DETERMINATION OF THE PULP CONTENT OF CONCENTRATED CITRUS JUICES[1]

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The amount of pulp in concentrated citrus juice influences a number of characteristics of the product. Olsen, Huggart and Asbell (4), showed that the pectinesterase activity causing objectionable clarification and gelation in concentrated juice is proportional to the pulp content. One problem in the commercial production of citrus concentrates is the lack of a reliable method for measuring pulp content. The purpose of this investigation was to compare and evaluate various methods for determining the quantity of pulp.

In the commercial manufacture of frozen concentrated citrus juices, pulpy cut-back juice is mixed with 55° Brix concentrate, as described by MacDowell, Moore, and Atkins (3), to give the finished 42° Brix product sufficient fresh fruit aroma and flavor, as well as to provide the juice sacs which give reconstituted juice the appearance of freshly squeezed juice. The pulp in citrus concentrate is a heterogeneous mixture of large and small particles of soluble and insoluble materials, originating chiefly from the juice sacs, albedo, or rag of the fruit. The total pulp in the product consists of both the fine pulp particles from the 55° Brix concentrate and the coarse pulp particles from the pulpy cut-back juice.

A centrifugal method (5), described by the Production and Marketing Administration of the U.S.D.A., for determining the percentage by volume of free and suspended pulp in canned concentrated orange juice has been in use for many years. Heid and Nielsen (2) briefly mention a method, used in commercial plants for determining the coarse pulp in a concentrate, in which the product is strained through a tea strainer with 0.04 inch openings in the mesh and the pulp rinsed, collected, and weighed.

EXPERIMENTAL PROCEDURE

Frozen concentrated citrus juices used for this investigation consisted of packs processed in the pilot plant at the Citrus Experiment Station and samples of commercial concentrates purchased at retail stores.

The *coarse* pulp content of the various concentrates was determined by a flotation method similar to that previously described by Olsen, Huggart, and Asbell (4). In this method the contents of a 6-ounce can of concentrate are weighed, placed upon a sieve and then thoroughly washed with tap water for exactly five minutes. The brass U.S. Standard Sieve No. 60 used has a diameter of approximately five inches and screen openings of 0.0098 in. or 0.250 mm. The coarse pulp retained on the sieve is next washed into a 250 ml. graduated cylinder containing 10 g. of C.P. NaCl and diluted with water to 250 ml. After being inverted several times to dissolve the salt, the cylinder is allowed to stand for exactly five minutes to allow the pulp to float to the surface of the salt water, and then the volume of the coarse pulp is read. The results are reported as milliliters of pulp per 100 grams of concentrate.

The *total* pulp content, by volume, of the concentrates was determined by the centrifugal method (5) with modifications in respect to the handling or treatment of the samples prior to or after reconstitution. In this method concentrate is thawed as rapidly as possible by immersing the can in running tap water. The heterogeneous pulp particles in the product then are sized uniformly by using either a Waring Blendor for three minutes or an Eppenbach colloid mill set to a clearance of 0.005 inch. The concentrate is then reconstituted on the basis of 30 g. per 100 ml. of reconstituted juice and the pulp content determined after centrifuging 50 ml. portions of the juice. The concentrate is reconstituted by weight rather than by volume since air is incorporated into the product when either the Waring Blendor or the colloid mill is used. The presence of air in the concentrate makes volume measurement difficult unless it is deaerated, which requires additional time.

The water-insoluble solids in the concen-

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trates were determined by the A.O.A.C. method (1) for fruits and fruit products in order to establish the relationship between insoluble solids and the pulp content of the concentrates, as measured by the different methods. Prior to the application of the A.O.A.C. method, pulp particles were sized by passing the concentrate through the colloid mill set to a clearance of 0.005 inch.

Experimental Results and Discussion

The pulp content of six commercial frozen concentrates, as determined by different methods, is shown in Table 1. There is no correlation between the results obtained by the centrifugal and flotation methods. When the pulp particles in the reconstituted juice were uniformly sized by mixing in the Waring Blendor for three minutes, the percentage of pulp by volume was lower than when the pulp particles were not sized prior to centrifuging.

TABLE 1

PULP CONTENT OF COMMERCIAL FROZEN CITRUS CONCENTRATES AS DETERMINED BY DIFFERENT METHODS

Sample No.	Type	Centrifugal Method: Pulp Content of Reconstituted (1:3) Juice—% by volume		Flotation Method: Coarse Pulp in Concentrate
		Waring Blendor Used		ml./100 g.
		No	Yes[1]	
C-1	Orange	7.5	5.5	13
C-2	Orange	8.0	6.0	18
C-3	Orange	9.0	5.5	9
C-4	Orange	9.0[2]	6.0	26
C-5	Grapefruit	5.0	4.0	8
C-6	Grapefruit	6.0	5.0	13

1—Reconstituted juice in Waring Blendor for 3 minutes to size pulp particles, then deaerated before centrifuging to prevent pulp from floating.
2—Pulp floating in centrifuge tube not included.

Deaeration of the reconstituted juice is necessary when the Waring Blendor is used to prevent the pulp from floating in the centrifuge tube. Centrifuge tubes also should be checked for accuracy of calibration, since deviations as great as 28 percent have been found in certain types of these tubes as purchased. Pulp determinations should also be made immediately after thawing the concentrate because on standing slight gelation and clarification of the concentrate may occur and then erroneous results will be obtained.

Pulp determinations by different methods, using samples from six experimental packs of frozen Pineapple orange concentrates containing different amounts of pulp, are reported in Table 2. When the pulp particles were not sized by the use of either the Waring Blendor or the colloid mill, floating pulp in the centrifuge tubes made an accurate determination of the pulp content impossible. The tendency of the pulp to float increased with the pulp content, and deaeration of the reconstituted juice was often necessary to avoid the presence of floating pulp. Lower values were obtained in all cases when the pulp particles were sized and the amount of pulp in the centrifuge tube was also more easily read. Sizing of the pulp particles in the concentrate by using either the Waring Blendor or the colloid mill gave approximately the same values for the pulp content. As the amount of total pulp or coarse pulp, as determined by the centrifugal or flotation methods, increased in these samples, so did the quantity of water-insoluble solids.

Data presented in Table 3 show the pulp content of five samples of commercial frozen

TABLE 2

PULP CONTENT OF EXPERIMENTAL PACKS OF PINEAPPLE ORANGE CONCENTRATE AS DETERMINED BY DIFFERENT METHODS

Sample No.	Centrifugal Method: Pulp Content of Reconstituted Juice—% by vol.						Flotation Method	Water-Insoluble Solids in Reconstituted Juice
	Reconstituted 1:3 by Volume				Reconstituted 30 g./100 ml. after Concentrate in		Coarse Pulp in Concentrate	
	In Centrifuge Tube			Waring Blendor 3 min.	Waring Blendor 3 min.	Colloid Mill 0.005 in.	ml./100 g.	% by Weight
	Top[1]	Bottom	Total					
E-1		9.0	9.0	6.5[2]	7.5	7.0	6	0.116
E-2	4.0	9.0	13.0	7.0[2]	8.0	8.0	20	0.139
E-3	8.0	9.0	17.0	8.5[2]	10.0	9.5	36	0.154
E-4	10.0	8.5	18.5	9.0[2]	10.0[2]	11.0[2]	58	0.173
E-5	8.0	11.0	19.0	11.5[2]	10.5[2]	12.0[2]	67	0.212
E-6	6.0	13.5	19.5	12.0[2]	13.0[2]	14.0[2]	75	0.283

1—Floating pulp loosely packed and difficult to estimate making determination of total pulp inaccurate.
2—Reconstituted juice deaerated to prevent pulp from floating.

TABLE 3

PULP CONTENT OF COMMERCIAL FROZEN CITRUS CONCENTRATES AS DETERMINED BY DIFFERENT METHODS

Sample No.	Type	Centrifugal Method — Pulp Content of Reconstituted Juice—% by Volume: Reconstituted 1:3 by Volume	Reconstituted 30 g./100 ml. after concentrate in Waring Blendor 3 min.	Reconstituted 30 g./100 ml. after concentrate in Colloid Mill 0.005 in.	Flotation Method: Coarse Pulp in Concentrate ml./100 g.	Water-Insoluble Solids in Reconstituted Juice % by weight
C-7	Orange	7.5	7.0	7.0	11	0.094
C-8	Orange	7.5	7.0	6.5	20	0.116
C-9	Orange	6.5	6.0	5.5	11	0.118
C-10	Orange	5.5[1]	5.5	5.5	22	0.076
C-11	Grapefruit	6.0	5.5	5.5	9	0.070

1—Pulp floating in centrifuge tube not included.

TABLE 4

COMPARISON OF AMOUNT OF PULP IN EXPERIMENTAL PACKS OF 42° BRIX PINEAPPLE ORANGE CONCENTRATES FROM THE 55° BRIX CONCENTRATE AND THE PULPY CUT-BACK JUICES USED

Sample No.	Cut-back Juice Used: Juice Passing through 0.027 inch Finisher, Volume Used %	Cut-back Juice Used: Pulp Passing through 0.125 inch Finisher, Volume Used %	Centrifugal Method — Pulp Content of Reconstituted Juice—% by Volume, Reconstituted 30 g./100 ml. after concentrate in Waring Blendor 3 min.	Colloid Mill 0.005 in.	Flotation Method: Coarse Pulp in Concentrate ml./100 g.
E-7	Water used for cut-back		7.5	7.0	4
E-8	100	0	7.0	7.5	5
E-9	75	25	8.0[1]	8.0	23
E-10	50	50	8.5[1]	9.0[1]	51
E-11	25	75	10.0[1]	8.5[1]	42
E-12	0	100	10.0[1]	9.5[1]	65

1—Reconstituted juice deaerated to prevent pulp from floating.

concentrates as determined by different methods. The water-insoluble solids in these products also are shown.

The pulp in a 42° Brix citrus concentrate comes from both the 55° Brix concentrate and the pulpy cut-back juice. To determine the proportion of total pulp coming from each of these two sources, six packs of Pineapple orange concentrate were prepared from a single batch of 55° Brix concentrate and several cut-back juices containing different amounts of pulp. In one pack, water was used as a cut-back to obtain a 42° Brix product that contained pulp only from the 55° Brix concentrate. Data presented in Table 4 indicate that from 73 to 87 percent of the total pulp in these 42° Brix products came from the juice that was used to make the 55° Brix concentrate, and that 13 to 27 percent came from the cut-back juices. Also a large amount of the fine pulp from the 55° Brix concentrate evidently was lost through the sieve when the coarse pulp content of these concentrates was determined by the flotation method.

SUMMARY

A centrifugal method (5) is satisfactory for the determination of the total pulp content of concentrated citrus juices provided that the heterogeneous pulp particles in these products are uniformly sized prior to the centrifuging of the reconstituted juice. Either a Waring Blendor or a colloid mill may be used for sizing the pulp particles. The most consistent results were obtained when the con-

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centrate was passed through the colloid mill before reconstituting and centrifuging.

A flotation method for the rapid estimation of the quantity of coarse pulp in frozen concentrated citrus juices was found to be satisfactory and is described. No relationship existed between the coarse pulp content and the total pulp content in 11 samples of commercial concentrates examined.

STUDIES ON THE ARTIFICIAL INFECTION OF ORANGES WITH ACID TOLERANT BACTERIA[1]

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A recent study by the authors (2) has shown that several species of bacteria occur and grow readily in orange juice. Indications were that some of these acid-tolerant bacteria may be in the juice because they were present in the fruit when it was on the tree. It would seem logical to assume that these same organisms would proliferate in citrus fruit when provided with a means of entry and if the pH of the juice is not below the limiting pH of the organisms. On the other hand, factors such as oxygen tension within the fruit and the natural physiological processes of the fruit itself might act as deterrents to the growth of bacteria. The studies reported here were conducted to provide information on the infection of citrus fruit by bacteria.

Bacteria pathogenic to citrus and known to cause diseases of concern to the citrus grower have been studied by several workers. Hasse (3) first isolated and described *Xanthomonas citri*, the casual organism of citrus canker. Black pit on citrus fruits was first described by Smith (5), who showed by inoculation experiments that the disease was due to *Pseudomonas syringae*.

Bacterial spot of South Africa resembles black pit of California but is caused by *Erwinia citrimaculans*. The disease was found in South Africa on lemon, tangerine, and mandarin and navel oranges; it was also induced by inoculation in shaddock, grapefruit, citron, and sour and sweet limes. The characteristics of the organism responsible for this disease were described by Doidge (1). Passalacqua (4) isolated and described a yellow-pigmented rod which he called *Bacterium citri deliciosae*, said to cause a disease on mandarins called "mal della terra."

These organisms usually infect the tissues of the tree itself or the surface of the fruit and, while the diseases caused by these organisms are important from the production viewpoint, external blemishes on the fruit are of little concern to the canner or concentrator. However, the internal quality of fruit used for production of frozen concentrate is of the utmost importance, and future investigations dealing with factors contributing to bacterial infection of citrus while the fruit is still on the tree may have important practical aspects for the canner.

There are several ways in which a citrus fruit conceivably could become inoculated with microorganisms while it is still attached to the tree. In the case of insect transmission the inoculation would be shallow and probably would not penetrate into the juice sacs, although a few insects might be able to penetrate a thin peel. Thorn injury, on the other hand, could result in a much deeper inoculation of the fruit. Microorganisms possibly may enter the fruit through other openings in the peel, such as those caused by hail, which do not extend into the juice.

INITIAL FRUIT INOCULATION EXPERIMENT

To determine which type of inoculation was required to infect citrus fruit with bacteria successfully very mature oranges were inoculated with several species of bacteria known to be capable of growing in sterile orange juice at a pH of 4.0 or less. The organisms used in this initial experiment were four of the acid-tolerant species described previously by Faville and Hill (2), namely, *Leuconostoc mesenteroides*, *Achromobacter* sp., *Xanthomonas* sp. "A," and an unidentified Gram-negative rod which grew at pH 3.23 in orange juice *in vitro*.

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