[Reprinted from FOOD TECHNOLOGY, 1956, Vol. X, No. 12, Pages 604-606]

A Continuous Process for Dehydrating Fruit Juices[a]

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(Manuscript received July 27, 1956)

IN THE FOOD FIELD concentrated and dehydrated products are assuming a position of ever-increasing importance. Witness the growth in frozen juice concentrates, powdered coffee, soup mixes, and dehydrated mashed potatoes, to name a few. In keeping with this trend, powdered fruit juices of late have been the object of very considerable interest. At least one company has been producing powdered citrus juices commercially *(7, 10)*. The U. S. Army Quartermaster Corps is particularly interested in the use of fruit juice powders because of their light weight and excellent keeping properties.

A batch technique for the preparation of powdered apple and grape juice products using vacuum shelf-drying has already been described by the authors *(5, 9)*. Juice reconstituted from these powders possesses excellent flavor, and storage tests show that when packaged with a desiccant the powders keep satisfactorily for over a year at 73° F. (22.8° C.) and over 6 months at 100° F. (37.8° C.) *(12)*.

THE PROCESS

Because vacuum shelf-drying is a relatively expensive batch operation, continuous methods of drying were investigated. The continuous belt, high-vacuum type drier used to produce citrus juice powders commercially could probably be used for the noncitrus juices. However, this type of drier is relatively expensive and is best suited to large-scale production. Also many of the noncitrus juices do not require high vacuum as they are less heat sensitive. A different approach was, therefore, taken in this work.

In the process developed, sweetened juice concentrate is quickly dried under moderate vacuum and at high temperature to a moisture content of 2 to 2½% in a special type of evaporator while remaining in a molten state. It is pumped out of the evaporator, mixed with a metered quantity of high-fold essence,[c] and chilled quickly on rolls to form thin brittle flakes which, after crushing, constitute the final product. One gallon of high-fold essence contains the aromatic volatile flavoring constituents of about 1000 gallons of fresh juice. The finished powders yield reconstituted juices which have pleasing natural color, flavor, and aroma.

A small integrated prototype plant using this continuous process has been operated at the Eastern Regional Research Laboratory with a production rate of thirty pounds of powder per hour. So far this pilot plant has produced powders from apple, Concord grape, and Montmorency cherry juices, and its use will also be extended to other fruit juices.

The flow sheet (Figure 1) and photographs (Figures 2 and 3) depict the continuous evaporative drying process and equipment. In the following description the numbers are those appearing in these figures. The most important piece of equipment is the mechanically agitated thin-film evaporator (No. 4).

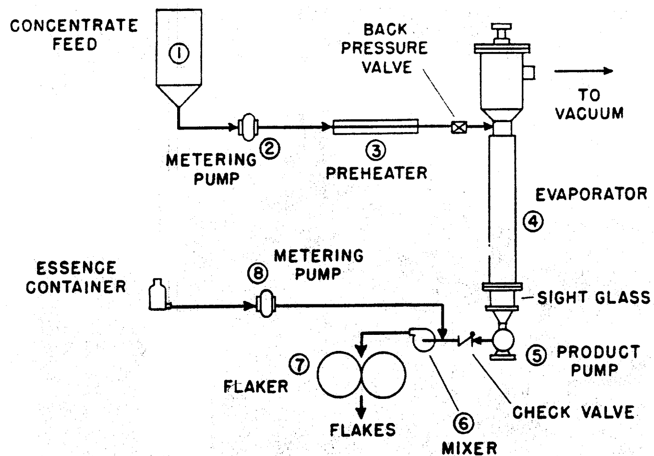

Figure 1. Flow sheet of the process.

Various designs are offered by several firms in the United States; the one used in these studies was a laboratory-size unit of the Turba-Film Evaporator[d] manufactured by the Rodney Hunt Machine Company of Orange, Massachusetts. This evaporator consists of a vertical hollow cylinder with a jacket; within the cylinder rotates an agitator having three straight vertical fins or blades. These blades clear the wall by about 0.030 inch and serve to keep the material being processed in a thin turbulent film against the wall. The agitator r.p.m. can be varied between wide limits. The discharge end of this evaporator was changed somewhat from the original design in order to facilitate flow of the very viscous molten product. This result was achieved by replacing a 1-inch diameter outlet tube with a 3-inch diameter sightglass above a short cone that extends right to the inlet of the discharge pump. On a commercial-size unit this modification might be unnecessary. Feed from a tank (No. 1) is metered by a pump (No. 2) through a preheater (No. 3) and enters the top of the evaporator. It flows down the inner wall by gravity, at the same time being carried around the wall by the action of the agitator, so that it actually descends in a flat spiral path to the bottom of the tube. The feed makes only a single pass; by the time it reaches the bottom of the tube it is fully concentrated. It drops through the sightglass and is discharged by a positive delivery pump (No. 5). Immediately downstream from the pump a sufficient quantity of approximately 1000-fold essence is injected continuously into the pipeline carrying the concentrate so that the ratio of essence constituents to solids is about the same as it is in fresh juice, assuming no losses during processing. The product enters a centrifugal pump (No. 6) whose function is to insure complete mixing and is then fed into the nip of a pair of revolving chilled metal rolls (No. 7) which reduce it to small brittle flakes approximately 0.015 inch thick. Approximately 100 seconds after the feed enters the evaporator it is delivered from the rolls as dried flakes. The flakes are coarsely crushed and then sealed in 4-ounce cans with an inpackaged desiccant[e] *(5, 6, 9, 11, 12)*.

To prevent the hygroscopic dried products from picking up moisture and caking, all operations in which the flakes or

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[a] Presented at the 16th Annual Meeting of the Institute of Food Technologists, St Louis, Missouri, June 12, 1956.

[b] A laboratory of the Eastern Utilization Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[c] Essence is an aqueous concentrate of the naturally occurring volatile flavoring constituents obtained from fresh juice by a process developed at the Eastern Regional Research Laboratory *(8)*.

[d] Mention of trade name or company in this paper does not imply it is recommended or endorsed by the U.S.D.A. over others not mentioned.

[e] Nine grams of pelleted calcium oxide (Desiccite 30 made by Filtrol Corp.[d]) in a heat-sealed envelope of dust-tight, vapor-permeable paper (Promset 831-X made by Mid-States Gummed Paper Co.[d]).

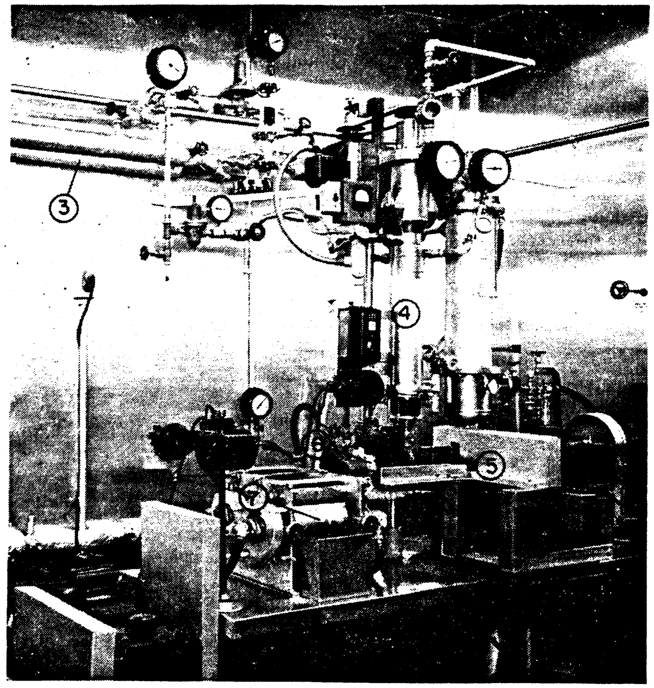

Figure 2. General view of apparatus. 3, preheater; 4, evaporator; 5, product pump; 6, centrifugal (pump) mixer; 7, flaking rolls.

powder are exposed to the atmosphere are carried out in a room where the relative humidity is maintained at about 10%.

PREPARATION OF FEED MATERIAL

Juice concentrate. The starting material for making the powders was the juice itself. Apple juice was prepared from purchased apples; grape juice came from commercial suppliers, either hot packed or frozen; and the cherry juice was a commercial frozen pack. It is believed that freshly prepared or frozen juices are preferable to the hot packed as they can be expected to tolerate more heat treatment during later processing without damage.

The juice is first stripped of essence in a continuous "essence recovery unit" *(2, 3, 4)*. The juice now stripped of its volatile aromas is enzyme-depectinized, filtered, and evaporated under vacuum to about 75% solids. Sugar (sucrose) is added in amount equal to 100% of the juice solids for apple, 50% for grape, and about 50% for cherry. This sucrose is added for several reasons: (1) it decreases the hygroscopicity of the material, making it easier to dry and to handle after drying; (2) it raises the softening temperature of the product making it less susceptible to caking in storage; (3) it helps retard flavor deterioration because, not entering into the browning reaction itself, it dilutes the monosaccharides and amino acids that interact to demage flavor; (4) being cheaper than juice solids, it lowers the cost of the final product. The sugar may either be dissolved in the juice before vacuum evaporation or added to the evaporated concentrate as a 75-80° Brix sirup. With apple and grape juices a small amount of citric or tartaric acid respectively is added to maintain a palatable sugar-acid ratio; with cherry juice this addition is usually unnecessary.

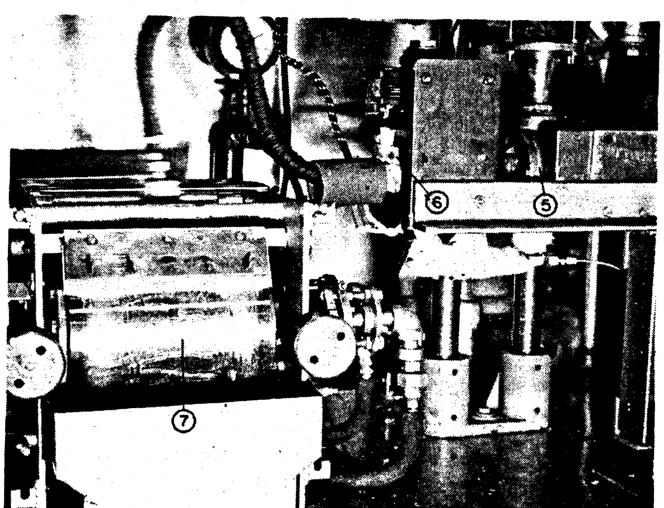

Figure 3. Close-up of apparatus. 5, product pump; 6, centrifugal (pump) mixer; 7, flaking rolls. Essence is introduced through narrow tube at right center.

High-fold essence. To keep the moisture content of the dried product low enough to prevent caking, only a small quantity of aqueous essence may be added to it. To convey enough of the aroma-bearing constituents, the essence must be about 1000-fold. This 1000-fold essence was prepared from the lower-fold essence recovered prior to evaporating the juice to concentrate. The apparatus employed was a 1-inch diameter glass fractionating column, packed with 0.16-inch x 0.16-inch stainless steel Protruded Distillation Packing made by Scientific Development Company.[d] The column was operated with continuous feed and drawoff of products. The height of packing was approximately 46 inches, 18 inches above, and 28 inches below, the feed point. Feed rates ranged from 8 to 16 ml./min. and product rates from 0.6 to 1.2 ml./min. With apple and cherry there was little loss of essence constituents to the column bottoms. With Concord grape a significant amount of methyl anthranilate did appear there, indicating the need for further work on the design of the most suitable column. However, the grape powder, as well as the others containing injected high-fold essence, contained ample natural fruit aroma when reconstituted to beverage and tested organoleptically.

OPERATING CONDITIONS

Data are presented in Table 1 showing typical values of the operating variables involved. The conditions used were quite similar for all three of the juices. One of the initial difficulties encountered in operating the evaporator was foaming. Excessive foaming causes holdup of concentrate in the evaporator tube and also greatly reduces the discharge rate of the pump with consequent heat damage to the product. To overcome foaming, 33 p.p.m. (based on the solids in the feed) of Dow Corning Antifoam AF Emulsion [d] was added to the concentrate just before use. The mixture was agitated continuously to prevent segregation.

Another problem which had to be overcome was leakage of air into the evaporator through the discharge pump and piping. Such leakage rises through the pump suction opening and prevents the concentrate from entering the pump; the result is prolonged retention in the evaporator and heat damage.

The discharge piping and the pump itself, particularly around the shaft, must be free from leaks before satisfactory operation can be assured.

SIGNIFICANCE

The economic feasibility of drying and marketing fruit juice powders has already been demonstrated in the case of orange and grapefruit. The cost of equipment to dry noncitrus juices by the evaporative technique presented here would be approximately one-fifth the cost of the drying equipment of the same capacity used for making citrus powders. Also the operating cost of the evaporative drying equipment should be at most no higher than that of the dryer used for citrus

TABLE 1

Operating conditions for continuous dehydration of fruit juices using mechanically agitated thin-film evaporator

Operating variable	Setting used in processing of:		
	Apple juice	Grape juice	Cherry juice
Feed			
Sugar addition based on juice solids, %	100	50	50
Brix, ° (= % solids)	75	75	75
Feed rate			
lb./hr.	40	40	40
lb. solids/hr.	30	30	30
Temp. entering evaporator, ° F.	135	135	135
Evaporator			
Rotor r.p.m.	1000	1000	1000
Rotor motor current, amp.	1.9-2.1	1.9-2.1	1.9-2.1
Abs. press., inches Hg	3.0	3.5[1]	3.0
Boiling pt. of water ° F. corr. to abs. press.	115	120[1]	115
Product outlet temp. ° F.	225	232	235
Boil. pt. rise, ° F.	110	112	120
Moist. content, %			
before injecting essence	2.1	2.3	2.1
after injecting essence	2.4	2.5	2.3
Steam on jacket			
p.s.i.g.	8	11	12
° F.	235	241	244
Rel. humidity in room, %	8-10	8-10	8-10
Cooling water temp. in chilling rolls, ° F.	35	35	35

[1] Higher absolute pressure used with grape to offset its greater tendency to foam.

particularly since the maintenance of high vacuum is not required. This fact coupled with the lower investment in equipment should result in a drying cost per pound of product equal to or less than that for the citrus powders. Therefore, the authors believe the production of full-flavored fruit powders from the less heat-sensitive juices using the evaporative drying technique presented here may hold promise of commercial success.

The physical form of the product from the evaporative process—small thin flakes—is such that a fairly short reconstituting time is achieved along with a desirable high bulk density. This bulk density, about 0.9 g./ml., is about one and one-half times that of powders made in the form of a puff or sponge by puff-drying techniques, and enables the same volume of juice to be reconstituted from a smaller package of powder.

Powders possess a distinct advantage over high-density (7-fold) liquid concentrates in regard to keeping properties at elevated temperature. Powdered apple and grape juice products prepared by the batch method keep for well over a year at 73° F. (22.8° C.) and for over 6 months at 100° F. (37.8° C.) *(12)*. The high density liquid concentrates also keep for a year at 73° F. (22.8° C.) but at 100° F. (37.8° C.) their shelf life is less than two months *(1)*.

Besides their use for reconstituting to beverage drinks, attention has been directed recently toward use of these powders as ingredients of prepared cake and dessert mixes to enhance natural fruit flavor. The powders can also be used for the convenient household preparation of fruit jellies.

SUMMARY

A practical process for continuously drying to powder the sweetened concentrates of apple, Concord grape and Montmorency cherry juices has been developed and successfully operated on a pilot-plant scale with a production rate of 30 pounds per hour. The equipment required is considerably less expensive than either vacuum shelf-driers or the continuous belt, high-vacuum type of drier, and is available as standard commercial units. The products have good flavor, color, and aroma, and their keeping qualities at room temperature and at 100° F. (37.8° C.) are expected to be the same as those of the corresponding vacuum shelf-dried products, which are excellent. Besides their use for reconstituting to beverage, the powders can be used to contribute natural fruit flavor to prepared dessert mixes and to form the base for dry fruit jelly mixes.

Acknowledgment

The authors wish to acknowledge the valuable technical assistance of Mr. Nelson H. Eisenhardt and Mr. Howard I. Sinnamon in carrying out the experimental work on which this paper is based.

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