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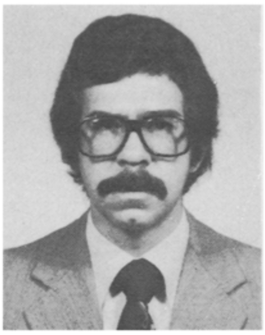

Direct Consumption of the Soybean

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ABSTRACT

Efforts in some Latin American countries directed toward the use of soybeans as a primary source of proteins for human nutrition have especially focused attention on simple home-level procedures such as the soaking and cooking of soybeans and the lime-cooking of corn-soybean mixtures. Data obtained with these two procedures indicate there is great potential in using soybeans directly in human feeding. Soaking soybeans in 0.25% $NaHCO_3$ for 8 hr and cooking for 20 min decreases trypsin inhibitor activity more than 80%, and 40 min of cooking gives chewiness indexes similar to those of common beans with acceptable texture (10-20). The protein efficiency ratio (PER) of a mixture that was 50% soybeans and 50% common beans was 60% higher than that of common beans alone. Considering acceptability and functional characteristics of "masa" (dough) and "tortilla," an optimum soybean level within the lime-cooking procedure was found to be 16%. Green pods of soybean varieties adapted to the tropics, at 65 to 85 days of maturation, have the same nutrient content (dry basis) as mature soybeans, with a good quality protein and a good content of B complex vitamins.

INTRODUCTION

Despite apparently sufficient food resources, the fact is that two-thirds of the world's inhabitants do not receive adequate nourishment. Protein-energy malnutrition is common in children, resulting in high morbidity and mortality. Proteins of animal origin are recommended because of their high quality for human nutrition, especially for children. However, these proteins are scarce, are difficult to preserve and are high priced; therefore, they are becoming useless to feed low income populations.

Legume seeds represent the most abundant source of protein. Their protein quality, especially when combined with cereals, is almost always high enough for adults and for children. Soybean is the most abundant legume, with an estimated world production for 1980 of 97.6 million tons; it is also the cheapest protein source at the consumer level, and has the highest protein quality among legumes.

Soybeans can be considered as sources of intermediate-quality protein, which is better than that of cereals and very much like that of meat, although of lower quality than that of milk and egg proteins, for soybean protein is only deficient in its methionine content (1).

In fact, soybeans have great potential as foods not only because of their high protein content (38% in the raw seed), but also because they are a good source of energy (18% fat), vitamins and minerals. Most of all, soybeans have a low price that is one-half to one-third that of common beans, which are staple foods in most Latin American countries.

For milennia, East Asian populations have used soybeans directly in their diet, while in western populations, soybeans are used primarily as a raw material for oil extraction and for feeding animals. Only a small amount of soybeans are used for direct human consumption, through a variety of industrialized soya-containing products that reach prices 3 to 10 times that of the soybean. Therefore, they are too expensive for target populations.

Direct consumption of soybeans seems to be the only way for many people in Latin America to benefit from this legume seed, especially since we know that the antiphysiological active substances in soybeans, such as trypsin inhibitors and lectins, are easily eliminated through simple cooking procedures because they are thermolabile.

This paper summarizes some of the efforts made in Latin America to use soybeans as a primary source of proteins for human nutrition. We will place special emphasis in two of these efforts, because they can be implemented as simple home-level procedures.

SOAKING AND COOKING

The usual procedure in most Latin American countries to prepare common beans is soaking and cooking in boiling water; when this procedure is applied to soybeans, cooking time increases several-fold. Berra et al. (2), showed that soaking in alkaline solutions reduces the cooking time for several legume seeds. Morales et al. (3) studied the effect of soaking beans in sodium bicarbonate ($NaHCO_3$) solutions (0-0.5%) for different amounts of time on the length of cooking time needed to inactivate trypsin inhibitor activity (TIA), and to obtain a texture similar to cooked common beans.

TABLE I

Trypsin Inhibitor (TI) Activity of Soybeans at Different Soaking and Cooking Times with Different $NaHCO_3$ Percentages in Solution (mg TI/g of sample)

Soaking		Cooking time (min)				
% $NaHCO_3$ in sol.	Time (hr)	0	10	20	30	40
0	6	59.74	7.89	5.26	4.21	3.94
	8	56.33	13.68	6.79	4.50	4.42
	10	55.55	23.84	12.26	8.31	6.31
0.25	6	52.62	15.00	8.45	6.04	4.76
	8	49.74	13.52	9.21	7.26	5.89
	10	49.88	15.00	7.89	5.26	4.47
0.5	6	47.70	5.03	4.72	4.55	4.43
	8	48.16	4.33	4.30	4.29	4.28
	10	37.64	10.21	7.02	5.63	4.82

Table I shows the TIA of soybeans treated under the conditions stated above. A slight decrease in TIA was observed by soaking only in plain water (control group). When the soybeans were soaked from 6 to 10 hr in 0.25 or 0.5% $NaHCO_3$ solutions, boiling for 20 min produced more than 80% inactivation of TIA, which is the level recommended by Rackis for human consumption (4).

The hardness of treated soybeans was tested through the "chewiness index" using an Ingstrom meter; indexes between 10 and 20 are considered optimal for common beans. Soybeans cooked for 20 min after soaking in $NaHCO_3$ solutions were unacceptably hard, but reached chewiness indexes of about 20 when the cooking time was prolonged to 40 min. Since the use of a 0.5% $NaHCO_3$ solution for soaking produced an unpleasant salty taste, the 0.25% solution was chosen as the most appropriate.

The protein efficiency ratio (PER) and the net protein utilization (NPU) were measured in soybeans soaked for 8 hr in a 0.25% $NaHCO_3$ solution and boiled for 20 and 40 min. The results are given in Table II. Raw soybeans, as expected, had values approximately 30% those of casein. Soaking and cooking raised the values to being indistinguishable from those of casein.

These high-protein values are not surprising since recent experiments have shown that soy protein isolates have the same quality as most animal proteins for human beings; this has been explained by the fact that sulfur amino acid requirements in humans are probably lower than those for rats (5). The procedure established above could encourage direct consumption of soybeans by poorer Mexican populations, since it provides products of high nutritive value and very low price without disrupting the peoples' cooking and consumption habits.

In Brazil, Sgarbieri et al. (6) have studied the nutritional and sensorial characteristics of different mixtures of soybeans and common beans. Results showed that mixtures of 20% soybeans and 80% common beans did not differ in acceptability from 100% common beans, whereas the preference test (hedonic scale) indicated practically the same mean value for mixtures with 20, 30, 40 and 50% soybeans. PER values of different mixtures of soybeans and common beans are shown in Table III. Mixtures were soaked for 6 hr and cooked in autoclave (1.5 kg/cm^2, 125 C) for 15 min. Data examination shows clearly that PER increases with the increase of soybeans up to 80% in the mixture. Thus the PER of the mixture 50-50 was 60% higher than PER of 100% common beans. It was also found that PER of the mixture with 80% soybeans reached a maximum value of 2.0, which is similar to that of

TABLE II

PER, NPU and Trypsin Inhibitor Activity of Soybeans at Different Conditions of Soaking and Cooking

Source of protein	No. of rats	PER ± S.D.	PER as % of casein PER	NPU ± S.D.	NPU as % of casein NPU	mg TI/g sample
Casein	10	2.5 ± 0.61	100	60 ± 11.9	100	–
Soybeans						
Crude and unsoaked[a]	10	0.66 ± 0.16	26.4	22 ± 6.0	36.7	59.7
Crude soaked[a]	10	1.17 ± 0.30	46.8	29.3 ± 4.1	47.1	49.7
Soaked,[a] cooked 20 min	10	2.77 ± 0.12	110.8	64.5 ± 11.0	107.6	9.2
Soaked,[a] cooked 40 min	10	2.82 ± 0.20	112.8	58.0 ± 8.5	96.8	5.9

[a]Soaking conditions: 8 hr in a 0.25% $NaHCO_3$ solution.

TABLE III

PER Value of Mixtures[a] of Soybeans and Common Beans (6)

Protein source		PER	
Common beans (%)	Soybeans (%)	(Casein 2.5)	PER as % of casein PER
100	0	1.0	40
65	35	1.3	52
50	50	1.6	64
20	80	2.0	80
0	100	2.0	80

[a]Soaked in water for 6 hr and autoclaved 15 min at 121 C.

100% soybeans.

As we have already said, the progressive introduction of soybeans into the diet of lower income groups in Latin America would be of great nutritional and economical importance.

ENRICHMENT OF TORTILLAS BY LIME-COOKING OF WHOLE RAW CORN-SOYBEAN MIXTURES

The basic cereal of many Latin American countries is corn, which is consumed in a large variety of forms. However, in most Central American countries and in Mexico, the main form of consumption is the well-known tortilla, made either at home or industrially by cooking maize with lime.

Considering that corn proteins are known to be deficient in lysine and tryptophan, many efforts have been made to improve their quality, especially by supplementing them with complementary proteins. Soybean protein has received much attention, especially through addition of soybeans into the normal lime-cooking of corn, without introducing an additional step to the "masa" production (7).

Some studies have suggested that optimum protein quality is obtained when whole corn flour, either raw or cooked, is supplemented with 4-5 g of soybean protein. The improved protein quality has been confirmed by nitrogen balance studies in which nitrogen retention values were similar to those from milk, but significantly above those obtained with common corn flour (8).

Soybeans increase not only the quality but also the quantity of corn protein in the tortillas. An optimum PER value is obtained when soybeans are added to corn directly into the lime cooking procedure to make up 30% of the mixture. This gives the maximum PER value with both corn and soy proteins, with a resulting increase of almost 100% protein in the final product and an improvement of more than three times the protein quality of whole raw corn (9).

However, considering the acceptability and functional characteristics of the dough (masa) and the final products (tortillas), an optimum soybean level in the mixture was found to be 16%. Table IV shows the protein quality of the enriched tortillas at two levels in comparison with casein. Data indicated that there was no significant difference between PER of the two mixtures, both being very close to that of casein. NPU values were found to be lower than PER values although there was a significant improvement when compared to values found with the unenriched tortillas (0% soybeans) (10,11).

Trypsin inhibitor and urease activity tests were carried out in final products and results indicated a low activity of both factors (below 5%) which meant there was almost total inactivation of the trypsin inhibitor during the lime-cooking and oven-cooking of the tortillas made from the final dough.

From these results, it may be concluded that enrichment of corn with no less than 8% whole soybeans increases protein content and protein quality, as well as energy content of tortillas. Furthermore, both processes inactivate the antiphysiological factors present in whole soybeans added to corn. This, as well as the increases in nutrient content and quality, are of great nutritive significance to corn-consuming populations in Latin America.

COMPOSITION AND NUTRITIVE VALUE OF GREEN SOYBEANS ADAPTED TO THE TROPICS

In keeping with efforts aimed toward the direct consumption of soybeans at a community level, the government of the state of Guerrero, Mexico, has implemented a program of "utilization and consumption of soybeans in rural communities." The program is based on development of new soybean genotypes by Banafunzi and coworkers at the Instituto Superior Autonomo Agropecuario del Estado de Guerrero (ISAAEG), and is oriented mainly to the consumption of the green pods. These new genotypes, when adapted to the tropics, have reduced growing times of 95 days after planting, therefore allowing more crops per year. The genotypes studied were: G_1–*BB* variety, developed at ISAAEG; G_2–*Mokopu-BM* variety, developed and adapted in Hawaii; and G_3–BM_2 variety, developed and adapted at ISAAEG.

A study was done by our group at the National Institute of Nutrition, Mexico, to provide information about the nutritive value of the soybeans at different stages of maturity, from 65 to 85 days. At 65 days, the green pods were immature and soft, whereas at 85 days the pods were almost completely mature, and a big percentage of the soybeans were yellow in color and hard.

Pods cut at 65,70,75,80 and 85 days after being planted were analyzed for proximal analysis (12), thiamine (13), riboflavin (14), ascorbic acid (15), trypsin inhibitor activity (16) and PER and NPU (17,18). Moisture was found, in general, to decrease from 73% at 65 days to 50% at 85 days, therefore increasing the nutrient content of the pods with the longer maturity period.

Table V shows the proximal analysis of the green pods at different periods of maturity, expressed on dry basis. Considering the general nutrient content, but especially the protein of the green soybeans in all cases, there is clearly no significant difference among the periods as well as among

TABLE IV

Protein Quality of Tortillas Enriched with Soybeans by Lime-Cooking of Whole Raw Corn-Soybean Mixtures (10)

Enrichment level (% of soybeans)	Protein content of mixture (g/100 g)	PER ± S.D.	PER as % of casein PER	NPU ± S.D.	NPU as % of casein NPU
Casein	–	2.5 ± 0.12	100	61.0 ± 0.80	100
0	9.5	1.2 ± 0.04	49	28.0 ± 0.50	46
8	12.4	2.1 ± 0.26	84	38.1 ± 0.60	65
16	14.7	2.2 ± 0.18	86	41.8 ± 0.20	70

TABLE V

Proximal Analysis of the Green Pods at Different Periods of Maturity (g/100 g sample dry basis)

Genotype	Maturity (days)	Crude protein	Ether extract	Ash content	Crude fiber	Carbohydrates[a]
	65	39.58	19.92	4.75	6.75	29.00
	70	40.27	21.97	4.80	6.96	26.00
G_1	75	40.63	22.27	5.18	7.01	24.91
	80	41.33	23.53	5.61	7.15	22.38
	85	41.87	23.69	5.63	7.30	21.51
	65	39.11	21.87	5.21	6.98	26.83
	70	39.86	22.00	5.31	7.10	25.73
G_2	75	40.13	22.08	5.32	7.23	25.24
	80	41.19	23.11	5.51	7.30	22.89
	85	41.67	23.23	5.63	7.42	22.05
	65	38.98	21.07	5.36	6.91	27.68
	70	39.53	21.12	5.37	6.94	27.04
G_3	75	39.94	22.23	5.39	7.12	25.32
	80	41.63	22.46	5.42	7.23	23.26
	85	41.92	22.49	5.59	7.80	22.20

[a]Carbohydrates by difference to 100 g of sample.

the genotypes. The analysis resembles that of mature beans of the known soy varieties. Therefore, it can be concluded that the green pods are similar to mature beans as a source of nutrients, considering that they only have to be dried.

Table VI shows that immature soybeans are a good source of thiamine and riboflavin, but a poor source of ascorbic acid. There was no difference between the vitamin content among the genotypes and the maturity of the green pods.

Trypsin inhibitor activity (TIA) was measured by the method of Kakade et al. (16). As shown in Table VII, in all cases, the TIA markedly increased the longer the maturity period, although it was not as high at 85 days as is normally found in mature beans. At 85 days, the amount of TIA was only 60% that of mature beans.

In all cases, TIA reached levels that could interfere with protein utilization, especially after 70 days of maturity, therefore indicating that green pods would need thermal processing before consumption. Samples of 65, 75 and 85 days of age were cooked in boiling water for 20 min to inactivate TIA, then were subjected to PER and NPU tests.

Considering NPU values to be more reliable than PER values, it is apparent from Table VIII that 85-day pods have a protein quality very close to that of casein; the G_3 variety, which is especially adapted to tropical conditions in the state of Guerrero, and the G_2 variety, ancestor of G_3 (developed originally in Hawaii), present high protein quality even in the samples cut at the 65th day. Consumption of properly boiled pods 65 to 58 days old could supply high-quality protein, fat, thiamine and riboflavin in amounts that could improve human nutrition at low cost.

Overall, direct consumption of soybeans is possible, utilizing relatively simple procedures that are compatible with current habits of poor populations in Latin America. The products obtained have a high nutritive value and are of adequate acceptability. Techniques like these could make real the long-awaited dream of bringing nutritional improvement to inadequately fed populations with soybeans.

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TABLE VI

Riboflavin, Thiamine and Ascorbic Acid Content of the Green Pods at Different Maturation Periods (mg/100 g of sample)

Genotype	Maturity (days)	Riboflavin	Thiamine	Ascorbic acid
	65	2.57	1.32	0.237
	70	2.71	1.19	0.237
G_1	75	2.95	0.92	0.227
	80	2.61	1.33	0.237
	85	2.85	2.09	0.207
	65	2.95	1.47	0.242
	70	2.71	1.14	0.247
G_2	75	2.71	1.13	0.217
	80	2.66	1.25	0.247
	85	3.04	1.77	0.247
	65	2.80	1.36	0.237
	70	2.85	1.38	0.227
G_3	75	2.85	1.12	0.247
	80	2.57	1.21	0.237
	85	3.09	1.79	0.237

TABLE VII

Trypsin Inhibitor Activity within the Different Maturation Periods of the Green Pods (mg TI/g of sample)

Genotype	Maturity (days)	Trypsin inhibitor
	65	9.29
	70	16.74
G_1	75	17.77
	80	22.59
	85	31.65
	65	10.25
	70	16.97
G_2	75	17.61
	80	19.92
	85	30.22
	65	14.62
	70	17.22
G_3	75	22.50
	80	22.43
	85	31.22

TABLE VIII

PER and NPU Values of the Green Pods at Different Periods of Maturity

Genotype	Days	PER ± S.D.	%	NPU ± S.D.	%
	65	1.82 ± 0.25	72.8	50.0 ± 7.98	80.6
G_1	75	2.00 ± 0.27	80.0	59.0 ± 8.40	95.1
	85	2.35 ± 0.45	94.0	59.3 ± 4.88	95.6
	65	1.78 ± 0.19	71.2	59.2 ± 5.75	95.4
G_2	75	1.73 ± 0.11	69.2	56.7 ± 5.66	91.4
	85	2.01 ± 0.17	80.4	61.3 ± 6.87	98.9
	65	1.73 ± 0.20	69.2	58.8 ± 6.15	94.8
G_3	75	1.73 ± 0.11	69.2	59.3 ± 6.82	95.6
	85	2.44 ± 0.31	97.6	58.9 ± 7.98	95.1
Casein		2.5 ± 0.43	100	62.0 ± 8.93	100

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Soybean Products for Feeding Infants, Children and Adults under Nutritional Stress

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ABSTRACT

This review points out the good quality of well-processed soya products. Normal infants, children and adults are able to utilize the protein and other nutrients present in the soya, when fed these products in amounts that will cover their needs. Under nutritional stress, such as in infant malnutrition, soya products such as soyamilk have been shown to help in the children's recovery. Clinical and biochemical data show that their recovery is similar to that obtained with cow's milk. Milk- or lactose-intolerant children and adults, who present a public health problem in some developing countries, could benefit from the high nutritive value and low cost of soy milk. Soya products have been shown to decrease cholesterol and other levels of blood lipids. Considering the availability of the several soya products in the market, this possibility has to be further explored. The utilization of soya products in preparing liquid formulas for oral or tube-feeding opens new fields for the treatment of several diseases, insuring at the same time adequate nutrition for the patients. From a practical point of view, in spite of all that is known about soybeans and soybean products, its use as human food, even in countries where it is produced in large quantities, is very low. It seems that local governments are not aware of the importance of soya for the solution to their serious food and nutrition problems. What is known on the subject has to leave the laboratories, research centers and universities and be transferred as food for the mouths of the needy populations. This has to be understood as an urgent duty of national governments. There is no doubt that soya is the cheapest and one of the best-quality foods available to help solve the present hunger problem of the world today.