Evaluation of the Bread-Baking Quality and Storage Stability of 12% Soy-fortified Wheat Flour Containing Sweet Cheese Whey Solids[1]

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ABSTRACT

Substitution of 1–3% commercial pasteurized grade A sweet whey solids (SWS) for wheat flour in a 12% soy-fortified bread flour mix containing sodium stearoyl-2-lactylate (SSL), increased bread volumes by 5–10% and decreased crumb compressibility during storage. Substitution of SWS lowered dough absorption by an amount equal to the added solids and progressively darkened crust color, making substitution beyond 2–3% impractical. High-heat skim milk solids or high-heat SWS substituted for wheat flour did not change loaf volumes, but α-lactose hydrate also increased loaf volumes. Soy-fortified bread wheat flour mixes containing 2% SWS and 0.5% SSL stored satisfactorily up to six months at 20–25°C and produced breads of higher volume than did their respective controls without SWS. The baking quality of both the control and the mix containing SWS stored at 36°C deteriorated extensively after two weeks. However, the addition of 3% shortening or 0.5% SSL to these mixes at the time of baking restored their volume losses. Added SWS caused no change of quality in taste or texture in the breads made from stored mixes.

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Since 1972, soy-fortified bread wheat flour blends have been used by the USDA in overseas food donation programs (Fellers et al 1976). Soy flour is an excellent source of protein to supplement wheat flour because it has a high protein content and a good balance of essential amino acids. Because the addition of high levels of soy flour to the formulation depresses loaf-volume, sodium stearoyl-2-lactylate (SSL) is added to wheat flour–soy flour blends to promote volume and bread quality.

Trade bakers are increasingly replacing nonfat dry milk (NFDM) with sweet cheese whey solids in blends with soy protein concentrates (Hugunin 1980). Dried sweet cheese whey contains 12–13% protein with nutritional quality better than that of casein (Wingerd et al 1970) and equivalent to that of egg albumin (Sahyun 1948). Because only about 50% of the annual 42 billion pounds of this surplus commodity is being used (Dairy Products Annual Summary 1980, Whey Products Institute 1981), officials of the USDA-ERS and of the ASCS asked us to find further outlets in the human food chain for this nutritious by-product by studying the baking quality of dried whey in soy-fortified wheat flour blends.

The objective of the present study was to investigate the possibilities of adding sweet whey solids (SWS) to 12% soy-fortified bread wheat flour intended for export, and to define the conditions that would produce a loaf of adequate volume and baking quality. To maintain a specified minimum protein level of 16.2% for the blend, SWS were substituted for wheat flour in the formula.

To ensure successful incorporation of SWS into the blends intended for export, we also conducted storage studies that simulated conditions under which shipments might be made. The blends could be subjected to hot, humid conditions for extended times. Because SWS may absorb moisture and stick together ("shot-ball") at relative humidities greater than 36% (Berlin et al 1968), we needed to determine whether loss in baking quality of the blend with added SWS occurred. Samples of a stored blend with SWS were baked and the breads subjected to organoleptic evaluation.

MATERIALS AND METHODS

Materials

An export-grade, enriched, unbromated, bleached bread wheat flour of 11.6% protein (N × 5.7), 0.50% ash, and falling number of 223 was used. It was fortified with Archer Daniels Midland baker's grade defatted soy flour of 6.5% moisture and, as specified by the supplier, had a protein dispersibility index of 70–79%. SSL used was supplied by Patco Products. For comparative purposes, a commercially prepared, export-grade, 12% soy-fortified blend of 11.9% moisture, supplied by the USDA-ASCS, was also evaluated. Lehigh Valley Dairy pasteurized grade A spray-dried sweet whey solids of 13.0% protein (N × 6.38), 67% lactose (67% of this crystallized as the α-hydrate), and 4.7% moisture were used for the bulk of the investigational work; its pH was 6.2. High-heat sweet whey solids of 2.4% moisture were prepared in the Food Science Laboratory Dairy Pilot Plant of ERRC by preheating fluid whey to 85°C for 30 min, concentrating to 40% total solids, and spray drying. Low-heat sweet whey solids of 2.4% moisture were made by preheating of the whey at 71°C for 15 sec before condensing and drying. Neither had any crystalline α-lactose hydrate. Foremost USP grade α-lactose hydrate and Nutritek 90 (demineralized whey), and Yankee high-heat NFDM solids suitable for breadmaking were evaluated. The NFDM had 4.0% moisture and 1 mg of whey protein nitrogen (WPN) per gram. Red Star compressed yeast was used.

Baking Methods

The baking formula, equipment, and procedures for 1-lb loaves were the same as given in Announcement W-15 of the ASCS (1975). The formula, modified for inclusion of whey solids, is given in Table I. As specified, no shortening was used in the formula. Whey solids were substituted for an equal weight of wheat flour in the formula to keep the total mix weight constant. Since the falling number of the bread wheat flour (223) exceeded the specification of a minimum of 200, no malt was added. Up to 40 ppm of potassium bromate are called for in the specifications. The formula with no sweet whey solids was considered the control.

Since the above reference is not readily available, the details of

TABLE I
Formula for 12% Soy-fortified Bread

Ingredient	Percent of Blend[a]
Wheat flour	88 minus percent sweet whey solids[b]
Defatted soy flour	12.0[b]
Sweet whey solids	0.0–4.0[b]
Sucrose	4.0
Compressed yeast	2.5
Salt	2.0
SSL[c]	0.5
Potassium bromate	40 ppm
Water	variable

[a] Wheat and soy flours and sweet whey solids.
[b] 100% at 14% moisture.
[c] Sodium stearoyl-2-lactylate.

[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of a product by the USDA and does not imply its approval to the exclusion of other products that also may be suitable.

the procedure for 1-lb loaves are as follows: Exactly 700 g of combined wheat flour, soy flour, and SWS (all on 14% moisture basis [mb]) were scaled out. Doughs of variable absorptions were mixed at speed No. 1 for 30 sec, and at speed No. 2 for variable times, in a Hobart A-200 mixer to optimum consistency as judged by the baker. After the doughs were rounded by hand, they were fermented 105 min at 30°C and 80% relative humidity. Then 525 g of dough was scaled, rounded by hand, and relaxed 20 min at 30°C. Doughs were sheeted by immediately passing through the National Manufacturing Company Sheeter rollers set at 11/32 in., followed by a second pass at 7/32 in. After being curled by hand, they were placed in pans and proofed at 30°C in the cabinet to 2.5-cm height above the pan top or for a maximum of 70 min. After the loaves were baked at 218°C for 25 min and cooled for 5 min, volumes were read by rapeseed displacement.

So that limited supplies of flour could be saved, the pup bake procedure was used to evaluate stored mixes. Two hundred grams of 12% soy-wheat flour plus whey solids (14% mb) along with other ingredients listed in Table I were mixed with tap water in a Swanson-type mixer. Cleanup was expressed as the percentage of the total dough that could be mixed within the specified time period and removed by hand as a mass without scraping any dough adhering to the bottom and sides of the bowl. All dough was then removed and combined for testing. Dough samples of 150 g were scaled off and fermented as specified for 1-lb doughs. Doughs were passed through the National sheeter set at 9/32 in. for the first punch. At the end of the fermentation period, doughs were given two punches with the settings at 9/32 and 3/16 in., then molded by hand and panned. All doughs were proofed for 70 min and the height measured with templates. Baking was done at 230°C for 20 min, and volume measured after the loaves cooled for one-half hour.

TABLE II
Effect of Sweet Whey Solids (SWS) Replacement of Blend on Breadbaking of 12% Soy-fortified Commercial Blend[a]

Sample	Percent Water[b] Absorption	Mixing Time (min)	Dough Handling[c]	Proof Time (min)	Loaf Volume (cc)[d,e]	Crust Color[e]
Control	65	3.5	Undermixed	67	2,475 b	9.50 a
		5	Very good	61	2,485 b	9.00 a
		6.5	Overmixed	70	2,325 a	9.50 a
2% SWS	63	3.5	Slightly undermixed	61	2,612 c	8.50 b
		5	Very good	60	2,612 c	8.75 b
		6.5	Very good	60	2,562 c	8.50 b
4% SWS	61	5	Very good	60	2,537 bc	8.25 c

[a]0.5% sodium stearoyl-2-lactylate and 40 ppm potassium bromate added.
[b]14% moisture basis.
[c]Five-minute optimum dough handling.
[d]Duplicate loaves.
[e]Standard deviation. Loaf volume ±60 cc. Crust color ±0.14. Different letters indicate significant different at $P < 0.05$.

TABLE III
Effect of Sweet Whey Solids (SWS) on the Compression of Slices of 12% Soy-fortified Breads Made with Commercial Blend[a]

Percent Replacement of Flour	Compression[b] in Bread Stored			
	1 Day[c,d]	2 Days[c,d]	3 Days[c,d]	4 Days[c,d]
Test 1				
Control	11.6 a	15.0 b	17.3 b	20.0 c
2 SWS	11.5 a	13.3 a	14.8 a	17.3b
4 SWS	10.5 a	13.5 a	14.0 a	14.7 a
Test 2				
Control	9.9 a	16.7 b	18.2 b	17.7 b
4 SWS	9.3 a	11.5 a	12.8 a	15.8 a

[a]Different tests run on different days.
[b]Grams to depress 1.25-cm slice 3 mm.
[c]Standard deviation ±0.76 g.
[d]Different letters indicate very significant difference ($P < 0.01$) within each day of storage in each test.

Emphasis in bread scoring was given to differences in loaf volume, crust color, and grain because texture, crumb color, and loaf symmetry, and break and shred were much the same. Crust color and grain were judged with mounted standards assigned numbers by the author. The lightest, most appealing crust colors rated a score of 10, and the finest grain 18.

Data were statistically analyzed by the ERRC statistical section to determine significance of loaf volume, proof time, and crust color.

Analytical Procedures

Most chemical and physical analyses were performed according to AACC methods (1962). Flour moisture and protein content ($N \times 5.7$) were determined by methods 44-15 and 46-12, and milk solids and whey solids moisture by the toluene method 44-52. Flour ash was determined by method 08-01, and undenatured whey protein by method 46-22. Compression of bread slices was determined by method 74-10, using a Baker compressimeter. The bread was cooled for 1 hr, sealed in 1.5-mil polyethylene bags, stored at room temperature, and six center slices 1.25-cm thick cut on an Oliver bread slicer immediately before testing.

Farinograph absorption was determined by method 54-21, using 300 g of combined wheat flour, soy flour, and milk solids on a 14% mb according to the constant flour-weight procedure. Curves were centered on the 500-Brabender unit (BU) line, and absorption was reported on 14% moisture of the combined flour plus replacement milk solids.

Drop tests were conducted by dropping a proofed dough five times according to the Quality Bakers of America test (Jackel and Diachuk 1969). Lactose and percent crystallized lactose were determined by the method of Sharp and Doob (1941).

Total and retained CO_2 production of doughs was measured by the method of Barham and Johnson (1951) by taking 10.0 g of dough out of the mixer and putting it inside a plastic cup. This cup was inserted into a pressuremeter vessel containing either 20 ml of 23% NaCl to measure total CO_2 production, or 20 ml of 23% NaOH to measure CO_2 retained by the dough. The vessel was sealed with a mercury manometer cap and placed in a 30°C water bath. CO_2 pressure was measured at 200 min, equivalent to the time that the dough was fermented and proofed before baking.

Moisture pickup of sweet whey powders was evaluated by suspending 5.000-g portions (weighed on an analytical balance) over a 12% soy-fortified flour blend of 12.8% moisture in a bell jar. After three days at room temperature, samples were reweighed for moisture pickup and observed for appearance.

Flour Mixes

Flour mixes were made up by blending wheat flour, soy flour, and SSL in 10-lb lots (control) or additionally with SWS in a 4-gal sealed pail and then storing portions in sealed 1-qt mason jars at room temperature and at 36°C. Unblended portions of these materials were stored in the freezer at −14°C and recombined at the time of each test bake.

Panel Evaluation

Sliced breads of 1.5-cm thickness with the crusts removed were evaluated for both taste and texture on a 9-point hedonic scale (Peryam and Pilgrim 1957) by a panel of 13 judges. Although not experienced in evaluating breads, the judges had previous experience in taste-panel evaluation of a variety of food products.

Data were statistically treated by analysis of variance and Duncan's multiple range test to determine significance of results (Snedecor 1956).

RESULTS

Two to four percent replacement of a commercial 12% soy-fortified blend with equal amounts of commercial SWS permitted absorption to be decreased by an equivalent amount without changing dough-handling characteristics. The replacement produced bread of increased volumes exceeding the minimum specification of 2,550 cc, as specified in Announcement WF-15

(ASCS 1975) (Table II). Doughs with 2% SWS were tolerant to 3.5 to 6.5-min mixing, whereas the control was overmixed at 6.5 min. Crust colors of the bread with SWS were significantly darker and, at the 4% level, judged to be still darker. Loaf symmetry, crumb color, grain, and texture were judged much the same in all breads. However, the slices from the breads stored from two to four days and containing SWS made from doughs mixed 5 min were significantly more compressible, as measured by the Baker compressimeter than were slices of the controls (Table III). This may be because the larger-volume breads with SWS had thinner cell walls. Drop tests conducted on duplicate doughs with SWS compared favorably to those of the control. The control bread originally measured 2,450 cc. The bread with SWS measured 2,550 cc. The loaf volume of the dropped bread that contained SWS measured 1,937 versus 1,860 cc for the control.

Replacement of 12% soy-fortified export flour (no SSL) with 1.5% α-lactose hydrate slightly lowered farinograph water absorption, slightly increased arrival times and peak times, and promoted stability (Table IV). SWS progressively decreased absorption and increased arrival times, and especially at the 4% level, peak times. NFDM solids (3%) increased stability. All replacements decreased the mixing tolerance index (MTI).

Replacement of wheat flour with as little as 0.5–3% of SWS progressively increased loaf volume, and, at 1.0% or higher, though not statistically significant, progressively decreased proof times (Table V). Absorption was decreased by a like amount to obtain doughs of equal consistency. To clean up during mixing, whey doughs were scraped twice on the sides of the bowl and control doughs once, but all handled equally well. Crust color scores progressively decreased from 8.8 to 8 as SWS levels were increased from 0–3%.

Figure 1 shows the greater volume of breads containing 2% SWS (center slices) compared to controls from doughs of variable dough absorptions mixed 4 min. The bread slices are shown as pairs made from doughs of equal consistency. The bread containing SWS had the same volume (2,450 cc) at 58% absorption as did the controls at 62 and 64% absorption, and had a larger volume than that of the 60% absorption control of equal consistency. The grain of the bread with SWS is the same as or finer than that of the controls.

TABLE IV
Farinograph Characteristics of 12% Soy-fortified Export Flour

Percent Replacement of Wheat Flour	Percent Absorption	Arrival Time (min)	Peak Time (min)	Stability (min)	MTI[a] (min)
Control	63.6	4.0	7.0	6.0	65
1.5 Lactose hydrate	62.4	4.25	7.5	7.25	50
2 SWS[b]	61.8	5.0	7.5	6.0	55
4 SWS[b]	60.4	6.0	8.25	6.0	55
4 HH[c] SWS	60.8	6.0	8.5	7.5	30
3 NFDM[d]	64.2	4.0	7.0	8.0	40

[a]Mixing-tolerance index.
[b]Commercial sweet whey solids pasteurized at low heat.
[c]High heat.
[d]Nonfat dry milk.

TABLE V
Effect of Level of Commercial Sweet Whey Solids on Breadbaking[a] of 12% Soy-fortified Export Flour

Percent Whey Solids Replacement of Flour	Percent Absorption	Proof Time (min)	Loaf Volume (cc)[b]	Number of Loaves	Crust Color[b]
None	62	64.8	2,472 a	8	8.81 b
0.5	61.5	65.7	2,600 ab	6	8.67 ab
1	61	63.5	2,628 b	4	8.37 ab
2	60	61.7	2,680 b	6	8.03 a
3	59	60.5	2,706 b	4	8.25 ab

[a]Optimum mixing time of 3.5 min.
[b]Different letters indicate significant difference at $P<0.05$. Standard deviation: proof time, ±2.8 min; loaf volume, ±65 cc; crust color, ±0.29.

Optimum handling absorption was 62% for the control and 60% for the whey bread. Control doughs at 64% and doughs containing SWS at 62% absorption were too slack to handle. Both mixed similarly, requiring additional scraping of the sides of the bowl to clean up the dough.

Figure 2 shows the center slices of bread containing 1% SWS at 61% dough absorption compared to the control at 62% dough absorption. Both doughs handled similarly.

Addition of 3% NFDM solids did not increase loaf volume as did 2% SWS, demineralized whey solids, or 1.5% α-lactose hydrate (Table VI). Lactose-containing solids (LCS) were all added at a level to give equivalent amounts of lactose-containing levels. The high-heat NFDM solids produced a slack dough at 62% absorption that required several scrapings of the bowl before cleanup. All other LCS doughs required an additional scraping of the bowl compared to the control, but these handled equally well. Lactose significantly increased proof times. The fineness of the grain of the

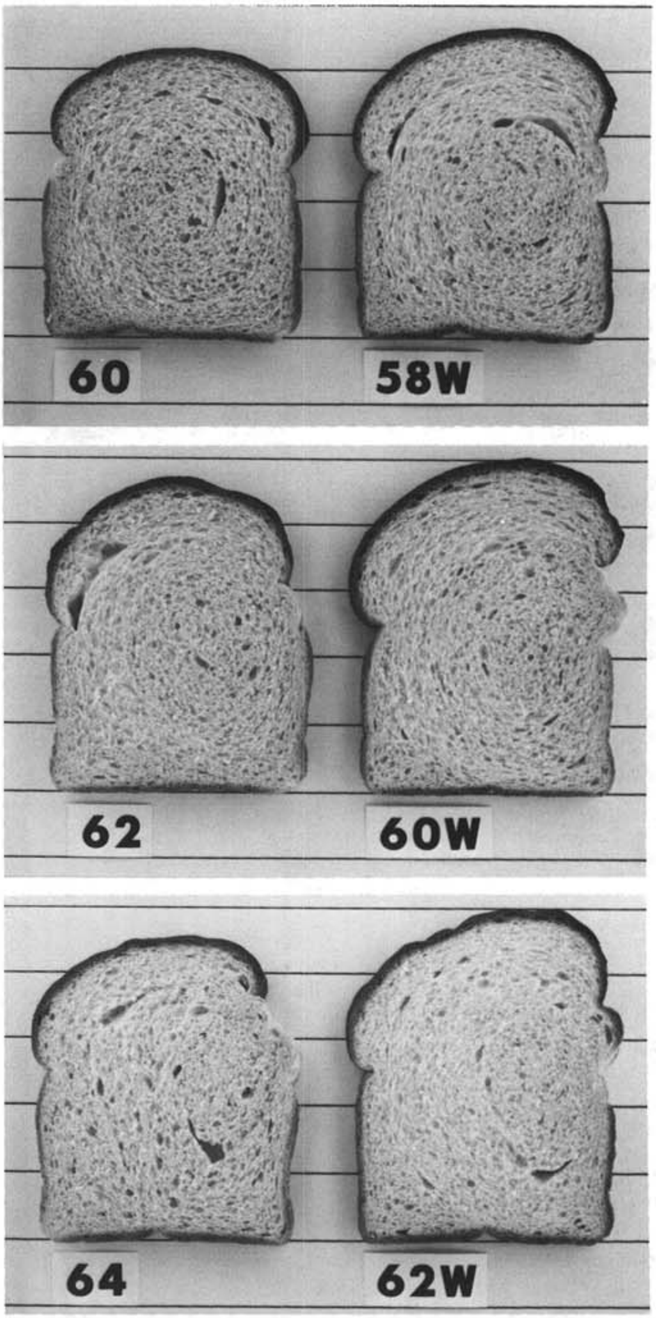

Fig. 1. Comparisons of center slices of breads made with and without 2% sweet whey solids (W) from doughs of equal consistency. Numbers = percent water absorption.

sliced breads was similar.

Replacement of wheat flour with SWS processed from high-heat-treated fluid whey produced bread of very significantly lower volume than that made with either commercially prepared whey solids or low-heat-processed whey solids made by ERRC (Table VII). The dough with low-heat SWS (12.2 mg of WPN per gram) required one more scraping (total of three) than the doughs containing the other two types of solids. The commercial SWS had 8.4 mg of WPN per gram, indicating that it was partially denatured and to have possibly received a heat treatment higher than conventional pasteurization, which denatures very little protein. All doughs were rated very good for handling. The crust colors of the SWS breads were rated 7.5 and were judged to be excessively dark. Federal brand yeast was used in this experiment.

Increasing levels of SSL added to soy-free wheat flour counteracted the loaf volume-depressing effects of 3% SWS and significantly increased the loaf volumes of both the controls and the whey-fortified breads (Table VIII). The addition of 0.5% SSL gave the highest volumes. The addition of 3% shortening to SWS containing doughs also significantly increased loaf volumes. Doughs were not proofed beyond 70 min, as specified in Announcement WF-15 for soy-fortified flavors. Dough handling was very good. Although not shown in Table VIII, addition of 3% shortening to 12% soy-fortified wheat flour containing 3% SWS but not SSL also increased loaf volume to 2,800 cc, compared to 2,600 cc for the control with no SWS.

Variable mixing times from 2.5–3.5 min for pup doughs containing 12% soy-fortified 11.6% protein export flour supplemented with 2% SWS produced breads of significantly increased volume compared to their respective controls (Table IX). Doughs mixed for 3 min gave optimum handling and a nearly equivalent percent for cleanup. Heights of all SWS-containing doughs proofed for 70 min were equal to or exceeded those of their controls. Table X also shows that 2% SWS increased average proof heights. CO_2 production over 23% NaCl and CO_2 retention over 23% NaOH were not significantly affected. However, the significantly larger volume of the SWS breads as well as their higher average dough-proof heights are thought to be a valid reflection of the greater CO_2 retention of SWS doughs.

Samples of 12% soy-fortified 11.6% protein wheat flour blend containing 2% SWS stored up to six months at 20–25°C and at −14°C produced breads of significantly higher volume in every case than their respective controls with a statistical probability of <.0001 (Table XI). Statistical interactions, also with a probability of <.0001, showed that the length of storage producing significant changes in volume was dependent on both the storage temperature and the treatment. Significant loss of volume in breads from both control and SWS blends stored at room temperature but not at −14°C occurred after two months of storage. Both control and SWS blends stored at 36°C beyond two weeks produced breads of very significantly low volumes with a statistical probability of <.0001. They yielded dry-handling doughs that required an additional 0.5 min of mixing. When 0.5% SSL or 3% shortening was added at the time of bake to six-week-old blend samples stored at 36°C, their volumes increased as did those of the refrigerated blends, indicating that SSL had deteriorated in the stored mix. Hydrolysis of SSL at normal flour moisture has been suspected but not confirmed in published reports (Bean et al 1977). Shortening and SSL are largely interchangeable in their effects on loaf volume, although higher levels of shortening are required to produce equal volumes (Mecham et al 1976). These authors report that deterioration of SSL in the mix is responsible for losses in volume in the early stages at 38°C and that deterioration of soy and/or wheat flours are mainly responsible for volume losses after eight weeks of storage.

Relative humidity affects the free-flowing character of whey solids. Both high-heat (2.4% moisture) without crystalline lactose and a commercial low-heat pasteurized powder (4.0% moisture) with crystalline lactose were suspended in a bell jar over a soy flour blend (12.8% moisture) at 58% rh (measured by an inserted gauge).

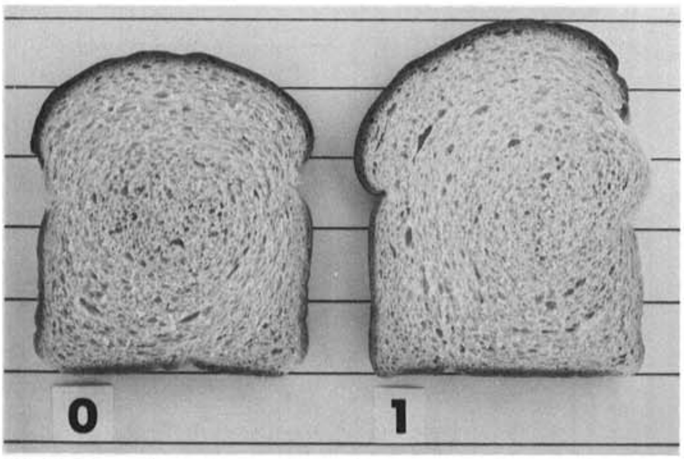

Fig. 2. Comparison of center slices of breads made with and without 1% sweet whey solids (1) from doughs of equal consistency. Control (0) 2,475 cc, 1% whey solids 2,675 cc. Doughs mixed for 3.5 min.

TABLE VI
Effect of Lactose Containing Solids (LCS) on Breadbaking[a,b] of 12% Soy-fortified Export Flour

Replacement of Flour[c]	Percent LCS Absorption	Proof Time (min)[d]	Loaf Volume (cc)[d]
3 HH nonfat dry milk	62	62.5 a	2,425 a
Control	62	66.0 ab	2,487 a
2 SWS	60	62.5 a	2,675 b
1.85 DM SWS	60	66.5 ab	2,600 b
1.5 Lactose	60.5	69.0 b	2,675 b

[a] Optimum mixing time, 3.5 min.
[b] Four loaves per sample.
[c] HH = high heat-treated; DM = 90% demineralized; SWS = sweet whey solids.
[d] Four loaves per sample. Standard deviation: loaf volume, ±61.2 cc; proof time, ±1.65 min.

TABLE VII
Effect of Soluble Whey Protein Nitrogen (WPN) of 4% Sweet Whey Solids (SWS) on Bread[a] of 12% Soy-fortified Export Flour

SWS Replacement of Flour[b]	WPN (mg/g)	Proof Time (min)	Loaf Volume (cc)[c]
Low heat	12.2	69.5	2,725 b
Commercial pasteurized	8.4	69.5	2,700 b
High heat	4.1	68.5	2,568 a

[a] Four loaves per sample.
[b] SWS = 57% absorption, 4 min of mixing time.
[c] Different letters indicate significant difference at $P<0.01$. Standard deviation: Loaf volume, ±30.1 cc; proof time, ±1.0 min.

TABLE VIII
Effect of Sodium Stearoyl-2-Lactylate (SSL) on Breadbaking of 12% of Soy-fortified Export Flour With and Without Sweet Whey Solids (SWS)[a]

Percent SSL	Proof Time (min)		Loaf Volume (cc)		Number of Loaves
	Control	3% SWS	Control	3% SWS[b]	
0	69	70[c]	2,487 b	2,290 a	2
0.28	69	65	2,900 de	2,775 cd	2
0.50	65	68	2,962 ef	3,037 f	2
0[d]	70[d]	70[d]	2,718 c	2,825 d	4

[a] Five-minute mixing time. Percent absorption: 60% control; 57%, 3% SWS.
[b] Loaf volume standard deviation, ±56 cc. Different letters indicate significant difference for each level of SSL at $P<0.05$.
[c] Proofed 70 min maximum but not up to height.
[d] Shortening (3%) added.

TABLE IX
Effect of 2% Commercial Sweet Whey Solids (SWS) Replacement of Flour on Pup Baking of 12% Soy-fortified Export Flour

Mixing Time (min)	Dough Handling[a]		Percent Cleanup[a]		Proof Height (cm), 70 Min[a]		Loaf Volume (cc)[a,b]	
	Control	SWS	Control	SWS	Control	SWS	Control[c]	SWS[c]
2.5	VG⁻	VG	85	80	1.35	1.65	695 bc	742 d
3.0	VG	VG	89	87	1.25	1.50	682 b	705 c
3.5	VG⁻	VG⁻	93	90	1.35	1.35	658 a	685 b

[a]Control, 62% absorption. SWS, 60% absorption. VG = Very good.
[b]Average of two loaves.
[c]Different letters indicate significantly different at $P < 0.05$. Loaf volume standard deviation ±6.6 cc.

TABLE X
Effect of 2% Sweet Whey Solids (SWS) Replacement of Flour on Dough Pressuremeter and Pup Baking of 12% Soy-fortified Export Flour

	Proof Height (cm), 70 min	Pressure[a] Over Hg (mm)		Loaf Volume[b] (cc)
		23% NaCl	23% NaOH	
Control	1.33	235.7	115.3	678 a
SWS	1.53	227	118.3	722 b
St. Dev.	±0.19	±7.3	±18.7	±9.8

[a]10.0 g of dough held 200 min at 30°C. Mix time = 3 min.
[b]Average of six loaves. Control, 62% absorption; SWS, 60% absorption. Different letters indicate significant difference at $P < 0.05$.

TABLE XI
Effect of Storage on the Loaf Volume of 12% Soy-fortified Export Flour as a Blend With and Without 2% Sweet Whey Solids (SWS)

Weeks of Storage Time	Loaf Volume (cc)[a]					
	−14°C		20–25°C		36°C	
	Control	SWS	Control	SWS	Control	SWS
0	682	750	682	750	682	750
2	727	740	695	740	700	685
	690	705	···	···	662	667
4	670	710	690	712	582	575
6	695	745	···	···	535	525
					680[b]	700[b]
					710[c]	710[c]
9	682	722	667	690		
13	672	682	618	637		
18	682	698	615	630		
26	682	705	645	674		
Average	686.9	717.4	···	···		

[a]Control blend, 12.4% moisture, 62% absorption. SWS blend, 12.2% moisture, 60% absorption. Loaf volume standard deviation ±14.6 cc.
[b]0.5% Sodium stearoyl-2-lactylate added at time of mixing.
[c]3% Shortening added at time of mixing.

The 12.8% moisture mix is close to the maximum moisture content (12.4%) allowed in a 12% soy-flour mix. The commercial low-heat powder did not cake after attaining moisture equilibrium in three days, even though its moisture increased to 9.25%. The high-heat powder with no crystalline lactose equilibrated at 8.36% moisture and did cake. The commercial low-heat powder resisted caking even for four days of storage at 80% rh and absorbed up to 13% additional moisture, whereas both laboratory-prepared low-heat and high-heat powders caked because water sorption caused the lactose to crystallize as the hydrate. No shot-balling or agglommerating of whey solids was noted in any stored mix made with commercial-grade whey solids, substantiating the findings, which showed that these solids remained free-flowing at the equilibrium rh of the mix.

The taste of the crust or crumb and the crumb texture from 1-lb loaves containing 2% SWS baked from fresh flours were judged not significantly different by a panel on a 9-point hedonic scale. The taste and texture of slices from breads made from mixes stored for three months at −14°C, room temperature, and 36°C, rated similarly and not significantly different on the 9-point hedonic scale. The crumb taste of the controls scored from 6.15 to 6.46, and that of 2% SWS bread crumbs scored from 6.07 to 6.38. Crumb textures were not significantly different and rated 6.15–6.20 for the control and 6.0–6.61 for the 2% SWS sample.

DISCUSSION

It was believed the soy flour used in this study was responsible for most of the smearing of the doughs. It was previously noted that even when suboptimal absorptions of 60% were used for the control 1-lb loaves and 58% for SWS, some smearing of doughs occurred, which required scraping. When using a different brand of defatted soy flour, negligible smearing of doughs occurred at optimum absorption. No smearing occurred with soy-free doughs or with a commercial mix supplied by the USDA-ASCS.

The effects of SWS on dough absorption, as judged by the baker, correlated similarly to those indicated by the farinograph. The farinograph absorption of the control and 3% NFDM solids were much the same. However, dough for baking was very slack when the water level used in the control was used for the NFDM solids. Decreasing the absorption of 3% high-heat NFDM solids to 1.5% less than the control produced a dough of very good handling consistency, equal to that of the control, but still produced bread of significantly lower pup loaf volume (649 cc versus 681 cc for the control). Commercial low-heat NFDM solids (8.4 mg of WPN per gram) did not cause significant volume changes but produced a dough that handled slightly less well than the control. SWS increased farinograph arrival times and caused increases in dough smearing during the initial stages of mixing. With levels of 2% SWS or less, this change in extent of smearing was small.

Low-heat soy flour of 70–80% soluble protein is the flour of choice that is included in the Government purchase blends. Since commercial low-heat SWS perform better in the mix than the high-heat SWS, their soluble protein as well as that of the soy flour in this particular formation may be proteins of choice. Most commercial SWS are considered low-heat-treated and are readily available.

Our study showed that as little as 0.5% and up to 2% commercial SWS could be incorporated into 12% soy-fortified bread wheat flour mix with minimal absorption and mixing changes, and would produce bread of improved volume and storing quality. Mixes with SWS stored at 20–25°C for up to six months produced breads of higher volume than their controls. Both controls and SWS blends stored at 36°C deteriorated within weeks after storage, and that of the SWS slightly more. This may be because SSL is needed for volume improvement of breads containing SWS. Otherwise, its exclusion or loss of activity will depress SWS bread volumes, relative to the control. For this reason, use of SWS in breads shipped to tropical countries may not be recommended.

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