoid any mechanical maceration of the pulp. A sample was drawn for centrifuge pulp determination. The second sample of fruit was extracted, finished and the juice held in the same manner as the first. The juice was then heated using a plate pasteurizer to approximately 195°F, plus or minus 3°, and immediately centrifuged.

All pulp levels in the juice were determined using a table top International Clinical Centrifuge Model CL, a procedure in common use in the citrus industry (3). The data was statistically evaluated using the General Linear Models Procedure (GLM Proc) available on the Statistical Analysis System (SAS) program. The program was run on the Vax 11/750 computer at CREC. Significance was determined using the critical value of the F statistic set for a 95% confidence level.

Table 1. Centrifuge settings.

| | |
|---|---|
| Feed rate | 5 gpm |
| Bowl pressure | 50 psig |
| Water pressure | 50 psig |
| Cycle time | 1.4-2.5 min. |
| Bowl dump time | 2.5-4.0 sec. |
| Feed temp. ambient | 63- 78°F |
| Feed temp. hot | 192-198°F |

## Results and Discussion

The results of this project are shown in Tables 2 and 3. The data is broken down by seasons, variety and within variety by % pulp before (feed) and after (prod.) being centrifuged. Also presented is the pulp removed (Dif), and the % pulp removed (% Dif). Any significant differences are between rows within the column and not between columns.

Table 2 shows the results for the first season of the project. The only significance found was in Valencia orange juice where the pulp levels in the product, the pulp removed, and the % pulp removed were all found to be significantly different ($P > .05$) between the two treatments. The pulp removed by centrifuging the juice hot was significantly greater.

For both the Hamlin and Pineapple juices, the % of pulp removed (% Dif) when the juice was centrifuged hot was greater than that removed at ambient temperature, but neither was found to be significantly different ($P < .05$).

Table 3 presents the data obtained from the 1986-87 season. Significant differences ($P > .05$) were found in the % pulp removed; 76.4% vs 52.8% and 65.6% vs 50.0% from the Pineapple and Valencia juices, respectively. Significant differences ($P > .05$) were also found between amount of pulp removed from Valencia juice during centrifuging and in the product after centrifuging for Pineapple orange juice. In all cases, the pulp removed and the % pulp removed in each variety were greatest in the juice centrifuged at approximately 195°F, compared to that centrifuged at ambient temperature.

As found during the 1985-86 season, there was no statistically significant difference ($P < .05$) between the two treatments when applied to Hamlin orange juice. However, both the amounts of pulp removed and, accordingly, the % pulp removed were greater when the juice was centrifuged at the higher temperature. These results show that it would be feasible to remove pulp after the juice has been heated. For example, a centrifuge could be placed after the first stage of an evaporator. Since the volume of liquid has been rduced by evaporation, a centrifuge of lesser capacity and therefore, cost could be employed to produce a desired pulp content in the juice.

During the course of the project, several minor problems were encountered in the operation of the centrifuge, which had a bearing on its efficiency. As mentioned in the Methods and Materials section, mathematical calculations were made in order to determine the settings needed to

Table 2. Mean pulp values (ml/100 ml) and percent pulp removal—1985-86 season.

| | Fruit Variety | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hamlin | | | | Pineapple | | | | Valencia | | | |
| Temp | Feed | Prod | Dif | % Dif | Feed | Prod | Dif | % Dif | Feed | Prod | Dif | % Dif |
| Ambient | 10.3 | 4.8 | 5.5 | 53.4 | 14.0 | 8.0 | 6.0 | 42.9 | 10.3 | 5.3[a] | 5.0[a] | 48.5[a] |
| 195°F | 9.5 | 4.3 | 5.2 | 54.7 | 15.0 | 7.5 | 7.5 | 50.0 | 10.3 | 3.3 | 7.0 | 68.0 |

[a]Statistically significant differences between rows, 5% level.

Table 3. Mean pulp values (ml/100 ml) and percent pulp removal—1986-87 season.

| | Fruit Variety | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hamlin | | | | Pineapple | | | | Valencia | | | |
| Temp | Feed | Prod | Dif | % Dif | Feed | Prod | Dif | % Dif | Feed | Prod | Dif | % Dif |
| Ambient | 9.2 | 5.2 | 4.0 | 43.5 | 12.7 | 6.0[a] | 6.7 | 52.8[a] | 12.0 | 6.0 | 6.0[a] | 50.0[a] |
| 195°F | 9.5 | 3.8 | 5.7 | 60.0 | 12.7 | 3.0 | 9.7 | 76.4 | 12.5 | 4.3 | 8.2 | 65.6 |

[a]Statistically significant differences between rows, 5% level.

remove approximately 50% of the pulp in the control (ambient temperature) juices. The results of the two season study showed that between 42.9 and 53.0% pulp removal was achieved. This variation can be decreased by noting several factors which affect centrifuge efficiency. Maintaining sufficient backpressure (bowl pressure) to insure an adequate bowl dump, as well as adequate water pressure and time needed for the bowl dump cycle are important factors needed for efficient operation. Maintaining a constant flow rate was also found to be a critical factor. As the flow rate fluctuated, it would have an effect on the backpressure of the unit and possible leaking of product from the bowl prior to and after the bowl dump cycle. Besides these mechanical factors, others such as fruit variety and juice viscosity must also be taken into account. These minor problems encountered can easily be overcome by an experienced operator and system monitoring. In order to insure that the centrifuge is operating to yield the desired results, samples of the product should be taken at regular intervals, approximately one minute after the bowl dump cycle. The minute delay gives the system time to equalize.

During the course of the two season project, material balances were made around the centrifuge and losses were maintained between 0.4 and 0.9% of the starting sample weight. These losses can also be minimized by continuous monitoring of the system.

In summary, a two season study on the effect of removing pulp by centrifuging juice from Florida's three major orange varieties at ambient and approximately 195°F was made. The results showed that statistically significant differences ($P > .05$) were found between the two treatments in both Pineapple and Valencia juices with the hot treatment yielding the highest % pulp removals. There were no statistically significant differences ($P < .05$) found between the treatments when applied to the juice from Hamlin oranges in either season. However, the hot treatment did yield a higher % pulp removal during each season.

Several minor problems were encountered during the project which affected centrifuge efficiency but all could be easily corrected by an experienced operator and system monitoring.

Material balances made around the centrifuge during each of the runs showed losses to range between 0.4 and 0.9%.


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