Use of Soy Proteins in Baked Foods

WILLIAM HOOVER, American Institute of Baking
PO Box 1448, Manhattan, KS USA

ABSTRACT

Technology for the utilization of soy products in bakery foods is well established and reasonably simple. We can expect the functional properties and flavor of soy products to be continually improved through major research efforts in the soy industry. Large scale protein fortification programs will be forthcoming as the world population continues to grow, and economics dictate more and more efficient sources of nutrients. Before this will be realized, however, careful evaluations of the nutritional requirements and the technical, economic and political situations in a country will have to be made and the constraints removed before widespread use of fortified bakery foods in the commercial sector can be realized. In developed as well as developing countries, the near term constraints for usage of soy proteins in bakery products are represented by food regulations or laws which must be changed before the full nutritional and functional assets of soy proteins can be realized to the benefit of the baking industry.

The largest commercial food use of soy flour in the U.S. is in bakery products. Commercial sales to the bakery trade in 1972 were estimated by one source to be 65 million lbs soy flour and grits and 9 million lbs soy concentrate (1). Still another source (2), estimated the total to be 100 million lbs in 1969 with a growth rate of 6% in snack foods and 1.5% in bread products. This market has developed rather slowly but steadily since World War II, when soy flour was first used as a substitute for milk powder in bread. To this day, the main usage of soy flour in breadstuffs is as a replacement for nonfat milk solids (NFMS). An industry source estimates the current usage of soy proteins in the U.S. baking industry to be about 132 million pounds per year.

It seems reasonable to begin a discussion of the role of soy flour in bakery products by describing the functional reasons for using milk solids in bread formulations. NFMS is used in the U.S.: (a) to increase moisture adsorption, (b) to provide lactose which gives browning reaction upon toasting, (c) to tenderize, (d) to give body and resilience, (e) to serve as a buffering aid, and (f) to provide nutrition.

The soy industry now supplies a wide range of products for the baking industry: (a) enzyme-active soy flour (used up to 0.5%), (b) toasted soy flour, (c) chemically treated soy flour, (d) lecithinated soy flour, (e) full-fat soy flour, (f) concentrates, and (g) soy isolates. Through process improvement and better quality control, the industry is now producing lighter colored, blander soy products with better functional properties for baking.

The "U.S. Standards of Identity" for enriched white bread allows the use of up to 3% NFMS or soy flour as optional ingredients. There is no limitation on nonstandardized breads. With today's soy flours, at the 3% level of substitution for NFMS, bakers do not find appreciable change in absorption, mix, and oxidant requirements.

Soy flour will provide, functionally, better water absorption, and, at least, as good a tenderizing effect, body, and resilience as will NFMS. The degree of color reaction can be controlled by partial substitution of dextrose or liquid-reducing sugars in place of the sucrose in the formula. The buffer value of NFMS is only significant when long sponge fermentation and floor times are used. With the trend toward shorter time processes, this factor is not too significant. Nutritionally, soy flour contributes slightly more than NFMS in bread at these levels. Generally, the protein efficiency ratio (PER) of unfortified white bread is considered to be 0.7 (relative to a value of 2.5 for casein). Turro and Sipos (3) found that bread containing 3% NFMS had a PER of 0.75, and breading containing 3% soy flour had a PER of 0.83.

About 7 million lbs soy flour were used in donut mixes and cakes in 1973. In donuts, soy flour has the special advantage of reducing oil pickup during frying, which results not only in a better quality donut, but is economical in that it lowers frying oil costs. Used in the range of 3-3.5% of the formula, soy flour also gives donuts a good crust color, improved shape, higher moisture absorption with the resultant improvement in shelf-life, and a texture with shortness or tenderness. Tests have shown a 50% decrease in fat uptake at soy flour levels of 10%. The optimum soy flour level is about 6%. Lecithinated soy flour can be used as an egg-sparing material.

In cakes, soy flour again is being used as a replacement for NFMS (4). It often is observed that cake tenderness and texture are improved. In addition, however, cake formulations are more tolerant to process and ingredient variations when about 2% soy flour is used. Three to six percent may be used in white or yellow cakes, and more moist and dense cakes may use from 5-12% soy flour (5). Cotton (1) reports better results with high fat soy flours in cakes than low fat or defatted soy flours. A good deal of research needs to be done to determine the interrelationships between various soy products, shortening levels, and emulsifying systems in cakes and donuts.

Soy flour can be used to good advantage in sweet goods. French (5) found that defatted flour or 6% lecithinated flour performs best for high-fat Danish pastry at 2-6% levels of usage. "Short" pastry items such as pie crusts, fried pie crusts and puff pastry can be machined more easily and will retain freshness longer when lecithinated or defatted soy flour is used at the levels of 2-4%.

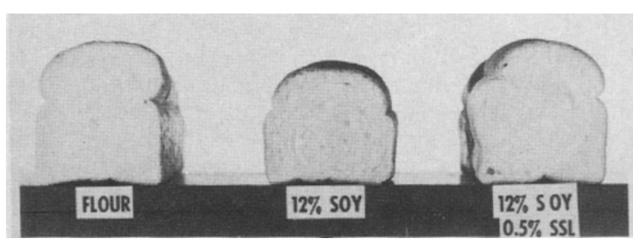

FIG. 1.

Soy flours are used in the 2-5% range in many bakery snack items. Although very little has been published about these usages, Cotton (1) believed that 14 million lbs soy were being used in 1973 in specialty bakery items. Some of the functional properties claimed are improved machinability of cookie doughs, with a resultant reduction of cripples; improved browning and improved flavor for pie crusts; and desired color and flavor for snack crackers. Shelf life of soft cookies can be extended considerably. In 1971, Tsen, Hoover and Phillips (6) reported finding that sodium stearoyl-2-lactylate (SSL), calcium stearoyl-2-lactylate (CSL), or ethoxylated monoglycerides provided a system which permitted the addition of levels of soy flour which would improve the nutritional value of breadstuffs significantly without detrimental effects upon their eating qualities.

Prior to this development, the addition of high levels of soy flour to wheat flour-based breads resulted in greatly reduced loaf volumes; coarse, open texture; off-white or yellowish color; and an off-flavor best described as "beany." The addition of small amounts of the previously mentioned chemicals does permit the addition of soy flour at levels which significantly improve nutritive value of the protein without altering the acceptability of the product. The resultant bread has normal loaf volume, fine-even crumb characteristics, color that is very close to a non-fortified bread, and normal bread flavor.

Nutritionally, the addition of higher levels of soy flour brings about some dramatic changes in protein nutritive value. The PER, it will be recalled, for white bread is about 0.7 and for bread with 3% soy flour added about 0.83. When the soy flour is increased to the 6% level, the PER climbs to 1.3, and, at the 12% level, the PER becomes 1.95. In addition to improvement in protein quality at the 12% soy flour level, there is 50% more protein in the fortified bread. Feeding studies with rats indicate a three-to-four-fold increase in growth rates of rats fed diets based upon the fortified bread compared to unfortified white bread.

This paper would not be complete without at least mention of full-fat soy flour, soy protein concentrates, and soy isolates in nutritionally improved breadstuffs. Actually, full-fat soy flour seems to be more functional than defatted soy flour in breads. For example, up to 24 parts full-fat soy flour can be used in formulas and produce the same type of bread quality achieved when using only 16 parts of defatted soy flour. While full-fat soy flour is more expensive in the U.S. than defatted soy flour, it may be the product of choice in countries where a solvent extraction industry does not exist or where pricing makes it economically attractive. At the same protein level of addition, soy concentrates and soy isolates show no advantage over defatted soy flour and are, of course, more expensive. It may be, however, that in certain bakery products where particularly high protein levels are wanted, these products will find some usage.

The first purchase of soy-fortified flour by the U.S. government was made in October 1972, and, since that time, several hundred million lbs have been used in school and institutional feeding programs in some 40 countries. The rate of distribution during the first ten months of this year indicates that nearly 175 million lbs will be used this year. An increase in the rate of usage is expected during the next fiscal year, and initial purchases by Jamaica and the Philippines under the Title I-PL 480 program is probable.

In addition to the highly acceptable properties of the fortified bread previously mentioned, at least two more positive attributes must be noted. The first, which is of significance in some markets, is the especially good toasting qualities of the bread. The second, which is of great value everywhere, is an extended or increased shelf-life. For breads normally thought to begin to be noticeably stale after three days, the same degree of staling would not be noticed until after five days when the soy flour and SSL are incorporated. This is due to the increased moisture absorption and retention of soy flour and to the known enhancement of "softness" of bread by SSL. On the other hand, the soy-fortified flour breads will become moldy faster than regular bread, because of a slightly higher moisture content and because they are a better nutrient medium for mold growth. Addition of calcium propionate is suggested where longer periods before consumption are anticipated.

Fortunately, the introduction of soy-fortified flour into bakery products requires very little change in bakery technology and no changes at all in bakery equipment. Good breads have been made using straight dough, sponge dough, short-time dough, and continuous procedures. Similarly, all types of breadstuffs have been made successfully with the soy-fortified flour. Three minor changes from normal baking procedure will result in optimum breads from soy-fortified flour.

First, the increased absorption of the soy requires that three-fourths to one part water be added for every part soy flour. Thus, on a 100 part 12% soy-fortified flour formula, 9-12 parts more water would be required for optimum dough development and workability. If water is added to "feel of dough," the bakery will add the right amount automatically.

Second, less mixing than normal dough will result in optimum bread quality. This is also a blessing, because most small bakeries in underdeveloped countries use either hand-mixing or slow speed mixers, and the doughs tend to be undermixed. This means that the baker will be closer to optimum mixing for soy-fortified flour breads than for his regular flour breads.

Third, a shorter fermentation time than normal is best for soy-fortified flour breads. Bakers interested in increasing capacity of throughput will find this to their benefit.

Soy-fortified flour fortunately has a remarkable versatility for many uses. If this had not been the case, its value as a Title II commodity would have been limited. As already stated, all types of breads, including unleavened Arab bread, French bread, buns, sweet rolls, oriental noodles and pan breads can be made from soy-fortified flour. Some institutional feeding programs are using cookies made from soy-fortified flour. Actually, all types of cookies can be made with excellent quality. Normal sugar cookies are about 5% protein (PER=0.5), whereas soy-fortified flour sugar cookies are 8% protein (PER=1.5).

Soy proteins can be added at high levels (5-20%) in cookies to significantly improve nutritional value and at the same time extend shelf life without adversely affecting spread ratios or other organoleptic qualities so long as the lactylates are used in the formulation.

Cakes of excellent quality also can be made from soy-fortified flour. For both cookies and cakes, an ingredient savings can be realized, because less shortening than normal is required when using soy-fortified flour.

FUTURE FOR SOY-FORTIFIED BAKERY PRODUCTS

Soy-fortified bakery products appear to be the best vehicle for protein improvement in diets in many parts of the world. Generally, breadstuffs are the number one convenience food eaten and liked daily by large masses of the population. This, coupled with the convenience of central fortification at flour mills, simplicity of technology, and the fact that the net cost on a nutritional basis, or sometimes on any basis, is lower than any other food that can be used in nutritional feeding programs, makes the future of soy-fortified bakery products seem bright.

Before the use of soy-fortified bakery products can become a reality as a major contributor to improved nutrition, however, a number of economic and political problems must be evaluated and solved. There is no panacea for application of these products in a wide number of countries. Later, the situation in each locality or each country must be carefully evaluated through in-depth feasibility studies to determine the technological, economic and political barriers which must be overcome before soy-fortified products can be widely used.

The complexity of any society or population group in respect to food and health was very well depicted by Donose and Greaves (7) in a figure titled "The Web of Nutrition." This figure depicts the system which exists in any city, village, country or region. The food system is finally balanced. If any element in the system is altered or adjusted, it will usually result in several adjustments or reactions in other parts of the system. Thus, we need to evaluate each component in the system, whether it is in the food marketing system or in the human part of the equation, to determine how it will be affected by the fortification of wheat flour with soy flour.

In a study sponsored by the United States Agency for International Development, 40 countries were evaluated by considering the following factors:

A. Population
  1. Total
  2. Percent rural
  3. Percent under 15
  4. Growth rate
B. Economic
  1. Per capita Gross National Product
C. Nutritional need
  1. Total calories per day
  2. Protein - g/day
  3. Protein from animal sources–g/day
D. Local or international nutrition programs
E. Government commitment to nutrition
F. Wheat consumption - per capita and trend
G. Wheat supply
  1. Domestic - 1,000 M.T.
  2. Import - 1,000 M.T.
H. Government controls on supply
I. Government agricultural, trade and price policies
J. Status of milling industry
  1. Capacity
  2. Mill location
  3. Level of technology
  4. Economic status
K. Status of baking industry
  1. Capacity
  2. Level of technology
  3. Economic status
  4. Types of breads, biscuits, and pasta products . . . production level
L. Pertinent laws and regulations
M. Protein resources
  1. Availability . . . quality
  2. Price
  3. Status of edible protein industry
    a. Capacity
    b. Level of technology
N. Institution for composite flour technology
O. Availability of cereal chemists and laboratories

After an examination of the 40 countries based primarily on secondary data, seven countries were chosen as best opportunities for introduction of soy-fortified flour on a commercial or nationwide basis. These were studied somewhat in depth by onsight feasibility analysis. Following these evaluations, Ecuador was chosen as an in depth case study with the support and assistance of the Ecuadorian government with the long range hope of developing a fortification policy for the country based upon soy-fortified flour. This has not become a reality as yet, however.

There are some key elements which have been learned from this series of evaluations. First, a very thorough feasibility is a must, and this should not include only technical feasibility. Economic evaluations taken within the social and political constraints must be made, and those economics have to be favorable. I do not believe that nutrition needs alone will cause any government to establish a policy for fortification if the economic factors are not favorable, or another problem, such as improvement in trade balance, cannot be solved as a result of the fortification program. No government, as yet, has set out nutrition as the top priority goal for the government, and thus studies must identify the key factor or factors or government or national policy which will be the beneficiary of a fortification effort.

In each instance there will be factors in the economy which will be favorably affected by an alteration of flour-based food by fortification, and there will be elements which will perhaps view the results as unfavorable to their business enterprises. These must be clearly identified and allies made of those who will be benefited and methods developed to ease the negative results which might affect any portion of the economy.

There is a general belief that the cost of soy-fortified bakery products would without question be higher than the normal wheat-based food. Several viewpoints can be taken to evaluate the cost of soy-fortified bakery products. One example is to consider the ingredient cost for white pan bread using the relative cost for wheat flour, soy flour, SSL and shortening. Because breads using soy-fortified flour can be made with reduced or even no shortening levels, the ingredient cost of soy-fortified bread is essentially the same as white bread without milk solids and, of course, less expensive than bread made with milk solids.

Since the procurement of soy-fortified flour under Title II Public Law 480 began, the cost of soy-fortified flour has run rather consistently 5 to 6% more than regular wheat flour. However, there is a 6 to 7% increase in yield of bread from soy-fortified flour that offsets the increased flour cost.

Still another viewpoint can be illustrated from a school lunch program such as the one in the Phillipines which previously was based on a fortified bread, the formula for which called for flour, nonfat milk solids, and vegetable oil. Using soy-fortified flour, the same nutrition is being provided in a bun which has a cost of nearly 1 cent per child per day less than the product that it has replaced.

Commodity prices and price relationships vary so widely in the world because of freight differentials, governmental agricultural pricing and taxing policies, that each country must be examined individually to determine the cost of soy-fortified bakery products in relation to the prevailing breadstuffs. In our feasibility analysis, we have never found a situation where soy-fortified bread, as consumed, would cost more than 3% more than regular bread, and we have found instances where the cost of the bread produced with soy flour would be less than the current baked commodity.

REFERENCES

1. Cotton, R.H., JAOCS 51:116A (1974).
2. Hammonds, T.M., and D.L. Call, A.E. Res. Bull. 321, Cornell University (1970).
3. Turro, E.J., and E. Sipos, Baker's Dig. 42: No. 6:61 (1969).
4. Turro, E.J., and E. Sipos, Ibid. 44: No. 1:58 (1970).
5. French, F., Ibid. 51: No. 5:98 (1977).
6. Tsen, C.C., W.J. Hoover, and D. Phillips, Ibid. 45: No. 2:20 (1971).
7. Donose, G., and J.P. Greaves, FAO Nutrition Newsletter, July, (1971).