Nutritional Contribution of Soy Protein to Food Systems[1]

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ABSTRACT

From the nutritional point of view, soybeans can play a significant role in at least three aspects: as a source of supplementary and complementary protein, as a source of calories, and as a source of nitrogen. The protein role is probably the most important for food systems of developed and underdeveloped populations, while the role as a source of protein and calories applies more to food systems of developing populations. Soy protein efficiently supplements cereal grain protein, because it corrects the lysine deficiency of cereals. In some cases, for example with maize, it also corrects the tryptophan deficiency. On the other hand, the essential amino acid pattern of soybean protein complements that of other protein sources, for example cereal grains, cottonseed flour, and, in general, lysine deficient protein sources. This makes feasible the preparation of foods of optimum protein quality and of a high protein content. Because of its quality, soybean protein can replace animal protein without a significant decrease in nutritive value, for example as milk and meat extender; for diets low in quantity and quality of protein and deficient in calories, soybeans, as full-fat flour, provide both. Because of cultural eating habits, it is difficult to conceive the use of soybeans as complete substitutes of common beans; therefore, efforts should be made to use soy protein in combination with common foods used by populations to whom soybeans are foreign food. Examples of the nutritional benefits derived from the use of soybean protein as flour or protein concentrate or as full-fat soybean flour are given, particularly for foods consumed in Latin American countries. Besides the role soybeans play in human foods, they also play a significant role in the animal industry as a very important component of diets. The efficiency of the swine and poultry industry would be lower if it were not for the nutritional contribution of soybeans.

INTRODUCTION

The availability of protein foods is becoming more difficult throughout the world. In the developed countries, animal protein is becoming more costly, while, in the underdeveloped world, this kind of protein has been absent from the diet for the majority of the population for quite some time.

A very useful breakthrough came with the development of the technology to process vegetable protein products into foods which resemble meat. This kind of technology is finding increasing use in the developed world. On the other hand, similar attempts, although not as sophisticated, have been made with vegetable proteins for foods used in the underdeveloped countries. Even though the fundamental knowledge is available and various products have been tested, a breakthrough similar to that observed in the developed world has not been possible yet. There are various reasons for this, the most important being the kind of socioeconomic status of the population for whom such products were developed.

Among the various vegetable proteins tested, the one which has proved to be effective is that from the soybean. Even though soybean protein is one of the best in quality among vegetable sources, its indiscriminate use to replace other protein sources should be assessed carefully to preserve a good intake of high quality protein. This is even more important when the product from soybeans to be used is a fraction of the original protein or has undergone some kind of processing which may decrease the original protein quality of whole soybean protein.

This presentation attempts to define the various nutritional roles soybean protein plays, by means of basic nutritional information and in terms of food preparations for people in both developed and underdeveloped countries.

ROLE OF SOYBEAN PROTEIN

Quality of Soy Protein

The protein quality of the soybean is very well documented in experimental animals. Results of many studies are summarized in Table I. As with most legume foods, raw soybeans reduce wt gain, as well as protein efficiency ratio (PER). However, heat processing, when done under well controlled conditions, results, in all cases, in an improvement in growth and protein quality. Many results have shown that soy protein is deficient in sulfur containing

[1]One of 13 papers presented in the symposium, "Soy Protein," at the AOCS Spring Meeting, Mexico City, April 1974.

TABLE I

Known Nutritional Facts on Soybean Protein in Experimental Animals

1.	Raw soybean meal reduces wt gains and protein efficiency ratio (PER).
2.	Wt gains and PER increase when raw soybean meal is steam-heated for as little as 15 min. Maximum values are obtained when moisted meals are autoclaved for 15 min, or for 2 hr when autoclaved dried.
3.	Growth inhibitors are destroyed by heat.
4.	Protein quality increases significantly when soybean protein products are supplemented with methionine.
5.	Other types of heat processing, such as toasting, also destroy growth inhibitors and increase protein quality.

TABLE II

Quality of Soy Flour Protein Fed to Children (1)

Protein source	Age (years)	Protein intake g/kg/day	True protein digestibility (%)	Biological value
Soy flour	8-9	1.2	84.0	63.5
Soy flour + DL-methionine		1.2	86.4	74.9
Skim milk		1.2	87.1	82.6

TABLE III

Quality of Soybean Protein in Young Adults (2)

Protein source	Age (years)	Nitrogen intake g/day	Apparent digestibility (%)	Nitrogen balance g/day
Soybean protein (TVP)[a]	12-16	4.0	79	−0.08
Soybean protein (TVP) + 1% DL-methionine			80	+0.48
Beef			82	+0.32

[a]TVP = textured vegetable protein.

TABLE IV

Quality of Soybean Protein in Adult Human Subjects (3)

Protein source	Nitrogen intake g/day	Crude protein *digestibility*	Nitrogen balance g/day
Soybean protein (TVP)[a]	4.0	79.4	−0.70
Soybean protein (TVP) + 1% DL-methionine		79.2	−0.45
Beef		81.4	−0.30
Soybean protein (TVP)	8.0	81.6	0.78
Soybean protein (TVP) + 1% DL-methionine		80.1	0.72
Beef		82.7	0.74

[a]TVP = textured vegetable protein.

amino acids, and their addition brings about a significant improvement in wt performance and protein quality.

Results on the quality of soybean flour proteins are not as available in humans as in experimental animals. However, some results have been reported. Parthasarathy, et al., (1) fed 8-9 year old children 1.2 g full-fat soy flour protein/kg body wt/day with and without methionine addition. The results obtained are summarized in Table II. On soy flour alone, the average biological value, i.e. the amount of protein retained from that which was absorbed, was 63.5%. The addition of 1.2 g methionine/16 g nitrogen to the soy flour increased biological value to 74.9%, equivalent to 90.6% of the biological value of skim milk protein. True protein digestibility was slightly lower with soybeans than with milk.

Older human subjects were used by Korslund, et al. (2) to evaluate the quality of soybean textured protein. The results obtained by these authors are presented in Table III. The subjects were fed 4 g nitrogen from soy protein as textured vegetable protein with and without methionine supplementation and from beef. Nitrogen balance was negative when the protein fed was TVP, in comparison with a relatively high retention from beef. However, the additon of methionine increased nitrogen retention to values higher than those from beef.

Studies also have been carried out with adult human subjects. Kies and Fox (3) reported the nitrogen balance results shown in Table IV, with adults fed two levels of protein from soybean protein and from beef. At the lower level of nitrogen intake, even though all values were negative, beef protein gave a better nitrogen retention than soy textured protein with or without the addition of methionine. This amino acid improved nitrogen retention at the low levels of nitrogen intake but not when it increased to 8.0 g/day. At this high level, all protein sources fed gave similar nitrogen retention values. In a more recent study, shown in Figure 1, Kies and Fox (4) showed that, when soy protein replaces beef protein on an equivalent basis, protein quality decreases which would be expected due to a higher relative deficiency of methionine in soy protein.

Analyses of the data presented, as well as those from other investigators, indicate that the conversion of soy protein into highly processed products decreases protein

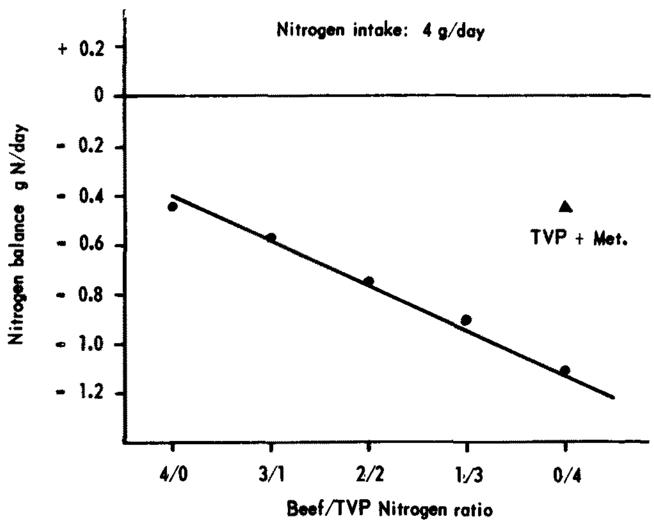


FIG. 1. Effect of change in beef/textured vegetable protein (TVP) nitrogen ratio upon nitrogen balance of human adults (4). Met = methionine.

quality. This is shown in Tables V and VI. Whole soy protein is of relatively good quality, but its processed products have lower protein values. Not only that, but it appears that some of the growth inhibitors have not been removed completely. This information is of much interest from the nutritional point of view, since, rather than upgrading or maintaining protein quality in foods by using soybean products, there may be a decrease in nutritional value (5,6).

These results show that soy protein in its different forms has a lower quality than animal protein and that it is improved by supplementing with methionine, its most limiting amino acid. On the other hand, soy protein is a very good source of lysine, amino acid deficient in most cereal grains. Because of its characteristic essential amino acid pattern, the greatest nutritional potential of soybean protein is related to the contribution it can make to balance the deficient essential amino acid composition of cereal grains, providing additional protein as well. On the other

TABLE V

Protein Quality of Soy Protein Products (5)

Product	Protein efficiency ratio	
	Without methionine	With methionine
Soy flour (defatted)	2.16 – 2.48	2.47
Soy protein concentrate	2.02 – 2.48	3.09 – 3.24[a]
Isolated soy protein	1.08 – 2.11	2.11 – 2.45[b]

[a]1.0% DL-methionine.
[b]1.5% DL-methionine.

TABLE VI

Protein Quality of Soy Protein Isolate, Fiber, and Soy Textured Food (6)

Soy protein	As received		Heat treated	
	Average wt gain (g)	PER[a]	Average wt gain (g)	PER
Isolate	–5	---	81	2.44
Fiber	59	1.88	72	2.23
Textured food	98	3.30	138	3.38
Casein	118	3.53	---	---

[a]PER = protein efficiency ratio.

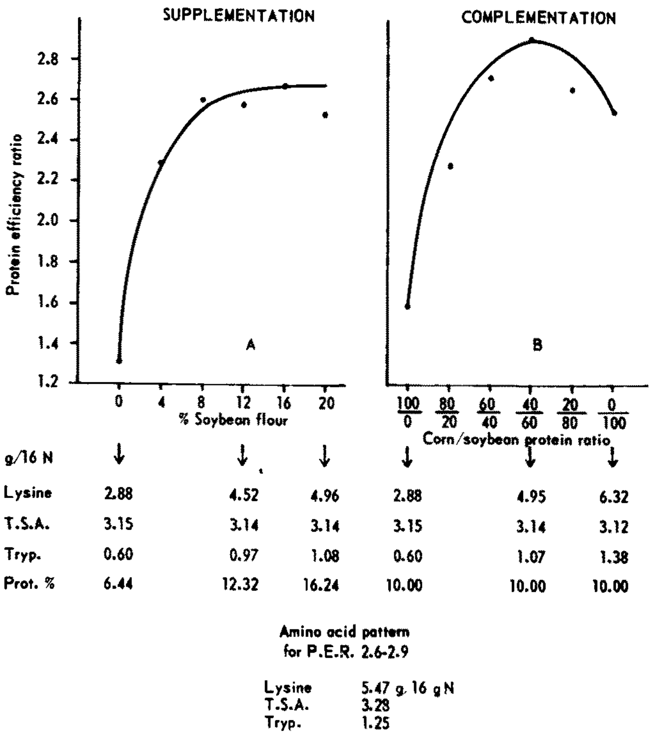
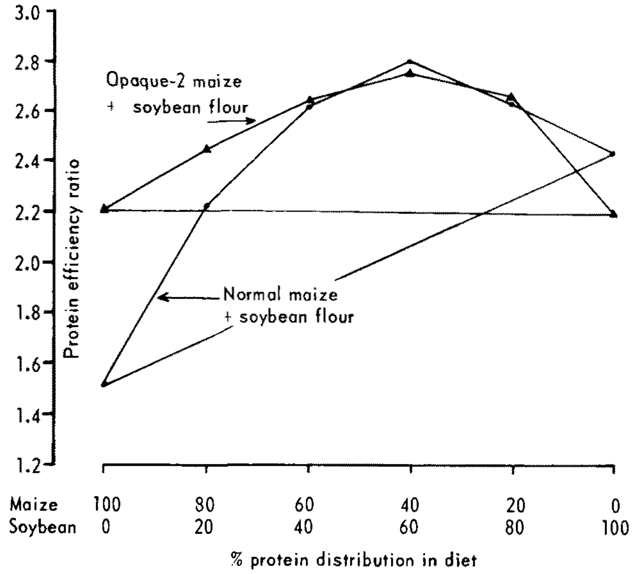


FIG. 2. Protein quality due to supplementation and complementation. PER = protein efficiency ratio, Prot. = protein, TSA = total sulfur amino acids, and Tryp. = tryptophan.

hand, because of the deficiency of methionine in soy protein and its increasing role as a protein extender for animal protein sources, it is felt that efforts should be made to select and introduce into agricultural cultivation soybean varieties with higher sulfur amino acid contents.

NUTRITIONAL ROLE OF SOYBEAN PROTEIN

On the basis of its essential amino acid pattern in comparison with that of other proteins, it may be indicated that soybean protein can play three roles: (A) as a supplementary protein, (B) as complementary protein, and (C) as a nitrogen source. These terms are closely related to each other, and the difference between them may not have



	Lys	Try	T.S.A..
	mg g N		
Normal maize	180	38	197
Opaque-2 maize	306	94	234
Soybean flour	395	86	195

FIG. 3. Protein efficiency ratio of combination of normal or opaque-2 maize and soybean flour. Lys = lysine, Try = tryptophan, TSA = total sulfur amino acids.

much practical significance. However, the nutritional role of soybean protein can best be appreciated if the difference between the three roles is indicated. Supplementation is defined as an increase in protein quality resulting from an increase in total protein and in essential amino acids, particularly the limiting amino acid of the protein being supplemented. On the other hand, by complementation is meant the improvement on protein quality resulting from the addition of amino acids only, which gives a better overall essential amino acid balance. However, amino acid deficiencies may still be present. Finally, the role of soybean protein as a source of nitrogen is defined as the replacement of part of a protein by soybean protein with no change in the quality of the protein being replaced. This is the commonly known protein extender role of soybean for animal protein which is becoming more and more important in food preparations.

To clarify further the differences between protein supplementation and protein complementation, Figure 2 is presented. The graph on the left was obtained by adding increasing amounts of soy protein to a fixed level of maize; therefore, protein content of the diets increased. This is defined as supplementary effect. On the other hand, the graph on the right was obtained by mixing maize and soy protein in different proportions but keeping protein content of the diet constant. This is complementary effect. At the bottom of the figure, the changes in some essential amino acids are shown for the two types of responses. In the case of supplementation, amino acids increase on a percentage basis or as percentage of the protein. However, there is an excess which is wasted, as indicated by higher ratios of lysine and methionine to tryptophan. On the other hand, in complementation, there is also an increase in amino acids. However, the quality of the protein is conditioned by the levels of the two protein components, where there is better balance between their respective essential amino acids (7).

Complementary Effect of Soy Protein Patterns

Soy flour and normal and opaque-2 maize: The proteins

TABLE VII

Effect of Amino Acid Supplementation of Soybean-Opaque-2 Maize and of Soybean-Normal Maize 60/40 Protein Combination (8)

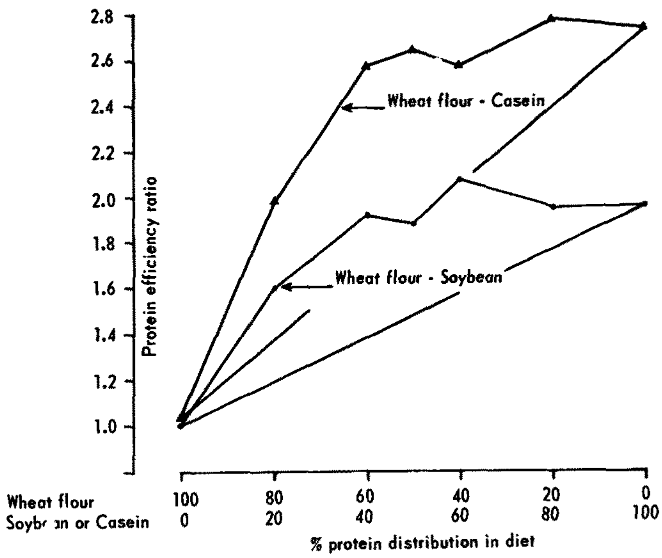
Maize	Amino acid % added	PER[a]
Opaque-2	None	2.30
	0.20 DL-methionine	2.65
	0.20 DL-methionine + 0.20 DL-threonine	2.95
	0.20 DL-methionine + 0.20 DL-threonine + 0.20 L-lysine HCl	2.66
Normal	None	2.23
	0.20 DL-methionine	2.81
	0.20 DL-methionine + 0.20 DL-threonine	2.85
	0.20 DL-methionine + 0.20 DL-threonine + 0.20 L-lysine HCl	3.06
Casein	---	2.65

[a]PER = protein efficiency ratio.

of soy flour and of maize, whether normal or opaque-2, have complementary amino acid patterns as shown in Figure 3. The results show that soy-normal maize, and soy-opaque-2 maize, have complementary patterns when they are mixed in a protein ratio of 60 soy to 40 maize. The difference between the two mixtures is in the wt gain they produced, but the maximum value for PER was the same. Examination of the amino acid patterns of both sets shows the largest difference to be in lysine, which is found in greater concentration in the soy-opaque-2 maize combination. Further comparison shows that the concentration of sulfur amino acids and of threonine is similar in both sets. It was, therefore, predicted that, in the soy flour-opaque-2 maize, the limiting amino acids are methionine and threonine, while in the soy flour-normal maize, the limiting amino acids are methionine, threonine, and lysine. These possibilities were tested, and results are shown in Table VII. The soybean-opaque-2 maize combination responded to the addition of methionine and threonine in the presence of the first. However, the soybean meal-normal maize responded to methionine, threonine, and lysine addition (9).

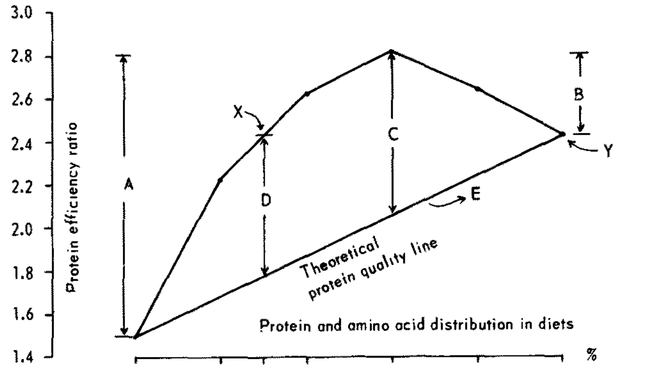
Wheat flour-soy flour and wheat flour-casein: The protein quality of isonitrogenous diets made from wheat flour and soy flour and from wheat flour and casein is shown in Figure 4. It is well accepted that the limiting amino acid in wheat flour is lysine, while both soy protein and casein are rich sources of this amino acid, as indicated in the bottom of the figure. On the other hand, soy protein and casein are known to be deficient in sulfur containing amino acids; however, wheat flour protein does not contain much higher amounts of them. Maximum quality of wheat flour and casein mixes occurred when wheat flour provided 55% of the dietary protein and both soybean and casein 45%. Higher PERs were obtained with wheat flour and casein than with wheat and soy flours. This is probably due to the higher content in casein of the key amino acids lysine and sulfur containing amino acids in mixtures of these ingredients (7).

Analyses of the response curves: Although the results presented have been interpreted in terms of the limiting amino acids in the proteins being studied and their mutual complementation, the results obtained in some cases are higher than expected, suggesting that other factors are influencing the results. One such factor is overall amino acid balance. It is, however, very difficult to estimate how much of the improvement is due to this factor, since the concomitant correction of the individual amino acid de-



	Lys	Met	Thr
	mg/g N		
Wheat flour	130	189	164
Soybean flour	395	195	246
Casein	504	218	269

FIG. 4. Protein quality of mixtures of wheat flour and casein and wheat flour and soybean. Lys = lysine, met = methionine, and thr = threonine.



P1	100	80	70	60	40	20	0
P2	0	20	30	40	60	80	100
Lys	307	381	417	453	527	599	673 mg 1.7 g N
Try	65	81	89	97	114	130	146 "
T.S.A.	336	335	335	335	333	333	332 "
Thr	424	423	422	422	421	420	419 "

FIG. 5. Protein quality of mixtures of normal maize and soybean protein. P-1 = protein 1, P-2 = protein 2, Lys = lysine, Try = tryptophan, TSA = total sulfur amino acids, and Thr = threonine. Lines A-E and points X and Y are explained in the text.

ficiencies also is changing the amino acid balance. Even though a higher protein quality is obtained, the mixture is still deficient in some amino acids as shown. Figure 5 indicates the changes which are taking place. Line A represents the increase in quality of protein P-1 by the contribution of amino acids, mainly the limiting amino acids in P-1 that protein P-2 makes. Similarly, line B represents the converse. Line E may be considered as the theoretical protein quality value of the various mixtures. Therefore, the actual increase in protein quality is represented by line C for the optimum mixture and line D by one of the various other mixtures, in this case the 70/30 mixture. Point X should have an amino acid pattern similar to point Y. However, it does not have, except in the limiting amino acids of protein P-2. From these considerations, it appears that the optimum mixture becomes limiting in those amino acids which do not change with

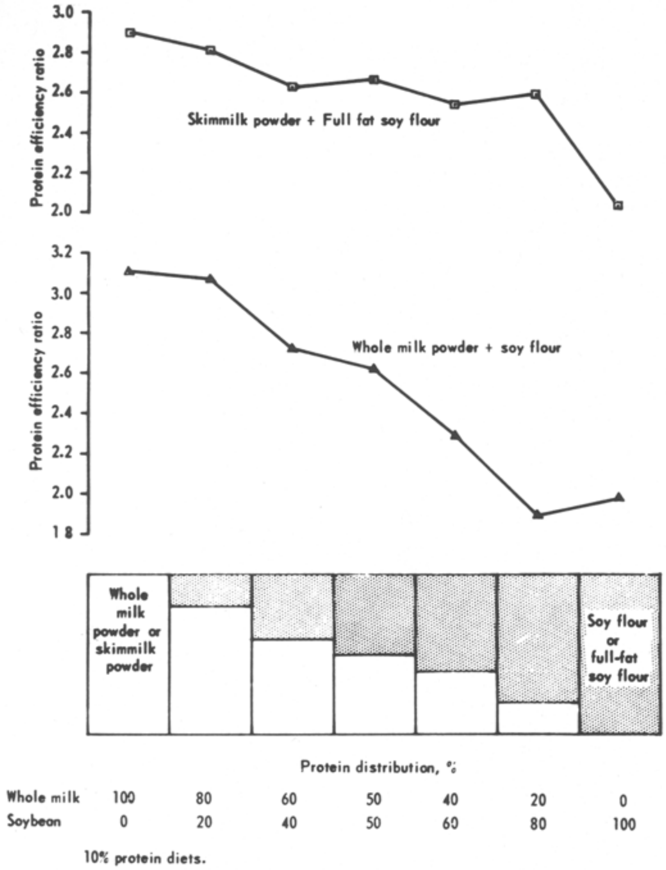


FIG. 6. Protein quality of milk and soybean protein mixtures.

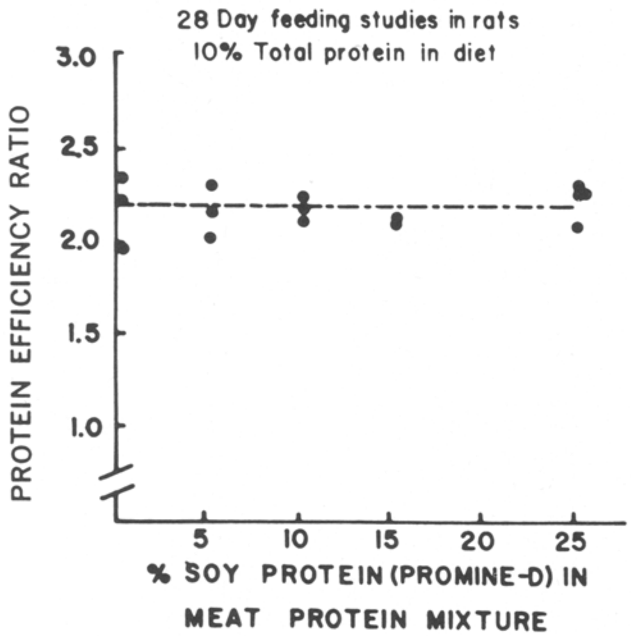


FIG. 7. Nutritional value of meat protein-soy protein mixtures (10).

different amounts of the component proteins. The second point which would be desirable is to be able to predict the protein quality of the optimum mixture which may be calculated from the individual essential amino acid patterns in comparison with a reference pattern. The theoretical protein quality then can be calculated from the individual protein quality values of the two components according to the degree in which they are combined. The question yet to be resolved is to what extent the theoretical protein quality value would be increased (7).

As Nitrogen Source

Soy protein can play an additional nutritional role called "a nitrogen source," carrying with it an amino acid balance which can replace other protein sources without altering the protein quality significantly. An example is shown in Figure 6. In this case, whole milk powder or skim milk powder protein was replaced on a protein basis by soy flour or full-fat soy flour. The results show that as more soy protein replaced milk protein, protein quality becomes significant, e.g. when 20% or more on a protein basis is replaced. This information may be useful to prepare milk formulation in which part of it is replaced by soy protein, therefore extending milk supplies. In this particular case, these results indicate that a food made of 12 g soy flour and 88 g whole milk powder or 18 g full-fat soybean and 82 g skim milk powder will have the same protein quality as whole milk or skim milk powder. A similar type of study was reported by Meyer (10) for mixtures of soy protein and meat. These results are shown in Figure 7. They indicate that protein quality remained essentially the same even when meat protein was replaced up to 25% by soy protein.

These results are of particular interest, since they would appear to contradict results previously established for human subjects. The explanation of the discrepancy is probably due to the original quality of the materials under study, suggesting the need to define as well as possible the materials used in such studies.

SOY PRODUCTS AS HUMAN FOODS IN DEVELOPED COUNTRIES

Textured soy foods offer many possibilities for human nutrition because of their adaptatibility to different forms of organoleptically good and economical products. Texture is obtained in two ways: (A) by way of a fiber spinning process, or (B) by thermo plastic extrusion. Both types of products are being used to replace part of the meat or to make simulated meat analogues (5).

The nutritional value of the thermo plastic extruded product has been tested with young and adult human subjects and results obtained by Kies and Fox (4) and Korslund, et al., (2) already have been presented. These products can replace meat protein up to a certain point without significantly decreasing the quality of the mixture.

Simulated beef products made from soy protein fiber also have been tested for their protein quality. These products contain, along with soy protein, other food components, such as vegetable fat, egg albumin, wheat gluten, soy meal, vegetable protein hydrolysate, and various additives. Therefore, the nutritional value is man-controlled. In a study reported by Bressani, et al., (6) a

TABLE VIII

Nitrogen Balance of Children Fed Milk and Soy Simulated Beef Granules (6)

Protein source	Nitrogen balance					Nitrogen	
	Intake	Fecal	Urine	Absorbed	Retained	Absorption	Retention
	mg/kg/day					Percent of intake	
Milk	342	52	210	290	80	84.8	23.4
Simulated beef granules	312	46	183	266	82	85.2	26.6

simulated beef granule was tested in experimental animals and children. Results with children are presented in Table VIII. Protein intake from both sources was set at 2 g/kg/day, and the values shown represent the average for 8 children. The nitrogen retention figures obtained suggest that, at this particular level of protein intake, both protein sources have similar quality. Additional tests indicated, however, that the biologic value of the simulated beef granule was 70.8% in comparison with a value of 80.6% for milk. The authors concluded that the protein quality of the granule was high, 80% that of milk, with adequate digestibility, acceptability, and freedom from adverse physiological effects.

The protein quality of soy meat was evaluated by Turk, et al., (11) in adults. The authors indicated that, with adults, positive nitrogen balances were observed with soy meat protein intakes of 0.375 g/kg/day and above. On the other hand, negative balances were observed with intakes of 0.258 g/protein/kg/day, and below. These results suggest, therefore, that the protein quality of the soy-meat products is as high as that of egg.

These results indicate that the protein quality of soy meat containing products is different, depending upon the manner in which soy protein is used. Those based upon textured soy protein with flavor added are lower in quality than those in which the textured protein is mixed with other protein sources. However, the first may be improved by methionine supplementation or consumed together with other foods which are rich sources of this amino acid.

USE OF SOY PROTEIN IN TRADITIONAL FOODS FOR LATIN AMERICA

Soy Flour

As background information on the possible uses of soy protein as applied to Latin America, representative results of dietary surveys for both urban and rural population groups will be presented. Although there are variations between countries and even between regions within countries and the values are the average intake, the patterns shown in Table IX are very indicative of the present situation. This is, by no means, improving. There are various facts which emerge from the results presented in the table. Urban diets are really not much different than those consumed by people in economically rich countries. Therefore, it may be concluded that, for these people, the role of soy protein is equal to the role it already is playing for people living in developed areas of the world.

However, the same cannot be concluded from an analysis of the results for rural populations or even for groups living in suburban areas. For these people, the role soy protein can play is as a supplement to cereal grains. Furthermore, it also may serve as an extender of animal products, however at lower economic costs.

In view of these considerations, examples of uses will be provided.

The role as supplementary protein is well documented, and some results (13-15) are presented in Table X. Analyses of these results show two points of interest. First is that the addition of relatively small amounts of soy flour increases the protein quality of the cereal grain and, secondly, that total protein also is increased in amounts of 4-5 g above what the cereal contains. Practical applications of these results already are being made but most of them in the developed countries.

Based upon the results shown, a protein supplement for maize flour for tortilla preparation was developed in our laboratories a few years ago (10). The formula is shown in Table XI. This supplement can be added to lime cooked industrial maize flours or at the time cooked maize is being ground at the village level at the rate of 8%. Its acceptance and long term effect is currently under study in Guatemala in a village with ca. 1700 families (17). The protein quality improvement as tested in children (18), caused by the addition of the supplement can be seen in Table XII. Intake protein was fixed at 1.25 g/kg/day with an adequate intake of calories, 100/kg/day. As seen in the nitrogen retained column, the 8% addition of the supplement increased retention to values close to those obtained with milk. Other applications have been shown in recent years. One of much importance is the use of soy flour, fat-free or full-fat, to make bread. The results of Tsen and Hoover (19,20) are shown in Table XIII. Bread made with 12% soy flour is, not only acceptable by the consumer, but it contains more protein of a better quality than common wheat flour bread. Similarly, pasta-type products have become very popular, and various preparations recently have been available. The protein quality of one type of pasta made from semolina, corn, and soy flour is shown in Table XIV. The product has a protein quality value of 1.31, almost twice as high as the commercial control or the semolina-corn pasta. The protein quality value is correlated highly with available lysine in the various products. An additional advantage of the food made with soy is the

TABLE IX

Average Daily Food Intake in Rural and Urban Guatemala[a] (12)

Food	Rural	Urban
Dairy products	125	*304*
Eggs	17	28
Meats	40	65
Black beans	50	45
Fresh vegetables	63	120
Fruits	19	63
Bananas and plantain	26	37
Tubers	14	22
Rice	16	27
Corn tortilla	*496*	157
Wheat bread	40	134
Other cereals	11	15
Sugar	53	71
Fats	8	20
Other (coffee, etc.)	10	23
Total cereals	547	306

[a]g/person.

TABLE X

Effect of Soybean Flour (SBF) as Protein Supplement to Cereal Grains

Cereal grain	Level of soybean (%)	Protein efficiency ratio	Additional soy protein (g)
Maize	---	1.00	4
Maize + SBF	8.0	2.25	
Rice	---	1.87	4
Rice + SBF	8.0	2.88	
Wheat flour	---	0.70	5
Wheat flour + SBF	10.0	2.01	
Whole wheat	---	1.32	5
Whole wheat + SBF	8.0	1.91	

TABLE XI

Soybean Flour Supplement for Lime Treated Maize (16)

Ingredient	Composition of supplement (%)
Soy flour	97.5000
L-lysine HCl	1.5000
Thiamine	0.0268
Riboflavin	0.0162
Niacinamide	0.1930
Ferric orthophosphate	0.6000
Vitamin A 250 SD	0.0313
Corn starch	0.1327
	100.0000
Rate of addition	8%

are limiting in the quality of the protein fed. These results suggest that, under ordinary conditions, the protein ingested is used as an energy source; however, when it is provided as a supplement to the diet, the protein ingested is used for purposes of body protein synthesis. That protein quality is also important is shown by the response to the amino acid supplements added. Finally, total protein intake also is limiting, since nitrogen balance results are higher when the animals consumed 4 g protein than when the intake was 3.0 g. The practical solution to this problem is not easy. First of all, additional intake of calories and protein cannot come from the same basic foodstuffs, maize and beans, because the amounts would be too large and bulky and, secondly, because of the cost. This approach, furthermore, will not correct the protein quality aspect. Correction of the caloric deficit by consumption of oil, although sound, is not possible because of cost. Therefore, other solutions should be found.

TABLE XII

Average Nitrogen Balance in Preschool Age Children Receiving Maize and Maize Plus Soybean Supplement

Protein source	Chronological age (months)	Protein intake g/kg/day	Nitrogen balance Intake	Absorbed	Retained	No. of children
			mg/kg/day			
Maize	30	1.25	192	144	30	6
Maize + soy supplement	30	1.25	197	154	63	6
Milk	24	1.25	195	157	75	7

TABLE XIII

Protein Quality of Bread with and without Soybean Flour (20)

Bread	Moisture (%)	Protein (%)	Gain[a] (g)	Gain g/protein consumed
White	9.5	14.0	32	0.92
12% Soy	9.2	18.3	120	1.55

[a]Diet, 91.5% ground bread + 2.0% vitamin premix + 2.0% mineral premix + 3.0% fat.

TABLE XIV

Protein Quality of Various Types of Pasta Products

Type of pasta	Lysine g/16 g N	Protein efficiency ratio
Commercial pasta	2.14	0.73 ± 0.14
Semolina:corn (40:60)	2.36	0.74 ± 0.14
Semolina:corn:soy (32:60:8)	3.21	1.31 ± 0.24
Semolina:corn (60:40) + 0.3% lysine	4.08	1.91 ± 0.41
Casein	---	2.79 ± 0.27

protein content, ca. 15% compared to the semolina-corn of 12%.

Full-Fat Flour

Results of various studies have indicated that the diets consumed by children and even by adults in developing countries are not only deficient in quantity and quality of protein but in calories as well. When these diets are supplemented with calories, their protein quality is increased, as shown in the nitrogen balance results in Figure 8.

In this study, using small dogs as experimental animals (22), the maize-bean diet in a ratio of 6.24 to 1 was supplemented with additional calories added as soybean oil, or supplemented with lysine and tryptophan or both. The treatments were studied at 3 and 4 g protein intake/kg body wt/day. The bars indicate the extent of the improvement, and it can be seen that caloric addition induced as good an improvement as the addition of amino acids which are limiting in the quality of the protein fed.

A possibility under study in our laboratories is through the use of the whole soybean which has been studied in the production of at least two types of foods, the tortilla made from maize and a high protein food also based upon maize (23).

The production scheme of tortillas from maize and whole soybeans is shown in Figure 9. A mixture of 85% maize and 15% soybeans was used because of previous results using 8% soy flour. Both levels provide similar amounts of protein. The product is quite similar to the common tortilla; however, it is of superior protein content and quality. These materials have been assayed for their protein quality, and representative results are shown in Table XV.

The results clearly show improved quality when the tortilla was made with 15% whole soybeans. What is of interest is that the tortilla contains additional oil which provides more calories, and these are effective in making better use of the protein, as indicated in the last group shown in the table.

The second type of product so far tested is one containing higher levels of protein and fat derived from soybeans. To learn which combination was nutritionally superior, various maize and whole soybean mixtures were processed as shown in Figure 10. This processing scheme is equal to the one used for tortillas. Previous studies suggested that the optimum level of lime to be used is the one shown in the figure. It also was found that, as the level of soybeans in the mixture exceeded 40%, recovery of solids decreased. This was interpreted as loss of protein and other compounds due to the alkaline cooking conditions used.

The products obtained were dried, ground, analyzed, and assayed for protein quality. The results are summarized in Table XVI. The protein quality column indicates that the combination giving maximum protein quality is the one based upon 72% maize and 28% whole soybeans (23). This product contains close to 18% protein and 10.0% fat and, therefore, is a high protein calorie food which could be a good supplement to the diets already consumed by many people in Latin America and other parts of the world.

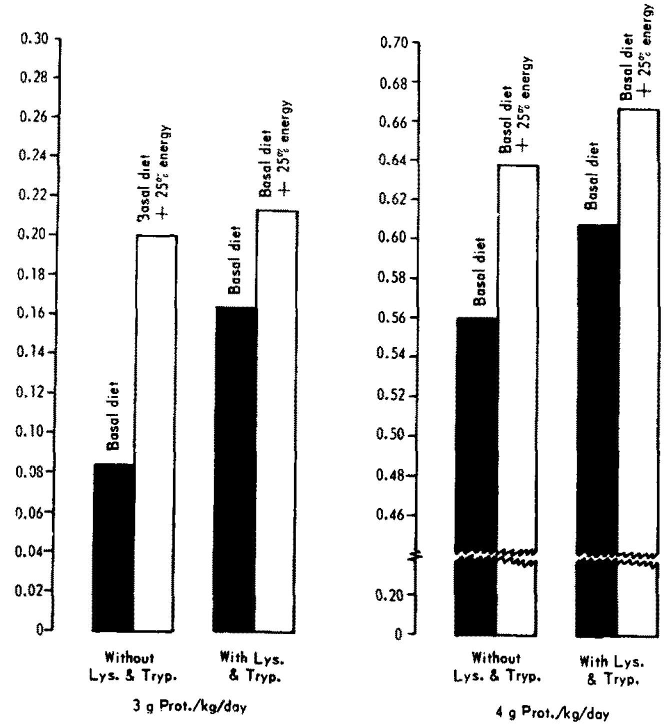


FIG. 8. Effect of adding lysine (Lys) and trypotphan (Tryp) to a maize-black bean diet with and without additional energy. Prot. = protein.

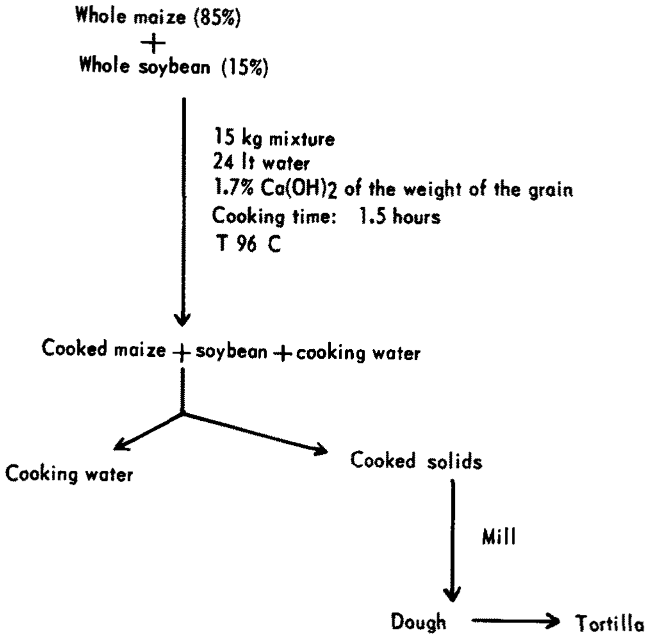


FIG. 9. Tortilla preparation from maize and whole soybeans. Soybean: harvested at Institute of Nutrition of Central America and Panama (INCAP) Experimental Farm (14.0% fat, 30% protein). Yellow maize: Azotea variety, harvested at INCAP Experimental Farm (8% protein).

Figure 11 summarizes into one scheme the two processes described to produce various types of foods based upon corn and soybeans.

The process adapts the processing technology commonly used for corn by native populations in Mexico and Central America for hundreds of years. The only missing component is the soybeans. The process as shown may be used to produce tortillas (as well as higher protein-calorie containing foods which can be used for soups, hot drinks, and other preparations) enriched with soybeans for immediate use or dehydrated. There are other applications. For

TABLE XV

Protein Quality of Tortilla Flour Alone and Supplemented with Soybeans

	Content in products			
Products	Protein (%)	Fat (%)	Average wt. gain (g)	PER[a]
Tortilla[b]	10.0	3.0	18	0.95
85% Tortilla + 15% soybean[c]	13.9	5.5	84	1.98
92% Tortilla + 8% soybean[c]	13.2	2.8	68	1.98
85% Tortilla + 15% soybean[c,d]	13.9	5.5	78	1.98
Casein[c]	---	---	124	2.60

[a]PER = protein efficiency ratio.
[b]Diet contained 9.0% protein.
[c]Diet contained 12.3% protein.
[d]Was not supplemented with 5% oil.

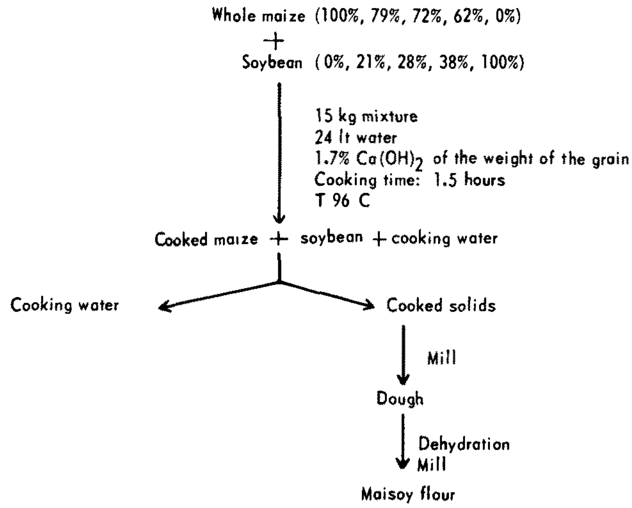


FIG. 10. Processing of mixtures of maize and soybean. Soybean: harvested at Institute of Nutrition of Central America and Panama (INCAP) Experimental Farm (14.0% fat, 30% protein). Yellow maize: Azotea variety, harvested at INCAP Experimental Farm (8% protein).

TABLE XVI

Protein and Fat Content and Protein Value of Maize-Whole Soybean Mixtures (22)

Mixture		Content of		
Maize (%)	Soybean (%)	Protein (%)	Fat (%)	Protein efficiency ratio
100	0	9.9	4.5	0.69
79	21	16.9	8.9	2.08
72	28	17.6	10.3	2.54
62	38	18.1	11.3	2.37
0	100	40.0	25.6	2.87
Casein		---	---	2.87

example, black beans are consumed cooked or fried. They contain ca. 22% protein and represent the main supplementary protein to those diets. Studies were carried out to find out if black bean-soybean mixtures would be higher in protein quality than black beans alone. The results are shown graphically in Figure 12. They indicate that there is an improvement up to a mixture with a protein distribution of 60% from black beans and 40% from full-fat soybeans. On a wt basis, this mixture contains 72% black beans and 28% soybeans; it contains ca. 28% protein and is of better quality than black beans. The results of other studies have shown that a food preparation of this nature significantly improves the quality of a cereal diet and common beans.

The value of soybeans as a human food has been demonstrated for many years in the oriental countries, and

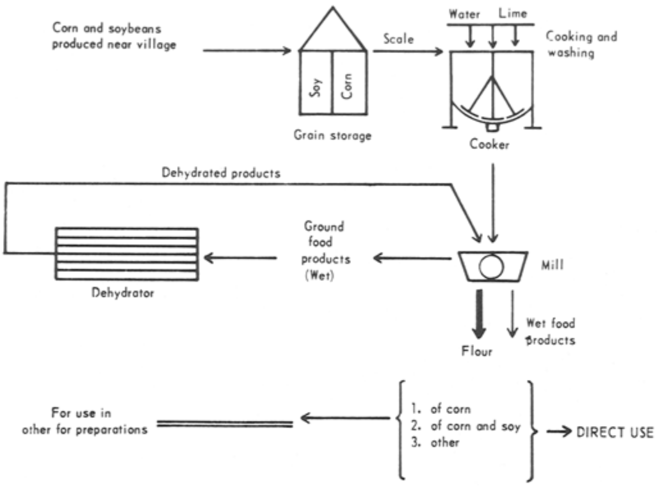


FIG. 11. Summary of the two processes described to produce various foods based upon corn and soybeans.

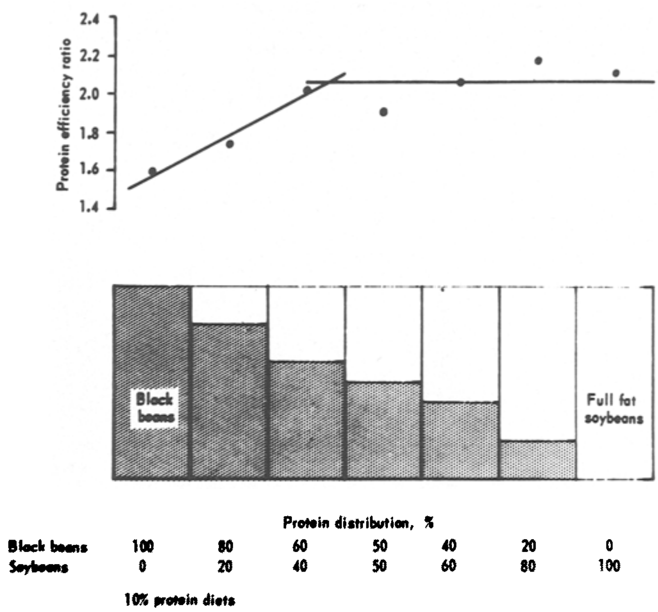


FIG. 12. Protein quality of black bean and soybean mixtures.

food science and technology are increasing its potential as a calorie and protein source for present and future populations of the world. This potential could be increased if consideration is given to the following points: (A) the introduction into agricultural production of genetically selected soybean varieties containing higher sulfur amino acid content/g protein, since this deficiency may be the factor responsible, to a relatively large extent, for limitations in the use of soybean to extend animal protein without changing protein quality; (B) a better control of processing conditions in transforming soybeans into the various soy protein edible products; and (C) the use of soybean products in appropriate amounts in combination with other protein sources, either of vegetable or animal origin, to maximize the efficiency of protein utilization.

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[Received January 8, 1975]