An Oil Fraction from Edible Beef Tallow as a Constituent of Whey-Soy Drink Mix

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ABSTRACT

In order to increase its potential as a food ingredient, an oil fraction derived from a commercial edible beef tallow was substituted for soybean oil in a formulation designed to yield a spray-dried free-flowing powder readily reconstitutable with water to yield a nutritious beverage. If desired, the beverage powder could be fortified with a vitamin-mineral premix containing iron. After 6 months of storage at 37 C, no significant difference in flavor score was observed between samples containing the beef tallow oil fraction and control samples containing soybean oil. There was also no significant difference in flavor scores received by samples containing the beef tallow oil fraction fortified with vitamins and minerals and fortified control samples. However, peroxide values were eight times greater in the unfortified control samples. The beef tallow oil fraction warrants further study as a food ingredient in engineered food systems where enhanced oxidative stability is desirable.

INTRODUCTION

Increasing world population, coupled with global food shortages, has brought about the development of new food products that incorporate large quantities of previously wasted by-products. An example of such a product is whey-soy drink mix (WSDM), a high protein, high fat, high calorie dietary supplement for preschool children that was developed specifically for use in U.S. Food-For Peace programs in developing countries (1). Under commodity specifications (2), this product is formulated with 41.5% sweet cheese whey solids, a by-product of the dairy industry. In addition, it contains 19% soybean oil and is fortified with 1% by weight of a vitamin-mineral premix containing iron complexed as ferrous fumarate.

Traditionally, dairy products have been protected from contamination with iron because it catalyzes lipid oxidation leading to the development of oxidized off-flavors in the products (3,4) with the ferrous ion being more influential than ferric (5,6). Dehydrated corn-based foods that contain up to 6% added soybean oil have been shown to be stable in the presence of added ferrous fumarate (7,8); however, WSDM contains a much higher level of soybean oil. Since oxidized flavor criticisms by trained judges have been associated with the vitamin-mineral fortification of WSDM (1,9), improved stability against the development of oxidative off-flavors would be a desirable feature of WSDM which is often stored for prolonged periods under adverse conditions in many tropical countries where it is distributed.

Beef tallow is a surplus by-product of the meat industry; about 2.5 billion kilos are produced annually in the United States (10), only about 211 million kilos of which was utilized as edible tallow in 1975 (11). Research and development activities carried out by the Physical Chemistry Laboratory at the ERRC have shown that edible beef tallow can be fractionated into several components of differing physical and chemical properties (12). One such component is a beef tallow oil fraction (BTOF) with characteristics similar to those of soybean oil (SO) but with greatly increased stability to oxidation (13).

We evaluated BTOF as a food ingredient by determining if BTOF could be substituted for SO in the WSDM formulation without altering the drying characteristics and reconstituability of the dry powder and by monitoring flavor and oxidative stability of the WSDM containing BTOF during storage.

EXPERIMENTAL PROCEDURES

Product Formulation

The formulation used for product preparation is shown in Table I.

Materials

Fluid, pasteurized Cheddar cheese whey containing 6.7% total solids was obtained from the Dairy Foods and Nutrition Laboratory, Beltsville, MD. Forty-two D.E. Corn syrup solids and defatted toasted soybean flour containing 52% protein, <1% fat, and 6.5% moisture were used for product manufacture.

The soybean oil (SO) used for preparation of the control was a commercial product that had been 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). The AOM stability (14) was 23 hr.

Commercially prepared vitamin and mineral premixes were dry blended into some samples at the 1% level. Minerals added were food grade calcium carbonate, zinc sulfate, ferrous fumarate, and potassium iodide. The added vitamins were A, B_1, B_2, B_6, niacin, panothenate, folic acid, B_{12}, C, D, and E. Levels added were in accordance with blended food products guidelines (15).

Preparation of Oil Fraction from Edible Beef Tallow

A commercial edible beef tallow was solvent fractionated to yield 65% of an oil fraction as previously described (12). The oil was steam deodorized at 2 mm Hg at 180-200 C for 3 hr. It was stabilized with 0.02% of a commercial antioxidant combination containing BHA, BHT, propyl gallate, and citric acid. The AOM stability was 238 hr. The oil contained 2.5% linoleic acid and no linolenic acid.

Production Methods

Twenty-five kg lots of a control powder containing SO and a powder containing BTOF were prepared by wet blending the soy flour, corn syrup solids, and edible oil into fluid sweet whey preheated to 38-43 C. The blend was pasteurized by a high temperature short time procedure at 77 C for 16 sec, homogenized in two stages at pressures of 175.8 kg/cm² and 38.7 kg/cm², condensed in vacuo to 40% total solids in a Harris Wiegand falling film evaporator, and spray dried in a 2.7 meter Grey Jensen dryer, equipped

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TABLE I

Whey-Soy Drink Mix

Ingredient	%
Sweet whey solids	41.5
Defatted soy flour	30.1
Corn syrup solids	9.2
Edible oil	19.2

TABLE II

Proximate Composition of Whey-Soy Drink Mix, Unfortified and Fortified with 1% by Weight of Vitamin-Mineral Premix

	Percentage of sample			
	Unfortified		Fortified	
Constituent	SO[a]	BTOF[b]	SO	BTOF
Protein (Total N x 6.25)	21.5	21.6	21.2	21.4
Fat	21.0	18.3	21.0	18.1
Ash	5.1	5.0	5.3	5.6
Moisture	1.2	2.0	1.4	1.8
Carbohydrate (by difference)	51.2	53.1	51.1	53.1

[a]Whey-soy drink mix containing soybean oil.
[b]Whey-soy drink mix containing the beef tallow oil fraction.

with a 0.075-cm nozzle at an inlet temperature of 146 C. One-kg lots of the cooled powder were then fortified if desired with the vitamin-mineral premix by dry blending for 10 min in a Patterson-Kelly twin shell dry blender rated for a product density of 31.5 kg/meter^3.

Packaging and Storage Conditions

For storage stability studies, samples of the powders containing SO and BTOF, both unfortified and fortified with vitamins and minerals, were air packed in No. 1 cans and stored in constant temperature incubators at -18, 25, and 37 C. Additional samples containing SO and BTOF, both unfortified and fortified, were packed under nitrogen in No. 211 x 414 cans and stored at -18 C.

Organoleptic Evaluations

All taste panels were composed of trained dairy products judges selected for sensory acuity (16), who had received additional training in recognition of beany, rancid, and reverted soybean oil flavors in accordance with instructions received from sensory evaluation specialists at the USDA Northern Regional Research Center (NRRC) (Warner, K.M., personal communication, 1974). Panels averaged 13 members; one panel had a minimum of 9 judges. For organoleptic evaluation, samples were reconstituted with distilled water to 15% total solids just prior to being tasted.

For the initial tasting, the reconstituted SO- and BTOF-containing samples, both fortified and unfortified, were compared to an identified WSDM control, arbitrarily given a score of 7, that had received an average flavor score of 6.7 from the 14-member soy panel at the NRRC using a quality scoring scale developed for corn-based foods and soy products (8,17). On this scale, 1 equaled strong undesirable flavor → 10 equaled excellent flavor; minimum acceptable flavor equaled 6. A hidden control was coded and presented to the judges as one of the coded randomized samples being evaluated. The score received by the hidden control served as the standard against which the scores of the other samples were compared. Separate panels were conducted for the unfortified products and the products fortified with vitamins and minerals.

Fresh SO-containing samples, unfortified or fortified with vitamins and minerals, packed under nitrogen, and stored at -18 C, were given arbitrary scores of 7 and served as the identified and hidden controls for organoleptic evaluation of the unfortified or fortified products during storage. BTOF-containing samples were withdrawn from storage at -18 C and 37 C for evaluation at approximately 4-week intervals for 6 months. SO-containing samples were evaluated after 3 and 6 months of storage.

In a limited study with 12-man panels, air-packed samples containing BTOF or SO were stored at 25 C and rated for preference over 1 yr by using the 9 point hedonic scale of Peryam and Pilgrim (18).

Statistical evaluations for significance were made by using analysis of variance and Duncan's multiple range test as described by Larmond (19).

Analytical Methods

AOAC procedures were used for the determination of total nitrogen, fat, moisture, and ash (20). Carbohydrate was determined by difference.

Dispersibility of the dry powders was measured by a modification of the procedure of Sinnamon et al. (21), sinkability by the procedure of Bullock and Winder (22), solubility index by a method recommended by the American Dry Milk Institute (23), and bulk density by a procedure developed by the Agricultural Marketing Service (24). Samples were evaluated in duplicate in all cases.

Fat for peroxide analysis was extracted from the powders without the use of heat by blending 1 g dry sample with 2 g Celite 545. The dry mixtures were placed in glass columns, 30 cm x 1 cm ID, equipped with coarse material glass discs. Peroxide containing fat was eluted into 25 ml volumetric flasks by using a benzene-methanol mixture (70:30). After appropriate dilution of the sample with the same solvent mixture, peroxide values were determined directly by the colorimetric procedure of Hills and Thiele as described by Stine et al. (25). All stored samples were checked for peroxide development at intervals of about 4 weeks.

RESULTS AND DISCUSSION

Powder Composition

No processing difficulties were encountered by substituting the beef tallow oil fraction (BTOF) for soybean oil (SO) in the whey-soy drink mix (WSDM) formulation. The proximate compositions of the unfortified and fortified WSDM samples prepared with SO or BTOF are shown in Table II. Commodity specifications require WSDM to contain at least 20% fat and 20% protein (2). Although no difficulty was encountered in extracting lipid from reconstituted SO-containing powders by the standard Röse-Gottlieb procedure for dried milk products, replicate large scale preparations of the BTOF-containing powders analyzed 2-3% low in lipid in spite of care taken in sample formulation. A slightly modified Folch extraction procedure (26) proved unsuitable as less than half of the lipid was extracted from the SO-containing sample by this procedure; it has been previously reported that the Folch procedure was unsatisfactory for the complete extraction of lipid from soybean meal (27). Sochlet extraction procedures have also been reported unsuited for the complete extraction of lipid from flours (28-30). Our results suggest that the Röse-Gottlieb procedure may also be unsuitable for complete lipid extraction from some blends containing soy flour; this point is still under investigation.

The vitamin-mineral premix was added in order to determine the effect of the presence of iron on the oxidative stability of the BTOF in a pilot food system as measured by flavor and development of peroxides in the lipid phase on storage. The fortified WSDM contained 17.6 mg iron/100 g dry powder. Previous work had shown that WSDM containing this level of iron was shelf stable for 18 weeks of storage at 43 C (1).

Physical Properties

In order to determine if the substitution of BTOF for SO in the formulation affected the ease of rehydration of the beverage powder when reconstituted with water, we evaluated some of the physical properties related to reconstitutability (Table III).

The sinkabilities of the powders containing BTOF, both fortified and unfortified, were greater than their controls. Because the densities of the oils used in product formulation were virtually identical, the increased sinkabilities, coupled with the slightly higher bulk densities of the BTOF-containing powders suggest that the structure of the dry particles was different. The dispersibility values of all samples were similar to values reported for nonfat dry milk (31). Because of this and because good sinkability is considered to be a desirable property in readily reconstituable powders (22), we concluded that the substitution of BTOF in the formulation had no deleterious effect on the ease with which the WSDM is reconstituted into a beverage.

TABLE III

Physical Properties of Whey-Soy Drink Mix, Unfortified and Fortified with 1% by Weight of Vitamin-Mineral Premix

Analysis	Sample: Unfortified SO[a]	BTOF[b]	Fortified SO	BTOF
Sinkability, %	48.1	75.5	42.7	61.4
Dispersibility, %	96.7	96.5	100	87.0
Solubility index, ml	5.0	5.5	5.5	5.2
Bulk density, g/cc	.37	.39	.40	.43

[a]Whey-soy drink mix containing soybean oil.

[b]Whey-soy drink mix containing the beef tallow oil fraction.

Oxidative Stability

Because of the adverse conditions under which WSDM may occasionally be stored, good storage stability characteristics of the edible oil used in the formulation are very important. the two measures of oxidative stability selected were organoleptic evaluation and determination of peroxide values during storage.

Although we wished to conduct extensive organoleptic evaluations in connection with flavor acceptability of the BTOF-containing product, we were unable to do so. During the development of WSDM, difficulties have been encountered repeatedly in obtaining data relative to flavor acceptability and flavor changes during storage, apparently because of the dislike of trained dairy products judges for the soy flavor (32); similar problems have been encountered with hedonic panels (9). The sample used as the identified control during the initial tastings was disliked by our panelists (scored 4.5) but was well accepted abroad (33) and received an acceptable flavor rating from the NRRC panel. It was concluded that our judges could not be asked to verbalize flavor acceptability based on NRRC criteria, although we continued to use a 10-point scale for scoring.

We believed that the use of an identified SO-containing control given an arbitrary score, regardless of acceptability of the flavor to the judges, would enable us to gain some information about flavor change in BTOF- and SO-containing samples stored under similar conditions in spite of our judges' bias against soy flavor. A hidden control included among the samples being evaluated permitted us to monitor scoring consistency and served as a reference for statistical analysis.

After the study began, judges complained that the identified control used in the initial tasting was developing a rancid off-flavor that was not present in the other samples. Therefore, fresh SO-containg samples, unfortified and fortified with vitamins and minerals, packed under nitrogen, and stored at -18 C, were given arbitrary scores of 7 and served as the hidden and identified controls for the remainder of the study. Because of the number of samples involved, stored SO-containing samples were tasted only twice during the storage period.

Initially, three of the four samples were rated significantly poorer than their hidden controls at the 95% confidence level but were not significantly different from each other (Table IVA); judges readily detected the hidden control. When a new identified control was substituted, scores given to the hidden controls for both sets of stored samples varied considerable. This suggests that the judges had difficulty in distinguishing flavor differences between the SO-containing controls and the air-packed BTOF-containing samples stored at -18 C. The results also showed that detectable flavor deterioration had occurred in the fortified BTOF-containing samples stored at 37 C for 29 days and in the unfortified samples after 55 days. After 83 or 85 days of storage at 37 C, flavor deterioration had also occurred in the SO-containing samples; however, scores received, although significantly lower than those given the hidden controls, were not significantly different from scores received by the BTOF-containing samples stored under similar conditions. After 167 days of storage, greatest deterioration was observed in the unfortified SO-containing sample stored at 37 C, even though the rating was not significantly different from that of the unfortified BTOF-containing sample stored at 37 C.

Measurement of peroxide values (Table IVB) clearly showed that the unfortified and fortified SO-containing samples steadily developed peroxides over the 167 or 169 day storage period at 37 C, whereas the BTOF-containing samples showed little change. Volunteered comments from some of the judges indicated that during storage at 37 C, a cooked, meaty type flavor was developing in the BTOF-containing samples, whereas rancid and oxidized flavors were detected in SO-containing products. A peroxide value of 60 was associated with decreased flavor score and oxidized and rancid flavor criticisms of SO-containing WSDM in an earlier study (9); peroxide values approaching this level were measured in SO-containing samples in this study. The peroxide data clearly indicate that, during extended storage under adverse conditions, WSDM containing BTOF when fortified with vitamins and minerals could be expected to maintain better oxidative stability as measured by development of peroxides than would a product containing SO.

Flavor acceptability of BTOF as a substitute for SO in the WSDM formulation remains to be clearly established. Even though the hedonic system seems to be undesirable for testing WSDM because of general dislike of the product (9,32), we wanted some indication of acceptability of the BTOF-containing product. The results of a very limited study using a 9-point scale indicated no significant difference ($P = 0.01$) between unfortified BTOF- and SO-containing samples stored at 25 C for 1 yr (Table V). Peroxides steadily increased over the storage period, with the greatest increase observed in the SO-containing sample. Even though flavor quality of both samples obviously decreased over the storage period as evidenced by the decreasing flavor score, both samples received ratings above 5, an acceptable score according to the method used. Data are not shown for the fortified products because the BTOF-containing sample received an unacceptable flavor rating initially and both products were rated unacceptable after 4 months of storage.

TABLE IV

Variation with Storage Time of Average Flavor Scores and Peroxide Value of Whey-Soy Drink Mix Stored at Different Temperatures

Sample	Unfortified							Fortified						
	Initial	26	55	83	111	138	167	Initial	29	57	85	113	140	169
Part A. Average flavor score[a] (Storage time, days)														
SO,[b] N_2 pack, -18 C (Hidden control)	7.18[a]	6.53[a]	6.53[ab]	6.82_a	6.73[a]	7.08[a]	6.67[a]	7.18[a]	6.84[ab]	6.45[a]	6.59[a]	6.76[a]	6.82[a]	6.71[a]
BTOF,[c] -18 C	6.18[b]	7.10[a]	6.73[a]	6.89[a]	6.93[a]	6.33[b]	6.82_a	5.81[b]	7.23[a]	6.79[a]	6.78[a]	6.30[ab]	6.78[a]	6.46[a]
BTOF, 37 C	---	6.35[a]	6.00[b]	5.67[b]	5.90[b]	5.33[c]	5.28[b]	---	6.00[b]	5.08[b]	5.09[b]	5.53[b]	5.00[b]	5.25[b]
SO, -18 C	6.31[b]	---	---	6.83[a]	---	---	7.11[a]	6.40[ab]	---	---	5.83[b]	---	---	6.85[a]
SO, 37 C	---	---	---	5.63[b]	---	---	4.61[b]	---	---	---	5.58[b]	---	---	5.25[b]
Part B. Peroxide value (meq O_2/kg fat)														
SO, N_2 pack, -18 C	---	4.2	13.6	7.9	3.9	14.8	12.0	---	0.6	2.5	1.2	1.8	3.3	4.2
BTOF, -18 C	4.9	3.7	2.6	4.0	1.7	4.2	3.8	0.3	1.3	1.0	0.7	0.5	2.8	0
BTOF, 37 C	---	3.5	4.5	4.1	2.9	7.7	5.5	---	1.7	0.5	1.3	1.0	2.8	0.3
SO, -18 C	5.7	5.2	4.2	4.2	4.2	4.6	4.2	2.5	1.1	3.3	2.0	1.6	3.2	1.1
SO, 37 C	---	17.1	28.3	36.0	46.7	62.2	44.5	---	3.9	10.6	21.0	38.6	49.9	48.9

[a]Two means with no letter in common differ significantly after applying Duncan's Multiple Range Test ($P = 0.05$).
[b]Whey-soy drink mix containing soybean oil.
[c]Whey-soy drink mix containing the beef tallow oil fraction.

On the basis of the results reported here, BTOF warrants further study as an ingredient in engineered food systems where enhanced oxidative stability is desirable. Improved fractionation and deodorization techniques for the preparation of BTOF should solve residual flavor problems.

TABLE V

Hedonic Flavor Score and Peroxide Values of Unfortified Whey-Soy Drink Mix Stored at 25 C for 12 Months

Sample	Storage time, months				
	Initial	4	6	9	12
	Average flavor scores				
SO[a]	6.83	5.54	5.90	---	5.75
BTOF[b]	6.43	5.46	5.70	5.35	5.16
	Peroxide value (meq O_2/kg fat)				
SO	5.7	36.1	37.9	---	63.6
BTOF	4.9	3.4	0.4	6.0	16.8

[a]Whey-soy drink mix containing soybean oil.

[b]Whey-soy drink mix containing the beef tallow oil fraction.

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