Spray-Dried Cheese Whey-Soy Flour Mixtures

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Abstract

Liquid sweet whey combined with full fat soy flour and then pasteurized, homogenized, concentrated in vacuo to 40 to 45% total solids, and conventionally spray dried yields a free-flowing powder of good nutritive value suitable for beverage purposes. Homogenization reduces the amount of settling of soy solids and produces a more milk-like suspension. Concentration in vacuo and spray drying reduces the typical beany flavor of soy flour. The product reconstitutes in water to yield a mild, cereal-flavored, sweet-tasting product which easily lends itself to artificial flavoring. The dried product has good storage life and resists oxidative change.

Stiffening federal and state policies against environmental pollution will soon demand adequate treatment of wheys before diversion into waterways as waste. This entails considerable expense. Therefore, new methods for the utilization or disposal of wheys should be developed. In consideration of the rapidly developing global food shortages, we have interested ourselves in converting whey to human food use. Since Sasaki and Tsugo (7) had shown that a nutritious milk-like beverage could be produced by extracting soybeans with hot whey, we investigated the processing of various sweet whey and soy flour combinations using conventional dairy product manufacturing techniques.

This paper reports simple methods for the production of a powder containing soy flour and whey solids which reconstitutes easily to a highly nutritious milk-like beverage.

The superiority of this product to a dry blend of soy flour and whey solids is demonstrated, along with the processing advantages accrued from the reduction of the viscosity of soy flour suspensions by addition of whey.

Materials and Methods [1]

Soy flour. Food-grade Staley's full fat soy flour containing 20.2% fat and 42.0% protein (N × 6.25) was used.

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[1] Mention of brand or firm names does not constitute an endorsement by the Department of Agriculture over others of a similar nature not mentioned.

Sweet whey. Sweet Cheddar cheese whey was obtained from milk processed at the Dairy Products Laboratory Research Building, USDA, Beltsville, Maryland. It was made by pasteurizing whole milk at 74 C for 15 sec, adding a 10% culture of *Streptococcus lactis* to the milk, and ripening one hour at 31 C. Exactly 85 g rennet per 454 kg of milk were added and after 30 min the curd was cut. The curds and whey were heated to 37 C for 30 min, then the whey drained off. After removal of fat, the whey was pasteurized at 74 C for 15 sec and cooled.

Preparation of whey-soy mixtures. Soy flour was mechanically stirred into whey to obtain a mixture having a total solids content of approximately 10%. This slurry was pasteurized continuously by holding at 77 C for 20 sec, homogenized in two stages using pressures of 387 and 38.7 kg/cm^2, and condensed to 40 to 50% total solids in a Harris-Wiegand falling film evaporator. The concentrates were spray dried in a Grey-Jensen dryer either in conventional fashion or using air injection (1).

A few small samples of concentrate were dried by mixing the cold concentrate with nitrogen, spreading the material in thin films on stainless steel trays, and removing water under vacuum in a shelf dryer, as done previously with milk (8). The dried material was reduced to a powder by grinding through a 0.03-cm screen.

The small lots of soy-whey concentrates used in viscosity studies were made as indicated, except that homogenizing was done by passing the suspension twice through a pilot-scale Manton-Gaulin homogenizer using pressures of 387 kg/cm^2 and concentrating under vacuum in glass flasks rotating in a custom-built laboratory scale evaporator.

Viscosity measurements. Viscosities of soy flour–whey mixtures were determined using a Haake Rotovisco viscometer equipped with a standard Couette measuring system, Model MVI. The spindle in the cup was rotated at 162 rpm to obtain the shear rate of 8.46 sec^{-1} used in all measurements. Since all fluids studied were non-Newtonian and exhibited small decreases in viscosity on stirring, readings were taken five minutes after rotation of the spindle was started, unless otherwise specified. All samples were held at 30 C during viscosity measurements and the data obtained were reduced to specific viscosities using the Staudinger equation (9).

Physical and chemical analysis of powders. Moisture, total fat, and bacteria content of the powders as well as their bulk densities and solubility indices were determined using standard procedures (2). Protein nitrogen was determined using the Kjeldahl method and the per cent of free fat in the powders was measured using the method of Tamsma *et al.* (10).

Organoleptic evaluation of powders. Powders and concentrates were reconstituted with water to make beverages containing 12% total solids. Consumer acceptability of products was judged using a nine-point hedonic scale (6). The flavor of the samples was also evaluated in terms of intensity of soy flavor using 18- to 20-man panels drawn from laboratory personnel. Each judge was supplied with a form consisting of a series of parallel perpendicular lines. The top of the lines was marked full soy flavor and the bottom labeled no soy flavor. A sample of soy flour dispersed in water established the full soy flavor standard. The judges then indicated the intensity of soy flavor in samples by placing a mark on sample lines they believed the sample to occupy between the designated extremes. The judge's response was later quantified by measuring the position of the mark from the no soy flavor position. An example of a judge's response as recorded on a score card is shown in Fig. 1.

Powder protein nutritional quality evaluation. Protein efficiency ratios were determined by the Wisconsin Alumni Foundation using Sprague-Dawley strain rats as described by the AOAC (5). Samples of dehydrated whey-soy mixtures were tested using casein as the control.

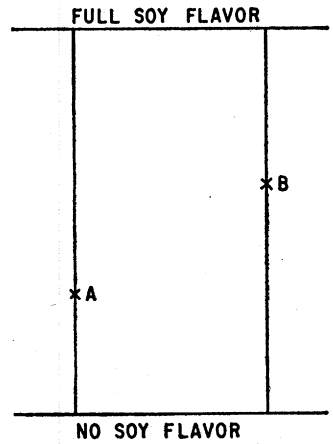

FIG. 1. Score sheet for determining degree of soy flavor in sample.

Results

Decreasing the ratio per cent soy flour to per cent whey solids in soy-whey mixtures will decrease the viscosity rise during the concentration step. This is shown graphically in Fig. 2. From this it can be seen that the viscosity of soy flour dispersed in water increased rapidly on concentration to the point where it would become difficult to pump above 20% total solids. However, the buildup of viscosity in systems containing one part soy flour and two parts whey solids is much slower during concentration, and the handling of 50% total solids containing mixtures having this ratio would be feasible in plant operations.

Evidence that interactions between whey and soy flour components in dilute solutions prevent excessive viscosity increases on concentration can be found in Table 1. When soy flour suspensions and wheys are separately concentrated and then mixed together, the observed viscosity of the mixtures is always higher than if the components are first blended together and then concentrated to the comparative total solids levels, as from Fig. 2.

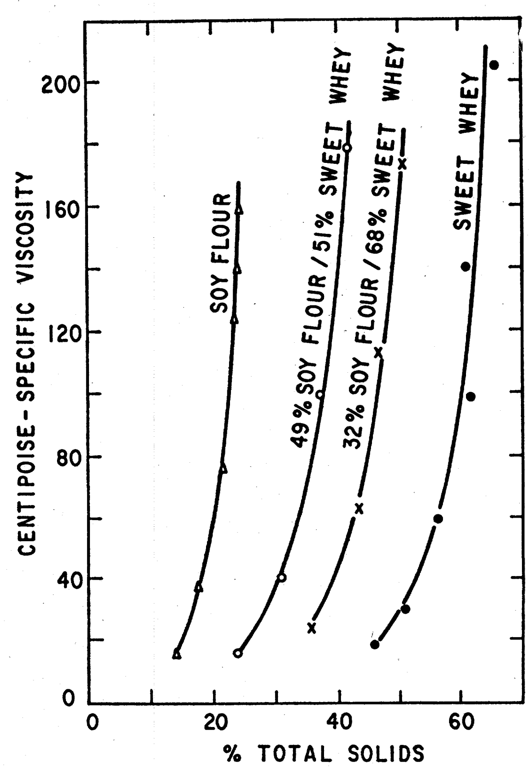

FIG. 2. Effect of total solids of sweet whey-full fat soy flour concentrates on specific viscosities.

TABLE 1. Viscometric interactions of sweet whey-soy flour at different total solids and per cent composition. Samples homogenized before condensing at 387 kg/cm².

Sample	Total solids	Specific viscosity
	(%)	(cp)
Suspension of full fat soy flour in water (A)	24.0	140
Solution of sweet whey solids in water (B)	64.5	204 Initial 155 (15 min later)
51% Whey solids from B 49% Soy solids from A	35.3	130
51% Whey solids (Fig. 2) 49% Soy solids	35.3	75
67.5% Whey solids from B 32.5% Soy solids from A	41.5	137
67.5% Whey solids (Fig. 2) 32.5% Soy solids	41.5	54
Suspension of full fat soy flour in water (C)	20.8	64
Solution of sweet whey solids in water (D)	56.5	56
51% Whey solids from D 49% Soy solids from C	30.6	53
51% Whey solids (Fig. 2) 49% Soy solids	30.6	39
67.5% Whey solids from D 32.5% Soy solids from C	36.3	51
67.5% Whey solids (Fig. 2) 32.5% Soy solids	36.3	30

The viscosities of soy flour–whey mixtures are relatively insensitive to normal heat treatments. It is only when the total solids of the systems rise above 45% that significant viscosity change can be associated with increased heat treatment, as shown in Fig. 3.

Homogenizing whey-soy flour slurries decreased specific viscosity, resulting in a decreased solubility index of the finished powder. Data describing these effects are presented in Table 2. As the pressure used to homogenize a

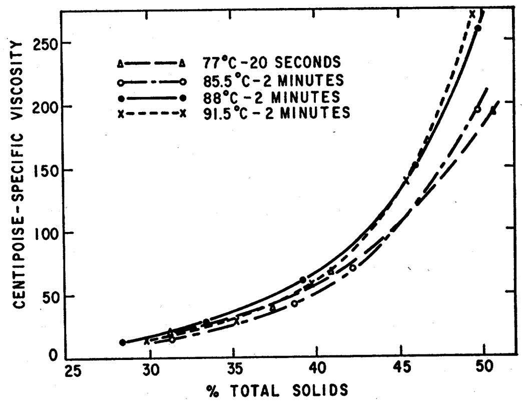

FIG. 3. Effect of temperature of heating before homogenation at 387 kg/cm² on specific viscosities of one part soy flour and two parts whey solids mixtures.

slurry of liquid whey and soy flour is increased, both the viscosity of the resultant concentrate and the amount of insoluble materials in the dehydrated material drop markedly.

This improvement of dispersion of soy flour solids in whey as effected by homogenization drastically alters the rate of particle settling in whey-soy flour mixtures. This can be seen in the photograph shown in Fig. 4. A sample of a reconstituted powder made by homogenizing, concentrating and spray drying a whey-soy flour blend and one made by combining a dry blend of the same quantities of soy flour and whey solids with water are shown. After standing two hours, no settling is observed in the homogenized and spray-dried sample (I), but a heavy sediment is observed in the mixture made from dry blended solids (II).

Even after homogenization, whey-soy flour mixtures contain small amounts of material that eventually settle out under the influence of gravity or can be removed by low speed cen-

TABLE 2. Effect of homogenization pressure on the resultant viscosity of 43.0% total solids concentrate of whey–full fat soy flour and solubility index of powder.

Homogenization[a]	Specific viscosity	Solubility index (powder)
(kg/cm²)	(cp)	(ml)
141	87.0	6.0
247	85.0	5.0
387	69.5	3.0-3.5
387[b]	70.0	2.0

[a] Homogenization of a mixture of liquid whey and soy flour prior to concentration.
[b] Continuous homogenization during concentration.

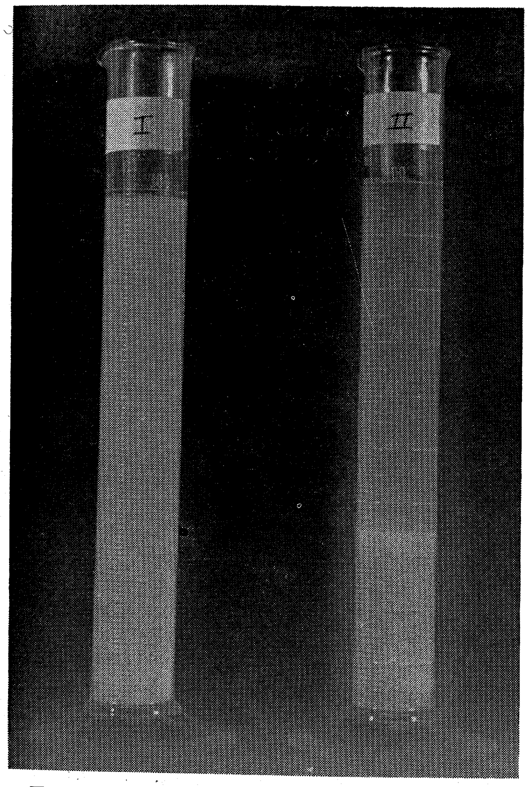

FIG. 4. I, 12% spray-dried whey-soy.
II, 4% soy flour + 8% whey solids.

trifugation. The composition of this water-washed material is given in Table 3, along with that of material settling out of nonhomogenized suspensions of soy flour in water. From the data it can be inferred that poorly dispersed solids remaining in whey-soy flour mixtures after homogenization arise primarily from the soy flour.

Even though homogenization greatly improves the physical stability of suspensions of soy flour, it has little effect on the promoting fat-protein interactions leading to low fat levels in the redried flour suspension. However, it is shown, by the data in Table 4, that whey contains an interfacially active material which on simple mixing of whey and soy flour followed by homogenization and then drying, protects the soy lipids from solvent extraction. As is found with milks (4) the manner of drying has a significant effect on the level of free fat in the product, i.e., spray drying yields the lowest level of free fat.

The drying characteristics of concentrated blends of whey and soy flour are similar to that of whole milk. They can be easily foam-dried under vacuum or spray-dried using conventional procedures. However, if the total solids content of the concentrates rises much above 45%, foam-spray-drying techniques must be used. Table 5 presents data showing the relationships between amount of air used in foam-spray drying of 50% total solids whey-soy flour concentrate and the moisture content and bulk density of the resulting powders.

On reconstituting the powders and tasting the resulting beverage a decrease in the soy flavor was found in the suspensions made by homogenizing soy flour into whey.

By following the flavor change of the product during the various steps of powder manufacture it was found that soy flavor was lost on addition of soy flour to whey and in the evaporating and drying steps. Using our newly developed scoring system we arbitrarily allotted 18 units to the distance between the no soy flavor position on the scale and full soy flavor of a 4% total solids suspension of homogenized soy flour. Under these conditions, the judges placed samples containing 12% total solids

TABLE 3. Analysis of washed sediment, dry weight basis, obtained by centrifuging whey-soy and soy flour suspensions at 1,600 rpm for ten minutes.

Total solids in sample	Homogenization pressure	Solids sedimented	Protein in sediment	Total solids that is sediment protein
(%)	(kg/cm²)	(%)	(%)	(%)
12% whey-soy[a]	387	6.2	28.0	7.5
4% soy flour[b]	387	17.1	30.9	12.0
4% soy flour	None	43.5	44.8	44.2

[a] Dried whey-soy mixture (22.75% protein).
[b] Full fat soy flour (44.0% protein).

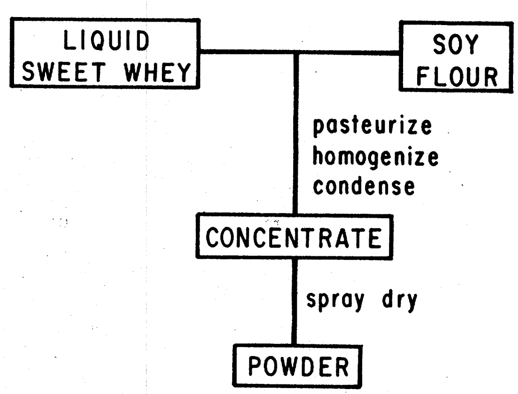

FIG. 5. Flow sheet for processing of sweet whey-soy flour powder.

TABLE 4. Effect of processing on per cent free fat of full fat soy flour and blends of full fat soy flour and sweet whey.

Sample	Homogenization pressure	Drying method	Fat	
			Total	Free fat
	(kg/cm²)		—(%)—	
1 part soy flour[b] 2 parts sweet whey solids	387	Spray	8.69	0.86
	141		8.45	3.50
	387		7.54	1.32
Soy flour[a]	None		20.1	100.0
	None	Shelf[c]	20.1	104.0
	105		20.1	96.5
	211		20.1	91.0
	387		20.1	82.0
1 part soy flour[b] 2 parts sweet whey solids	None		7.25	53.0[d]
			7.25	65.0
	387		7.17	13.8[d]
			7.29	18.5
Sweet whey	None	Spray	0.44	0.0

[a] Four per cent flour solids condensed to 20% total solids.
[b] Ten per cent soy flour and sweet whey solids condensed to 40% total solids.
[c] Dried 2.5-3 hr at 750 mm vacuum at 43 C.
[d] Sample injected with N_2 after concentration and just before drying during the same day.

having a whey solids to soy flour ratio of 2 at 12.2 units above the base on no soy flavor line. When this material was concentrated under low pressures to 40% total solids and diluted back to 12% total solids, the product rated 10.5. Spray drying the concentrate further reduced the soy flavor to 9.3. Using this evaluating method, the judges indicate a 50% loss in soy flavor by combination with whey followed by concentration and dehydration. The flavor of the processed product is thus superior to that of a dry blend of soy flour and whey solids.

While the process we have described produces a material with substantially reduced soy flavor, it is still relatively unacceptable to American palates. In Table 6 are data showing the consumer acceptance ratings of a whey-soy flour powder immediately after reconstitution and after storage for five days in a refrigerator. Also shown in this table is the improvement in flavor resulting from mixing the beverage with an equal volume of whole milk as well as the refrigerated storage stability of the mixture. For comparison purposes the hedonic rating of whole milk and whole milk-skimmilk mixtures are also presented.

Even though consumers expressed a slight dislike for the whey-soy mixtures, addition of simple flavors greatly improved their accept-

TABLE 5. Effect of level of injected air on properties of a spray dried 33% full fat soy flour and 67% sweet whey solids concentrate of 49.7% total solids.[a]

Level of air SCM/min[b]	Flow rate	Moisture in powder	Solubility index	Bulk density	
				Untapped	Tapped
	(kg/min)	(%)	(ml)	—(g/ml)—	
0.056	3.8	1.6	2.5	0.18	0.24
0.042	4.0	2.0	2.5	0.20	0.26
0.028	4.2	3.2	2.5	0.25	0.30
0.014	4.3	4.0	2.0	0.29	0.33

[a] Dryer inlet air, 143 C
Dryer outlet air, 99 C.
Nozzle size, 0.1 cm.
Nozzle pressure, 105 kg/cm².
Air pressure, 176 kg/cm².
[b] SCM/min = Standard cubic meters/minute.

TABLE 6. Panel ratings of 10% total solids whey-soy compared to milks. Nine-point hedonic scale.

Days storage at 7 C	Whey-soy	50% Whole milk + 50% whey-soy	50% Whole + 50% skim-milk	Whole milk
0	3.9	5.0	6.2	6.6
5	3.6	4.7	6.7	5.8

Day	Significant difference at 5% level	
0	a = 2	0.9
	a = 4	1.2
5	a = 2	0.9
	a = 4	1.1

a = distance apart in each array

ability. A cherry-vanilla flavored product rated 5.9 on a nine-point hedonic scale and a chocolate-flavored material rated 7.1, or equivalent to fresh whole milk.

The flavor of the dehydrated whey-soy mixtures is relatively stable. No oxidized flavor was found in samples stored in polyethylene bags at room temperature for seven months. A slight lack of fresh flavor was noted in stored samples; however, no significant change in consumer acceptance of stored products was noted.

When following our manufacturing procedures, powders of acceptable bacterial load are obtained. The usual total bacteria counts range from 2,000 to 5,000 per gram with coliforms completely absent.

The powders can be considered to be relatively nutritious with a good amino acid balance. Protein efficiency ratio values for a whey-soy flour blend averaged 2.42 and for a whey-soy flour-cornoil blend, 2.64. This efficiency value for casein was 2.50. Table 7 presents detailed analytical data describing the composition of the powders used in the efficiency tests.

Discussion

By following procedures schematically outlined in Fig. 5, powders can be produced which readily reconstitute to a high protein beverage whose physical stability and flavor is superior to that obtained from a dry blend of soy flour and cheese whey solids—its principal constituents.

The entire manufacturing procedure can be carried out utilizing standard equipment found in milk drying plants. The formulation is flexible, allowing for the easy addition of flavoring and adjustment of protein to carbohydrate ratios. The calorie density of the product can be further improved by addition of edible oils or fats before homogenization.

During the development of this product, we experienced difficulty in obtaining data relative to flavor changes in whey-soy flour mixtures during processing, because of the apparent natural aversion of skilled dairy product judges to soy flavor. It was, therefore, necessary to develop a scoring system which reduced verbalizations concerning flavor to a minimum and to reflect as little personal bias as possible. The judges were asked merely to place a mark along a line signifying their evaluation of the position the samples occupied between the two extremes in flavor we were interested in; in this case full soy flavor and no soy flavor. This scoring system seems unique and further work by our group indicates that it may be applicable to development work in other areas.

The product in its present stage of development can be considered either as a base amenable to further flavor manipulation or as an extender for milk supplies in nations deficient in high protein foods for child feeding.

Our work indicates that the whey-soy flour mixtures contain no materials that would accelerate oxidation of the whole milk with which it was mixed. Therefore, it seems reasonable that they could be used in the milk-toning operations now being carried out in India. Here,

TABLE 7. Analytical data on spray-dried samples made with full fat soy flour and sweet whey, with and without added cornoil.

	67% Sweet whey solids[a] 33% Full fat soy flour	55.2% Sweet whey solids[b] 27.6% Full fat soy flour 17.2% Cornoil
Concentrate		
Total solids (%)	43.0	42.0
Specific viscosity (cp)	85	57
Dry powder		
Moisture (%)	3.2	1.2
Protein (%)	22.75	18.15
Fat (%)	8.66	23.10
Ash (%)	6.50	5.44
Solubility index (ml)	2.5	3.0
Bulk density (g/ml)		
Untapped	0.50	0.38
Tapped	0.66	0.50

	a	b
Dryer inlet air	140 C	145 C
Dryer outlet air	94 C	100 C
Feed rate	3.6 kg/min	3.6 g/min
Nozzle size	0.075 cm	0.075 cm
Nozzle pressure	193 kg/cm²	225 kg/cm²

the high-fat Buffalo milk supply could be easily extended by using reconstituted products described in this paper. Development of foreign markets for materials of this type would help to reduce present environmental pollution by residues of the cheese manufacturing industry.

In light of recent work by Huang and Bayliss (3), showing certain ethnic groups possibly being intolerant to the lactose in milk products, any adoption of this powder for beverage purposes should be preceded by feeding trials with representative members of the potential consumer group.

References

(1) Bell, R. W., F. P. Hanrahan, and B. H. Webb. 1963. Foam spray drying methods of making readily dispersible nonfat dry milk. J. Dairy Sci., 46: 1352.

(2) Grading of Dry Whole Milk and Sanitary and Quality Standards. 1947. Amer. Dry Milk Inst., Bull. 193. Chicago, Illinois.

(3) Huang, Shi-Shaung, and Bayliss, T. M. 1968. Milk and lactose intolerance in healthy orientals. Scince, 160: 83.

(4) Nickerson, T. A., S. T. Coulter, and R. Jenness. 1952. Some properties of freeze dried milk. J. Dairy Sci., 35: 77.

(5) Official Methods of Analysis of the AOAC. 1965. 10th ed. p. 785.

(6) Peryam, D. R., and F. J. Pilgrim. 1957. Hedonic scale method for measuring food preferences. Food Technol., 11: Insert 9-15.

(7) Sasaki, R., and T. Tsugo. 1953. The manufacture of synthetic milk powder from whey and soy-bean. II. The manufacture and nutritive value of synthetic milk powder. 13th Int. Dairy Congr., 4: 606.

(8) Sinnamon, H., N. Aceto, R. Eskew, and E. Schoppet. 1957. Dry whole milk. I. A new physical form. J. Dairy Sci., 40: 1036.

(9) Staudinger, H. 1943. Die Hochmolecularen Organischen Verbindungen. Edwards Brothers Inc., Ann Arbor, Michigan. Copyright Julius Springer in Berlin, 1932.

(10) Tamsma, A., L. F. Edmondson, and H. E. Vettel. 1959. Free fat in foam-dried whole milk. J. Dairy Sci., 42: 240.