SOY-FORTIFIED WHEAT-FLOUR BLENDS. II. STORAGE STABILITY OF COMPLETE BLENDS[1]

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ABSTRACT

Soy-fortified wheat-flour blends, containing 0.5% sodium stearoyl-2-lactylate, were stored at −10° and 100° F at 13% moisture. The three soy flours compared were: 1) defatted and mildly heated, 2) full-fat, and 3) defatted and oxidized, with calcium salts added. Bread was baked by a straight-dough procedure with 3% shortening (2% for the full-fat blends) added to the doughs. Zero-time loaf volumes were about equal for the two defatted soy blends (12 parts soy flour:100 parts wheat flour), and slightly lower for the full-fat blends, which contained 14.5 parts of full-fat soy to provide the same soy protein:wheat protein ratio. At 13% moisture and 100° F, the defatted, mildly heated soy blend lost 11% in loaf volume in 26 weeks. Wheat flour alone, under the same storage conditions, lost 7 to 9% in loaf volume, depending on baking procedures. Blends containing the defatted and oxidized, or the full-fat soy flour lost about 20% loaf volume in 26 weeks. A change in storage conditions to either 10% moisture or 90° F reduced loaf volume losses to 10−15% for the oxidized soy-flour blends, and to about 5% for the full-fat soy blends. Off-flavors were present in bread from all of the blends after 24 to 28 weeks of storage at 100° F and 13% moisture.

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Nutritional advantages are gained by adding soy flour to wheat flour; baking performance of the blends is maintained by including sodium stearoyl-2-lactylate (SSL) (1−3). For these reasons, inclusion of such blends in food purchases for overseas aid programs was advocated. Specifications for 6 and 12% soy-fortified bread flour were prepared (4) and purchases and distribution began in October 1972. In the course of work on the specifications (5), little information could be found on the storage stability of flour blends containing different types of soy flours and/or SSL at the normal moisture levels of bread flour. In view of the warm and humid conditions and extended distribution times to which overseas shipments could be subjected, the studies reported here were carried out.

MATERIALS AND METHODS

The wheat flour was a commercially milled, Southwestern bread flour containing 11.5% protein and 0.48% ash (14% moisture basis), from 1970 crop wheat.

The three soy flours, all from commercial sources, were a full-fat soy flour, a defatted, lightly heated flour with a nitrogen-solubility index (NSI) in the 70 to 80% range, and a defatted soy flour further treated with hydrogen peroxide and calcium salts (6). Analytical data are given in Table I.

SSL was a commercial product ("Emplex", C. J. Patterson Co.). The basic soy-wheat flour blend was made up of 12 parts defatted soy flour, 100 parts wheat

[1]Presented in part at the 57th Annual Meeting, Miami Beach, Oct.−Nov. 1972.

Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

flour, and 0.5 parts SSL. When full-fat soy was used, 14.5 parts were added to bring the soy:wheat protein ratio to the same value as reached with defatted soy. To the basic blends were added vitamin A, thiamin, riboflavin, niacin, and reduced iron at normal enrichment levels, and calcium carbonate to bring the Ca:P ratio to about 1:1 (4). Potassium bromate was added at 10 ppm. When moisture adjustment was necessary, increases to 13% H_2O were accomplished by adding water while the blend was agitated in a twin-cone blender equipped with atomizer, or by exposing the blend in trays in a fermentation cabinet. To decrease moisture, trays of blend were held in a low-humidity room overnight to obtain 10% moisture samples. The flours and blends were stored in polyethylene bags inside 5-gallon tins with double-friction lids. The controls were maintained at −10° F and the test materials at 90° or 100° F. The tins were removed from cold or warm storage and allowed to stand at room temperature overnight. They were then opened and samples were removed for tests. Moisture determinations, made each time samples were removed, showed that moisture contents remained unchanged.

TABLE I
Composition of Soy Flours[a]

Type	Moisture %	Protein[b] %	Fat %	Ash %	NSI[c] %
Full-fat (FF)	5.1	41.8	22.4	4.8	35–45
Defatted, lightly heated (D7)	7.8	52.8	1.1	6.1	70–79
Defatted, oxidized, calcium salt added (DOx)	7.0	52.1	1.3	7.3	15–25

[a]Not corrected for moisture content.
[b]N × 6.25.
[c]From processor's description.

TABLE II
Formula and Procedure[a] for Baking Test

	Flour Basis %
Soy-fortified bread wheat-flour blend (including SSL), 14% moisture basis	100.0
Yeast, baker's compressed	2.5
Sodium chloride	2.0
Sucrose	4.0
Water	63–68
Shortening	
(with defatted soy)	3.0
(with full-fat soy)	2.0

[a]Mix in Hobart A120 or A200 equipped with MacDuffee-type bowl and fork or equivalent; adjust water temperature to give dough temperature of 84°±1° F. Mix at low speed 30 sec, then at medium speed to optimum dough development. Round dough by hand. Ferment 1-3/4 hr at 86° F. Scale to 525 g, round or sheet once, let recover 20 min. Then sheet once with an 11/32-in. gap between rollers, followed by once at 7/32 in. Curl by hand with slight pressure to elongate dough to fit pan for standard 1-lb loaf. Proof at 86° F to 1 in. above the pan (but do not proof more than 70 min). Bake 25 min at 425° F. Measure loaf volume immediately on removal from oven by rapeseed displacement method.

Bread was baked by a straight-dough procedure (Table II) identical to that described in the specifications for soy-fortified flours (4), except that 3% shortening was added to the doughs containing defatted soy blends, and 2% to doughs of the full-fat blends. (Shortening was omitted from the specifications test to make it more sensitive to the dough conditioner.) Optimum mixing and absorption were judged by appearance and feel of the doughs; in all cases mixing times were shorter and absorption was higher than for doughs not containing soy, as reported by others (1,3). Duplicate bakes (two pup loaves from each) made on two different days have been averaged.

Farinograms were run by the constant-flour-weight method in a 50-g bowl (7).

Increases in titratable acidity of water-saturated *n*-butyl alcohol extracts were used to measure formation of free fatty acids (8).

For sensory evaluation, 1-lb loaves were baked and held overnight at room temperature in polyethylene bags. Just prior to testing, the loaves were sliced and all the crust was trimmed off. A laboratory panel of 20 experienced appraisers (not necessarily experienced in judging bread) ranked four coded samples, including a −10° F control, in order of least off-flavor. Order of presentation was randomized and each comparison was replicated on a different day. Panelists also were asked to indicate whether a sample was acceptable or not.

RESULTS AND DISCUSSION

Loaf Volume Changes

Loaf volume changes occurring after storage of blends at three temperature-moisture combinations are shown for the defatted, oxidized soy flour (DOx) blends in Fig. 1. The changes are shown as percentage of the loaf volume of the

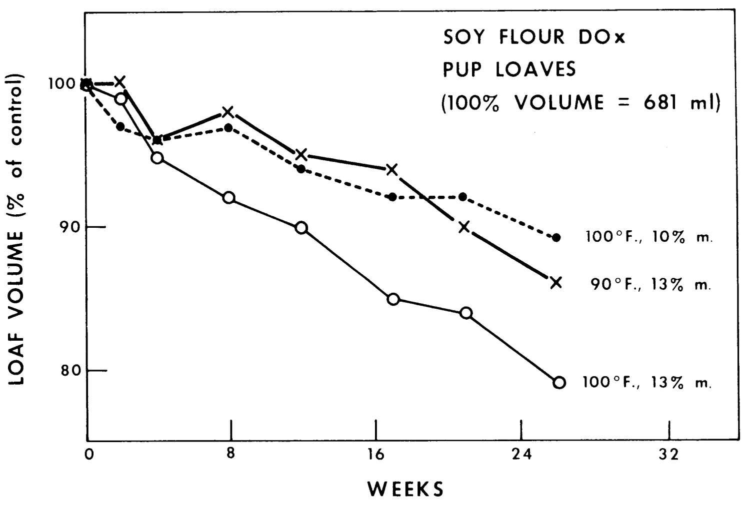

Fig. 1. Loaf volume changes for blends containing the defatted, oxidized soy flour stored under three moisture-temperature conditions.

same blends stored at −10° F. A steady deterioration occurred at 100° F, 13% moisture, reaching a 21% loss in 26 weeks. Lowering the temperature to 90° F, or the moisture to 10%, decreased the rate of loss of loaf volume by about one-third to one-half. For comparison, the wheat flour alone without SSL was stored at 13% moisture and 100° F. When baked by the procedure used for the soy-fortified blends, it lost 7% in volume compared to its −10° F, 13% moisture control, which had a volume of 731 ml. When baked by the Finney and Barmore baking procedure (9), with added nonfat milk solids, 3 hr fermentation, etc., it lost 9% from a control sample volume of 766 ml. Thus, the average percentage loss for the wheat flour alone was less than half that found with the DOx blend at 13% moisture and 100° F.

Corresponding results for the full-fat soy flour (FF) blends are shown in Fig. 2. At 100° F and 13% moisture, the loaf volume losses in the first 12 or 17 weeks were somewhat slower than for the DOx blend, but accelerated later so that the percentage loss in 26 weeks was nearly the same (20%). Under the less severe storage conditions (either 90° F or 10% moisture), the FF blends maintained loaf volume through 21 weeks.

The defatted, mildly heated soy flour (D7) was not included in the first storage comparisons because it had not been proposed originally for use in the soy-fortified flours. Later, however, a blend was held at 100° F and 13% moisture, along with −10° F control, but intermediate conditions were not used. Original loaf volume was 686 ml. Loaf volume decrease during the first 12 weeks was intermediate to the DOx and FF soy blends but then was less rapid, so that at 26 weeks the volume loss was 11% as compared to the 20 and 21% loss for the other soy blends. The greater availability and lower cost of the D7 soy flour had already strongly indicated its use in the blends; the additional observation of superior stability of baking performance was a further recommendation.

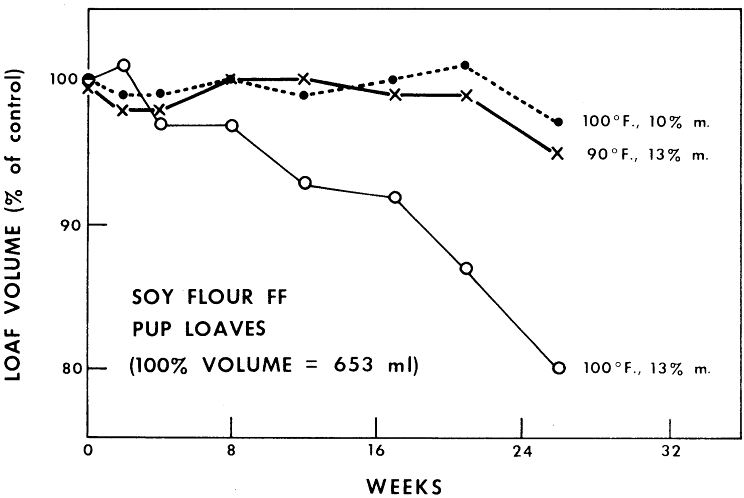

Fig. 2. Loaf volume changes for blends containing the full-fat soy flour stored under three moisture-temperature conditions.

Farinogram Changes

Farinogram mixing curves were run only on the DOx and FF blends, and not on the D7 blends. Changes in the farinograms of the DOx blends during storage were minor. Peak time for all samples fell in the range of 6.0 to 7.0 min, with no effect of temperature, moisture, or storage time apparent. Stability was somewhat more variable, the range being 10.5 to 13.5 min. Again, however, no trends were apparent, with most values included in a spread of 11.5 to 12.5 min.

In the FF soy blends, some lengthening of peak time occurred early in storage in the 13% moisture samples. The control peak time averaged 4.5 min. At 8 weeks and later, the average peak time for the 90° F samples was 6.75 min, and for the 100° F sample it was 7.0 min from 2 weeks on. At 10% moisture, no change occurred. In contrast to the peak time values, however, the stability values showed no regular trend.

Free Fatty Acids

Increases in free fatty acid content were moderate. Maximum increases for both the DOx and D7 defatted soy blends in 26 weeks (13% moisture, 100° F) were 14 μeq per g of sample. For the FF blends, it was slightly higher at 20 μeq per g, presumably reflecting the additional oil substrate contributed by the soy. The increases observed were about the same size as those found with Flour Blend A, the all-wheat blend containing 70 parts white flour and 30 parts wheat protein concentrate (10). In contrast to the case with Flour Blend A, however, the changes did not correlate well with loaf volume changes in storage. For example, as shown in Fig. 2, the FF soy blends at 13% moisture, 90° F, and at 10% moisture, 100° F, maintained loaf volume equally well, and much better than the 13% moisture, 100° F, sample. But, as shown in Fig. 3, the 10% moisture, 100° F

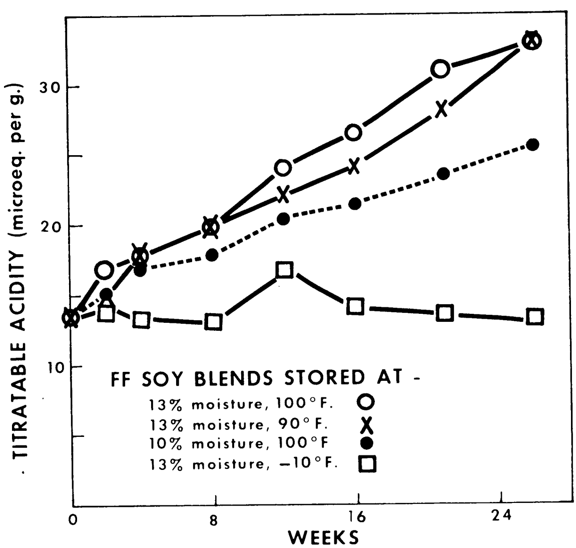

Fig. 3. Changes in titratable acidity of lipids of blends containing full-fat soy flour stored under the indicated moisture and temperature conditions.

sample increased in free fatty acids more slowly than either of the 13% moisture samples, which were nearly equal.

With the DOx soy blends, the free fatty acid values (Fig. 4) did not differ enough to reflect the baking performance differences indicated in Fig. 1. The D7 soy blend at 13% moisture, 100° F, gave free fatty acid values near those of the corresponding DOx blend.

Flavor and Odor Changes

When baking tests were made during the storage studies, the presence of off-flavors and -odors was first noted at 21 weeks in some DOx and FF blends. Sensory evaluations were then initiated at 24 weeks. Sensory results for DOx and FF samples are given in Table III. As expected, the −10° F controls had the least off-flavor and the 13% moisture, 100° F samples had the most off-flavor. The difference was significant (1% level) for both panel sessions for both types of soy flour. Also, a 3% lowering of moisture content appeared to retard development of off-flavors more than a 10° F lowering of temperature. An indication of acceptability of the bread samples (Table IV) was consistent with the ranking results, again indicating the greater effect of a 3% moisture decrease as compared to a 10° F temperature decrease. Both blends stored 24 weeks at 13% moisture and 100° F gave bread considered acceptable by less than half the panel.

Corresponding evaluations could not be made for the D7 soy blends as samples had not been stored at the intermediate conditions. However, after 27 weeks the 13% moisture, 100° F sample was judged significantly different than the control (−10° F storage) sample, when evaluated in a set of samples which also included three samples in which the wheat flour and soy flour held separately at −10° or 100° F had been blended in different combinations (*e.g.*, −10° F soy flour plus 100° F wheat flour). The results will be presented in a following paper; however, they indicated that at 100° F and 13% moisture, the wheat flour was

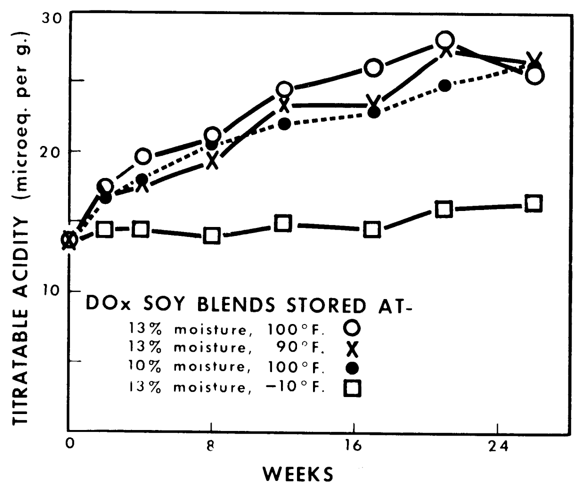

Fig. 4. Changes in titratable acidity of lipids of blends containing defatted, oxidized soy flour stored under the indicated moisture and temperature conditions.

more responsible for off-flavors than the D7 soy. Therefore it seems reasonable to expect that blends of the D7 soy would be at least as stable as FF and DOx blends.

GENERAL DISCUSSION

Deterioration of experimental soy-wheat flour blends showed up both in loaf volume and in flavor; the latter became objectionable to most of the panel members before 26 weeks if blends were stored at 100° F and 13% moisture. Whether such blends are in fact stable enough for use in overseas aid programs can, perhaps, only be determined by experience of acceptability after distribution through regular channels; the high moisture conditions used in this study may have been more severe than necessary. Nevertheless, the results suggested care in handling and caution in the amounts purchased until some experience was obtained.

In addition, loaf volume decreases obtained with a wheat flour typical of those distributed in overseas aid programs were less rapid than those of soy blends. As an estimate, loaf volume decreases of 15% might still permit acceptable, but compact, bread to be baked from soy blends; further loss in volume, however,

TABLE III
Flavor Ranking[a] of Breads from Soy-Wheat-SSL Blends Stored 24 Weeks

Storage Conditions	Total Rank Sums of Replicate Panels (N=20)			
	DOx Soy panel test		FF Soy panel test	
	No. 1	No. 2	No. 1	No. 2
−10° F, 13% moisture	37**	38**	26**	29**
100° F, 10% moisture	43	45	46	44
90° F, 13% moisture	54	49	61*	57
100° F, 13% moisture	66**	68**	67**	70**

[a]Lower numbers represent least off-flavor and higher numbers represent most off-flavor.

TABLE IV
Acceptability of Bread from Soy-Wheat-SSL Blends Stored 24 Weeks

Storage Conditions	DOx Soy		FF Soy	
	Ratio yes:no[a]	yes %	Ratio yes:no[a]	yes %
−10° F, 13% moisture	31:5	86	37:6	86
100° F, 10% moisture	29:6	83	33:9	79
90° F, 13% moisture	22:13	63	28:13	68
100° F, 13% moisture	14:21	40	17:24	41

[a]Yes = acceptable; no = not acceptable.

could hardly be tolerated. Under the most severe storage conditions used, off-flavors had developed and were reaching an unacceptable level at about the same time that loaf volume had decreased 10 to 20%. Acceptability for nonleavened products would be lost also. Other wheat and soy flours may, of course, differ somewhat in stability, but it seems doubtful that any would remain acceptable much longer than the defatted, lightly heated soy and the unbleached wheat flour under the same adverse conditions.

The question of which ingredients are principally responsible for the deterioration is considered in a following paper.

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