Uses of Soy Protein in Mixed Protein Systems to Meet Nutritional Needs

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ABSTRACT

Soya products can be introduced into animal protein food systems to supplement animal protein. This can serve to increase the total protein available to target populations. Nutritional studies have demonstrated that mixtures of soya protein and meat or soya protein and fish are of a biological quality similar to that of meat or fish protein when fed alone. Soya products also can be used in mixed protein systems with vegetable proteins to complement amino acids. Many studies with human subjects have demonstrated the utility of soya products in a variety of soya-cereal foods that can serve as the major source of protein for infants and children.

INTRODUCTION

Food technologists frequently use soya products in foods because of some attribute they add to the food such as texture, water binding capacity, or suspension in water. The soya product will be used either because of some unique quality or because it can enhance to the food at a cost less than that of an alternative ingredient. These attributes that ingredients add to a food system are known to the food technologist as functional properties. Because of their versatile nature, soya products can be used in a number of food systems to meet nutritional objectives.

SOYA PROTEIN IN ANIMAL PROTEIN SYSTEMS

Throughout the world, when given a choice, people prefer to eat animal products rather than vegetable products. Thus, as populations become more affluent, their consumption of animal protein increases. Soya products can be introduced into animal protein systems in order to supplement animal proteins. In this way, the total protein available to a population can be increased. Examples of such food systems are emulsified meat and dairy food systems.

Mixtures of animal protein and soya protein are of nutritionally high quality. Steinke et al. (1) investigated the quality of mixtures of isolated soya protein and various animal and vegetable proteins by measuring the protein efficiency ratio (PER) with rats. Although the applicability of rat assays can be questioned because they tend to underestimate the nutritional value of proteins for humans, it is worthwhile to note that the PER of 50:50 mixtures of animal protein and isolated soya protein were, in most cases, excellent and quite comparable to that of casein (Table I). These favorable protein quality measurements are proof that mixtures of animal and soya protein have biologically high quality.

Nutritional experiments with human subjects further demonstrate the nutritionally high value of animal protein supplemented with soya protein. Young et al. (2) fed human subjects a range of mixtures of isolated soya protein and skeletal beef muscle as the sole source of protein in the form of an emulsified bologna-like food. A single test level of 0.6 g protein/kg body weight/day was fed to the subjects. This level of beef protein was adequate to meet the nitrogen needs of the subjects. Nitrogen balance was measured and found to be similar no matter what level of isolated soya protein replaced beef. The results showed that mixtures of beef and soya protein are of nutritionally high value when fed at levels to meet the nitrogen requirement. In a second study (3), these investigators determined the amount of dietary nitrogen from beef or a mixture of beef and soya protein was required to bring subjects into nitrogen balance. This represented the amount of nitrogen required when a specific source of dietary protein was fed. The results showed that a 50:50 mixture of beef and isolated soya protein was as effective as beef in meeting the nitrogen requirements of the human subjects.

Inoue et al. (4) investigated the nitrogen requirement of subjects fed either fish protein in kamaboko made from fish paste (surimi), a 50:50 mixture of isolated soya protein and fish paste, or isolated soya protein. Results of this study demonstrated that fish protein and a 50:50 mixture of isolated soya protein and fish protein were equally effective in meeting the nitrogen requirement of the subjects. Kies and Fox (5) measured the nitrogen balance of human subjects fed different ratios of nitrogen from beef and extruded soya flour (TVP) at levels of nitrogen below the protein requirement. The subjects received an intake of 4.8 g of nitrogen/day (30 g of protein). The nitrogen balance of the subjects was poorer when a greater proportion of the nitrogen came from soya flour. However, in another investigation (6) in which the subjects were fed higher levels of nitrogen (8.8 g of nitrogen/day, 55 g of protein/day) beef protein and the extruded soya flour promoted similar levels of nitrogen balance. Results showed that the effect on nitrogen balance of the various beef:soya mixtures in these studies depended on whether the measurement was made above or below the protein requirement.

The studies just cited show that soya products can be used to improve human nutrition in mixed food systems containing animal protein by increasing the total amount of dietary protein available.

The esthetic quality of a protein delivery system can be improved by adding soya protein to animal protein products or animal protein-like products because people prefer

TABLE I

Protein Quality, As Measured by Rat Protein Efficiency Ratio (PER), of Mixtures of Proteins in Which Nitrogen Is Furnished in a Ratio of 1:1 by Animal Protein and Isolated Soya Protein (ISP)[a]

Protein source	PER
Egg albumin/ISP[b]	2.8[c]
Whole egg/ISP	2.6
Lactalbumin/ISP	2.6
Casein/ISP	2.3
Processed cheese/ISP	1.9
Turkey/ISP[b]	2.6
Beef/ISP	2.7
Pork/ISP	2.6
Tuna fish/ISP	2.6

[a]Data from Steinke et al. (1).
[b]Average of 2 samples.
[c]Values corrected to casein at 2.5 PER.

to eat animal products. Soya protein products make it possible to improve the quality of nutrition by increasing the total dietary protein available through mixtures of soya and animal protein.

USE OF SOYA PROTEIN TO COMPLEMENT VEGETABLE PROTEIN

People in many parts of the world subsist on monotonous diets that are largely composed of grains or tubers. When these commodities are deficient in protein or one of the essential amino acids, soya products may be used to help overcome some of the problems of protein-calorie insufficiency. In an all-vegetable food system, soya products may be introduced to meet two nutritional objectives: provide needed essential amino acids by complementation of the grain protein, and provide higher total levels of dietary protein.

In order to demonstrate how the protein in soya products can be used to meet nutritional objectives in vegetable food systems, we calculated a series of diets to find out how much of a single grain or tuber and isolated soya protein would be needed to meet the energy, protein and amino acid requirement of a 3- to 5-year-old child. The nutritional requirements that were used are shown in Table II. The caloric requirement was based on FAO recommendations (7). Two protein requirements were used, one based on FAO requirements of 1.19 g/kg body wt/day and another requirement based on the amount of protein that would have to be consumed if the protein requirement is 8% of the calories, the level of protein found in mother's milk (8). The available amino acid requirements, which were based on the pattern suggested by Williams et al. (9), were calculated by multiplying the level of amino acids in the pattern by the protein requirement.

Protein requirements for humans are usually expressed as grams of a well utilized protein such as whole egg or milk. We interpreted this to mean that the requirement is for a protein that is completely digested. Consequently, digestible protein contents of the foods were calculated from the crude protein values (Table III), drawing largely from digestibility coefficients summarized elsewhere (10). The values for caloric content and the level of crude protein and amino acids in the foods were drawn from several sources (11-13). Available amino acids were calculated by multiplying the amino acid level by the digestibility coefficient.

The amounts of grain or tuber and isolated soybean protein required to meet caloric, digestible protein and available amino acid requirement of a 1,360-Kcal diet containing at least 16 g digestible protein/day are shown in Table IV. Using this type of nutrient requirement, the protein and amino acid requirement were met with no supplemental protein or amino acids when all the calories were supplied by wheat flour, maize, rice or potatoes. Rather low levels of isolated soya protein were needed to meet the requirements of diets composed of sorghum and ragi millet whereas somewhat higher levels of protein were needed to meet the requirements of diets based on cassava meal or sweet potatoes, because these tubers are very low in protein. Lysine was the limiting amino acid in the mixtures of isolated soya protein and sorghum, ragi millet and sweet potatoes, whereas valine was the limiting amino acid in the mixture with cassava meal.

The amounts of grain or tuber and isolated soya protein needed to meet the requirements of calories, digestible protein and available amino acids of a 1,360-Kcal diet containing at least 27.2 g of digestible protein/day are shown in Table V. The level of isolated soya protein used

TABLE II

Nutrient Requirements Used to Calculate Amounts of Grains or Tubers and Isolated Soya Protein for Model Diets

	Protein level	
	Lower	Higher
Kcal/kg	101	101
Kcal/day[a]	1360	1360
Digestible protein		
g/kg/day	1.19	2.03
g/day[a]	16.0	27.2
% of calories	4.7	8.0

[a]Assumes 1- to 3-yr-old child weighing 13.4 kg.

TABLE III

Energy and Protein Values Used to Calculate Amounts of Grains or Tubers and Isolated Soya Protein Required to Meet Nutritional Requirements

Grain or tuber	Kcal/g	Crude protein (%)	True digestibility (%)	Digestible protein (%)
Wheat flour[a]	3.65	12.8	94	12.0
Maize, ground	3.55	9.5	87	8.3
Rice, polished	3.63	7.1	89	6.3
Sorghum, ground	3.32	10.1	85	8.6
Ragi millet	3.27	7.4	79	5.8
Cassava meal	3.52	1.6	85	1.4
Sweet potatoes	1.14	1.3	85	1.1
Potatoes	0.76	2.0	85	1.7
Isolated soya protein	3.12	88.5	95	84.1

[a]80-90% extraction.

TABLE IV

Mixtures of Grains or Tubers and Isolated Soya Protein (ISP) That Meet the Requirements of 1,360-Kcal Diet with at least 16 g of Digestible Protein

	Grain or tuber (g)	ISP (g)	Limiting amino acid
Wheat flour	373	0	–
Maize, ground	383	0	–
Rice, polished	375	0	–
Sorghum, ground	408	2	Lysine
Ragi millet	414	2	Lysine
Cassava meal	373	15	Valine
Sweet potatoes	1174	7	Lysine
Potatoes	1790	0	–

TABLE V

Mixtures of Grains or Tubers and Isolated Soya Protein (ISP) That Meet the Requirement of 1,300-Kcal Diet with at Least 27.2 g Digestible Protein

	Grain or tuber (g)	ISP (g)	Limiting amino acid
Wheat flour	368	5	Lysine
Maize, ground	374	10	Lysine
Rice, polished	366	10	Lysine
Sorghum, ground	397	13	Lysine
Ragi millet	403	13	Lysine
Cassava meal	361	29	Valine
Sweet potatoes	1142	18	Leucine
Potatoes	1764	6	Total sulfur amino acids

in diets based on wheat flour, maize, rice, sorghum, or ragi millet was determined by the amount of lysine needed to meet the requirements of the child. Because of their high lysine content, soya products are excellent sources of protein to complement the proteins of these grains. When the lysine requirements of the grain-soya protein mixtures were met, the requirements for digestible protein and the other amino acids were also fulfilled. The situation with cassava meal and sweet potatoes was less clear. Calculations suggest valine and leucine were limiting amino acids in mixtures with isolated soya protein. Further investigations are needed to ascertain if valine or leucine were truly limiting. The limiting amino acids of mixtures of potatoes and soya protein were the sulfur amino acids. The calculations in this study suggested that isolated soya protein does not complement the amino acids in potato protein particularly well.

There have been a number of studies in which the protein quality of a variety of mixed vegetable proteins has been measured both in adults and children. These studies have been summarized and reviewed in detail (14-19). However, one or two other studies are worthy of special mention. Panemangalore and coworkers (20) supplemented a diet of poor quality, composed predominantly of rice, with either soya flour, soya flour and methionine or skim milk. The diets were fed to children. When the rice diet, which provided a level of 1.4 g of protein/kg body wt/day, was supplemented with soya flour and methionine or skim milk to provide 2.4 g of protein/kg body wt/day, similar positive nitrogen balances, of 112 and 113 mg/kg/day were observed. However, the nitrogen balance of the children fed the rice diet supplemented with soya flour was also excellent, 96 mg/kg/day. These results show that supplementation of a largely vegetable diet with an adequate level of soya flour can produce a quite acceptable level of nitrogen balance.

Kies and coworkers (21) compared the nitrogen balance of subjects fed millet, triticale, soya flour, or mixtures of the two grains with soya flour. The results demonstrated that at this admittedly deficient level of protein intake, the soya flour was quite effective in improving protein quality of either the millet or triticale.

Bressani (19) recently summarized several investigations on the nutritional value of combinations of soya and cereals or mixed diets. These results, which are summarized in Table VI, indicated that, overall, the protein quality of mixed food systems containing soya products is excellent. Graham and Baertl (22) summarized studies in which the protein quality of a number of predominantly vegetable foods containing soya flour was measured in children. Their studies demonstrated that a variety of cereal-soya mixtures could serve as the major or sole source of protein in diets of infants and children, although the protein quality of the cereal-soya mixture was somewhat inferior to casein (Table VII). These workers went on to explain that the difference in protein quality between the soya-cereal mixtures and casein was quite likely due to poorer digestibility. They pointed out that this could be overcome by processing technology. The important thing to note in these studies is that the protein quality of the mixtures is quite satisfactory and the mixtures are capable of maintaining adequate protein nutrition in children when fed as the major source of dietary protein.

TABLE VI

Summary of Various Studies or Evaluation of Soybean Products in Children[a]

	N retention with milk (%)	Reference
Soya/rice	97	23
Soya/corn	78	24
Soya/mixed diet	129	25
Soya/corn	126	26
Soya textured food	114	27
Corn 92/soya 8	83	28

[a]Calculated from summary by Bressani et al. (19).

TABLE VII

Nitrogen Absorption and Retention of Soya-Cereal Foods in Children[a]

	Absorption (%)	Retention (%)	Retention relative to casein
Soya flour/corn meal/skim milk	73.0	27.4	81
Soya flour/corn meal/skim milk[b]	78.1	33.8	100
Soya flour/corn meal/methionine	74.6	26.5	78
Soya flour/corn flour/wheat flour	77.6	24.9	74
Soya flour/corn flour/wheat flour/ methionine	79.6	26.7	79
Soya flour/wheat flour/wheat conc.	75.7	23.4	69
Soya flour/whole wheat flour	78.7	25.4	75
Soya flour/oat flour	80.6	25.9	77
Casein	86.8	33.8	100

[a]Taken from Graham and Baertl (22).
[b]Full-fat soya flour.

REFERENCES

1. Steinke, F.H., E.E. Prescher and D.T. Hopkins, J. Food Sci. 45:323 (1980).
2. Young, V.R., N.S. Scrimshaw, B. Torun and F. Viteri, JAOCS 56:110 (1979).
3. Scrimshaw, N.S., and V.R. Young, in "Soy Protein and Human Nutrition," edited by H.L. Wilcke, D.T. Hopkins and D.H. Waggle, Academic Press, New York, NY, 1979, p. 121.
4. Inoue, G., T. Takahashi, K. Kishi and T. Komatsu, "Soy and Soybean Products for Human Consumption," XIth International Congress on Nutrition, Rio de Janeiro, Aug.-Sept., 1978.
5. Kies, C., and H.M. Fox, J. Food Sci. 38:1211 (1973).
6. Kies, C., and H.M. Fox, Ibid. 36:841 (1971).
7. FAO/WHO, "Energy and Protein Requirement," FAO Nutrition Meeting Report Series, No. 52, FAO, Rome, Italy, 1973.
8. FAO/WHO, "Protein Requirements," World Health Organization Technical Report Series, No. 301, WHO, Geneva, Switzerland, 1965.
9. Williams, H.H., A.E. Harper, D.M. Hegsted, G. Arroyave and L.E. Holt, Jr., in "Improvement in Protein Nutriture," National Academy of Sciences, Washington, DC, 1974, p. 23.

10. Hopkins, D.T., in "Protein Quality in Humans: Assessment and In Vitro Estimation," edited by C.E. Bodwell, J.S. Adkins and D.T. Hopkins, Academic Press Inc., NY (in press).
11. Watt, B.K., and A.L. Merrill, "Composition of Foods," Agric. Handbook No. 8, U.S. Dept. Agric., Washington, DC, 1963.
12. Waggle, D.H., and C.W. Kolar, in "Keystone Conference–Soy Protein and Human Nutrition," edited by H.L. Wilcke, D.T. Hopkins and D.H. Waggle, Academic Press, Inc., New York, NY, 1979, p. 42.
13. "Amino Acid Content of Foods and Biological Data on Proteins," FAO Nutritional Studies No. 24, FAO, Rome, Italy, 1970.
14. Liener, I.E., "Nutritional Value of Food Protein Products in Soybeans, Chemistry and Technology, Vol. I, Proteins," edited by A.K. Smith and S.J. Circle, The AVI Publishing Co., Inc., Westport, CT, 1972, p. 203.
15. Liener, I.E., JAOCS 54:454A (1977).
16. Wolf, W.J., and J.C. Cowan, "Soybeans as a Food Source," CRC Press, Inc., Cleveland, OH, 1975.
17. Monckeberg, F., E. Yanez, D. Dallester, C.O. Chichester and T. Lee, in "Protein Nutritional Quality of Foods and Feeds, Part 2," edited by M. Friedman, Marcel Dekker, Inc., NY, 1975, p. 417.
18. Bressani, R., in "Proceedings of the International Soya Protein Food Conference," Am. Soybean Assoc., St. Louis, MO, 1978, p. 30.
19. Bressani, R., L.G. Elias and J.E. Braham, in "Nutritional Improvement of Food and Feed Proteins," edited by M. Friedman, Plenum Press, New York, NY, 1978, p. 29.
20. Panemangalore, M., H.N. Parthasarathy, K. Joseph, A.N. Sarkaran, M.N. Rao and M. Swaminathan, Can. J. Biochem. 42:641 (1964).
21. Kies, C., H.M. Fox and L. Nelson, J. Food Sci. 40:90 (1975).
22. Graham, G.G., and J.M. Baertl, JAOCS 51:152A (1974).
23. Huang, P., T. Tung, M. Lee and H. Wei, in "Proceedings International Conference on Soybean Protein Foods," Peoria, IL, ARS/USDA Pub. No. 71-35, 1966, p. 183.
24. Dutra de Oliveira, J.E., N. de Souza, T.A. de Rezende, L.A. Valiente, V.F. Boyd and E.E. Doggy, J. Food Sci. 32:131 (1967).
25. Dutra de Oliveira, J.E., and N. de Souza, Arch. Latinoam. Nutr. 17:197 (1967).
26. Bressani, R., F. Viteri, D. Wilson and J. Alvarado, Ibid. 22:227 (1972).
27. Bressani, R., F. Viteri, L.G. Elias, S. de Zaghi, J. Alvarado and A.D. Odell, J. Nutr. 93:349 (1967).
28. Viteri, F., C. Martinez and R. Bressani, in "Mejoramiento Nutricional del Maiz," edited by R. Bressani, J.E. Braham and M. Behar, Publication INCAP L-3, 1972, p. 195.

Requirements for Foods Containing Soy Protein in the Food for Peace Program

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ABSTRACT

Under the Food for Peace Program, whole grains, milled wheat flour, milled rice, soybean oil, soybean flour, nonfat dry milk, soya-containing blended food supplements, and soya-fortified processed foods are provided by the U.S. to needy people abroad to alleviate malnutrition. These commodities are used in maternal/child health programs, school feeding, food for work projects and disaster relief. The wide diversity of nutritional requirements and traditional food preferences has led to development of nine soya-containing food types, which are used in the PL-480 Title II donation program as blended food supplements or fortified processed foods. Research studies have led to the development of product specifications. Blended food supplements include the standardized mixtures of corn-soya-milk (CSM), instant CSM, wheat-soy blend and whey-soy drink mix. These foods, developed to fulfill the nutritional requirements of preschool children, contain from 17.5 to 29.7% either toasted-defatted or equivalent full-fat soya flour, along with vitamins and minerals. In addition, 4-19% soya oil is added to improve caloric density. These products contain 19 or 20% minimum protein and 6 or 19% minimum fat content. Fortified processed foods include soya-fortified bulgur (SFB), soya-fortified bread wheat flour (SFWF), soya-fortified cornmeal (SFCM), soya-fortified sorghum grits (SFSG), and soya-fortified rolled oats (SFRO). These foods contain toasted soya flour, grits, or flakes added at 12-15% levels. Fortified foods are generally consumed by people other than infants.

INTRODUCTION

For more than a generation, the U.S. has been a leader in exporting foods to alleviate hunger among the 0.4 to 1.2 billion (estimated) malnourished people in the world (1). Since the inception of Public Law 480 (PL-480), the Agricultural Trade Development and Assistance Act, the U.S. has exported over 265 million tons of food valued above $26 billion (1). The major objective of this program was to relieve world hunger using our surplus commodities. Donations are included under Title II of this act and comprise ca. 20% of total food aid. From 1955 to 1966, the donation program averaged ca. 2 million tons/year. The principal Title II commodities shipped during this period were wheat, feed grains, rice, nonfat dry milk (NFDM), and edible oil. Because these were years of surplus in the U.S., the program served the dual purpose of feeding the hungry and reducing surplus commodities held in U.S. warehouses and grain elevators.

In 1966, the law was amended and PL-480 became known as the Food for Peace Program, which featured a new emphasis on nutrition. Authority was provided for enrichment and fortification of commodities to improve their nutritional values and for international programs to combat malnutrition in children. This legislation removed the requirement that a commodity be in surplus to be eligible for distribution. The Secretary of Agriculture now determines the agricultural commodities to be used.

For several years prior to the change in legislation, there was a growing awareness of the need to provide more nutritious foods through the donation program. In the early 1960s, there was a shortage of nonfat dry milk, which was the only PL-480 high-protein food specifically suited for infant and child feeding. Guidelines for blended food supplements were established in 1965 for the nutrient composition of formulated foods. These guidelines were developed by the U.S. Department of Agriculture (USDA) in cooperation with the Agency for International Development (AID) and the National Institutes of Health (2). The formulated foods were to serve as supplements in diets of young children, pregnant and lactating women, or in emergency feeding of adults.

Guidelines (3,4) included the requirement for corn or wheat to be used as the basic cereal components, whereas soya flour and nonfat dry milk were included as protein supplements. The essential amino acid distributions in soy-