

## GRAPEFRUIT JUICE QUALITY IMPROVEMENT STUDIES INTRODUCTION AND SCOPE OF THE STUDY AND THE EFFECT OF PROCESSING VARIABLES, TEMPERATURE AND DURATION OF STORAGE ON THE QUALITY OF GRAPEFRUIT JUICE

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**Abstract.** The quality improvement program for grapefruit juice was carried out in several parts, but the main emphasis was placed on the study of extracting and finishing parameters on grapefruit juice quality. Survey of quality of commercially produced canned grapefruit juice collected from the manufacturing plants and from the supermarket stores in different parts of the U.S., the development of better color measurements for white and pigmented grapefruit, mineral content of Florida grapefruit juice, and the variations in spectral properties of canned grapefruit juice are the other topics discussed in this symposium. Juice obtained from fruit with high extracting and finishing pressures was found to have lower flavor score and higher limonin and naringin content than juice obtained with low pressures. Furfural measurements can be used as an indication of storage temperature and duration. Juice stored at temp higher than 70°F (21°C) decreased rapidly in flavor quality with corresponding increase in furfural.

The use of grapefruit in processing in Florida during the decade 1966-76 has fluctuated between 18-30 million boxes<sup>1</sup> (4). During the 1975-76 season, 44% of the processed grapefruit was utilized in canned grapefruit juice and 31% in the manufacture of frozen concentrated grapefruit juice (4). The movement of processed grapefruit products during this period has not paralleled that of orange mostly due to the need for a quality improvement program as introduced for frozen concentrated orange juice (FCOJ) by the Florida Citrus Commission in 1965. While most of the initial success of orange juice products in Florida was due to the development of FCOJ, the primary factor that led to the current success of this product was the successful implementation of a quality improvement program and determination by the industry to achieve high quality. The industry agreed to adopt the juice yield control which included regulating extractor and finisher pressures, barring the use of water-extracted soluble orange solids (also called washed pulp solids) in FCOJ, the increase of soluble solids content in the 3 + 1 reconstituted concentrate from 11.8°Brix to 12.8°Brix and the limitation of sinking pulp content. Another factor that contributed to the successful marketing of orange juice was the development of objective color measurement methodology to give the processors a means of standardizing color. The consumer was also made aware of the nutritive value of citrus products.

The grapefruit quality improvement study will follow some approaches similar to those for FCOJ quality improve-

ment with emphasis placed on the quality of single strength canned juice because of the large production of the latter. Emphasis is also placed on the development of methodology to measure objectively the quantity of limonin and naringin, the 2 known bitter principles in processed grapefruit products. These bitter principles have been found to occur in abundance in the peel and rag of the fruit especially in the less mature fruit (6, 8).

The color of grapefruit juice presents a different problem for standardization from that of orange juice because of the existence of 2 distinct colors of grapefruit, namely the white and the pigmented varieties which are both used in juice production. These juices are sometimes packed separately and other times mixed. At present, there is no objective method for measuring the color of grapefruit juice. The development of an instrumental method would give the processors a means of standardizing color.

Canned single-strength grapefruit juice produced by Florida citrus processors and that collected from various area supermarkets was surveyed to determine the flavor of these products at the time of production and after going through the regular retail channels. The relationship of the flavor of the juice to the other quality parameters such as acidity, storage conditions, and bitter principles was also studied.

Citrus products provide some important mineral elements essential in human nutrition. The values of these elements in FCOJ has been documented (9). A more comprehensive study of the mineral element content of grapefruit juice was made by analyzing these elements by atomic absorption spectroscopy.

Spectral characteristics of grapefruit juice are indications of some of the chemical components present. Absorption at some of the ultraviolet wavelengths were known to be associated with polyphenols, flavonoids and ascorbic acid (7). A survey of these spectral characteristics of grapefruit juice samples was made.

The above mentioned studies, together with the study of effect of processing variables and storage conditions, are part of the grapefruit quality improvement studies to be reported in this symposium. The first paper will only deal with the processing variables and storage effect on quality of grapefruit juice. Other topics will be discussed in subsequent papers in this symposium.

### Materials and Methods

#### *Processing variable study*

*Samples.* Because the effect of extracting and finishing was especially important with the early season, relatively less mature fruit, samples were collected at approximately two week intervals between September 12 and January 25 in the 1974-75 season and between August 21 and January 5 in the 1975-76 season. Fruit of the 'Marsh Seedless' and 'Duncan' cultivars were obtained from both the packing house or sectionizing plant as eliminations,<sup>2</sup> and directly

<sup>1</sup>For metric conversions see table near the front of these Proceedings. Ed.

<sup>2</sup>Fruit graded out by fresh fruit packers purely for surface blemishes. Ed.

from the grove. Fruit from the commercial packing house or sectionizing plant were available at an earlier date than those of the grove run, but fruit of the most desirable sizes were usually not present in these lots. The grove run fruit were of all sizes.

Twenty to forty 85-pound boxes were brought to the Center packing house on each sampling date and sized. Composite samples were constructed to contain fruit size distribution proportionate to that of the overall load. Each composite sample contained about 3 85-pound boxes.

*Extraction and finishing procedures.* In the 1974-75 studies, an FMC Model 391 in-line extractor and an FMC Model 35 finisher were used. Settings providing the various extracting and finishing effects were made according to the manufacturer's recommendations. In addition, a State Test extraction (5) was made with each run. For the 1975-76 study, an Automatic Machinery Corp. (AMC) extractor and finisher were added. The settings to achieve the various extracting and finishing effects with this equipment were also according to manufacturer's recommendations. Because only one AMC extractor was available for this study, only fruit of 4-4 1/2 inch size was used during the 1975-76 season.

*Analytical.* The percentage juice yield, as well as some of the chemical and physical analyses of the juice, were made on each run. Total soluble solids content (TSS) was determined by a hydrometer, acidity by titration and pulp content by the centrifuge method (10). Naringin was determined by the Davis procedure (1) and limonin by the high pressure liquid chromatography (HPLC) method of Fisher (3). Flavor was scored by the taste panel at the Center using a 9 point hedonic scale where 1 = dislike extremely and 9 = like extremely. Usually 10 to 12 judges were on each panel and the numerical average of the scores was used.

### Storage Studies

*Sample.* 'Marsh Seedless' grapefruit obtained as packing house eliminations were extracted with an FMC Model 391 in-line extractor and passed through an FMC Model 35 finisher. The finished juice was pasteurized and packed in 12 oz cans and stored at various temperatures ranging from 40°F (4.4°C) to 100°F (37.8°C) in 10°F increments. Sufficient cans were stored at each temperature for the various analyses to be made.

*Analysis.* At weekly intervals, juices stored at 80°, 90°, and 100°F were analyzed for furfural using the method of Dinsmore and Nagy (2). The taste panel evaluated the flavor of these samples. Similar flavor evaluations and analyses for furfural were made on those samples stored at temperatures of 70°F and lower but on bi-weekly intervals.

## Results and Discussion

### Processing Variable Studies

The analytical results of 'Marsh Seedless' grapefruit of the 1974-75 season, obtained from packing house eliminations and from the grove, are presented in Table 1 and Table 2, respectively. Juice from hard extraction settings had higher limonin and naringin contents and lower flavor scores than the corresponding samples extracted using milder conditions. Less severe extraction conditions lowered juice yield but produced juices with slightly higher flavor scores. Similar results were obtained with juice of the 'Duncan' variety but are not presented here. The State-Test extraction produced a juice, in many instances, having comparable characteristics to those from the soft extraction conditions.

Table 1. Effect of extracting condition on the juice characteristics of 'Marsh Seedless' grapefruit from the packing house eliminations. (1974-75 Season)

Extracting system	Juice yield (%)	Juice characteristics						
		°Brix	Acid (%)	Ratio	Pulp (%)	Davis (ppm)	Limonin (ppm)	Flavor score
September 12-13, 1974								
State Test	44.92	9.00	1.06	8.5	12.0	495	5.0	5.5
Soft	48.48	9.05	1.11	8.2	8.5	540	6.0	5.3
Medium	50.10	9.00	1.05	8.6	9.0	595	8.0	4.7
Hard	56.78	9.00	.97	9.3	10.0	905	9.0	4.7
September 24-25, 1974								
State Test	43.08	8.70	1.21	7.2	11.0	515	8.0	4.6
Soft	45.62	8.70	1.23	7.1	9.0	550	7.0	4.6
Medium	48.21	8.70	1.25	7.0	8.0	585	7.0	5.2
Hard	54.48	8.80	1.17	7.5	17.0	880	10.0	4.2
October 7, 1974								
State Test	44.81	8.50	1.03	8.3	10.0	565	4.0	5.6
Soft	49.89	8.55	1.04	8.2	9.0	640	3.0	5.2
Medium	51.39	8.50	1.03	8.3	8.0	630	4.0	5.3
Hard	59.44	8.30	1.00	8.3	17.0	910	8.0	4.3
November 8, 1974								
State	45.14	9.15	1.39	6.6	10.0	565	5.0	5.2
Soft	46.54	9.05	1.40	6.5	8.0	505	6.0	4.9
Hard	53.13	9.25	1.35	6.9	9.0	685	7.0	4.7
December 17, 1974								
State Test	51.63	10.25	1.26	8.1	14.0	540	2.0	6.0
Soft	54.47	10.35	1.27	8.2	12.5	550	2.0	6.2
Hard	61.49	10.38	1.25	8.3	12.0	835	3.0	5.7

Table 2. Effect of extracting condition on the juice characteristics of 'Marsh Seedless' grapefruit harvested from the field. (1974-75 Season)

Extracting system	Juice yield (%)	Juice characteristics						
		°Brix	Acid (%)	Ratio	Pulp (%)	Davis (ppm)	Limonin (ppm)	Flavor score
October 22, 1974								
State Test	49.00	8.35	1.13	7.4	9.0	595	5.5	5.8
Soft	49.43	8.35	1.17	7.1	7.0	545	4.0	5.4
Medium	50.00	8.45	1.13	7.5	7.0	555	3.0	5.4
Hard	54.00	8.40	1.11	7.6	11.0	740	4.5	5.1
December 4, 1974								
State Test	51.73	8.85	1.10	8.0	10.5	530	3.0	6.2
Soft	52.13	8.65	1.14	7.6	8.0	595	2.0	6.2
Hard	57.56	8.80	1.08	8.2	7.0	725	4.0	5.8
December 30, 1974								
State Test	52.84	9.30	1.13	8.2	10.5	530	3.0	6.3
Soft	52.62	9.25	1.14	8.1	8.0	505	1.5	6.9
Hard	56.81	9.30	1.09	8.5	8.0	745	1.5	6.3

The 1975-76 results also indicated that the extracting conditions were directly related to the amount of limonin and naringin content in the juice from comparable fruit samples. The juice extracted from the fruit with lower pressures averaged slightly higher in flavor (Fig. 1). However, there was a seasonal trend of limonin content, flavor, and the soluble solids/acid ratio of these fruit. The multiple regression coefficient with flavor as the dependent variable was .911. The following flavor prediction equation was calculated:

$$\text{Flavor Score} = 0.7433 \times \text{Ratio} - 0.1362 \times \text{Limonin} - 0.0884$$

There is also evidence that the 2 kinds of extractors gave significantly different naringin and limonin values (Table 3).

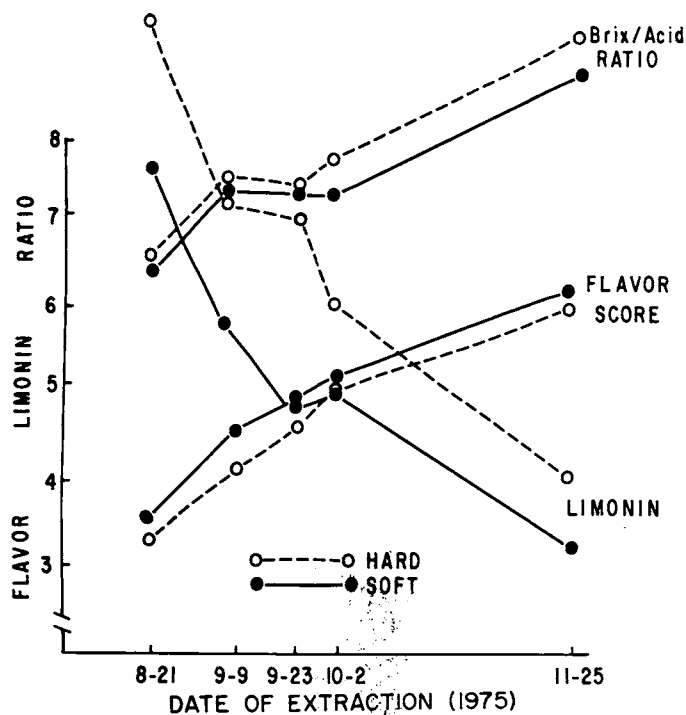


Fig. 1. Effect of extraction on the flavor, soluble solids to acid ratios and limonin content of grapefruit juice. (Average values of both AMC and FMC extractors.)

Table 3. Differences in limonin and naringin content of grapefruit juice from two types of extractors on 2 cultivars of grapefruit.

Date of sample	Naringin (ppm)			Limonin (ppm)		
	State Test	Extractor Az	Extractor Bz	State Test	Extractor Az	Extractor Bz
‘Marsh Seedless’						
10/16/75	450	376	474	4.1	4.9	4.1
11/12/75	445	346	399	4.7	5.2	3.6
12/23/75	392	321	383	3.6	4.2	3.0
‘Duncan’						
10/28/75	298	277	319	3.1	3.6	2.7
12/10/75	431	320	412	1.2	2.6	1.6
1/ 5/76	377	356	418	1.4	1.9	1.8

<sup>z</sup>Average values of both soft and hard extractor settings.

### Storage Studies

The furfural content and the flavor scores of the samples of juice stored at different temperatures are shown in Figure 2. With the initial flavor score of slightly greater than 6 (like slightly flavor category), samples stored at 100°F increased in furfural rapidly with a corresponding decrease of flavor quality. A distinct off-flavor was detected after 6 weeks resulting in a flavor score of about 4 (dislike slightly category). Similar trends were found with samples stored at 90°F and 80°F but at a slower rate. Samples stored at 70°F decreased in flavor and increased in furfural only slightly even after 6 months. Little or no change in flavor scores or furfural was found in samples stored at 60°F or lower.

### Conclusion

The Florida Department of Citrus has initiated studies for the improvement of grapefruit juice quality. These studies, in addition to the extraction variable and storage

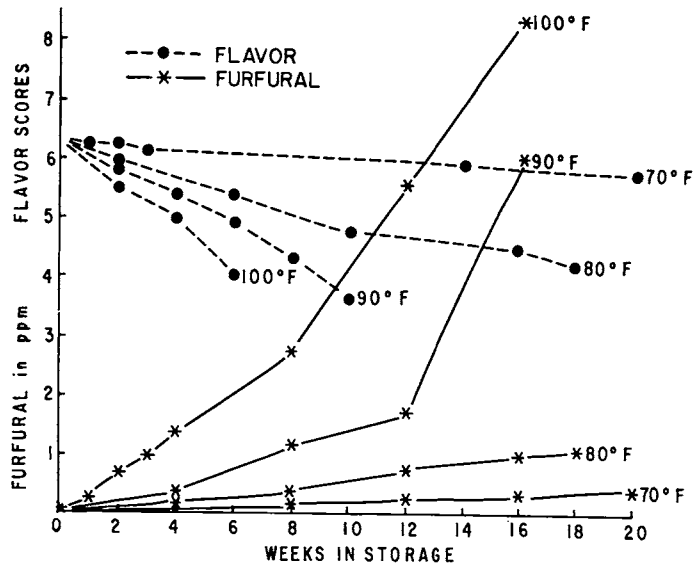


Fig. 2. Effect of storage, time and temperature on the flavor score and furfural content of canned grapefruit juice.

effect reported in this paper include: surveys of the quality of canned grapefruit juices produced at the plants and after they have passed through the regular retail channels, juice color, the mineral content, and the spectral characteristics of grapefruit juice.

Extractor and finisher settings corresponding to hard extraction produced higher juice yields than soft settings but also juices having higher limonin and naringin content and lower flavor scores. There was a seasonal trend in the limonin content, flavor score and the soluble solids to acid ratios. Using the flavor score as the dependent variable, the multiple regression coefficient with the ratio and limonin content was calculated to be 0.911. The difference in naringin and limonin contents of the juice from the two types of extractors may be due to the differences in extracting principles.

Juice stored at 100°F developed distinct off-flavor in 6 weeks with corresponding increase in furfural. Juices stored at 90° and 80°F also went off-flavor but at slower rates. Juice stored at 70°F or lower did not produce appreciable off-flavor even after 6 months of storage.

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