Soy Products in Bakery Goods

ROBERT H. COTTON, ITT Continental Baking Co.,
Rye, New York

ABSTRACT

Applications of soy proteins in baking are reviewed and original data on taste and texture tests are presented. New foods employing soy for nutritional improvement are described. A plea is made for production of soy proteins with higher baking functionality and improved taste.

INTRODUCTION

Bread, after many centuries, still remains one of man's principal foods. To provide for his protein requirements, his enjoyment of variety, and his need for vitamins A and C and other micronutrients, he seldom tries to live on bread alone. Nevertheless, bread is a major component of many national diets. It is fortified in the U.S. and many other countries with iron, vitamins B_1, B_2, and niacin. Furthermore, in the U.S. most of the popular white bread has been made for many years with some non-fat dry milk (NFDM) solids.

NFDM imparts added desirable flavor and some added stability in storage. It increases the nutritive value of bread, due to the absolute amount of its added protein plus the improvement of wheat protein caused by extra lysine supplied by milk. Wheat protein is deficient in lysine (Table I). Unfortunately, the supply of NFDM has not kept pace with demand and it almost has become priced out of the market as a normal bread ingredient, as the price has climbed from $.125/lb in 1950 to $.50/lb in August 1973. It is still used in a few breads, however.

BREAD PRODUCTION

Ca. 15 years ago our company began studies aimed at partial replacement of milk with soy flour (1). Today our white bread (and many of the other white breads in the U.S.) contains about 1.5-2.0 lb soy flour/100 lb wheat flour. We supplement this with dry whey, a by-product of cheese manufacture. Whey protein provides desirable flavor and crust color plus high lysine supplementation. Table II gives a typical American bread formula.

In bread production with low levels of soy flour, up to ca. 3%, we do not expect any appreciable change in absorption, mix, and oxidant compared with NFDM. At higher levels of soy flour, more bromate can be beneficial—ca. 10 ppm increase for 5% soy and 30 ppm increase for 12% soy. Sodium stearoyl-2-lactylate or ethoxylated monoglycerides have more beneficial effect than oxidants. Soy flour takes ca. 3/4 lb extra water for each lb added to formula. At a level of 12% soy flour, bread dough requires about one third less mixing. These adjustments are made to optimize bread volume, grain, and texture.

In our original work we could use only small amounts of soy flour because of noticeable taste imparted to white bread. We used a mixture of milk, soy, and whey. Today, our taste panels can detect no difference in white bread made with ca. 2% milk compared to bread made with equivalent added protein in the form of soy flour and whey.

Tables III and IV show flavor panel test data for two levels of soy flour addition. These were paired comparison tests where the participants rated each bread on a seven-point scale for each of seven characteristics. Higher ratings indicate more uneven texture, more bitter taste, moister, blander, more pleasant aroma, softer texture, and sweeter taste. Participants also were asked which sample they preferred. The data indicate that these low levels of soy flour can replace some of the milk without any appreciable change in the bread characteristics. When we exceeded 1.1% soy we had noticeable off-flavors in our bread; today we can go to somewhat higher levels. Data in Table V indicate that 2% soy in white bread is a bit too high a level for the

TABLE I

Amino Acid Content of Certain Wheat, Soy, and Milk Proteins

	Defatted soy flour[a] Cargill	Soy protein isolate[a] Ralston-Purina Edi-Pro N	Soy protein isolate[a] Grain Processing Company Pro-Fam 90	Soy protein concentrate[a] Grain Processing Company Pro-Fam 70	Non-fat dry milk[b]	Dried whey[c]	Casein casein[b]	Wheat flour[c]
Protein (Nx6.25), percent	53	90	90	70	35.9 (Nx6.38)	12.9	90	11.7 (Nx5.7)
Amino acids (g/16 g N)								
Arginine	7.15	—	7.27	7.45	3.73	2.21	4.10	4.14
Histidine	2.55	—	2.92	2.41	2.69	1.70	3.04	1.94
Isoleucine	4.74	4.7	4.62	5.01	6.51	5.60	6.59	3.71
Leucine	7.69	7.8	8.14	8.43	10.02	8.70	10.11	6.06
Lysine	6.23	5.7	6.57	6.77	7.94	8.10	8.06	2.54
Methionine	1.36	1.2	1.00	1.13	2.50	1.74	3.10	1.55
Phenylalanine	4.91	5.4	5.51	5.49	4.94	3.36	5.42	4.42
Threonine	4.09	3.5	3.96	3.95	4.70	5.90	4.30	3.07
Tryptophan	1.40	1.1	0.90	0.90	1.44	1.20	1.34	1.09
Valine	5.15	4.8	4.57	5.71	7.00	5.50	7.44	4.32
Cystine	1.36	—	0.90	0.89	0.91	1.50	0.38	2.03
PER[d]	2.0-2.2	1.8	1.7	2.0	3.10	3.2-3.4	2.5	0.6

[a]Manufacturer's data.
[b]See ref. 2.
[c]See ref. 3.
[d]PER = protein efficiency ratio.

TABLE II

Typical American White Bread Formula

Flour enriched	100
Water	65
Yeast	2.5
Yeast food[a]	0.5
Salt	2.25
Sugar	8.0
Shortening	3.0
Mono- and diglycerides	0.5
Nonfat dry milk or soy flour and dry whey	2.0
Calcium propionate	0.125

[a]Yeast food contributes 15 ppm bromate, plus ammonium and calcium salts.

TABLE III

Flavor Panel Ratings of White Bread with 2% Milk or a Combination of 1.15% Milk and 0.75% Soy Flour[a]

Characteristic	2% Milk	1.15% Milk 0.75% soy flour
Even - uneven texture	3.53	3.66
Bitter - not bitter	4.95	5.57
Dry - moist	4.89	5.74
Flavorful - bland taste	3.61	3.32
Unpleasant aroma - pleasant	5.19	5.59
Soft - very soft	4.21	4.79
Not sweet - sweet	3.47	4.16
Preferred 1.15% milk - 0.75% soy	-20 (Not significant)	
Preferred 2% milk	-15	
No preference	- 3	

[a]Tested in the first day after baking.

TABLE V

Panel Evaluation of White Bread on Third Day after Baking

Characteristic	2% Soy flour	2% Milk
Even - uneven texture	3.55	3.53
Bitter - not bitter taste	4.35	5.38
Dry - moist	3.95	4.08
Flavorful - bland	4.72	4.10
Unpleasant aroma - pleasant	4.88	5.15
Soft - very soft	4.05	4.15
Not sweet - sweet	2.98	3.68
Preferred 2% soy flour -	10	
Preferred 2% milk -	28 (Significant)	
No preference -	2	

flavor we desire.

So far we have implied that on the American market—especially in bread—soy flour usage is limited by flavor considerations.

Specialty breads, particularly those designed to be high in protein content, are another story. A slight flavor difference from white bread is no disadvantage. It is expected by the consumer. Certainly in a world short of protein, a bread high in protein must have a useful role. Work by Tsen and Hoover (4) and Pomeranz and Finney (5,6) demonstrates that high amounts of soy flour—up to 24 lb/100 lb wheat flour—can be used in bread with acceptable volume, grain, and texture. So far this has not been a major item of commerce in the U.S., but it does have potential value in bringing good protein economically to the market anywhere in the world. Mizrahi, et al., (7) has described use of soy flour in bread in Israel.

If one's objective is a loaf of bread with high consumer appeal and high protein level and quality, as measured by a protein efficiency ratio (PER) of 2.5, it may be advisable to add other proteins to the soy and wheat flour. For example, an experimental loaf in our laboratories has a PER of 2.5 (equal to that of casein). This was achieved through the use of soy protein, cheese whey, casein, lysine, and vital wheat gluten. Table VI shows PER for several commercial soy products. There is a good possibility that bland fish flour also can be used to bring bread's PER to a level of 2.5. Certainly there are many possible routes to this end. (See Jansen [15] for a discussion of bread protein supplementation.) Economics and repeat sales on the market remain the two critical factors in the life of such breads.

FULL-FAT SOY FLOUR

So far we have talked only about defatted soy. Full-fat soy flour is used in limited amounts in American bread because of its lipoxidase action. This aids in producing a whiter crumb.

We estimate that, today in the U.S., the annual usage of defatted soy flour in bread is ca. 50 million lb with another 14 million lb going to specialty baked items and crackers. Some of the delicious cocktail crackers, for example, have soy listed on their labels as an ingredient. We estimate the soy flour content as 2-5% total ingredient wt. This produces a pleasant nut-like character to the product. Tsen, et al., (16) has developed high protein cookies using soy flour.

Ca. seven million lb soy flour with varying fat levels is used in doughnut mixes and cakes. Generally, it is believed that soy helps regulate the amount of oil picked up by the doughnut during the frying stage. Usage of soy flours in certain commercial cake formulations is not well understood. Empirically, we know that certain cake formulations are more tolerant to process and ingredient variations when soy is used at ca. 2% than when it is absent in the formula.

In limited tests, with sponge type cakes, a general correlation was noted between fat level in soy flour and overall quality. High fat soy flour resulted in better

TABLE IV

Flavor Panel Ratings of White Bread at 1 and 5 Days of Age

Characteristic	First day		Fifth day	
	2% Milk	1.1% Soy + 0.75% milk	2% Milk	1.1% Soy + 0.75% milk
Even - uneven texture	3.41	2.69	4.06	3.64
Bitter - not bitter	4.90	4.55	4.94	5.15
Dry - moist	5.55	5.22	3.06	4.15
Flavorful - bland taste	3.72	3.21	4.64	3.79
Unpleasant - pleasant aroma	4.69	4.69	4.70	5.12
Soft - very soft	4.79	4.79	3.12	4.08
Not sweet - sweet	3.38	3.90	3.54	3.73

Preference - None		2% Milk	1.1% Soy + 0.75% milk
First day	0	14	15
Fifth day	2	13	18

TABLE VI

Protein Efficiency Ratios (PER) of
Soy Flour, Protein Concentrates, and Isolates

Proteins	Heat treatment	PER[a]
Soy flour, defatted	Light	2.03-2.33[b]
	Toasted	2.39[c]
Soy flour, full fat	Moderate	1.82[d]
	Toasted	2.15-2.25[d]
Concentrates	Unheated	1.14-1.55[e]
	Heated	2.00-2.36[f]
Isolates	Unheated	1.13-2.00[g]
	Heated	1.22-1.91[g]

[a]Corrected PER based on casein = 2.50.
[b]See ref. 8 and 9.
[c]See ref. 10.
[d]See ref. 11.
[e]See ref. 9.
[f]See ref. 12 and 13.
[g]See ref. 9 and 14.

products than low fat or defatted soy.

The principal advantage was in eating quality at the end of several days. In at least one test, however, a full fat soy failed to show an improvement over the low fat type. We feel confident that fat level, although it demonstrates noticeable effects on cake quality, is not the only significant factor in the contribution made by soy to cake and doughnuts. We hope to do more research in this area.

Chemical extraction and mild hydrolysis of proteins from soybeans can produce whipping agents. These are used in prepared cake mixes, certain sponge cakes, icings, and meringue powders. We do not know the annual production of these vegetable protein whipping agents.

There are several situations which require unique nutritional products. An example is school breakfast in low income areas in schools where there is neither a kitchen nor funds for a cook and service staff. Our laboratories (17,18) have developed a breakfast supplement in the form of a cake or a doughnut which, when eaten with an 8 oz. glass of milk, provides ca. a third of a child's recommended daily requirements for nutrients. Refinement and testing of the products were done with the help of the Food and Nutrition Service, U.S. Department of Agriculture (USDA) and Rutgers University. Table VII shows present USDA standards for the product.

Ted McCloud of the Memphis, Tennessee, school system will describe its use during this meeting. The cake-like supplement, called Astrofood Cake, contains ca. 2.5% soy protein from soy flour plus soy isolate, while the Astrofood Doughnut contains ca. 4% protein derived from the same sources. Rat feeding tests show these products to have a PER of ca. 2.3 compared to casein PER equal to 2.5 as a standard. The soy protein represents 25% cake protein and 40% doughnut protein and, thus, makes a significant contribution to this new food. Here, again, selection of proteins to use depended upon relative costs and palatability. It is easy to formulate a food having all required nutrients but difficult, indeed, to produce a texture and flavor the school children will eat and enjoy repeatedly. Without this palatability all the nutrition in the world is a waste, since the children would not eat the product.

Future soy protein products, hopefully, will continue to improve in flavor. Soy flours today have noticeably less beany taste than they did 15 years ago. In bread production there are few ingredients one can add that do not depress loaf volume and general bread quality. Wheat gluten must carry such ingredients. As we go to really high protein breads, more vital gluten plus surfactants are required to get the grain, texture, volume, and taste we believe our customers want. Egg protein can be used as a supplement without major effects on bread quality, but this is expensive. Of course, we do use eggs in cake production.

TABLE VII

FNS[a] Specifications for Breakfast Supplement

Nutrient	FNS-Inst. 783-5	
	Minimum	Maximum
Weight (oz)	2	4
Moisture (%)	—	40
PER (Casein 2.5)	2.0	—
Fat (%)	—	22
Ash (%)	b	b
Fiber (%)	—	0.8
Carbohydrate (%)	b	b
Protein (g)	5.0	—
Energy (kcal)	250	—
Vitamin A (IU)	785	1250
Vitamin E (IU)	5	—
Thiamin (mg)	0.26	—
Riboflavin (mg)	0.13	—
Vitamin B_6 (mg)	0.26	—
Vitamin B_{12} (mcg)	1.25	—
Vitamin C (mg)	25	—
Niacin (mg)	2.65	
Iron (mg)	4.4	—
Calcium (mg)	120	—
Phosphorus (mg)	120	—
Magnesium (mg)	30	—
Folacin (mg)	0.04	—

[a]Food and Nutrition Service, U.S. Department of Agriculture.
[b]Not specified.

FUTURE TRENDS

Is it possible to develop soy protein products with film-forming properties akin to those of gluten or egg white? This would expand soy utility vastly. As to flavor, we look for more work with special emphasis on fermentation of soy, as the Orientals have done for centuries. This leads to bland tasting products with a wide range of physical forms. C.W. Hesseltine (19) and his group at the USDA in Peoria, Ill., are studying ways to use the ancient principle of fermentation to improve soy functionality. Perhaps they can improve its amino acid pattern too through development of proteins during fermentation. Hopefully, such proteins developed by microbiological utilization of the carbohydrates in soy flour will be rich in lysine and methionine. Turning again to functionality, the baking industry is plagued with enormous ingredient cost increases. A soy protein which could whip and heat denature like egg white would be of interest in cake products.

This presentation has been concerned primarily with soy usage in the U.S. wholesale bread and cake industry. Obviously, soy products have many other uses in baking around the world. For example, in certain developing countries there are no facilities for solvent extraction of soybeans to produce vegetable oil and defatted soy flour. One can make full fat soy flour relatively easy. This can go into bread and help in two ways: first, is the obvious nutritional improvement, and second, in countries where wheat is scarce, usage of soy plus stearoyl lactylates in the bread formula makes possible incorporation of 2-5% native flour, such as maize or cassava, with good overall nutritive value. The fat in the full fat soy flour provides shortening effect and needed calories. The final bread is somewhat creamier in color and lower in volume than our white bread, but it is quite acceptable. In fact, there is reason to believe the American public is now less demanding of a pure white, high volume loaf than it was 15 years ago. Thus, we see more soy flour used in bread, both in the U.S. and around the world.

ACKNOWLEDGMENTS

S.T. Titcomb and C.T. Tan provided support.

REFERENCES

1. Rainey, W.L., and F.E. Horan, Baker's Dig. 35:34 (1961).
2. U.S. Department of Agriculture, Home Economic Research Report 4, December 1957.
3. FAO-UNICEF, United Nations, Nutritional Studies 24 (1970).
4. Tsen, C.C., and J.J. Hoover, Cereal Chem. 50:7 (1973).
5. Pomeranz, Y., M.D. Shogren, and K.F. Finney, Ibid. 46:503 (1969).
6. Pomeranz, Y., M.D. Shogren, and K.F. Finney, Ibid. 46:512 (1969).
7. Mizrahi, S., G. Zimmerman, Z. Berk, and U. Cogan, Ibid. 44:193 (1967).
8. Horan, F.E., "Proceedings of the International Conference on Soybean Protein Foods," U.S. Department of Agriculture, ARS 71-35:129 (1967).
9. Longenecker, J.B., W.H. Martin, and H.P. Sarett, J. Agr. Food Chem. 12:411 (1964).
10. Joseph, K., M. Narayana Rao, M. Swaminathan, K. Indiramma, and V. Subrahmanyan, Ann. Biochem. Exp. Med. 20:243 (1960).
11. Mustakas, G.C., W.J. Albrecht, G.N. Bookwalter, J.E. McGhea, W.F. Kwolek, and E.L. Griffin, Jr., Food Technol. 24:1290 (1970).
12. Meyer, E.W., "Proceedings of the International Conference on Soybean Protein Foods," U.S. Department of Agriculture, ARS 71-35:142 (1967).
13. Wilding, M.D., E.E. Alden, and E.E. Rice, Cereal Chem. 45:254 (1968).
14. Rackis, J.J., A.K. Smith, A.M. Nash, D.J. Robbins, and A.N. Booth, Ibid. 40:531 (1963).
15. Jansen, G.R., Amer. J. Clin. Nutr. 22:38 (1969).
16. Tsen, C.C., E.M. Peters, T. Schaffer, and W.J. Hoover, Baker's Dig. 47:34 (1973).
17. Cotton, R.H., in "Application of Technology To Improve Productivity in the Service Sector of the National Economy," Natl. Acad. Eng., Washington, D.C., 1973, p. 205.
18. Cotton, R.H., A.J. Allgauer, A.W. Nelson, D.W. Koedding, and R.R. Baldwin, Cer. Sci. Today 16:188 (1971).
19. Hesseltine, C.W., and H.L. Wang, in "Soybeans: Chemistry and Technology, Vol. I, Proteins," Edited by A.K. Smith and S.J. Circle, Avi Publishing, Westport, Conn., 1972, p. 389.