4274*

Production and properties of a nutritious beverage base from soy products and cheese whey

Production and properties of a nutritious beverage base from soy products and cheese whey

V. H. Holsinger, C. S. Sutton, H. E. Vettel, L. F. Edmondson,
P. R. Crowley, B. L. Berntson, and M. J. Pallansch

U. S. Department of Agriculture
Agricultural Research Service
Eastern Regional Research Center
Philadelphia, Pennsylvania 19118
USA.

ABSTRACT

Fluid sweet cheese whey, full fat soy flour, soybean oil, and corn syrup solids, when combined, pasteurized, homogenized, condensed *in vacuo* to over 40 % total solids and spray dried yield a freeflowing powder, readily reconstitutible with water to form a nutritious beverage with high protein content. A vitamin-mineral premix may be dry blended with the powder to increase the nutritional quality further. The formulation of the product is flexible and the taste quality is bland. The product shows good storage life and resists oxidative change in the dry state.

INTRODUCTION

Milk production in developing countries has often been inadequate to meet the nutritional need of the population. For many years commodities and processed foods, including nonfat dry milk, have been purchased by the U. S. Department of Agriculture (USDA) for distribution to needy people abroad by the U. S. Agency for International Development (AID) through the United States Voluntary Agencies, through government-to-government bilateral agreements, and through contributions to the World Food Program of the Food and Agricultural Organization of the United Nations (Johnson, 1973). Over 100 million people in about 90 developing countries have participated in these programs (Senti, 1974).

Due to the steady decline in milk production, nonfat dry milk is in short supply and priced out of reach for overseas distribution in U. S. Food-For-Peace programs (Anonymous, 1974). In late spring of 1973, a joint USDA-AID effort was begun to develop a nutritious beverage powder mix specifically formulated as a

---

Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

dietary supplement for preschool children receiving inadequate protein. It was not intended to serve as the sole source of food. When reconstituted with water, the beverage was to supply all the nutrients of whole milk; it was also to be cheaper than nonfat dry milk to produce and ship overseas.

The work reported here describes the production and properties of a new whey-soy beverage powder designed to serve as a nonfat dry milk replacer. The storage stability characteristics of the powder as determined by flavor and chemical measurements are also discussed.

MATERIALS AND METHODS

Ingredients

Food grade full fat soy flour containing 42.7 % protein, 20.2 % fat and 4.4 % moisture was used in the preparation of the product. The soybean oil used was refined, partially hydrogenated and winterized. It also contained methyl silicone, polysorbate 80, polyglycerides and the antioxidants butylated hydroxy toluene (BHT) and butylated hydroxy anisole (BHA). Sweet whey used for the prototype was fluid pasteurized Mozzarella whey preconcentrated at the cheese plant to 16 % total solids (TS). The corn syrup solids employed for the industrially produced prototype were a 42 DE product. Commercially prepared vitamin and mineral premixes were used to fortify the whey-soy beverage mix.

Production Methods

Over 4.000 kilos of a commercial prototype for the whey-soy beverage powder were prepared by wet blending full fat soy flour, corn syrup solids and soybean oil into fluid sweet whey in a stainless steel tank equipped with a turbine agitator. The formulation used for production is shown in Table 1. The wet blend, heated to 38-43° C, was homogenized in a Manton-Gaulin 1135.5 liter per hour homogenizer in two stages using pressures of 175.8 kg/cm^2 and 38.7 kg/cm^2. The mixture was then pasteurized by a high temperature short time procedure at 77° C for 15 seconds and condensed to 47 % TS in a single stage down blast evaporator rated at 454 kilos of water/hour evaporation. Preheat temperature before evaporation was 77° C and pump out temperature 38-43° C. The concentrate was spray dried using a 4.2 meter diameter anhydrous PEEBLES—TYPE DRYER: The inlet air temperature was 149° C and outlet temperature 93.3° C. Powder outlet temperature was 49° C. 182 Kilo lots of the cooled powder were dry blended with 1 % by weight of the vitamin-mineral premixes using a 0.57 cubic meter PK twin shell blender operated for 10 minutes. A flow diagram of the procedure is shown in Figure 1.

Packaging and Storage Conditions

For storage stability studies, samples of the fortified and unfortified spray dried beverage powders were packed in No. 1 cans in a nitrogen-hydrogen mixture (95 : 5) and stored at —18° C. An oxygen scavenging catalyst was included to remove residual oxygen. These samples served as controls. Additional samples of the two powders were air packed in 2 mil thick polyethylene bags which were heat sealed. These samples were stored in constant temperature incubators set at 25 and 43° C.

Organoleptic Tests

Withdrawals from storage at all temperatures were made after 1, 2, 4, 8, 12, 18, 20, and 24 weeks. The samples were reconstituted to 15 % TS just prior to tasting. Coded randomized samples were presented to a panel of experienced dairy product judges and rated by using the nine point hedonic scale devised by Peryam and Pilgrim (1957). The panel was also asked to identify specific flavors and rate their intensity on a scale of 0-4. A samples score sheet is shown in Figure 2. Flavor intensity values (FIV) for oxidized and rancid flavor cirticisms were calculated from this score sheet by computing the total intensity score for each flavor and dividing by the total number of judges.

Statistical evaluations for significance were made on the experimental data after completion of each taste panel. Analysis of variance and Duncan's Multiple Range Tests according to Larmond (1970) were used to obtain results at each storage interval.

Analytical and Physical Tests

Proximate compositional analysis was carried out on the unfortified commercial prototype by a commercial laboratory. Procedures used for the determination of total nitrogen, fat, moisture, and ash in the whey-soy beverage powder were those recommended by the AOAC (1970). Carbohydrate was

TABLE 1

Formulation of unfortified whey-soy beverage powder

Ingredient	Percent
Sweet whey solids.	41.7
Full fat soy flour.	36.9
Soybean oil.	12.3
Corn syrup solids.	9.1

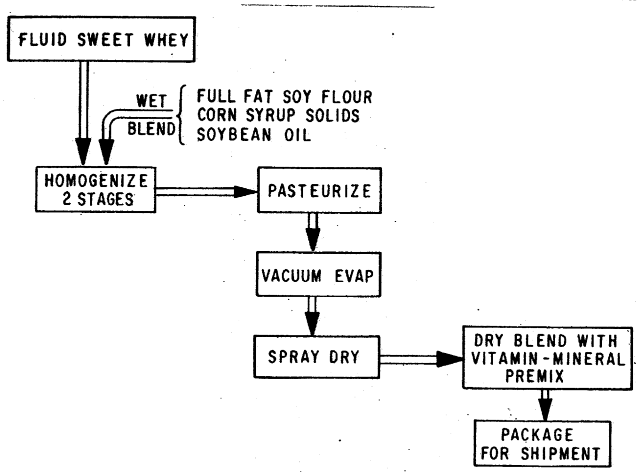

Fig. 1.—Production of whey-soy beverage powder.

SCALE

0 = NONE 3 = DISTINCT
1 = QUESTIONABLE 4 = STRONG
2 = SLIGHT

Please use one of the above numbers to describe the intensity of each flavor listed below

FLAVOR CRITICISM	SAMPLE CODE								
COOKED									
FEED									
RANCID									
STALE									
OXIDIZED									
OTHER									

Fig. 2.—Intensity score sheet used for evaluation of whey-soy beverage powder.

determined by difference and caloric content by calculation. Dispersibility of the dry samples was measured by a modification of the method of Stone *et al.* (1954) as developed by Kontson *et al.* (1965). sinkability by the procedure of Bullock and Winder (1960) and solubility index and bulk density by methods recommended by the American Dry Milk Institute (1947).

Peroxide values were determined on all stored samples as another measure of oxidative stability. Fat for peroxide analysis was extracted from the powders without the use of heat by blending the dry samples with Celite 545 (1 : 2). The dry mixtures were placed in glass columns, 30 cm x 1 cm I. D., equipped with coarse sintered glass discs, and peroxide-containing fat was eluted into 25 ml volumetric flasks by using a benzene: methanol mixture (70 : 30). After appropriate dilution of the samples with the same solvent mixture, peroxide values were determined directly by the colorimetric procedure of Hills and Thiele as described by Stine *et al.* (1954).

Animal Feeding Studies

Animal feeding studies were conducted on the unfortified prototype by a commercial laboratory. The protein efficiency ratio (PER) assay was conducted according to an AOAC procedure. The sample was compared to ANRC reference casein. Protein evaluation, using the net protein utilization (NPU) method was conducted according to the procedure of Miller and Bender (1955).

RESULTS AND DISCUSSION

Of prime importance in the development of the new nonfat dry milk replacer was the decision to use whey in the formulation. Research activities carried out by USDA's Dairy Products Laboratory (DPL) had already shown that sweet whey-soy flour mixtures could be spray dried using conventional dairy plant equipment to produce powders readily reconstitutible with water to yield milk-like beverages (Guy *et al.*, 1969). Because whey contains levels of sodium and potassium considered to be too high for ingestion by very young children, additional pilot plant runs were made at DPL in order to gain information about how the new product should be formulated with whey to meet the nutritional needs of preschool children.

Edible oil added to the formulation not only served as a diluent to aid in reducing the osmotic activity of water in the reconstituted beverage, but also helped satisfy the requirement that the new whey-soy drink should be a significant source of calories. In order to reduce the osmolality of the reconstituted beverage still further and, at the same time, supply a sweetening effect to reduce soy flavor, a high molecular weight material, 42DE corn syrup solids, was included in the formulation. Inclusion of these two ingredientes reduced the salt concentration of the whey by 20 % in the finished powder.

Experimental whey-soy flour formulations containing additional soybean oil and significant amounts of corn syrup solids were sucessfully spray dried in the DPL pilot plant using the techniques developed by Guy *et al.* (1969). There were no changes in solubility and dispersibility of the dried powder upon reconstitution. In addition, organoleptic evaluation of the reconstituted products showed reduced levels of soy flavor in the new formulations.

On the basis of these results, the ARS whey-soy formulations were modified further by nutritionists to meet AID requirements. An industrially prepared prototype, financed by AID under a Participating Agencies Service Agreement with USDA's Economic Research Service (ERS) was produced for evaluation using the formulation shown in Table 1. The primary objective was met in that the product contains a significant amount of sweet whey solids. Most of the protein is contributed by the soy flour. The proximate composition of the new beverage powder is shown in Table 2. One per cent vitamins and minerals were added to the powder for testing. The composition of the vitamin-mineral mix is shown in Table 3.

Another requirement of the new beverage powder was that its PER, based on animal feeding studies, should not be less than 1.8 and preferably higher. The industry prototype had a corrected PER of 2.1 compared to reference casein of 2.5. The NPU value was 75 compared to a value of 84 for casein.

The beverage powder was also required to be easily reconstitutible in water. Physical properties related to reconstitubility are shown in Table 4. The slight

TABLE 2

Proximate composition of unfortified whey-soy beverage powder

Component	Percent
Protein (total N × 6.25)	21.2
Moisture	3.9
Ash	5.1
Fat	21.4
Fiber	0.8
Carbohydrate	47.6
Calories/100 g dry powder	468

TABLE 3

Composition of vitamin-mineral premix added to whey-soy beverage powder

Vitamins added	Amount/100 g dry powder
	I.U.
Vitamin A	1930
Vitamin D	233
Vitamin E	8.72
	mg
Thiamin	.32
Riboflavin	.45
Niacin	5.78
Vitamin B_6	.19
Vitamin B_{12}	.005
Calcium pantothenate	3.21
Folacin	.23
Ascorbic Acid	46.8
Minerals added	
Calcium	280
Iron	17.6
Iodine	.05
Zinc	1.05

TABLE 4

Physical properties of whey-soy beverage powder

Test	Unfortified	Fortified
Solubility index	4.0 ml	4.3 ml
Dispersibility	89.3 %	81.7 %
Sinkability	69.7 %	81.8 %
Bulk density		
Untapped	.48 g/cc	.45 g/cc
Tapped	.61 g/cc	.67 g/cc

change in solubility index of the product fortified with vitamins and minerals over the unfortified product, probably reflects the presence of the slowly dissolving mineral salts added. Although fortification somewhat reduced the dispersibility of the spray dried powder, the sinkability, another measure of rate of powder hydration, was increased, so the overall solubility was not noticeably affected when the powder was reconstituted for tasting.

Trials carried out in the DPL pilot plant showed that foam-spray drying, used as a method of making readily dispersible nonfat dry milk (Bell *et al.*, 1963), improved the dispersibility of the whey-soy beverage powder; however, there was a corresponding reduction in bulk density.

The new beverage powder was also required to have good storage stability characteristics. To aid in assuring good oil stability and good initial flavor, highly refined, partially hydrogenated soybean oil containing added antioxidants was used in the formulations. Organoleptic evaluation and determination of peroxide values during 6 months' storage at three different temperatures were used as two measures of oxidative stability of the whey-soy beverage powder.

Samples were reconstituted for organoleptic evaluation within 1 hour of the time set for the panel. Long standing after reconstitution promoted the development of oxidized flavor in the sample fortified with vitamins and minerals, particularly if an electric blender was used for mixing.

Table 5 shows hedonic flavor rating of the whey-soy beverage powder stored at three different temperatures for various times. The unfortified sample stored at 43° C showed a significantly lower score from its control after 8 weeks of storage. The fortified sample stored at 43° C showed a significantly lower score only after 18 weeks of storage. None of the samples stored at −18° C and 25° C showed any significant change in flavor score over the 6 month storage period. The hedonic flavor scores shown in Table 5 for the fortified sample tended to be lower at all temperatures and storage times than the scores for the unfortified powder. Examination of the intensity values for off-flavors detected by the judges indicated

TABLE 5

Average hedonic flavor scores of samples of whey-soy beverage powder stored at three different temperatures

Storage temperature (°C)	Time of storage - weeks 0	1	2	4	8	12	18	20	24
	Hedonic rating								
	Fortified								
−18.		3.7	4.7	3.8	3.3	4.3	5.3	5.3	4.8
25.	4.5	3.3	4.4	3.8	3.8	4.3	4.9	4.0	4.7
43.		4.1	4.3	3.3	3.0	3.3	3.1*	3.2*	2.4*
	Unfortified								
−18.		4.9	4.6	4.7	5.0	5.0	5.7	5.3	6.0
25.	5.0	5.1	4.4	4.5	4.5	4.3	4.9	5.5	5.7
43.		4.4	4.3	4.0	3.5*	3.3*	3.7*	3.0*	2.0*

* Significantly different from the control at the 1 % level.

that the fortified beverage powder received a greater number of oxidized flavor criticisms at most temperatures and storage times than the unfortified powder. The results are shown in Table 6.

TABLE 6

Variation with storage time of flavor intensity values for oxidized flavor for whey-soy beverage powder stored at three different temperatures

Storage temperature (°C)	Storage time - weeks								
	0	1	2	4	8	12	18	20	24
					Fortified				
–18.		.86	.29	.83	1.3	.67	.14	.67	.50
25.	1.0	.86	.29	.50	.50	.67	.29	1.5	.83
43.		.14	.29	.67	1.0	1.3	1.57	1.3	3.0
					Unfortified				
–18.		0	.14	0	0	0	0	.33	0
25.	0	0	.29	.16	.18	0	.14	.17	0
43.		0	0	.33	.83	1.0	.57	1.2	2.67

TABLE 7

Variation with storage time of peroxide values of whey-soy beverage powder stored at three different temperatures

Storage temperature (°C)	Storage time - weeks								
	0	1	2	4	8	12	18	20	24
					meq oxygen/kg fat				
					Fortified				
–18.		4.5	2.0	5.5	10.9	–	1.4	2.2	4.8
25.	7.7	4.7	10.2	12.6	19.4	–	30.5	15.1	8.7
43.		3.6	0.4	9.9	9.6	–	59.5	85.4	86.0
					Unfortified				
–18.		5.0	20.3	15.2	14.9	–	18.1	12.1	15.1
25.	10.3	5.9	19.4	21.9	23.3	–	40.9	38.2	44.3
43.		4.2	21.9	18.5	17.2	–	87.0	114	163

Analysis of variance showed the hedonic scores of the fortified samples during the first half of the storage study to be significantly lower than the scores of the unfortified sample set. Experienced judges could detect a flavor difference between the fortified and unfortified samples with regard to oxidized flavor, even though this difference was not reflected in the hedonic ratings during the latter half of the storage study. Rancid flavor criticisms were only made for those samples stored at 43° C whose hedonic flavor scores were significantly lower than controls.

Peroxide values for the samples stored at different temperatures for various times are shown in Table 7. Examination of the data show that those samples stored at 43° C which had significantly lower flavor scores, had elevated peroxide values in most cases. The peroxide values for all samples of the fortified beverage powder were consistently lower at all storage times and temperatures than the peroxide values of the unfortified counterpart.

The presence of iron in the vitamin-mineral premix used to fortify the whey-soy beverage powder may offer an explanation for the oxidized flavor criticisms we observed in the early stages of the storage test as well as the decreased peroxide values of the fortified samples. List *et al.* (1974) have shown that an increase in iron content of soybean oil results in an increase in anisidine value, a measure of α,β unsaturated aldehydes contained in the fat. These compounds are formed by the breakdown of fat hydroperoxides; List *et al.* (1974) believe that iron may catalyze the formation of these products from the hydroperoxides and have correlated elevated anisidine values with decreased flavor score. Our results suggest that a similar effect may be occurring in the whey-soy beverage powder fortified with iron as one of the components of the vitamin-mineral premix.

CONCLUSIONS

The data presented here indicate that the new whey-soy beverage powder has the nutritional quality and storage stability required for use in international food donation programs. Acceptability tests carried out in six test countries by two consultants to USDA (Rodier *et al.,* 1973) using the fortified industry prototype, showed that there is a high probability that the beverage powder will be accepted in preschool feeding programs in most of the developing countries. The cost to produce the whey-soy beverage powder is estimated at 42.77¢/kilo (Moede, 1974), less than 15¢/liter of reconstituted beverage. The volume of nonfat dry milk shipments abroad under the Food-For-Peace Program was approximately 136 million kilos annually. It is estimated that annual shipments of the whey-soy beverage mix may reach a level of 55 million kilos in 2-3 years. As a food supplement for preschool children, whey-soy drink can help supply the calories, protein, and other nutrients necessary to meet the requirements of feeding programs in less-developed countries.

ACKNOWLEDGMENTS

The authors thank F. Talley for assistance with the taste panels and V. Metzger for assistance with the statistical analysis.

REFERENCES

American Dry Milk Institute, Inc. 1947. The grading of dry whole milk and sanitary and quality standards. Bulletin 913. Chicago, Illinois.

Anonymous, 1974. The beverage made to order. Farm Index 13 (3): 19.

AOAC. 1970. "Official Methods of Analysis", 11 th ed. Association of Official Analytical Chemists, Washington, D. C.

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

Bullock, D. H. and Winder, W. C. 1960. Reconstitutability of dried whole milk. I. The effect on sinkability of the manner of handling freshly dried milk. J. Dairy Sci. 43 : 3.

Guy, E. J., Vettel, H. E., and Pallansch, M. J. 1969. Spray-dried cheese whey-soy flour mixtures. J. Dairy Sci. 52 : 432.

Johnson, P. E. 1973. High-protein foods for peace. Cereal Sci. Today 18 : 138.

Kontson, A., Tamsma, A., and Pallansch, M. J. 1965. Effect of particle size distribution on dispersibility of foam spray dried milk. J. Dairy Sci. 48 : 777.

Larmond, E. 1970. Methods for sensory evaluation of food. Publication 1284, Canada Department of Agriculture, Ottawa, Canada.

List, G. R., Evans, C. D., Kowlek, W. F., Warner, K., Boundy, B. K., and Cowan, J. C. 1974. Oxidation and quality of soybean oil: A preliminary study of the anisidine test. J. A. O. C. S. 51 : 17.

Miller, D. S. and Bender, A. E. 1955. The determination of the new utilization of proteins by a shortened method. Brit. J. Nutr. 9 : 382.

Moede, H. H. 1974. Cost of whey-soy-drink mix for human consumption. U. S. Department of Agriculture, Economic Research Service, Marketing Research Report 1021, Washington, D. C.

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

Rodier, W. I., III, Wetsel, W. C., Jacobs, H. L., Graeber, R. C., Moskowitz, H. R., Reed, T. J. E., and Waterman, D. 1973. The acceptability of whey-soy mix as a supplementary food for preschool children in developing countries. Technical Report 74-20-PR. U. S. Army Natick Laboratories, Natick, Massachusetts.

Senti, F. R. 1974. Soy protein foods in U. S. assistance programs. J. Amer. Oil Chem. Soc. 51 : 138 A.

Stine, C. M., Harland, H. A., Coulter, S. T., and Jenness, R. 1954. A modified peroxide test for detection of lipid oxidation in dairy products. J. Dairy Sci. 37 : 202.

Stone, W. K., Conley, T. F., and McIntire, J. C. 1954. The influence of lipids on self-dispersion and on ease of dispersion of milk powder. Food Technol. 8 : 367.