SOY-FORTIFIED WHEAT-FLOUR BLENDS. III. STORAGE STABILITY OF INGREDIENTS AND INCOMPLETE BLENDS[1]

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ABSTRACT

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Soy flours, a baker's patent bread flour, and blends containing sodium stearoyl-2-lactylate (SSL) were stored at 13% moisture and 100° F (or −10° F for controls). Bread was baked with 100 parts wheat flour plus 12 parts soy flour. A defatted, lightly heated soy flour improved slightly, although a defatted, oxidized soy flour and a full-fat soy flour did not change in bread-baking properties in 26 weeks. The wheat flour lost about 15% in loaf volume potential despite the inclusion of 0.5% SSL and 3% shortening in doughs, and complete blends lost more loaf volume potential, suggesting that SSL decomposed or that changes in the flours made the SSL less effective. Panel evaluation of the taste of breads baked with the defatted, lightly heated soy flour after 27 weeks' storage showed that the wheat flour was the principal source of off-flavors that had developed at 100° F. Bread from a blend of the soy flour stored at 100° F and wheat flour stored at −10° F was not distinguished from bread for which the complete blend was stored at −10° F.

The nutritional advantages of soy-fortified bread flours have been known for a long time, and acceptable breads can be produced from such flours by the use of sodium stearoyl-2-lactylate (SSL) in the doughs (1). When stored at 100° F and 13% moisture, however, complete blends lost from 10% to more than 20% in loaf volume (depending in part upon type of soy flour and baking formulations, especially shortening level) and developed off-flavors in less than 6 months (2). It was important to determine whether the deteriorations observed were principally in the soy flour, wheat flour, or SSL, in order to suggest appropriate remedial actions. Work carried out to that purpose is reported here.

MATERIALS AND METHODS

The principal bread flour and the soy flours were the same lots described previously (2).

Moisture content of the wheat and soy flours was increased to 13% or more by exposing thin layers in trays to the humid air in a fermentation cabinet, or decreased in a low-humidity room.

Storage and baking procedures were as described in (2). The evaluation of intensity of off-flavors by a panel was changed somewhat from the preceding study. Bread was prepared as before, but five samples were ranked from 1 to 5 with a rank of 1 representing a flavor most like the control and rank 5 least like the control. A control sample was labelled, but a second control sample was included as an unknown in the set of five samples. Judges were asked to taste the

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labelled control first and then rank the remaining samples. Each sample was coded, and the order of tasting was randomized for two replications with 10 judges for each replication.

RESULTS AND DISCUSSION

Effect of SSL

In an attempt to evaluate the stability of SSL in the blends and the extent of deterioration of the flours that could not be compensated for by SSL, soy-wheat flour blends were stored without SSL. After storage, samples were baked with SSL added to doughs at mixing, and also without SSL. The loaves were compared to bread from stored samples of complete blends (*i.e.*, with SSL added before storage rather than at the time of baking).

Results with the full-fat (FF) soy blends are shown in Fig. 1; 2% shortening was added to these doughs. In the early stages of storage (0 to 2 weeks), 0.5% SSL (wheat-flour basis) either added at the mixer or present in the blend gave about a 5% increase in loaf volume over the "no SSL" blend. The effectiveness of SSL when stored in the blend then appeared to diminish. Although the results are not precise enough to establish differences at any one storage period, the "SSL in blend" sample loaf volumes consistently stayed below those of the "SSL at mixer" sample and above those of the "no SSL" sample. Thus, it appeared that much of the effect of SSL on loaf volume was lost early in storage, but that the total loss in loaf volume during 26 weeks at 100°F, 13% moisture, was much larger than could be attributed to decomposition of SSL in the complete blend. Deterioration of the soy and/or wheat flours was mainly responsible for volume losses after about 8 weeks' storage.

Results with the defatted, oxidized (DOx) soy blends (Fig. 2) are similar,

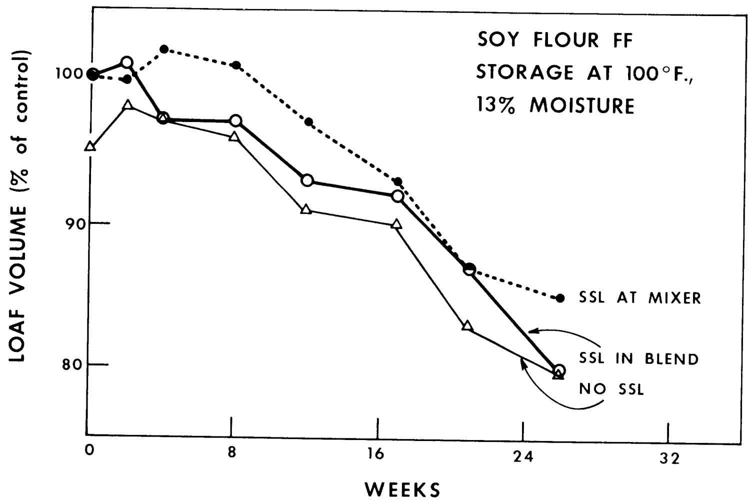

Fig. 1. Effects on loaf volume of storage and SSL additions to stored blends and doughs. Full-fat soy flour, 14.5 parts; wheat flour, 100 parts; SSL, 0.5 parts.

although the spread with and without added SSL appeared somewhat smaller (3% shortening was added to these doughs). It is evident, however, that the effect of SSL added at the mixer is largest in the early stages of storage, and that after about 12 weeks, deterioration in the soy and wheat-flour blend is the principal reason for loss in loaf volume.

The same comparisons were not made with defatted, lightly heated (D7) soy flour blends. However, when D7 became the soy flour of choice to be included in government-purchased blends (3), it was included in the following storage experiments designed to examine soy and wheat flours separately with respect to rate of deterioration.

Stability of Soy and Wheat Flours

Figure 3 shows loaf volumes from D7 soy blends in which the soy and wheat flour were stored separately or as a complete blend at 100°F and 13% moisture. The upper curve indicates that storage of this soy flour at 100°F and 13% moisture produces a small but definite improvement in its bread-baking characteristics. The intermediate curve shows that the ability of the wheat flour to carry the soy deteriorates gradually when both are stored at 100°F. Thus, the improvement that occurs in the soy is not enough to compensate for the loss of carrying ability that occurs in the wheat flour. The bottom curve shows that the total blend stored at 100°F did not retain its loaf volume potential as well as the flours stored separately at 100°F with SSL added at mixing. This may be explained by decomposition of SSL during storage or by an effect of one flour in speeding the deterioration of the other, *e.g.*, the wheat flour may provide a source of enzymes or microorganisms that act on the soy flour, or chemical reactions between wheat and soy flours may destroy functional groups needed for SSL to be effective.

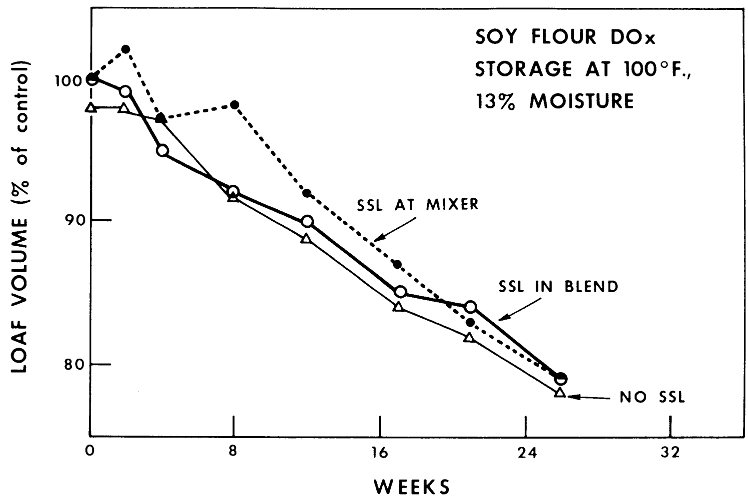

Fig. 2. Effects on loaf volume of storage and SSL additions to stored blends and doughs. Defatted, oxidized soy flour, 12 parts; wheat flour, 100 parts; SSL, 0.5 parts.

From these observations, and similar ones made with FF and DOx soy flours, the data shown in Table I were calculated. They provide some comparisons of the different soy flours and indicate that the defatted, lightly heated type is the best choice with respect to retention of loaf volume potential. Blends of wheat flour stored at −10° F with soy flours stored at 100° F (all at 13% moisture) for 26 weeks

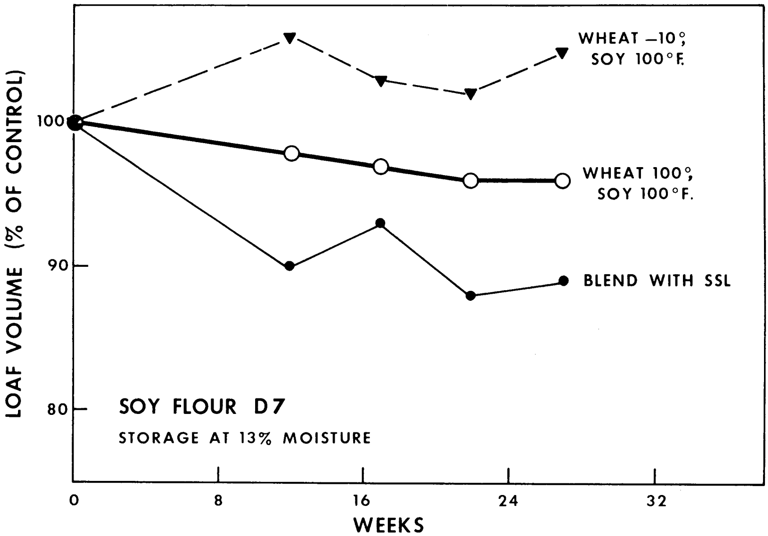

Fig. 3. Changes in loaf volume when separate components were stored at 100°F, compared to those resulting from storage of the complete blend. Defatted, lightly heated soy flour, 12 parts; wheat flour, 100 parts; SSL, 0.5 parts. (No additional SSL was added to the stored complete blend at the time of baking.)

TABLE I
Change in Bread Loaf Volume with Storage of Wheat and Soy Flours Separately and as a Blend with SSL (13% moisture, 26 weeks)

Sample Combination	Loaf Volume as Percentage of −10° F Control		
	D7[a] %	DOx[a] %	FF[a] %
Wheat flour, −10° F;[b] soy flour, 100° F	106	99	98
Wheat flour, 100° F;[b] soy flour, 100° F	96	87	84
Blend with SSL, 100° F	87	79	84

[a]D7, defatted, lightly heated soy flour; DOx, defatted, oxidized soy flour with added calcium salts; FF, full-fat soy flour.
[b]SSL added at dough-mixing.

were baked (top line, Table I). In contrast to the D7 soy flour, neither DOx nor FF soy flours improved with storage but remained essentially unchanged in their effects on breadmaking. When both wheat and soy flour were stored at 100° F, loaf volumes were smaller, the loss (top line values minus second line values) being attributed to the wheat-flour storage at 100° F, but these losses differ little among the soy flours (10% *vs*. 12% *vs*. 14%). However, when the complete blends were stored, volume loss with the blend containing DOx soy was definitely the worst. The difference suggests that the lower loaf volume as compared to the other soys may be an effect of the DOx soy on the wheat flour, perhaps an overoxidation.

The 2 or 3% shortening added in baking these loaves minimized the effect of any loss of SSL during storage of the complete blends. Shortening and SSL are largely interchangeable in their effects on loaf volume of these blends, although higher levels of shortening are required to produce equal volumes.

Flavor Stability in Flours

After 27 weeks of storage of D7 soy and wheat flours and blends, a panel evaluation of bread from the stored samples was carried out. Good consistency was shown for the two replications (Table II). The blend held at −10° F (control) was ranked best as expected, but the wheat −10° F, soy 100° F sample was not found to be significantly different. The wheat 100° F, soy −10° F sample, however, was ranked considerably worse, and with both wheat and soy, or the complete blend, at 100° F, the rankings were successively lower.

The data indicate that the principal source of off-flavor in storage at 100° F and 13% moisture was the wheat-flour component rather than the soy, whether the wheat flour was stored separately or in a complete blend. The larger proportion of wheat flour in the blends may be partly responsible; *i.e.*, an intensity of off-flavor in 12 parts of soy flour that would be undetectable after dilution with 100 parts wheat flour free of off-flavor might be detectable with the proportions reversed. However, a relatively greater stability of flavor of defatted soy flours perhaps could be expected. Defatted soy flours usually fall within the 5 to 10% moisture range (4). The heat treatment to which they are subjected (to destroy various inhibitors and enzymes) and the desolventizing after extraction of oil no doubt are responsible for the normally low moisture. Enzyme levels and,

TABLE II
Flavor Ranking of Breads after Storage of Wheat and Soy[a] Flours Separately and as a Blend with SSL

Sample Combination	Total Rank Sums		Total
	Rep. 1	Rep. 2	
Blend with SSL, −10° F	15	20	35**
Wheat, −10° F; soy, 100° F[b]	22	20	42
Wheat, 100° F; soy, −10° F[b]	30	32	62*
Wheat, 100° F; soy, 100° F[b]	40	36	76**
Blend with SSL, 100° F	43	42	85**

[a]D7 soy flour (defatted, lightly heated).
[b]SSL added at dough-mixing.

probably, microorganism populations are also lowered, and these changes could contribute to the stability of the D7 soy even after its moisture content was raised to 13% for these experiments, in contrast to the instability of the wheat flour.

When pairs of samples were compared directly, the tolerance of the soy flour to storage at 100°F became more apparent. This is shown in Table III. No significant flavor differences were found between bread prepared from the complete blend stored at −10°F and bread prepared from a blend including soy flour stored at 100°F, but highly significant differences were found between the same control blend and blends in which the wheat flour was stored at 100°F. Furthermore, soy samples stored at 100°F had significantly less off-flavor than wheat samples stored at the same temperature. It is also apparent that no adverse soy-wheat interactions occurred in the blend during storage at 100°F (last line, Table III).

In contrast to the results with D7 soy flour, limited observations with the DOx and FF soy flours suggest that these soy ingredients stored in a blend with wheat flour may develop more off-flavor than the ingredients stored separately. As shown in Table IV with DOx soy flour, storage of the wheat flour alone at 100°F for 27 weeks was enough to produce significant off-flavor when other ingredients in the comparison were stored at −10°F (first pair of samples). A wheat-soy blend stored at 100°F was even more readily distinguished from the flours stored separately at −10°F (second pair). Furthermore, the blend stored at 100°F was found to have much more off-flavor ($P < 0.001$) than the combination of wheat flour 100°F and soy flour −10°F (third pair). Thus, the blend in storage developed off-flavors appreciably more intense than those with flour alone at 100°F. Similar results were obtained with the FF soy flour.

These observations may be related to the effects of these soy flours on loaf volume (preceding section). That is, the D7 soy flour would be expected to be the least likely to affect wheat flour when stored in blends. In contrast, the DOx soy, by reason of the peroxide treatment to which it had been subjected, might have a definite oxidizing effect on wheat flour during 6 months of storage; and FF soy, because of its oil content, could provide a substrate for lipase activity, with the resultant increase in free fatty acids being deleterious to both baking and organoleptic properties.

GENERAL DISCUSSION

From the observations reported here, the deterioration of soy-wheat flour blends over several months' storage at 13% moisture and 100°F can be attributed largely to the wheat-flour component. This is indicated whether loaf volume losses or evaluations of off-flavor are used as guides. As would be expected, and as found in previous work (2), stability can be increased by lowering either moisture content or temperature. A shorter-term loss of effectiveness of SSL also appears to occur at 13% moisture (2).

The results with respect to stability of the different types of soy flour appear consistent with the effects that might have been predicted from knowledge of the baking behavior of wheat flours. However, the results should not be considered to have general validity until the observations have been extended in several ways. In particular, D7 type soy flours from different processors, crop years, etc., should be checked. More precise comparisons among soy flours could be ob-

TABLE III
Rankings of Pairs of Samples (D7 Soy)

Samples Compared	Least Off-Flavor In		N	Exact Probability
	Sample 1	Sample 2		
Blend, −10° F *vs.* wheat, −10° F; soy, −10° F	11	9	20	...
Blend, −10° F *vs.* wheat, 100° F; soy, 100° F	17	3	20	0.0026
Blend, −10° F *vs.* wheat, 100° F; soy, 100° F	19	1	20	0.00004
Blend, −10° F *vs.* blend, 100° F	18	2	20	0.0004
Wheat, −10° F; soy, 100° F *vs.* wheat, 100° F; soy, −10° F	15	5	20	0.0414
Wheat, −10° F; soy, 100° F *vs.* wheat, 100° F; soy, 100° F	15	5	20	0.0414
Wheat, −10° F; soy, 100° F *vs.* blend; 100° F	19	1	20	0.00004
Wheat, 100° F; soy, −10° F *vs.* wheat, 100° F; soy, 100° F	14	6	20	0.115
Wheat, 100° F; soy, −10° F *vs.* blend, 100° F	15	5	20	0.0414
Wheat, 100° F; soy, 100° F *vs.* blend, 100° F	11	9	20	...

TABLE IV
Rankings of Pairs of Samples (DOx Soy)

Samples Compared	Least Off-Flavor In		N	Exact Probability
	Sample 1	Sample 2		
Wheat flour, −10° F; soy, −10° F *vs.* Wheat flour, 100° F; soy, −10° F	34	14	48	0.006
Wheat flour, −10° F; soy, −10° F *vs.* Wheat-soy blend, 100° F	40	8	48	0.000003
Wheat flour, 100° F; soy, −10° F *vs.* Wheat-soy blend, 100° F	40	8	48	0.000003

tained if the development of off-flavor were checked at regular intervals rather than only at about 6 months after some indication of off-flavors had been obtained. Also, the shortening added in baking the bread certainly was a factor in loaf volume, but it is not known what effect the added shortening may have had on the detection of off-flavors in the bread.

Concern for stability in *storage* of soy-wheat flour *blends* is a recent development arising from the demonstrations that SSL and other additives could counteract the adverse effects of soy flour in bread. The exploratory experiments reported here suggest additional work on storage changes in these soy flour-wheat flour-additive systems.

Literature Cited

1. TSEN, C. C., HOOVER, W. J., and PHILLIPS, D. High-protein breads. Use of sodium stearoyl-2-lactylate and calcium stearoyl-2-lactylate in their production. Baker's Dig. 45(2): 20 (1971).
2. BEAN, M. M., HANAMOTO, M. M., MECHAM, D. K., GUADAGNI, D. C., and FELLERS, D. A. Soy-fortified wheat-flour blends. II. Storage stability of complete blends. Cereal Chem. 53: 397 (1976).
3. AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE, U.S. DEPARTMENT OF AGRICULTURE. Purchase of soy-fortified bread flour for use in export programs, Announcement WF-9 (September 27, 1972). (ASCS Commodity Office, P.O. Box 8377, Shawnee Mission, KS 66208).
4. WILDING, D. M. Processing of soybeans. In: Soy: The wonder bean. Symp. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1971).

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