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SURVEY OF COMMERCIAL ORANGE JUICE EVAPORATOR-PUMPOUT CONCENTRATE

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Abstract. **From January-June 1981, 59 samples of orange juice evaporator-pumpout concentrate from Florida commercial plants were collected to determine if correlations between flavor, commercial juice yield and other parameters existed. Seven commercial processing plants representing 4 geographical citrus producing areas in Florida participated in the study. Results showed that during this freeze year, the mean flavor score of all samples fell within the close range of 4.1-4.7 or between the middle of the "dislike slightly" and the lower end of the "neither like nor dislike" flavor categories, respectively. The range of flavor scores indicated that on a composite sample basis, flavor was not significantly influenced by plant locale, processing technique or degree of freeze damage to the fruit utilized.**

The purpose of this paper is to evaluate orange juice evaporator pumpout concentrate to determine any statistically significant correlations between the various physical, chemical and organoleptic analyses which were tested, and actual commercial juice yields. The January 13, 1981 freeze affected all but the first sampling period.

The Juice Definition Program (JDP) (1, 2, 3) of the early 1970's covered various effects of soft and hard-squeeze extraction and finishing on yield and quality of single-strength juice. In 1981 Barros et al. (4) reported on the effects of soft and hard-finishing on the quality of juice produced from oranges, most of which contained some degree of freeze damage.

Materials and Methods

At the request of the Florida Citrus Processors Association a total of 59 pumpout concentrate samples were collected from 7 commercial Florida processing plants representing the northern, central, southern and Indian River citrus areas.

The pumpout samples were composites made up from a plant's weekly production of concentrate. During a single 24-hr period, a total of 2 samples at 9-hr intervals were drawn from the pumpout stage of the evaporator and placed in a 1-gal (3.785 liters) plastic container. At the end of the processing week 12 to 14 individual samples (this number varied per production schedule) had been drawn and made up the composite for that particular week. There were 11 sampling periods throughout the course of this study, the first being January 5-11, 1981 and the last June 8-14, 1981. Samples were kept at 0°F until analyzed. The concentrates, taken directly from the pumpout stage of the evaporator, did not include oil addition or other products, such as add-back pulp or cutback juice.

After each sampling period, samples were collected by either Florida Department of Citrus (FDOC) or United States Department of Agriculture (USDA) personnel and brought to the Agricultural Research and Education Center (AREC), Lake Alfred for evaluation. The various samples were, when possible, analyzed within a week of production, thus minimizing any degradation of quality due to storage. In addition to the pumpout samples, a juice-yield report corresponding to the week's production was obtained.

Each sample was evaluated for 11 analytical and subjective quality parameters. The analyses and the procedures (except for limonin), which are in common use in the citrus industry have been previously referenced (1, 2, 3, 6) and are listed in Table 1. Juice samples were reconstituted to 12.3°Brix for all analyses requiring single-strength juice. Each sample was evaluated for flavor by an 11 to 12-member taste panel using a 9-point hedonic scale where 9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely, etc. A stepwise, multiple, linear-regression analysis of the data was made using flavor as a dependent variable. Mathematical and statistical analyses were made using the General System Automation Computer (GSA) available at AREC.

Table 1. Characteristics used in quality determination.

°Brix	Flavor
% Acid	Color number
°Brix/% Acid ratio	Optical density
% Sinking pulp	Total glycosides (ppm)
Viscosity (cps)	pH
Limonin (ppm)	

Results and Discussion

A summary of results based on the total data accumulated during this study is presented in Table 2. The flavor of the pumpout samples was the prime concern of the study. As can be seen in the table, flavor scores ranged from a minimum of 2.7 to a maximum of 5.3 with the mean flavor score at 4.4. The majority of scores (68%), however, fell within the range of 3.9-4.9 or between the middle of the "dislike slightly" and the middle of the "neither like nor dislike" flavor categories, respectively. It must be considered that none of the samples tested contained any cold-pressed oil, essence oil or cutback juice. The addition of 1 or more of the above would normally be made prior to a USDA flavor evaluation. Fig. 1 illustrates the progression of flavor scores during the period studied. Flavor scores did not show an immediate decline after the January 13 freeze but continued to increase slightly during the early-midseason. They reached their lowest point in April. The low flavor scores

Table 2. Summary Commercial Orange Juice Evaporator-Pumpout Concentrate—59 samples from 7 processors.

	Mean	Min.	Max.	Standard deviation
Flavor (points)[z]	4.4	2.7	5.3	3.9- 4.9
Limonin (ppm)[z]	3.0	0.7	7.0	1.4- 4.6
Brix (degree)	64.5	55.5	70.5	61.4- 67.7
Acid (%)	4.6	3.1	6.7	3.8- 5.4
Ratio (b/a)	14.3	10.2	19.1	12.1- 16.5
Viscosity (cps)	4182	754	10,138	2533- 5831
Color number[z]	36.9	34.6	39.0	35.7- 38.1
pH[z]	3.7	3.4	4.0	3.6- 3.9
Pulp (%)[z]	12.3	8.0	17.0	10.5- 14.2
Optical density	1.04	0.92	1.15	0.97- 1.11
Glycosides (mg/100 ml)[z]	123	79	186	100- 145
Yield (% fact s.t.)[y]	100.5	87.3	106.2	96.8-104.2

[z]Samples reconstituted to 12.3°Brix.
[y]Commercial juice yield based on percent factored State Test yield.

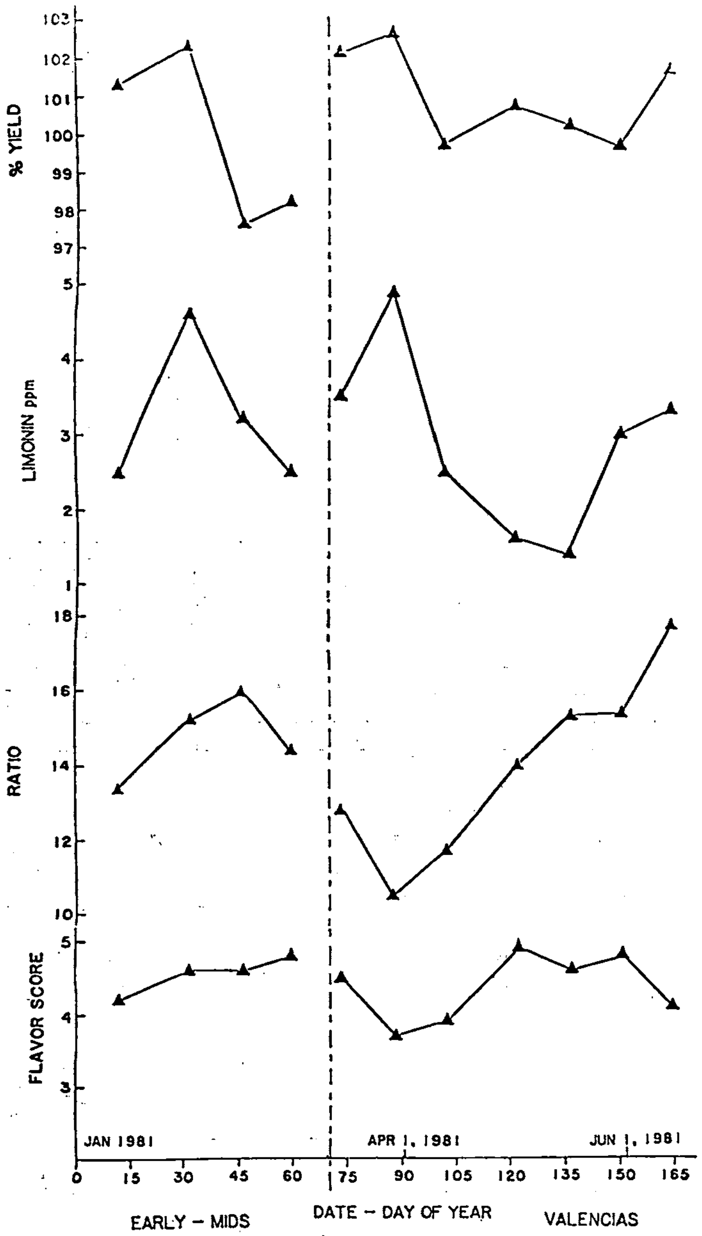

Fig. 1. Percent yield, limonin, ratio and flavor score vs. time of harvest.

seen in early April can possibly be explained by the processing of the early 'Valencia' crop which would have been comprised of rather low °Brix/% acid ratio fruit at that time. As shown in Fig. 1 in early sampling periods ratio seemed to follow the same trends found with flavor score. As with flavor the ratio reached its lowest point in late March-early April and then later began a dramatic increase, possibly due to the effect of the freeze.

Statistical correlation between flavor and the various parameters studied can be seen in Table 3. Ratio, % acid and limonin all showed correlation with flavor significant at the 99% level. Correlations with optical density, glycosides and pH were determined to be significant at the 95% confidence level. Significance for all comparisons was determined at the 95% level or greater.

Table 3. Flavor correlation coefficients—Commercial Orange Juice Evaporation-Pumpout Concentrate.

Maturity	–0.009
Brix	0.020
Acid	–0.450**[z]
Ratio	0.402**
Centrifuge solids	0.123
Optical density	–0.306*
Concentrate viscosity	0.101
Color	0.009
Glycosides	–0.256*
Limonin	–0.508**
pH	0.271*
Yield	–0.146

[z]Significant at the 5% (*) or the 1% (**) level.

A statistical analysis of reported yields did not produce any significant correlation with flavor. As presented in Fig. 2 a trend can be seen which indicates that flavor scores de-

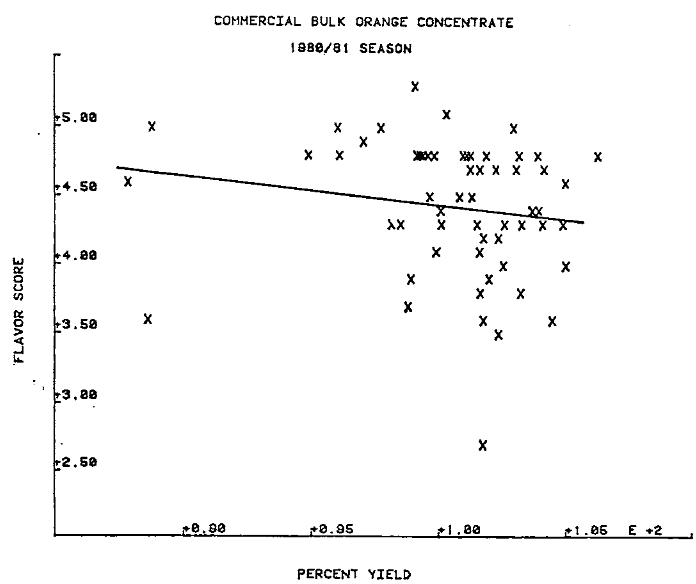

Fig. 2. Flavor score vs. percent yield.

creased as juice yields increased. As shown in Table 2, reported yields ranged from a low of 87.3% of factored State Test yields to a reported high of 106.2%. The mean was determined to be 100.5% and 1 standard deviation about the mean (68% of all samples fell within this range) was 96.8-104.2%. Fig. 1 indicates that the reported plant yields dropped sharply within 2 wk of the freeze. This same trend was seen in reports by the Division of Fruit and Vegetable Inspection on weekly orange yields (5). Yields are then seen to fluctuate from the remainder of the season. None of the other parameters studied showed any significant correlations with yield.

Limonin, a key factor in studies which relate to juice quality, referenced earlier, was determined by the immunoassay procedure of Mansell (6). Limonin and flavor gave a correlation coefficient (r) of –0.508 (Table 3) which was determined to be significant at the 99% level. This was the highest coefficient of correlation determined with flavor, although by statistical interpretation, could have only a moderate effect on flavor, the negative value indicating that as limonin values increased in the juice, flavor scores decreased. An examination of Fig. 3 which is a representation

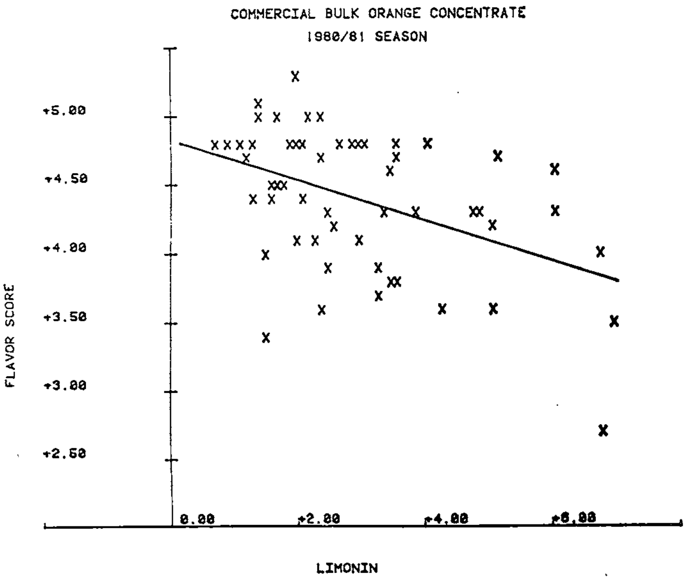

Fig. 3. Flavor score vs. limonin.

of the relationship between flavor and limonin for all samples, shows the negative effect of increased limonin in the juice on flavor scores. Table 2 indicates that limonin values obtained during this study ranged from a minimum of 0.7 ppm to a maximum of 7.0 ppm, with the majority of samples falling between 1.4-4.6 ppm. The mean value was determined at 3.0 ppm. Limonin showed the largest percent variation of all the parameters studied with a factor of 10 difference between the maximum and minimum values obtained. A study of Fig. 1 shows the progression of limonin throughout the period of this study. Fig. 1 indicates a sharp increase and then decrease following the freeze and a second increase in late March and early April coinciding with the processing of the first 'Valencias'. These increases were followed by a pronounced decrease until the end of May. Statistical analysis found no significant correlation between limonin and reported juice yields. Highly significant correlations were found between limonin and both optical density, and total glycosides.

An overall flavor prediction equation was determined with a coefficient of determination (r^2) value of 0.51. The equation was derived in the form:

$$\text{Flavor Score} = 2.5 - (0.1 \times \text{limonin}) - (0.8 \times \%\ \text{acid}) + (0.00011 \times \text{viscosity}) - (0.2 \times \text{ratio}) + (0.2 \times \text{color No.}) - (0.07 \times \text{maturity}).$$

Maturity, as used in the equation, was based on the period of sample collection, i.e., samples from the first collection dates, January 5-11, were assigned a maturity value of 1; the second set were assigned a 2, etc.

A further study into the effect of yield, limonin, etc. on flavor scores was made on an individual plant basis. Table 4 depicts the parameters which gave statistically significant

Table 4. Flavor correlations by plant—Commercial Orange Juice Evaporator-Pumpout Concentrate.

Plant Number	1	2	3	4	5	6	7
Date							
°Brix	*z						
% Acid			*				**
Ratio			*				**
Centrifuge solids							
Optical density						**	
Concentrate viscosity						**	
Flavor							
Color							
Glycosides						**	
Limonin					**		
pH			**				*
Yield							

zSignificant at the 5% (*) or the 1% (**) level.

correlations with flavor on an individual plant basis, that is those parameters found to be significant at the 95% level or greater. As the figure indicates no plant showed juice yield to produce a significant correlation with flavor at the 95% level. Furthermore the data did not indicate any parameters which consistently gave significant correlations with flavor on a plant-to-plant basis. Only a superficial examination of individual plant data was made due to the limited number of samples obtained from each plant.

Although this study indicated that yield did not significantly correlate with flavor, and that other parameters such as limonin, % acid and Brix-to-acid ratio had only a moderate effect, it must be kept in mind that this study was made using composite samples containing as many as 14 individual samples, with factors that have contradicting effects on yield and flavor.

In summary, data accumulated between January and June 1981, from commercially produced orange juice evaporator-pumpout concentrate showed statistically significant flavor correlations with limonin, % acid and Brix-to-acid ratio. Limonin presented the highest degree of correlation, and ratio was determined as the only parameter which gave a statistically significant positive correlation with flavor. Flavor scores showed the majority of samples to fall between the middle of the "dislike slightly" and the middle of the "neither like nor dislike" flavor categories, respectively. None of the samples obtained contained added oil, essence oil or cutback juice.

A statistically significant correlation between flavor and reported juice yields was not found on the basis of the industry-wide data. However, a slight negative trend was observed which indicated that as juice yields increase, flavor scores decreased. Reported yields fell within the range of 87.3% to 106.2% of factored State Test juice yield and a calculated mean of 100.5%. A sharp decline in juice yields were observed following the January 13 freeze.

Limonin values obtained through an immunoassay procedure produced significant correlations with optical density and total glycosides in addition to flavor. Limonin values showed the greatest percent variation of all parameters studied with a factor of 10, the difference between minimum and maximum values. Following the freeze the data presented also showed for limonin a sharp increase followed by an equally sharp decrease.

A flavor prediction equation based on all the data obtained was determined with a coefficient of determination (r^2) of 0.51.

Finally, individual plant data, although limited, did not show any consistent flavor correlation with the parameters studied. None of the plants showed any significant correlations between flavor and their reported juice yields.

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STORAGE STABILITY AND QUALITY OF HIGH BRIX ORANGE CONCENTRATE[1]

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Abstract. **Florida is the second largest producer of citrus in the world producing 5.14 million metric tons (125.8 million boxes) during the 1981-82 season. The Florida citrus industry is constantly looking for methods to become more competitive by reducing its production and energy costs. High brix orange concentrates offer significant energy savings during storage and distribution because of their reduced volume and increased microbial stability at higher temperatures. A 14 to 16% savings of storage costs can be realized using 72° brix rather than 62 to 65° brix concentrate for storage. An additional 16 to 32% savings can be calculated using storage temperatures of −1°C (30°F) to 4.4°C (40°F) rather than traditional storage temperatures, about −6°C (21°F).**

Samples from the 3 principal orange cultivars in Florida ('Hamlin,' 'Pineapple,' and 'Valencia') were harvested late in their maturity, extracted, and concentrated to approximately 72° brix with a TASTE evaporator. Samples were stored in 6 oz metal cans at −22.2°C (−8°F), −6.7°C (20°F), 4.4°C (40°F) and 26.7°C (80°F) for up to a year. Duplicate samples were analyzed for quality parameters initially and at monthly intervals during storage. Orange concentrate samples were also diluted to 70, 68, and 65° brix and inoculated with several osmophilic yeast isolates. Microbial growth and visible evidence of spoilage were monitored during storage at 4.4 and 30°C.

No appreciable change in product quality was found among storage temperatures of 4.4°C and lower. However, during 1 yr of storage at 26.7°C, the samples changed in color (CR = 23 went to 65; N = 34 finishing at 41), absorbance by brown pigments increased from 0.0 to 0.420, vitamin C decreased from 69 to 2 mg/100 ml and furfural increased from 0 to 1150 ppb.

Current situation. Florida citrus processors are continually looking for alternatives to reduce their costs so they can maintain their profit margins and remain competitive. Competition from foreign orange concentrate manufacturers is increasing. Brazil's Sao Paulo 1981 orange crop was 7 million metric tons (180 million boxes) (1, 2). Orange juice is also in competition with other breakfast drinks as well as other fruit drinks and beverages. Consumers are caught in a price squeeze and are demanding better value for their food dollars. All of these factors point to stiffer competition for Florida citrus processors.

During the 1981-82 season, 5.1 million metric tons (126 million boxes) of oranges were harvested in Florida with more than 90% of that total processed as concentrates or single strength juice. Storage of concentrates is usually in large, low temperature, bulk facilities or tank farms and may be for extended periods of time (up to 1 yr). Factors affecting storage cost include product concentration, storage temperature, capital costs of facilities and labor.

Alternatives. First, orange concentrate has traditionally been stored at about 62° brix. One reason was that the old, low temperature evaporators the citrus industry used before the 1960's produced an unstable concentrate that had gelation problems above this concentration. At 62° brix, 38% of all storage costs are spent on storing water. A 16% savings (10/62) is possible by increasing the concentration by 10° brix to 72° brix. This is a direct energy and storage cost savings.

Secondly, tank farm storage temperatures normally range from −1 to −12°C (30 to 10°F). Some concentrate is also stored in drums at even lower temperatures (−18°C or 0°F) (21). A 16 to 32% savings in refrigeration costs may be found by using storage temperatures of −1 to 4.4°C (30 to 40°F) rather than −6.7°C (20°F). Shipping, distribution, in and out warehouse charges are also increased (2 to 4 times

[1]Florida Agricultural Experiment Stations Journal Series No. 4304. The authors wish to acknowledge the assistance of Ben F. Wood in helping with the analysis. For metric conversions, see Table at the front of this volume.