# Breadmaking Characteristics of Wheat Flour Fortified with Various Commercial Soy Protein Products

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**ABSTRACT**

Fifteen commercial soy protein products chosen to represent variations in chemical characteristics were used to fortify wheat flour. While such fortification affected bread characteristics adversely, high-protein soy products, namely, concentrates and isolates, had a more pronounced effect even at a low level (10%) of fortification. Most soy flours, especially full-fat and high-fat products, however, permitted fortification at the 15 to 20% level, and produced breads of acceptable volume, flavor, and overall quality, with resultant substantial increases in protein content and greatly improved amino acid balance.

Fortification of wheat flour with high-protein, high-lysine material to increase protein content and improve essential amino acid balance of the resultant baked products, especially bread, has been recognized for some years (1–8). For a substantial improvement in protein content and nutritional quality of wheat flour, a high-level fortification is necessary to be of real significance in combatting worldwide protein malnutrition. The value of such fortification would then depend largely on the acceptability of the baked product. Of the various potential protein-rich additives tested, soy protein preparations seem to hold a greater promise, here and overseas, because of their ready availability and low cost per pound of protein. But, more importantly, they appear to meet more closely the requirements of baking quality. Perhaps not all commercially available soy protein products for baking can be used at levels high enough to achieve substantial increase in protein and lysine content and yet obtain a product of acceptable quality. The present work was undertaken to examine this.

TABLE I. FORMULATION AND METHOD (STRAIGHT-DOUGH) OF BREADMAKING

| Ingredient | % |
|---|---|
| Flour | 100.0 |
| Yeast | 3.0 |
| Yeast food | 0.5 |
| Salt | 1.5 |
| Sugar | 5.0 |
| Monoglycerides | 0.5 |
| Sodium stearoyl-2- lactylate | 0.5 |
| Fat (including that from soy) | 5.0 |
| Water | see Table III |

Mix 2 min. at no. 1 speed; remaining time (see Table III) at no. 2 speed in Hobart N-50 three-speed mixer, using bowl and hook. Ferment 90 min.; punch; bench time, 30 min.; round; intermediate proof, 10 min.; mould; pan-proof to desired template height or to a maximum of 75 min.; and bake at 425°F. for 25 min.

TABLE II. GRANULATION AND CHEMICAL PROPERTIES OF VARIOUS SOY PREPARATIONS AND WHEAT FLOUR

| No. | Particle Size (U.S. Sieve) mesh | PDI[1] % | Protein[2] % | Ether Extract % | Ash % | Moisture % |
|---|---|---|---|---|---|---|
| | | | *Soy isolate* | | | |
| 1 | 200–400 | 73 | 87.7 | 0.1 | 4.3 | 4.9 |
| | | | *Soy concentrate* | | | |
| 2 | 150–325 | 29 | 67.0 | 0.2 | 4.2 | 4.4 |
| 3 | 150–400 | 11 | 68.0 | 0.5 | 5.2 | 4.1 |
| | | | *Soy flour (full-fat)* | | | |
| 4 | 200–325 | 10 | 41.0 | 23.2 | 4.8 | 6.1 |
| | | | *Soy flour (high-fat)* | | | |
| 5 | 325–400 | 37 | 48.2 | 12.5 | 6.0 | 5.1 |
| 6 | 325–400 | 48 | 48.0 | 11.8 | 5.8 | 5.2 |
| | | | *Soy flour (defatted)* | | | |
| 7 | 325–400 | 19 | 51.5 | 1.1 | 6.9 | 7.0 |
| 8 | 325–400 | 54 | 53.2 | 0.8 | 6.4 | 6.2 |
| 9 | 200–400 | 37 | 54.0 | 0.7 | 6.4 | 5.8 |
| 10 | 325–400 | 13 | 52.6 | 1.1 | 8.2 | 7.4 |
| 11 | 325–400 | 65 | 52.6 | 1.2 | 6.0 | 6.1 |
| 12 | 200–400 | 61 | 53.2 | 1.2 | 5.9 | 7.7 |
| 13 | 200–400 | 20 | 52.9 | 1.1 | 6.1 | 7.0 |
| 14 | 200–400 | 45 | 52.9 | 1.3 | 6.3 | 7.0 |
| | | | *Whey-soy blend* | | | |
| 15 | 325–400 | 79 | 27.5 | 0.1 | 8.5 | 5.3 |
| | | | *Wheat flour* | | | |
| 16 | 200–325 | 23 | 11.5 | 1.0 | 0.5 | 12.9 |

[1]Protein dispersibility index.
[2]N × 6.25, but N × 5.7 for wheat flour.

## MATERIALS AND METHODS

Fifteen soy protein products, obtained from six different manufacturers and chosen to represent variations in chemical properties, were used to fortify patent flour from hard red winter wheat. Protein, dispersible protein, fat, ash, and moisture contents of these samples were determined by the standard AOAC methods (9). Particle size approximation was made by sifting these products through standard U.S. sieves of ascending mesh sizes.

Three levels of fortification with soy were tested (10% soy, 90% wheat flour; 15% soy, 85% wheat flour; and 20% soy, 80% wheat flour). Breads, using soy-fortified wheat flour, were made by the straight-dough procedure (Table I). Assessment of water absorption and mixing requirements of the dough was made by conducting a series of absorption tests. A more critical assessment was, however, made during actual test bakes. Loaves were weighed and their volume measured (rapeseed displacement) the morning after the breads were baked. Specific loaf volume (cu. in. per oz.) was then calculated. After the volume had been measured, loaves were sliced and general bread quality, based on appearance (including break and shred, crust and crumb color, grain and texture) was assessed; flavor evaluation was also made by the baking technologist.

## RESULTS AND DISCUSSION

Protein content of the soy products tested varied greatly, as did their protein solubility; apparently, these depend on the degree of heat and/or chemical treatment given during preparation (Table II). Soy products can be classified by protein content into three major categories: flours, concentrates, and isolates.

Since in our earlier experience (10) the straight-dough method was found to be a preferred method of baking high-protein breads, all baking was done by this method. Better results have been reported by others (11, 12) using other methods of baking. Sodium stearoyl-2-lactylate (0.5%) was used as a standard additive to improve baking performance. Its addition has been shown (7,11–13) to increase dough tolerance to protein-rich materials used at high levels and thus to produce a better crumb, grain, and loaf volume. To accommodate all soy products and yet keep the fat content constant, fat in the formula was maintained at a somewhat higher level, 5% (Table I).

Water absorption and mixing requirements of the doughs varied greatly (Table III). Heat-treatment of soy, which denatures protein and decreases its solubility (dispersibility), is reported to increase water absorption (14). Apparently because of this, the two soy protein concentrates, and not the isolate, exhibited tremendously increased water absorption capacity. Most soy flours, however, differed little in this regard, in spite of sizable differences in their protein solubilities. It appeared that protein solubility did not alone determine the water requirement of the soy products tested. In most cases, water absorption tended to increase with the level of soy used in fortification. Dough mixing time was the highest for one of the soy protein concentrates, but no consistent trend emerged otherwise (Table III).

Other physicochemical characteristics of soy (besides those which affect water absorption and mixing requirements of the dough), such as flour granulation, protein content and dispersibility, fat content and composition, and the presence

TABLE III. RHEOLOGICAL CHARACTERISTICS OF WHEAT FLOUR FORTIFIED WITH VARIOUS SOY PROTEIN PRODUCTS

| | Water Absorption, ml/100 g. Soy % | | | Mixing Time, min. Soy % | | |
|---|---|---|---|---|---|---|
| No. | 10 | 15 | 20 | 10 | 15 | 20 |
| | | | *Soy protein isolate* | | | |
| 1 | 64 | 68 | 73 | 26 | 17 | 36 |
| | | | *Soy protein concentrate* | | | |
| 2 | 83 | 88 | 93 | 22 | 15 | 32 |
| 3 | 87 | 93 | 98 | 43 | 45 | 49 |
| | | | *Soy flour (full-fat)* | | | |
| 4 | 60 | 63 | 68 | 35 | 31 | 32 |
| | | | *Soy flour (high-fat)* | | | |
| 5 | 60 | 64 | 69 | 26 | 23 | 20 |
| 6 | 61 | 66 | 70 | 27 | 25 | 22 |
| | | | *Soy flour (defatted)* | | | |
| 7 | 66 | 71 | 72 | 33 | 21 | 29 |
| 8 | 63 | 68 | 70 | 33 | 21 | 29 |
| 9 | 62 | 67 | 72 | 32 | 24 | 36 |
| 10 | 60 | 64 | 69 | 32 | 27 | 27 |
| 11 | 61 | 65 | 70 | 24 | 18 | 22 |
| 12 | 59 | 64 | 69 | 25 | 19 | 26 |
| 13 | 66 | 71 | 76 | 27 | 23 | 23 |
| 14 | 63 | 68 | 72 | 26 | 26 | 26 |
| | | | *Whey-soy blend* | | | |
| 15 | 50 | 56 | 59 | 31 | 38 | 39 |
| | | | *Wheat flour (no soy)* | | | |
| 16 | | 63 | | | 35 | |

and proportion of various ingredients, determine the bread quality. Flour granulation apparently did not affect bread quality since all soy products tested approximated wheat flour in fineness (Table II). Soy must be heat-treated in order to dispel objectionable beany flavor. This is reported to result also in the improvement of loaf volume (15). In agreement with the results of Ofelt et al. (1,2) but contrary to those of others (14), the degree of heat-treatment of soy (measured in terms of protein solubilities) did not appear to influence bread quality (Tables II and IV). The variations in protein content and fat composition of the soys tested (fat level was kept constant) seem to be the two main factors which affected bread quality. Soy and other nongluten proteins have been repeatedly shown (4,16) to have deleterious effects on bread quality. Recently, it has also been shown (7) that the baking quality of defatted soy flour is inferior to that of the full-fat soy flour, even when compared on equivalent protein basis.

TABLE IV. BREAD CHARACTERISTICS OF WHEAT FLOUR FORTIFIED WITH VARIOUS SOY PROTEIN PRODUCTS

| | Loaf Volume | | | | | | General Bread Quality, score[1] | | | Flavor[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total, ml. | | | Specific, cu. in./oz. | | | | | | | | |
| | Soy % | | | Soy % | | | Soy % | | | Soy % | | |
| No. | 10 | 15 | 20 | 10 | 15 | 20 | 10 | 15 | 20 | 10 | 15 | 20 |
| | *Soy protein isolate* | | | | | | | | | | | |
| 1 | 1,775 | 1,075 | 850 | 6.77 | 3.92 | 3.00 | 2.0 | 1.3 | 1.4 | ++ | + | + |
| | *Soy protein concentrate* | | | | | | | | | | | |
| 2 | 2,000 | 1,300 | 1,050 | 7.51 | 4.41 | 3.41 | 2.2 | 1.3 | 1.4 | + | + | + |
| 3 | 2,100 | 1,800 | 1,450 | 7.65 | 6.19 | 4.65 | 2.4 | 1.7 | 1.5 | + | + | + |
| | *Soy flour (full-fat)* | | | | | | | | | | | |
| 4 | 2,200 | 2,050 | 1,850 | 8.95 | 8.07 | 7.16 | 3.1 | 2.6 | 2.3 | ++++ | ++ | ++++ |
| | *Soy flour (high-fat)* | | | | | | | | | | | |
| 5 | 2,250 | 2,300 | 2,100 | 9.00 | 9.05 | 8.00 | 3.2 | 2.8 | 2.6 | ++++ | ++ | ++++ |
| 6 | 2,300 | 2,350 | 2,250 | 9.20 | 9.10 | 8.58 | 3.3 | 2.9 | 2.4 | ++++ | +++ | ++++ |
| | *Soy flour (defatted)* | | | | | | | | | | | |
| 7 | 2,225 | 2,225 | 1,150 | 8.62 | 8.23 | 4.25 | 3.2 | 2.9 | 1.6 | ++++ | ++ | + |
| 8 | 2,350 | 2,325 | 1,275 | 9.25 | 8.73 | 4.71 | 3.3 | 2.8 | 1.6 | ++++ | ++++ | + |
| 9 | 2,300 | 2,350 | 1,000 | 9.05 | 8.82 | 3.70 | 3.2 | 2.8 | 1.6 | ++++ | ++++ | + |
| 10 | 2,025 | 2,075 | 1,350 | 8.10 | 8.04 | 4.99 | 2.9 | 2.7 | 1.7 | ++++ | ++++ | ++++ |
| 11 | 2,300 | 2,225 | 1,300 | 9.20 | 8.49 | 4.88 | 3.2 | 2.7 | 1.6 | ++ | ++++ | ++++ |
| 12 | 2,250 | 2,150 | 1,225 | 8.86 | 8.07 | 4.60 | 3.1 | 2.7 | 1.6 | ++++ | ++++ | ++++ |
| 13 | 2,300 | 2,200 | 2,025 | 8.91 | 8.26 | 7.37 | 3.2 | 2.6 | 2.3 | ++++ | ++++ | ++++ |
| 14 | 2,300 | 2,075 | 1,375 | 9.05 | 7.91 | 5.08 | 3.2 | 2.5 | 1.6 | ++++ | ++++ | + |
| | *Whey-soy blend* | | | | | | | | | | | |
| 15 | 1,925 | 1,800 | 1,825 | 7.70 | 6.97 | 7.06 | 2.0 | 2.1 | 2.1 | ++ | +++ | ++++ |
| | *Wheat flour (no soy)* | | | | | | | | | | | |
| 16 | | 2,450 | | | 9.65 | | | 3.3 | | | ++++ | |

[1]Based on: Appearance, crust and crumb color, texture and grain. Very good, 4; good, 3; fiar, 2; and poor, 1
[2]Unacceptable, +; slightly acceptable, ++; moderately acceptable, +++; and acceptable, ++++

Results presented in Table IV seem to support this. The presence of naturally occurring emulsifiers in soy (lecithin, glycolipids, etc.) apparently influenced bread quality quite favorably. Mizrahi et al. (17) reported that the addition of 1% lecithin greatly counteracted the decrease in the volume of wheat bread fortified with 6% isolated soy protein. Most defatted soy flours differed little in their performance (Table IV), probably because only slight differences existed in their chemical composition.

In the overall acceptability of bread, flavor plays a decisive role. In present studies, although some soy products produced loaves of acceptable volume and general quality, they also exhibited strong beany flavor which seriously curtailed their overall acceptability. On equivalent protein basis, soy protein isolate tends to be slightly low in lysine and the most limiting amino acids (methionine and cystine) than the soy flours. Also, the production of soy protein isolate and concentrate in technologically less-developed countries, where the problem of protein malnutrition is more severe, may be less practical. The use of soy flours, especially full-fat and high-fat flours, thus may be more suited for the production of good quality high-protein bread.

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