SANITATION IN A CITRUS CONCENTRATE PLANT

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The most unprecedented development ever observed in the food industry is that of frozen concentrated orange juice which was first produced commercially in Florida during the 1945-46 season. The product was quickly accepted by consumers who were attracted by its convenience and by its flavor which closely resembled that of fresh orange juice. The demand accelerated the first season’s production of 226,000 gallons to 21,647,000 gallons by 1949-50, and to about 75,000,000 gallons in 1956-57, of which 72,-000,000 were produced in Florida. In addition, Florida produces nearly 4,500,000 gallons of various other citrus concentrates annually. There are now 28 concentrate plants in Florida which utilize nearly 60% of the orange crop annually. To do this, the plants must operate 24 hours a day and 6 to 7 days a week during the five peak months of citrus production.

This tremendous increase in volume has created numerous sanitation problems, primarily because these frozen concentrates are a non-sterile food product. Recognition of this fact has led to establishment of superior sanitary standards and the use of the most modern equipment and processes. For example, after leaving the fruit extractors, juice is handled entirely in stainless steel equipment and is not touched by human hands. Equipment is designed for easy cleaning and is readily accessible. The floors of plants are constructed of cement or tile and metal is employed for construction instead of wood wherever practical. In-plant chlorination of water is normal practice as is use of highly chlorinated water for sanitizing after clean-up.

For the benefit of those who have never visited a citrus concentrate plant, the following is a brief description of the processing of frozen orange concentrate. At most plants fruit is received by truck, dumped on to a conveyor system, graded for maturity and soundness, stored in bins, washed, regraded and sanitized prior to entering the extractors. Juice leaving the extractors passes through a series of finishers which removes the seeds and pulp. Product prior to entering the evaporators is pumped to large storage tanks which are either held under atmospheric pressure or vacuum. In the evaporators juice is concentrated to the desired solids content, measured as Brix. It is also flash heated either as it enters the evaporators or early in the process of concentrating to reduce enzyme activity and thus retard separation and gelation. The concentrate then enters the blending tanks where it is mixed with fresh juice to replace some of the volatile constituents which were lost during evaporation. The blended (42° Brix) product is either pumped through Votators where it is slush-frozen, or to cold wall tanks. The chilled or semi-frozen concentrate is then held in holding tanks prior to filling into cans. The finished, canned concentrate is quick-frozen in a blast or alcohol freezer, cased and stored in a cold storage warehouse at 0 to -10°F. until shipped through commercial channels to the market.

Due to the magnitude of the subject, this paper will be restricted to a discussion of the more common sources of bacterial contamination encountered in processing orange concentrate. Also to be discussed are cleaning procedures employed by Minute Maid, and biological methods used to detect microbial growth during processing operation.

Microorganisms Found in Frozen Citrus Products

Fortunately, the pH values of citrus concentrate, which average from 3.4 to 4.0, (4, 18), limit the growth of microorganisms to those capable of tolerating this acid medium. Organisms known to grow in single strength juices of these acid foods (not including lemon or lime juice) are lactic acid and acetic acid bacteria, yeasts, and molds. Of this group, organisms belonging to the genera Lactobacillus and Leuconostoc are of prime concern to bacteriologists. Lactic acid bacteria have been frequently implicated in the production of abnormal flavors and odors in concentrates, among which are those described as being similar to “buttermilk” (7, 8, 16). The principal species associated with this type of spoilage are Lactobacillus brevis and plantarum and Leuconostoc mesenteroides and dextranicum (7). Acetic acid bacteria, yeasts, and molds, on the other hand, generally do not grow rapidly enough to build up large populations under conditions that normally prevail during concentration of the juice. Coliform bacteria and related types (e.g. Erwinia) are frequently present on/or in oranges even before they are harvested (20, 21). Furthermore, laboratory tests have demonstrated that coliform organisms sometimes are present in orange juice in spite of rigorous aseptic care in harvest and regardless of the amount of aseptic washing given the fruit before extraction (1, 5). Routine tests made in a number of Florida plants have shown a very low incidence of coliform bacteria in orange concentrate (20, 21). Analysis of these studies shows a very high percentage
of false positive reactions occur in Florida and California (20, 21, 22, 23). Martinez and Appleman (10) also have encountered false positive coliform reactions caused by yeasts. The unreliability of these standard coliform tests as applied to citrus has been shown by Wolford (24, 25) to result from the natural fermentable constituents of orange juice transferred to the test medium with the inoculum.

There are no data to indicate that coliform bacteria actually grow in citrus juices. On the other hand, there is considerable evidence to show that coliform bacteria can retain their viability for extended periods in frozen orange concentrate, but die off rapidly in fresh or reconstituted juices (5, 6, 19). It is the opinion of Dack (5) and others (20, 21) that the coliform organisms are of no public health significance in frozen citrus products. It is also the opinion of Vaughn, et al. (20, 21) that the coliform index of frozen concentrate is of no value for detecting possible fecal contamination that might contain Salmonella species; especially when product has been stored before placement in commercial channels, since Salmonella and Shigella types cannot survive for sufficiently long periods in the acid environment of citrus juices or concentrates; nor can the spores of Clostridium parabotulinum, types A and B, germinate, even though they may be present.

### Fruit Grading

The soundness of fruit entering the extractors is so important in controlling final product quality that proper grading of fruit cannot be too strongly stressed. If unsound fruit composed of a large percentage of drops, soft deteriorated spots, splits, etc. is permitted to enter the extractors it not only contaminates juice room equipment and evaporators, but may also result in “stale” or “old fruit” flavors in the finished product. For this reason fruit is carefully graded before entering the bins and again before the extractors. In the initial operation unsound fruit received at the plant is sorted out, and fruit damaged in the bins removed by the final graders. In a previous study (15) it was found both fruit surfaces and extracted juice from splits and deteriorated fruit were heavily contaminated with microorganisms, as indicated in data presented in Table 1. It is quite obvious from

### Table 1 — Microflora on the surfaces and in the extracted juice of sound and defective fruit

<table>
<thead>
<tr>
<th>Type of Fruit</th>
<th>Contamination on fruit surfaces</th>
<th>Contamination of extracted juice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total microflora per orange</td>
<td>Total microflora per ml.</td>
</tr>
<tr>
<td></td>
<td>Test 1</td>
<td>Test 2</td>
</tr>
<tr>
<td>Sound Fruit</td>
<td>74,000</td>
<td>500</td>
</tr>
<tr>
<td>Drops</td>
<td>64,000</td>
<td>855,000</td>
</tr>
<tr>
<td>Splits</td>
<td>113,700,000</td>
<td>21,400,000</td>
</tr>
<tr>
<td>Deteriorated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit</td>
<td>3,250,900</td>
<td>44,200,000</td>
</tr>
</tbody>
</table>

these results that if defective fruit is not removed from the line by final graders it will readily “seed” juice extracted from sound oranges.

### Extraction of Fruit and Preparation of Juice for Concentrate

Up to this point we have discussed the need for microbial control when fruit enters the processing plant. Unless an efficient sanitation program is maintained, microorganisms harbored on fruit surfaces will seed juice extraction and/or handling equipment.

### Extractors and Juice Lines

There are two principal types of commercial juice extractors used by the frozen concentrate orange juice industry; namely—Brown (Brown Citrus Machinery
Company) and the F.M.C. In-line (Food Machinery Corporation). Both machines are satisfactory from a sanitation standpoint if cleaned properly.

Juice from the extractors is conveyed by gravity to the finishers either by a 4-inch stainless steel tube or by means of a juice trough. Unless sanitary precautions are adhered to, slime and/or citrus solids will build up on the inner walls of the tube, and covers and sides of the juice trough, resulting in a source of contamination. To minimize microbial build-up from these sources in our plants, extractors, product header lines and troughs are flushed with chlorinated water at 4-hour intervals. Effect of this type of intermittent cleaning will be discussed in another section of this paper.

**Dead Ends**

A dead end occurs where a product flows into an area without an outlet. Sanitarians are on a constant lookout for dead ends which may be found in any part of the piping system in a plant. A few years ago they were not uncommon in juice troughs and header lines. Juice in these areas, being stagnant, becomes a medium for microbial growth and product coming in contact with it is readily seeded with microorganisms. The potential build-up that may occur from a dead end is shown in Table 2 (14). A similar area of stagnation also occurs in juice troughs and header lines when extractors farthest away from the finishers are shut down due to inadequate fruit supply. Extractors removed from the line for any length of time should be thoroughly flushed with chlorinated water.

**Finishers**

A standard screw-type finisher is usually used in removing seeds and pulp from the juice. This process provides one of the major sources of contamination. Generally speaking, a finisher is a difficult piece of equipment to keep in a sanitary condition. It contains areas that are not readily accessible, especially the discharge end of the first finisher and pulp enclosure between the two units in a double finisher installation. It was found, in one plant, that pulp adhering to the walls of the finisher would sour in approximately 6 or 7 hours if not removed during the intermittent cleaning operation. Citrus solids and hesperidin continually build up on finisher screens. To eliminate this source of bacterial build-up, they are changed at least once every 8 hours, or more frequently if required.

**Juice Holding Tanks**

Juice after leaving the finishers is held in one or more holding vessels either under atmospheric pressure or vacuum prior to entering the evaporators. These tanks may range from a few gallons to several thousand gallons in capacity. Product carried under vacuum usually is deaerated prior to entering the tank.

Holding vessels, especially those where juice is held under atmospheric pressure, require periodic cleaning to prevent them from being a source of contamination. In some installations, not under vacuum, foam readily forms on the surface of the juice. When this occurs, special precautionary measures should be taken to minimize microbial growth. Draining the tank and flushing with chlorinated water may not suffice unless all foam is removed from the vessel in one operation. A sizeable bacterial build-up resulted in evaporator feed juice in one plant (14) where this was not done during the intermittent cleaning period, as data in Table 3 indicate.

**Table 2 — Bacterial Contamination from Dead End in Juice Trough**

<table>
<thead>
<tr>
<th>Date</th>
<th>Juice from extractor next to dead end (per ml)</th>
<th>Juice from dead end in juice trough (per ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 28</td>
<td>2,800</td>
<td>470,000</td>
</tr>
<tr>
<td>Feb. 3 (AM)</td>
<td>25,000</td>
<td>51,000</td>
</tr>
<tr>
<td>Feb. 3 (PM)</td>
<td>23,000</td>
<td>77,000</td>
</tr>
<tr>
<td>Feb. 4</td>
<td>3,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Feb. 6</td>
<td>27,000</td>
<td>106,000</td>
</tr>
</tbody>
</table>

**Table 3 — Contamination of Juice in Evaporator Feed Tank with Excess Foam Build-up**

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Juice entering Tank (per ml)</th>
<th>Product leaving Tank (per ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>144,000</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>816,000</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>420,000</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>200,000</td>
</tr>
</tbody>
</table>

*Data obtained over a 2-day period.

Deaerated evaporator feed juice may also be a source of contamination when the system is not functioning properly so as to cool the juice (14). Table 4 shows bacterial build-up which occurred over a 4-day interval when difficulty was encountered in operating the system. The vacuum tank had a sour odor when examined after a run of approximately 96 hours. Table 5 shows that little or no increase in contamination of deaerated evaporator feed juice occurred during a period when the tanks were working properly (temperature range 49-60°F.) (14).
Table 4 - Contamination of Deaerated Evaporator Feed Juice
(Vacuum Tank Not Functioning Properly; Usually Operates at 55°F.)

<table>
<thead>
<tr>
<th>Date</th>
<th>Juice entering vacuum tank (per ml)</th>
<th>Juice leaving vacuum tank (per ml)</th>
<th>Temp. (°F) range of juice leaving tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 15</td>
<td>11,000</td>
<td>32,000</td>
<td>47 - 70</td>
</tr>
<tr>
<td>Jan. 16</td>
<td>25,000</td>
<td>77,000</td>
<td>68 - 72</td>
</tr>
<tr>
<td>Jan. 17</td>
<td>21,000</td>
<td>110,000</td>
<td>60 - 68</td>
</tr>
<tr>
<td>Jan. 18</td>
<td>24,000</td>
<td>371,000</td>
<td>67</td>
</tr>
</tbody>
</table>

*Vacuum Tank not flushed or cleaned during processing period.

Table 5 - Contamination of Deaerated Evaporator Feed Juice during Period When Vacuum Tank Is Operating Properly

<table>
<thead>
<tr>
<th>Date</th>
<th>Juice entering vacuum tank (per ml)</th>
<th>Juice leaving vacuum tank (per ml)</th>
<th>Temp. (°F) range of juice leaving tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 19</td>
<td>1,000</td>
<td>2,000</td>
<td>51</td>
</tr>
<tr>
<td>Jan. 20</td>
<td>3,700</td>
<td>5,000</td>
<td>57 - 60</td>
</tr>
<tr>
<td>Jan. 21</td>
<td>1,000</td>
<td>4,000</td>
<td>56</td>
</tr>
<tr>
<td>Jan. 22 (AM)</td>
<td>1,000</td>
<td>3,000</td>
<td>49 - 54</td>
</tr>
<tr>
<td>Jan. 22 (PM)</td>
<td>13,000</td>
<td>15,000</td>
<td></td>
</tr>
</tbody>
</table>

*Vacuum tank not flushed or cleaned during processing period.

Centrifuge

The centrifuge, which is usually associated with the dairy industry, is beginning to find some application in the removal of pulp solids from orange juice prior to entering the evaporators. Bacteriological studies made in two plants have shown that the centrifuge can be operated continuously up to 24 hours after cleaning without becoming a serious source of contamination. It was also noted that after the unit has been cleaned, juice leaving the centrifuge for the first 8-12 hours is usually lower in microflora than product entering. The opposite is generally true after longer periods of operation.

Stabilizer

As previously stated, stabilizing, the term employed to designate use of heat to treat juice, is usually accomplished by flash heating the product either as it enters the evaporators or early in the process of concentration. Temperatures ranging from 150°-190°F. are employed, with holding times of 2 to 15 seconds followed by rapid cooling within the exchangers or by flashing the juice to the evaporators. Under normal operating conditions this type of heat treatment results in an 80-99% reduction in bacterial population (12). It was found (12) where a plate heat exchanger is employed to heat the juice that, from time to time, instead of a reduction in bacterial counts after heat treatment an actual increase resulted (Table 6). A further investigation showed that the regenerative section of the unit was the source of bacterial build-up. The contaminating organism was isolated and identified to resemble closely Lactobacillus buchneri. Optimum conditions for growth of the organisms in orange juice were in the Brix range of 12 to 20° at temperatures between 110°-120°F. At 78°F, it grew at a much slower rate, and at 130°F, no growth occurred.

Control of this type of contamination can be accomplished in a number of ways, some of which are: (a) eliminate any regenerative or cooling section of the heat exchanger operating in the critical temperature range (approximately 100°-120°F.) and flash juice directly into next stage of evaporation; (b) clean stabilizer thoroughly every 4 to 6 hours; (c) cool juice, after heating, to a temperature above the growth range of the organism; and (d) stabilize juice above 30°C Brix.

Evaporators and Finished Product

The evaporators, which are of various designs, are operated under high vacuum and low temperatures (approximately 65-80°F.) Juice is concentrated to the proper degree Brix, and up to 75% of the water may be removed. It has been our experience that evaporators are not a potential source of contamination, providing they are properly cleaned and have not been on the line for extended periods of time. In our plants they are generally operated between 60 to 80 hours, then shut down and thoroughly cleaned.

Subsequent processing equipment consisting of blending tanks, Vocators, and filler bowls are not a source of contamination during operating periods, since concentrate in these units is usually in the tem-
perature range of 25°F. to 30°F. Of interest here, is a brief reference to Minute Maid's exclusive new development which involves use of inert gas to protect juice from air during the entire process. Air has been found to harm flavor of frozen concentrate and shorten its storage life. While not necessarily a function of sanitation, this development is an important step forward in improvement of flavor quality of frozen concentrates.

Finished canned product (42° Brix), due to stabilizing and the high sanitary standards followed by the industry, has a very low level of bacterial contamination. Our orange concentrate, for example, had an average count during 1957-58 season of less than 10,000 microorganisms per ml. (see Table 7).

Table 7 - Finished product counts for orange concentrate (42° brix) for 1957-58 season

<table>
<thead>
<tr>
<th>Month</th>
<th>Plant No. 1 Av. per ml*</th>
<th>Plant No. 2 Av. per ml*</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>700</td>
<td>300</td>
</tr>
<tr>
<td>January</td>
<td>1,000</td>
<td>2,900</td>
</tr>
<tr>
<td>February</td>
<td>800</td>
<td>1,500</td>
</tr>
<tr>
<td>April</td>
<td>1,200</td>
<td>2,400</td>
</tr>
<tr>
<td>May</td>
<td>5,200</td>
<td>3,200</td>
</tr>
<tr>
<td>Average for Season</td>
<td>1,600</td>
<td>2,100</td>
</tr>
<tr>
<td>Number of Samples Examined</td>
<td>307</td>
<td>331</td>
</tr>
</tbody>
</table>

*All counts are the number of microorganisms per ml. of reconstituted juice using orange serum agar as the plating medium at 30°C. for 48 hours.

Cleaning and Sanitizing

If good quality is to be maintained in the production of a highly perishable product such as frozen orange concentrate, it is essential that it be protected from contamination by microorganisms. Microbial growth, if not controlled by an effective cleaning program, may result in yeasty, fermented, and buttermilk flavors in the finished product. To minimize contamination from microorganisms, the frozen citrus concentrate industry has established a highly efficient sanitation program (2). The approach to the problem may vary from plant to plant but the basic fundamental sanitary principles are more or less followed throughout the industry.

Minute Maid, for example, has established a definite cleaning program which may be broken down into component parts:

1. Continuous cleaning which is necessary to maintain good appearance.

2. Intermittent type cleaning while plant is in operation, or cleaning parts of the plant temporarily taken out of production for long enough periods to clean them properly.

3. General clean-up which occurs when the plant is completely shut down.

The necessary tools have also been provided to accomplish the clean-up in a minimum of time with a minimum of effort. High-pressure cleaning systems have been installed in our plants. The use of jet detergent guns in conjunction with this system permits the cleaning of inaccessible areas more quickly and thoroughly than is possible with other available equipment (13). Water hoses have been equipped with nozzles designed to produce sprays for general washing and flushing purposes. Detergent hoses are also available for cleaning the equipment. In-place cleaning systems (C. I. P.), which greatly improve the efficiency of cleaning, have been installed in some of our evaporators. In the citrus concentrate industry there are two basic methods used to clean the evaporators (17). In our installations the flooding principle is used for cleaning that is, the surface is flooded with solution under low pressure. The other type depends upon a rotary sprayer which applies detergent solution to the surface being cleaned. Both methods are effective cleaning tools. The type selected depends upon evaporator design and individual preference.

After each clean-up the entire plant is inspected to insure the equipment is in proper sanitary condition. Prior to start of operations all processing equipment is sanitized by circulating chlorinated water, having a minimum concentration of 25 p.p.m., for at least 15 minutes before rinsing with clear water.

Great care is taken in the selection of detergents for the specific cleaning job involved; i.e., mild alkaline detergents for use in hose, and for equipment subject to corrosion by highly alkaline materials, and highly alkaline detergents or caustic solutions for cleaning evaporators, and for circulating in pipelines which are not dismantled during cleaning. New cleaning agents are also continually being tested throughout the processing season. For example, this season we are using, for the first time, a chelated-type caustic which is proving very effective for cleaning the evaporators.

During processing operations chlorinated water flushes are used at periodic intervals to control microbial contamination in juice extraction equipment, header lines, or juice troughs, finishers, fresh juice tanks, etc. This intermittent type of cleaning, which is believed generally employed by the industry, consists of back-flushing this equipment every 4 hours with chlorinated water of approximately 25 p.p.m. from the plant surface water supply. Chlorinated water flushing is a very effective means of controlling bacterial contamination. In one study, where samp-
les of juice were plated prior to and just after this type of cleaning, a reduction in total counts ranging from 35-62% was obtained (13).

Detection of Contamination by Laboratory Methods

Data have been presented to show several specific sources of contamination. The effect of a routine sanitizing program to control bacterial activity has been discussed. However, during a processing run a bacterial build-up may occur due to poor fruit, undetected source of microbial growth, laxity in cleaning, or a combination of factors which may result in seeding the plant and ultimately causing spoilage if not immediately detected.

Diacetyl and Microscopic Tests

Diacetyl and microscopic tests, which require less than an hour to perform, have been developed as a rapid procedure for the detection of microbial activity in processing orange or grapefruit concentrate (3, 9, 14). The diacetyl test is a colorometric method for the detection of diacetyl, and acetylpropionic acid in orange juice principally by organisms belonging to the genera *Lactobacillus* and *Leuconostoc*.

The microscopic method (direct count) requires the examination of a stained film of dried juice under a high-powered oil immersion objective. This procedure shows total microflora in a sample examined. In our plants the microscopic method is used for evaporator feed juice, and diacetyl procedure is employed for concentrate and cutback juice. Finished product is not routinely analyzed. These tests are made during processing operation every 4 hours. A steady increase in microscopic count or diacetyl concentration indicates a bacterial build-up. When this occurs an inspection of the plant is made and the source of contamination eliminated as soon as possible.

Plate Counts

Plate counts, the method used by the dairy industry to determine the total number of viable organisms in a product is also employed by the concentrate processors. The plates are counted after 48 hours of incubation at 30°C on orange serum agar (pH 5.4). In our plants samples of juice from various processing operations are plated. These tests, usually referred to by the citrus industry as “line checks,” are made just before the plant is shut down for cleaning and again shortly after it is placed in operation. The finished product, on the other hand, is plated every third hour of production.

By following the biological control methods discussed, we have been able to detect microbial build-up in our processing operations, sources of contamination, and determine the efficiency of each clean-up. These procedures have also been highly successful in preventing spoilage of our product.

Summary

Lactic acid bacteria constitute the most important index of processing sanitation in the production of high quality frozen citrus products. Coliform bacteria are indicative of no apparent public health hazard in frozen citrus concentrates, partially concentrated, or single strength citrus juices.

The brush washer and chlorinated water rinses effectively reduce fruit surface contamination. The effectiveness of these sanitizing operations is minimized, however, if subsequent fruit handling equipment is not kept in a sanitary condition. Slimy fruit sizers and conveyor belts, especially those in the juice room, are all contributing factors.

Defective fruit not removed in the final grading operation is heavily contaminated with microorganisms, both externally and internally. An efficient fruit grading system is essential to prevent seeding juice extracted from sound oranges.

Information is presented to show that extractors, juice lines, finishers, and juice holding tanks can be potential sources of contamination if not kept in a sanitary condition. Evaporators, blend tanks and filler bowls are not a potential source of bacterial build-up providing this equipment is properly cleaned and not operated for extended periods.

Proper tools are necessary to maintain an efficient sanitation program which includes both cleaning and sanitizing operations.

Data are presented to show that direct microscopic examination and diacetyl tests, on the product in process, are very important tools in detecting microbial activity during periods of trouble. Total viable count is also an important instrument in the over-all biological control program.

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Literature Cited


