3. For other fruits, as well as for citrus, a characteristic regression of Brix/acid ratio on pH probably exists for each genus.

LITERATURE CITED


5. Florida State Department of Agriculture, Citrus and Vegetable Inspection Division, Annual Reports, 1949-50 through 1957-58.


22. United States Department of Agriculture, United States Standards for Grades (of the various citrus juice products). Agricultural Marketing Service. (Issued under Sec. 205, 60 Stat. 1090; 7 U.S.C. 1624)


PROCESSING FREEZE-DAMAGED ORANGES

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Oranges which had been frozen on the tree during the 1957-58 freezes, were used in studies of the effect of several juice finishing procedures, and elapsed time periods between freezing and harvesting on juice yield and quality characteristics of both juices and concentrates. Freezing conditions occurred over much of the citrus producing area of Florida on December 12 and 13, 1957, resulting in serious fruit injury. Freezing conditions returned on January 9, 10, and 11, 1958; February 4 and 5; and again on February 17, 18, and 19, 1958.

Physical and chemical changes in citrus fruits damaged by freezing have been reported. Gary (7) reported physical breakdown of fruit tissues, loss of juice, formation of hesperidin crystals, loss in titratable acidity, and increase in pH in freeze-damaged oranges. Burdick (4) observed immediate evidence of freeze damage in the wet appearance of the central vascular bundles and albedo and evidence of dryness and translucence of juice sacs in both oranges and grapefruit. Later changes included drying or granulation and the formation of hesperidin crystals in oranges. Acidity as well as total juice content decreased. Bartholomew, Sinclair and Horspool (1) noted in addition to the loss of juice and acid a reduction in soluble solids, Moore, Rouse, Atkins, Huggart, and Barron (11) found less gelation and clarification in commercial concentrates prepared after the December 12, 1957 freeze than in similar products of the 1956-57 season. This was probably due to changes in processing methods. Westbrook (12) in working with freeze-damaged oranges found pectinesterase was not materially affected while the total pectins increased with degree of injury. High relative viscosities were found in concentrates of freeze-damaged Pineapple oranges while Valencia products had...
low values regardless of extent of freeze injury. Gelation and clarification occurred in concentrates of freeze-damaged Pineapple oranges even though the juice had been heated at 175° F. Heat stabilization of the juice of freeze-damaged Valencia oranges was not necessary. He reported heat treatments necessary to control physical stability of concentrates contributed to the development of off-flavors.

**Experimental Methods**

One block each of Parson Brown, Pineapple, and Valencia orange trees was selected as a source of fruit. The temperature in each of these blocks was known to have dropped to 25° F. or lower for a period of at least five hours on December 12, 1957. Each block consisted of a group of adjacent trees of the same age and size, growing on the same soil type, exposed to the same climatic conditions, and receiving the same cultural treatment.

Two to three harvestings of each variety were made at two-week intervals. Each lot of fruit harvested, consisting of 25-30 boxes of fruit of one variety, was taken directly to the laboratory, mechanically randomized, inspected for extent of freeze damage, and placed in 40° F. storage. All fruit were processed within three days following harvesting. The juice was extracted from units of 5 to 6 boxes, passed through a finisher, heat treated, and concentrated. Cutback was added to 42° Brix, oil added for flavor fortification, and the product canned and frozen for later analysis.

The percent of severely damaged fruit was determined on each lot of fruit by the method used by the Florida Department of Agriculture, Citrus and Vegetable Inspection Division at the time of harvest. When the first two pickings of Parson Brown and Pineapple oranges were made, damage was judged by the appearance of wetness of juice cells or translucence of the central vascular bundles in a cut at the stem end. When later harvests were made, dryness had developed and this property, as observed in a cut near the stem end, was used as the criterion.

Fruit which had experienced the same freezing conditions was separated into two portions according to the amount of damage shown in a center cut, extracted on a burr reamer, processed in a uniform manner and examined for differences in physical characteristics of single strength juices and 42° Brix concentrates and flavor of reconstituted juices. In some cases the fruit was hand reamed and in others the halves were placed in a Brown extractor. A Chisholm-Ryder Model F finisher was used in all cases. This experiment was performed at each of two harvests of Parson Brown and Pineapple oranges made one and three weeks after the December 12, 1957, freeze.

Another series of experiments was designed to test the effects of different finishing procedures on the quality of processed products. The finishers included a rotating 24-mesh screen, and Chisholm-Ryder Model F and Model C units. The Model F finisher is a small conical screen, screw type unit with a spring loaded orifice. This unit was equipped with a 0.027" screen. The Model C screw type finisher is larger and employs a cylindrical screen. This unit had been modified as described by Bissett and Veldhuis (2). Controlled pressure on a diaphragm at the end of the screw shaft was maintained by air. This permitted the annular pulp orifice to open or close in accord with the amount of pulp passing through. Air pressure settings of 4 and 6 pounds and screens of 0.020" and 0.038" openings were used. The Brown juice extractor was used in these experiments.

Tests for physical characteristics were made on single strength juices and 42° Brix concentrates and for flavor on reconstituted juices. The experiments were performed on all harvests of Parson Brown, Pineapple, and Valencia oranges.

The juice from each processing variable, except for a small portion for cutback purposes, was heat treated at 190° F. in a tubular heat exchanger in 6 seconds, and cooled to 60° F. in 3 seconds in a second heat ex-

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Table 1. Comparison of juices of fruits showing different degrees of internal freeze damage

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Brix</th>
<th>Citric acid, %</th>
<th>Brix-acid ratio</th>
<th>pH</th>
<th>Susp. solids, %</th>
<th>cloud</th>
<th>Peufal x 10⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parson Brown</td>
<td>Less</td>
<td>12.35</td>
<td>0.86</td>
<td>14.5</td>
<td>13.0</td>
<td>18.0</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>Damaged</td>
<td>12.25</td>
<td>0.76</td>
<td>15.5</td>
<td>13.8</td>
<td>19.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Pineapple</td>
<td>Less</td>
<td>9.65</td>
<td>0.60</td>
<td>16.2</td>
<td>14.0</td>
<td>18.0</td>
<td>44.8</td>
</tr>
<tr>
<td></td>
<td>Damaged</td>
<td>9.75</td>
<td>0.64</td>
<td>15.3</td>
<td>12.0</td>
<td>18.0</td>
<td>49.7</td>
</tr>
</tbody>
</table>

2The mention of trade products does not imply that they are recommended by the Department of Agriculture over similar products not mentioned.
Table II. Relationship of time between freezing and harvesting to extent of fruit damage, juice yield and juice characteristics

<table>
<thead>
<tr>
<th>Weeks after December 12, 1957</th>
<th>Parson Brown</th>
<th>Pineapple</th>
<th>Valencia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severely damaged, %</td>
<td>28</td>
<td>42</td>
<td>68</td>
</tr>
<tr>
<td>Juice yield, %</td>
<td>52.0</td>
<td>47.1</td>
<td>41.3</td>
</tr>
<tr>
<td>Brix °</td>
<td>12.2</td>
<td>12.5</td>
<td>11.1</td>
</tr>
<tr>
<td>Citric acid, %</td>
<td>0.90</td>
<td>0.74</td>
<td>0.59</td>
</tr>
<tr>
<td>Brix-acid ratio</td>
<td>13.7/1</td>
<td>17.0/1</td>
<td>19.2/1</td>
</tr>
<tr>
<td>pH</td>
<td>3.7</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Suspended solids, %</td>
<td>11.1</td>
<td>11.5</td>
<td>17.0</td>
</tr>
</tbody>
</table>

changer using circulating ice water. The juice was then concentrated in a falling film evaporator at 75° F. to 55° Brix and cut back to 42° Brix with unheated juice. Oil in the amount of 0.04% by volume was added to the concentrate. The product was canned and quickly frozen in an air blast at 0° F.

**Analytical Methods**

Yields were determined by maintaining a materials balance on a weight basis. The Brix of the juice was measured by refractometer; acid (as anhydrous citric) by titration with standard alkali; oil by distillation, and suspended solids by the method used by the U. S. Department of Agriculture in grading canned grapefruit juice. The pH was measured with a glass electrode. PE activity was determined by a modified method previously described by Bissett, Veldhuis, and Rushing (3); cloud by the method of Leoffler (8); total pectin by the method of McCready and McComb (9); soluble pectin by that of McComb and McCready (10); flavonoids by the Davis method (5); and gelation by the standard method for gel test (6). Viscosities were recorded as relative viscosity as measured by a Stormer viscosimeter at 70° F. using a 26 gram weight. The reconstituted juices were tasted by members of the staff for opinions of their general overall acceptability and the character of any off flavors present.

**Results and Discussion**

No flavor differences were noted in the products prepared from fruit which were halved and separated according to extent of physical damage, nor were differences observed in the physical characteristics as shown in Table I.

This series of experiments indicated that fruit which has experienced freezing conditions undergoes the same loss in quality regardless of the extent of physical damage shown in the cut fruit.

In every case juice yields decreased with increased time from freeze to harvest as is shown in Table II. All fruit for any one variety were from a single block of trees and the degree of fruit damage was the same for each lot of fruit processed. Freeze-damaged fruit continue to dry out following injury and under the system of grading appear to be more severely damaged with each subsequent processing date. This is seen in Table II where the amount of severely damaged fruit ranged upward from 28%.

Regulations of the Florida Citrus Commission, Lakeland, Florida, controlling use of fruit in the manufacture of frozen orange concentrate permitted a 5% tolerance of freeze-
damaged fruit from December 17 to 31, 1957; use of 15% severely damaged fruit from December 31, 1957, to January 3, 1958; and effective January 3, 1958, 25% severely damaged fruit was permitted. It is therefore, apparent that neither the Parson Brown nor Pineapple oranges were acceptable for the manufacture of frozen concentrated orange juice.

Valencia variety oranges, immature at the time of the December 12 freeze, were of acceptable maturity late in April. When the first harvest was made, the regulations permitted the use of fruit yielding 40 pounds or more of juice per 90-pound box. Visual observations for severely damaged fruit were no longer used as criterions of acceptance. When the second harvest was made, the minimum yield had been reduced to 35 pounds per box. The Valencia oranges of both harvests met requirements as shown in Table II.

The characteristics of juices extracted from Parson Brown oranges one, three, and five weeks after freezing are presented in Table II. The Brix value of the juice did not change between the first and third weeks but was found to be considerably lower five weeks after freezing. The citric acid content decreased at a rather constant rate during the processing period. During this period there was an increase in Brix-acid ratio, pH, and suspended solids in the juices.

The characteristics of the juices of Pineapple oranges did not change materially during the period between harvests one and three weeks after freezing as shown in Table II. There was some reduction in juice yield and increase in suspended solids content of the juice.

The Valencia oranges were immature at the time of the December 12 freeze and processing was delayed until tests showed a Brix-acid ratio of 13 to 1 had been attained. During the two-week interval between processings there was a reduction in juice yield, loss of acid, and increase in Brix-acid ratios as shown in Table II.

Juice yields varied also with the method of finishing as shown in Table III. The lowest average yield of 39.3% was obtained when using a rotating 24-mesh screen and the highest yield of 47.2% when using a Model C finisher equipped with an 0.020" screen and operating at a 6-pound pressure setting. The finisher combination of a Model C and an 0.033" screen at 4-pound pressure setting produced a yield only slightly greater than that of the rotating screen, yet when this unit was used at a 6-pound setting, the yield compared

<table>
<thead>
<tr>
<th>Finisher</th>
<th>Screen opening</th>
<th>Pound setting</th>
<th>% Juice yield</th>
<th>Pectinesterase (PBU/ml x 10^4)²/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary screen 24-mesh</td>
<td>-</td>
<td>39.3</td>
<td>32.8</td>
<td>22.6</td>
</tr>
<tr>
<td>Model C</td>
<td>0.033&quot;</td>
<td>4</td>
<td>41.0</td>
<td>28.8</td>
</tr>
<tr>
<td>Model C</td>
<td>0.020&quot;</td>
<td>4</td>
<td>46.0</td>
<td>37.8</td>
</tr>
<tr>
<td>Model C</td>
<td>0.020&quot;</td>
<td>6</td>
<td>47.2</td>
<td>36.9</td>
</tr>
<tr>
<td>Model C</td>
<td>0.033&quot;</td>
<td>6</td>
<td>47.0</td>
<td>46.9</td>
</tr>
<tr>
<td>Model F</td>
<td>0.027&quot;</td>
<td>-</td>
<td>46.6</td>
<td>54.0</td>
</tr>
</tbody>
</table>

1/ Average - all varieties, all dates
2/ Average - all dates
very closely with that of the 0.020" screen at the 6-pound setting. Yields were slightly lower when using either the Model C finisher equipped with an 0.020" screen operated at a 4-pound setting or the Model F finisher fitted with an 0.027" screen.

Pectinesterase activity in extracted juices varied with juice finishing methods and variety of fruit. As will be seen in Table III, the PE increased with increased yields except that juices processed in the Model F finisher had the highest PE activity. At times during the operation of this finisher, fruit pulp and rag would become temporarily complicated in the exhaust port probably creating abnormal internal pressures. This condition may have contributed to the increase in the PE content of the extracted juice. Pectinesterase activity was greatest in juices of Parson Brown oranges and lowest in those of Valencias.

The total pectin content of the concentrates varied with finisher practices. Similar values were obtained for each variety finished in the rotating 24-mesh screen and the Model C unit at a 4-pound pressure setting as shown in Table IV. Somewhat higher values were found when the juices had been finished in the Model C unit at a 6-pound setting while the highest total pectin values were in juices finished in the Model F unit. Under similar processing procedures, the total pectin contents of juices of Parson Brown and Pineapple oranges were comparable. Similar Valencia products contained less pectins. No relationship could be demonstrated between time of harvesting following freezing and the pectin content of the prepared concentrates. Soluble pectin values account for half to two-thirds the total pectin present. Differences in soluble pectin due to processing methods were less consistent than those for total pectins.

In general, the relative viscosity values of the concentrates increased with increased finisher pressures as shown in Table V. Orange juices of any one variety finished in a rotating 24-mesh screen or a Model C unit at a 4-pound setting produced concentrates having similar viscosities. Values were somewhat higher in concentrates which had been finished at a 6-pound setting. Again as was the case with both PE and pectin values, the viscosities of concentrates processed in the 0.027" screen of the Model F finisher were much higher than when other finishers were used. Concentrates of Pineapple oranges had the highest relative viscosities while those of Valencias were lowest. There was no consistent trend between the time of processing following freezing and the viscosity of the prepared concentrates.

Flavonoid values of the concentrates did not vary widely with either processing procedure or fruit variety as shown in Table VI. Products finished in the Model F unit contained somewhat more flavonoids than those of the other finishing procedures. Pineapple orange concentrates had somewhat higher flavonoid values than those of either Parson Brown or Valencia oranges processed in a similar manner. There was no evidence of change in flavonoid values with delay in harvesting following freezing.

Flavor evaluations of the prepared frozen concentrates indicated that none were equal to that expected of fully mature undamaged fruit. With the exception of Valencia concentrates there was a deterioration in flavor with both increased juice yield and time of processing from freezing.
Parson Brown concentrates prepared one week after freezing were of acceptable flavor except for those finished in the Model F unit which were considered poor. When fruit of this variety was processed three weeks after freezing only concentrates of juices finished in the rotating 24-mesh screen were of acceptable flavor, while all Parson Brown concentrates processed five weeks after freezing were of poor flavor.

Pineapple orange concentrates processed one and three weeks after freezing were rated not acceptable in flavor. Products finished in the rotary screen were rated least objectionable and those finished in the Model F unit the poorest in flavor.

The flavors of all Valencia concentrates were considered to be fair to good with little if any differences being associated with juice finishing practices or time of processing.

Samples of all concentrates were placed in 40° F. storage and re-examined for flavor after one week. There was a marked deterioration in flavor of all Parson Brown and Pineapple products. Very little flavor change was observed, however, in Valencia concentrates.

The concentrates were tested for cloud stability both in 40° F. storage for periods up to one week and by the five-hour treatment at 105° F. All products retained an excellent cloud during these abuse tests.

Tests for gelation included a three-hour treatment at 105° F. and a 24-hour incubation at 80° F. Gelation was observed by both methods in concentrates of Parson Brown and Pineapple oranges which had been processed through the Model F finisher, but none in products of other finishers. No gelation was observed, however, in Valencia concentrates.

The concentrates were acceptable under the regulations and were considered to be fair to good with little if any differences being associated with juice finishing practices or time of processing.

LITERATURE CITED