Nutritive Value and Dietary Properties of Soy Protein Concentrates[1]

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ABSTRACT

A nutritional study was made to determine the protein quality of soy protein concentrates in contrast to the cereal proteins. Comparisons were made to evaluate the synergistic effects of soy and cereal protein in various combinations. Seven-week rat-feeding studies were made at critical levels of protein in the diet. Commercial protein breads were compared with a soy protein concentrate as the single source of protein in the diet. Statistical analysis showed the soy protein to be significantly superior to white bread or any of the commercial high-protein breads tested. Increasing the percent of soy protein in relation to the white bread protein produced significant increases in protein quality to a maximum at 75% soy protein, 25% white bread protein. Then a decrease from this maximum resulted at 100% soy protein in the diet. A striking difference was noted when weight gain comparisons were made between soy protein bread and white bread, without adjustment of the protein. There are highly significant protein quality differences among commercial protein breads. Soy protein concentrates aid substantially in improving the quality of the protein source.

"High-protein" food products have received considerable attention recently, with emphasis on their nutritional aspects. Soy products are among those protein sources that have enjoyed a rapid increase in availability during the last 10 to 20 years. This abundance of good-quality protein can have a significant effect on the nutritional level of our fast-growing population, particularly in view of world needs for protein.

The supplemental properties of proteins from different sources are well known; however, extension of the basic principles of nutritional supplementation to practical applications can easily lead to erroneous estimates of the protein values of food mixtures. Such misinterpretations come largely from the assumption that the biological quality of a protein, as determined by use as the sole source of protein in a diet, reflects the value it will have when used with other proteins. Actually, the dietary value of a protein depends, to a large extent, upon its ability to supply needed amino acids not adequately supplied by other components.

Cereal proteins, when used as a major dietary source, have been inadequate in meeting the needs of the undernourished nations of the world. They are limited with respect to the amounts and quality of protein available, and are more efficiently utilized in combination with proteins from other sources or when supplemented with the limiting amino acids (1,2,3). High-quality protein, by providing generous amounts of the essential amino acids, will often compensate for the deficiencies of lower-quality proteins in a diet. Thus, improvement of the diet results from upgrading the lower-quality protein by supplementation, as well as by enriching the diet with some preformed complete protein.

The rates of digestion and absorption of various proteins differ in the body. The value of a protein in enhancing the quality of another depends

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largely on its ability to provide the essential amino acids, at the proper time, for full utilization of the protein mixture. Therefore, data on amino acid composition for the several proteins in a diet mixture give valuable information on probable protein values; but before the supplemental relationship can be predicted confidently, feeding studies of blended proteins must be made. Inasmuch as the amino acids in soy protein tend to complement those in wheat flour—which is often a major component of low-cost diets—it is important to know in some detail the complementary characteristics of these two proteins.

The experiments described below were made to determine the supplemental value of soybean concentrates when used with bread protein and to compare various commercial protein breads with a soy-wheat bread.

MATERIALS AND METHODS

To evaluate the quality of soy protein concentrates and determine their supplemental value for wheat protein in bread, various protein sources were fed singly and in combination with each other. The AOAC Standard Protein Quality Evaluation method was used, modified to extend the feeding period to 7 weeks (4). The bread samples were air-dried, ground, and blended with other components to give diets having an adequate supply of all nutrients except protein, which was limiting in amount or quality, or both. Protein level in the diets was 9.09%, and the fat, carbohydrate, fiber, and ash were adjusted to constant levels. Each diet was fed *ad libitum* to 10 individually caged weanling male albino rats. The rats were weighed twice a week, and weights and feed consumptions are reported for 7 weeks. Water was given *ad libitum.* Protein efficiency ratios (PER) were calculated and the data were analyzed statistically. One group was fed reference casein as a standard.

Four samples of commercial protein breads, varying in protein content from 9 to 13%, were compared with commercial white bread and a bread in which soy protein concentrate supplemented the wheat protein. The commercial "protein" breads included the following added proteins: bread A, nonfat dry milk (NFDM); bread B, soy flour and NFDM; bread C, NFDM and lactalbumin; and bread D, wheat gluten. The experimental soy bread contained NFDM at approximately the same level as commercial white bread.

The soy protein concentrate used was Swift's Food Protein (SFP). It contains 70% protein and is prepared by removal of the soluble carbohydrate material from defatted soy protein. The bread samples containing SFP were made in our laboratories by substituting SFP for 15% of the bread flour.

RESULTS AND DISCUSSION

The feeding of diets containing the commercial protein breads resulted in significantly lower weight gains than those obtained with the soy breads (Fig. 1, upper graph). It should be noted that growth response is lower with protein bread D than with white bread. As might be expected, the rats fed these protein breads were significantly smaller than those fed white bread supplemented with soy. At the end of 7 weeks, rats in the group fed white bread were losing a noticeable amount of hair and coat luster. This compari-

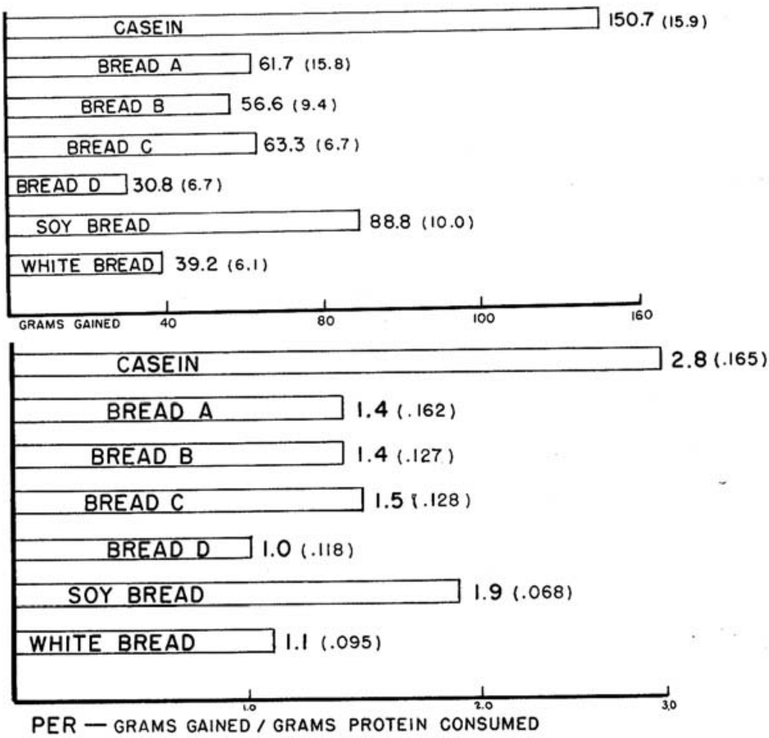

Fig. 1. Comparison of protein bread diets (lower graph, PER's). Numbers following each bar represent the mean and (in parenthesis) standard deviation for the particular diet. Standard Error of Means for the Experiment: 4.817 (PER's, 0.44). Values differing by 11.16 (PER's, 0.15) are significant at 0.05 level (Duncan's Multiple Range Test for Ranked Means).

son shows that the percent protein in a food is no reliable indicator of the nutritional value or quality of the protein.

Figure 1, lower graph, shows the PER's of these same protein sources. There is an obvious correlation between the growth of the rats (Fig. 1) and the quality of the protein eaten. Here again, the commercial protein breads are shown to be significantly inferior to the bread made with SFP. Bread D, as noted before, contains wheat gluten as an added protein source, whereas the others contain nonwheat protein sources which slightly improve their quality.

The next series of figures allows a more quantitative definition of the supplemental values of soy protein concentrate and wheat proteins. In Fig. 2, the upper graph shows the weight gains of rats fed combinations of SFP and white bread. The protein in the diet came from white bread and SFP in the percentages shown on the chart. There is a dramatic increase in growth as the diet is changed to include SFP. Mixtures in which 50% of the protein was supplied by white bread and 50% by SFP were of near optimal quality, with peak values when the protein was 25% from bread and 75% from SFP. Gains on these two diets were greater than those made

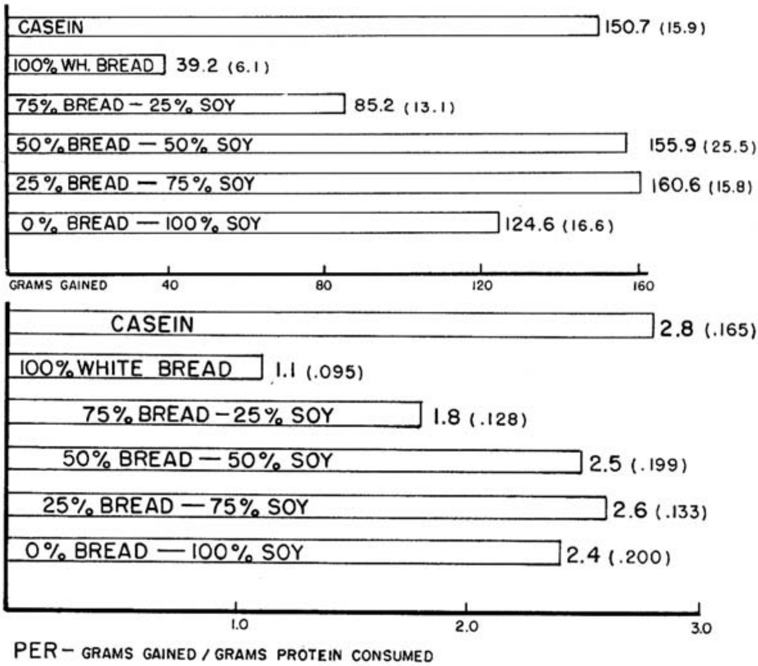

Fig. 2. Supplemental values of soy and cereal products (protein source at left). Lower graph, PER's. See caption for Fig. 1 regarding statistical data.

by the group fed the casein diet. When the protein was 100% SFP, a significant decrease from maximum gain was observed.

A fourfold increase in weight gains resulted when the cereal protein was optimally supplemented with SFP. As in the case of weight gain, combinations of the two protein sources gave significantly better PER's than either bread or SFP alone (Fig. 2, lower graph). This illustrates quite effectively the synergistic or complementary effect of one protein on another—the quality of the mixture is better than that of either protein alone.

This response is to be expected when one considers the amino acid balance in soy and wheat proteins. The lysine content of soy protein effectively supplements the deficiency in wheat protein, resulting in a better optimal balance in the protein mixture.

Weight gains of rats fed diets containing equal percentages of either SFP-fortified bread or a commercial white bread are shown in Fig. 3. In this case, the protein levels were not the same; they were proportional to those of the original breads. Here we get a 470% increase in weight gain from a 60% increase in dietary protein level. This illustrates the combined effects of quantity and quality. Maximal growth cannot be attained even with good-quality protein, if the amount in the diet is too low; neither can it be achieved by increasing the levels of poor-quality protein.

Table I gives food disappearance data for the combined protein bread diets. It should be noted that the diets containing soy protein were con-

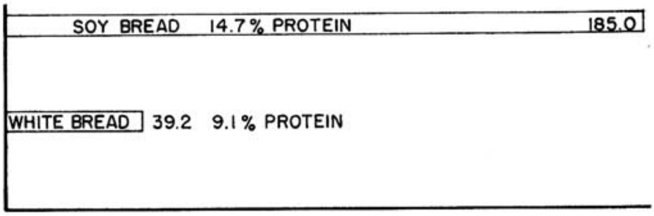

Fig. 3. Gain of rats fed diets containing soy bread and white bread without adjustment of protein level.

TABLE I

FOOD DISAPPEARANCE DATA FOR THE PROTEIN BREAD DIETS[a]

Protein Source	Means	St. Dev.	St. Dev. of Mean	Protein Source	Means	St. Dev.	St. Dev. of Mean
	g.	g.	g.		g.	g.	g.
Standard casein	596.6	59.3	18.7	White bread (100%)	380.3	39.6	12.5
Bread A	465.9	65.9	20.8	Bread 75%, soy 25%	516.3	60.9	19.3
Bread B	434.4	46.2	14.6	Bread 50%, soy 50%	676.9	76.9	24.3
Bread C	451.1	33.5	10.6	Bread 25%, soy 75%	672.4	53.6	16.9
Bread D	338.9	43.8	13.8	Soy 100%	579.2	47.1	14.9
Soy bread	516.8	57.6	18.2	Soy bread[b]	672.7	73.3	23.2

[a] The standard error of the means for the experiment is 17.7.

[b] Protein not adjusted in diet.

sumed in higher amounts than was the commercial high-protein bread diet. The soy protein diets at optimum levels exceeded the standard casein diets in amounts of food consumed.

Scientifically, the supplemental effect of one protein upon another can be very impressive, but from a practical point of view, "the proof of the pudding is in the eating." A food is not a food until some person has put it into his mouth, chewed it, and swallowed it. A new food product cannot be commercially successful until a substantial number of people will come back and buy it, and repeat this process over and over. Organoleptic studies in our own laboratory have demonstrated the preference for soy bread over existing high-protein breads. Further studies by Mugler *et al.* at Kansas State University, reported at the 52nd AACC Annual Meeting (5), have confirmed our observations. These authors state that addition of a limited amount of soy concentrates to bread not only increases its nutritive value but tends to improve desirability and attract the consumer to accept the specialty bread.

In view of the world deficit of protein, it seems logical to attempt improvement in quality of the total dietary protein by appropriate supplementary foods. When the protein conventionally used in diets is poor, nutrition can more readily be improved by increasing the quality of protein in the diet (by supplementation) than by increasing intake of the low-quality protein. In fact, with some diets of vegetable origin, the protein quality is so poor and the level so low that supplementation is the only way to achieve adequate nutrition. This, of course, is the approach being taken by groups attempting to improve health in protein-low regions of the world (6). It can be equally effective in other parts of the world where people subsist from choice or necessity on low-protein foods.

Acknowledgment

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Literature Cited

1. Hartman, R. H., and Rice, E. E. Supplementary relationships of proteins. J. Am. Diet. Assoc. 35: 34–37 (1959).
2. National Research Council-National Academy of Sciences. Food and Nutrition Board. Evaluation of protein nutrition. Publication 711. Washington, D. C. (1959).
3. National Research Council-National Academy of Sciences. Food and Nutrition Board. Cereal enrichment in perspective. Washington, D. C. (1958).
4. Association of Official Agricultural Chemists. Official methods of analysis (9th ed.), p. 785. The Association: Washington, D. C. (1965).
5. Mugler, D. J., Mitchell, J. D., and Hurley, W. C. Utilizing soy protein concentrates in bread. Cereal Chem. (in press).
6. Scrimshaw, N. S., and Bressani, R. Vegetable protein mixtures for human consumption. Fed. Proc. 20: 80–88 (1961).

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