IMPROVING THE NUTRIENT QUALITY OF CEREALS

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NUTRITIVE QUALITY IMPROVEMENT OF DIETS BASED ON CORN

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The importance of cereal grains in the nutrition of millions of people around the world is well recognized. Because of their relatively high intake in developing countries, cereal grains cannot be recognized only as energy sources, since they provide significant amounts of protein as well. It is also well known that cereal grains are low in protein concentration and that the quality of their protein is limited by deficiencies of essential amino acids, mainly lysine. The above statements represent the reasons for the intensive research efforts being carried out to improve the protein quality of the cereal grains by genetic means or agronomic interventions. Extraordinary results have already been obtained, although other desirable attributes of the cereal crop, such as yield and physical characteristics, in some cases should also be improved. In the meantime, the need for increased cereal grain availability is overwhelming. Although increased productivity is being obtained, the quality of the protein remains the same. Because of well defined sociological trends in developing countries, more people will depend in future years on industrialized food products and it would appear, therefore, that a logical and efficient way to improve protein quality would be by supplementation procedures. This approach seems to represent the best method to increase agricultural production and to achieve improved nutrition as well.

The present report deals with the improvement of the protein quality of diets based on corn. The information in this paper has been divided into five sections, dealing first with the nutritional quality of typical diets consumed in some Latin American countries; followed by some basic information on the improvement of the protein quality of corn. The third section deals with the physical and nutritional characteristics of fortified tortillas, including nutritional stability under processing; the fourth section includes systems for the addition of the supplement. The last section summarizes the nutritional evaluation of diets containing the supplemented tortilla and Opaque-2 corn ending with prospects for future work and implementation of the research findings.

I. The Nutritional Quality of Typical Diets Consumed in Some Latin American Countries

The initial place to start the description of the work concerning the improvement of the nutritional quality of corn in the form of the traditional tortilla, consumed in various countries in Latin America, is a consideration of the type of diet ingested by rural people in these countries. Since the preschool children population is more affected by the lack of a balanced and ample nutrient intake, the diet to be discussed is that ordinarily consumed by this population group.

By means of dietary surveys, the data shown in Table 1 were obtained.

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TABLE 1

FOOD INTAKE OF PRESCHOOL CHILDREN IN RURAL GUATEMALA 1/

Food	Intake as consumed	
	g/day	%
Tortillas	103.5	31.9
Bread	19.5	6.0
Rice	16.1	4.9
Beans	47.9	14.7
Sugar	28.9	8.9
Meat broth	26.4	8.2
Beef	4.8	1.5
Egg	7.8	2.4
Vegetables	21.2	6.5
Fruits	29.4	9.1
Potato	4.3	1.3
Bean broth	12.5	3.8
Coffee	2.6	0.8
Total	324.9	100.0

1/ Arch. Latinoamer. Nutr. 24:221, 1974.

2/ Lime-treated corn.

The data indicate the consumption of thirteen food items with cereal grains making up 42% of the total weight, starchy type foods 19%, beans about 15%, vegetables around 6.5%, and animal food products about 4%. Since the data represent average values from a relatively large group of children, it is obvious that some probably do not get any animal protein source at all, and those who might consume some probably do so at the most two or three times per week. Therefore, the picture for most of the children is quite poor. Of the total intake of 325 g, 32% comes from corn, this food being ingested in the largest amount, followed by beans on an item basis (10).

Food composites of this diet were analyzed with the results shown in Table 2.

TABLE 2

CHEMICAL COMPOSITION AND PROTEIN QUALITY OF RURAL PRESCHOOL CHILDREN DIET 1/

	As consumed g/day	%
Moisture	210.2	64.7
Dry matter	114.7	35.3
Protein	14.0	4.3
Fat	2.9	0.9
Crude fiber	2.9	0.8
Ash	2.6	0.8
Energy (kcal)	455	140 2/
PER	1.58	

1/ Arch. Latinoamer. Nutr. 24:221, 1974.
2/ kcal/100 g.

The total intake of 325 g is made up of 210 g of water equivalent to 64.7% and 115 g of dry matter, equivalent to 35% of the total intake. The dry matter provides 14 g of protein, 2.9 g of fat, 2.6 g of minerals and 455 kcal of energy. The protein content of the diet was 4.3% with 0.9% fat and 140 kcal/100 g. On the basis of the protein and calorie content of corn and beans as consumed, calculations indicate that lime-treated corn provides 31% of the total protein and 45% of the energy, while beans supply 24% of the protein and 12% of the energy. Therefore, corn constitutes the main food item in terms of protein and calorie contribution to the whole diet.

For children, less than five years of age, the protein ingested from the diet represents about 82% of the gross protein and 76% of the energy needs, therefore, both nutrients are present in deficient amounts. The protein quality of the diet as determined by the PER method is 1.58, which is equivalent to a biological value of 48%. Therefore, the amount of effective protein is significantly less than the 82% adequacy on a gross protein intake basis. This information permits the conclusion, therefore, that corn is the most important food, that the diet is deficient in total protein content, of a low quality, and that it is also low in energy content.

The nutritional importance of other nutrients in the diet is also of interest. Rather than showing contents in the diet, results are presented in Table 3, showing the biological effect of the addition of groups of nutrients, to a corn-beans diet used for experimental convenience, although it may be argued that other food items may provide some of these nutrients (6).

TABLE 3
LIMITING NUTRITIONAL FACTORS IN BASIC CORN-BEAN PRESCHOOL CHILDREN DIET[1/]

Nutrients added	Average diet intake, g/28 days	Average weight gain, g/28 days	PER
None	271 ± 8.8[2/]	26 ± 2.3[2/]	1.09 ± 0.07[2/]
+ Vitamins	367 ± 18.7	49 ± 4.0	1.52 ± 0.06
+ Minerals	388 ± 15.8	65 ± 4.3	1.91 ± 0.06
+ Calories		23 ± 1.23	0.95 ± 0.05
+ Lys + Tryp	266 ± 14.4	26 ± 2.5	1.10 ± 0.08
+ Vit + Min + Lys + Tryp	484 ± 14.7	107 ± 4.9	2.55 ± 0.06

[1/] Basic diet: 72.4% corn + 81% beans.
[2/] Standard error.
In: Nutritional Improvement of Maize, 1972.

The results shown indicate that vitamin additions, as well as mineral additions alone, tend to improve the quality as indicated by an increasing food intake which, in turn, results in better weight gain and protein quality as determined by PER. Of interest is the fact that the addition of the two amino acids lysine and tryptophan, previously determined as limiting the protein quality of the diet, added without the vitamins and minerals, did not improve food intake, weight gain, or protein quality. Furthermore, the addition of calories as oil did not induce any favorable change with respect to the control. However, when all items were added together, there was a significant improvement in all the measurements made.

This information then, suggests that the diet is deficient in vitamins and minerals, which are needed if the full benefit of improving protein quality is to be obtained. However, amino acid supplementation, although improving quality of protein does not increase protein concentration, which in our opinion is also necessary. In this respect, it is of interest to examine the results in Table 4.

TABLE 4

EFFECT OF INCREASING PROTEIN INTAKE FROM BASIC CORN-BEANS DIET[1/] ON NITROGEN BALANCE

Protein intake	Nitrogen retention g/kg/4 days	Ave. Wt. gain, g/4 days
3	−1.02	−101
4	−0.02	− 7
5	+0.96	13

1/ Diet: 82.6% corn + 13.2% beans + other ingredients.

In: Arch. Latinoamer. Nutr. 24:221, 1974.

In these studies protein intake was increased from 3 to 5 g/kg/day in experimental animals (10). The intake of 3 g/kg/day in the experimental animals used is equivalent to a protein and energy adequacy of 82 and 76% in children, respectively. The effect of increasing protein intake was measured by the nitrogen balance method and weight changes were also obtained. It can be seen that increasing protein intake resulted in an increase in nitrogen retention from a negative value of -1.02 to a positive one, of 0.96. Weight gain also increased. These data indicate that a higher intake of the diet would have a positive effect on growth and nitrogen retention, even with a poor efficiency of utilization. Children, of course, cannot voluntarily increase their protein intake as carried out for experimental animals, because of bulk and because of the amounts of food available at home. As indicated before, an alternative means of achieving higher intake of protein would be to increase protein concentration of the diet.

So far the limitations of the diet in terms of protein content and quality have been discussed as well as of other nutrients. As indicated, calories are also deficient. Some experimental evidence shown in Figure 1 demonstrates the effect of energy addition to the diet. These data were obtained in experimental animals using nitrogen balance techniques (10). The results show that increasing energy intake 25% at two levels of protein intake, of 3 and 4 g/kg/day, without or with lysine and tryptophan added, results in higher nitrogen retention values at either level.

EFFECT OF ADDING LYSINE AND TRYPTOPHAN TO A MAIZE-BLACK BEAN DIET WITH AND WITHOUT ADDITIONAL ENERGY

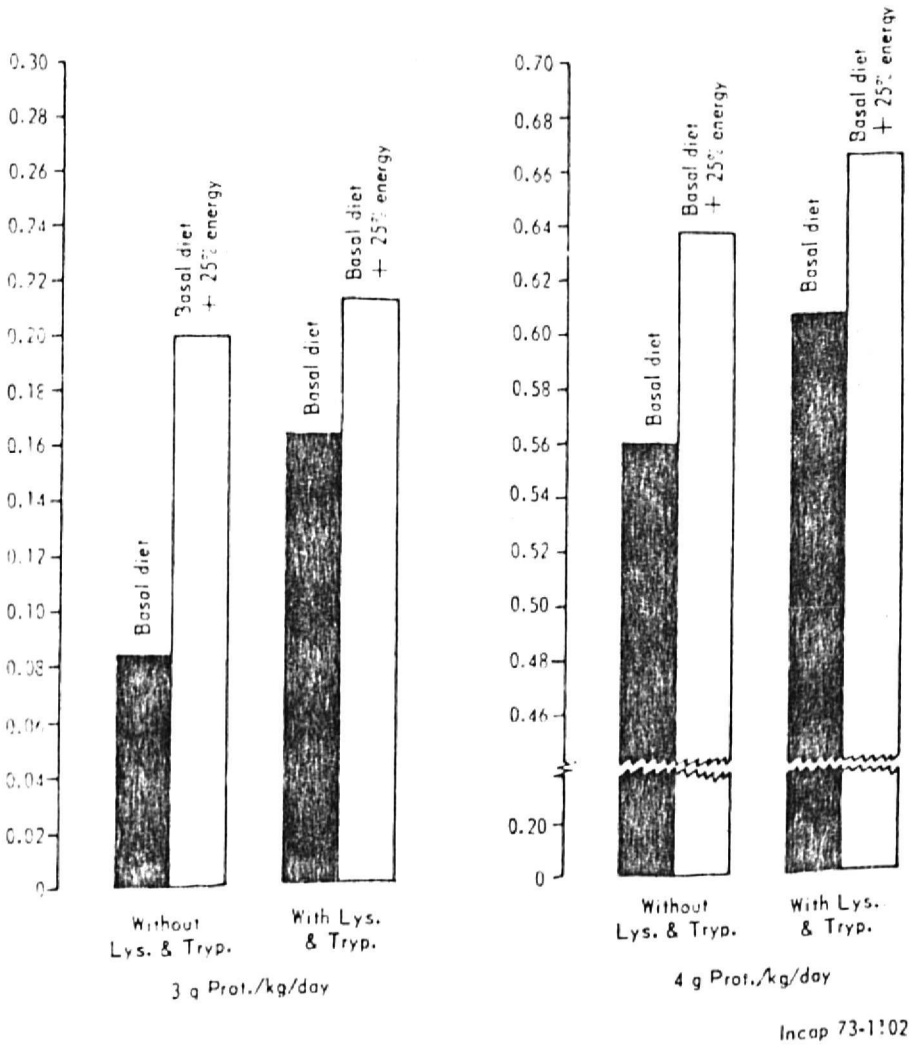

FIGURE 1

This evidence indicates, therefore, that the quality of the diets can also be improved when the energy density of the diet is increased, provided total intake is increased. The problem then is to develop a supplement which would increase total protein concentration, have a better protein quality, additional vitamins and minerals, and increased energy content. All these, of course, should be done without altering significantly the physical or organoleptic quality of the main item in the diet, corn.

II. Basic Nutritional Studies on the Improvement of the Protein Quality of Corn

There are many studies published on the subject of improving the protein quality of corn proteins. And it is well-known that corn protein is deficient in the essential amino acids, lysine and tryptophan. In order to follow our approach to the problem, summarized information will be presented on the limiting factors for improved protein quality of corn, within the context that it represents the main food component of the diet.

A summary of various studies carried out with lime-treated corn in experimental animals are shown in Table 5.

TABLE 5

SUPPLEMENTATION OF LIME-TREATED CORN WITH AMINO ACIDS

Amino Acid added, % 1/	Average Weight gain, g	PER
None	32	1.21
Lysine (0.21%)	41	1.51
Tryptophan (0.10%)	22	1.15
Lysine (0.31%) + Tryp (0.05%)	100	2.66
Lys (0.31%) + Tryp (0.05%) + Threo (0.20%) + Ileu (0.20%) + Met	112	2.69

1/ L-Lysine HCl, DL-Tryp, DL-Ileu, DL-Threo, DL-Met.

Arch. Latinoamer. Nutr. 18:123, 1968.

The evidence indicates a limited improvement from lysine addition alone, and no effect from the single addition of tryptophan. However, when both amino acids are added together, there is a significant increase in weight gain and protein quality. Other amino acids added together with lysine and tryptophan do not improve performance any further (3). Evidence of the same nature has also been obtained in children (1). Even though the addition of the two amino acids improved the protein quality of corn proteins, total protein concentration remains the same. Since the diet consumed by children, as shown in previous results, is low in total protein, it was felt that a more complete improvement would be one which included in one intervention both higher protein content and higher protein quality. Therefore, studies were carried out to determine the optimum levels in terms of protein quality of the protein supplements added to corn. Some of these results are shown in Table 6.

TABLE 6

RECOMMENDED LEVELS OF PROTEIN CONCENTRATES TO SUPPLEMENT LIME-TREATED CORN

Protein concentrate	Level %	PER
None	-	1.00
Casein	4.0	2.24
Fish protein concentrate	2.5	2.44
Soybean protein isolate	5.0	2.30
Soybean flour	8.0	2.25
Torula yeast	2.5	1.97

J. Agr. Food Chem. 6:517, 1963.

All proteins added increased the protein quality of corn, because they are good sources of the two limiting amino acids in corn proteins (4). Furthermore, the protein content is also increased in the mixture from about 2 to 4 g. By means of this approach, it was felt that the basic corn-bean diet consumed by the child population would be increased in terms of total protein as well as in protein quality.

More recent considerations suggest that besides higher protein content and quality, it would be desirable to increase energy content as well. An approach was attempted, which so far is giving good results. This approach consists in the addition of whole soybeans to corn, which would provide protein content, protein quality, and energy as well because of the oil in soybeans (5). The results of various studies indicated that soybeans could be cooked together with corn by the traditional way in which corn is processed in some Latin American countries. Some representative nutritional results of this approach are shown in Table 7.

TABLE 7

PROTEIN QUALITY OF LIME-TREATED CORN SUPPLEMENTED WITH LIME-COOKED WHOLE SOYBEANS

	PER	Utilizable protein, %
Lime-treated corn 1/, 2/	0.95	2.1
85% lime-treated corn + 15% lime-treated whole soybeans 1/	1.98	7.1
92% lime-treated corn + 8% soybean flour 1/	1.98	6.6
85% lime-treated corn + 15% lime-treated whole soybeans 3/	1.98	7.1
Casein 1/	2.60	9.4

1/ 5% refined soybean oil added.
2/ Diet contained: 9.0% protein. All other diets had 12.5% protein.
3/ No oil added.
J. Food Sci. 39:577, 1974.

It can be seen that a 15% addition of whole soybeans is equal in its effects to 8% soybean flour, providing an equal or similar increase in protein content and quality. The data shown in the table also indicate that the additional energy provided by soybeans is of nutritional benefit as indicated by the results in the last line of the table. Therefore, it would appear that by using 15% whole soybeans, with 85% corn, a food is produced which is equal to the traditional tortilla but of much better nutritional value.

The results thus obtained were used to formulate the composition of the supplement to be used to improve the protein quality of corn protein as well as the nutritional value of the whole diet. The formulation is shown in Table 8. Besides the protein source, the complete supplement includes thiamine, riboflavin, niacin, iron, and vitamin A. All of these nutrients are deficient in the diets as consumed (6).

TABLE 8

FORMULATION OF LIME-TREATED CORN SUPPLEMENT 1/

Ingredient	Composition of the supplement	Content of 8% added to maize, g
Soya flour	97.5000	7.800000
L-Lysine HCl	1.5000	0.120000
Thiamine	0.0268	0.002196
Riboflavin	0.0162	0.001296
Niacinamide	0.1930	0.015440
Ferric Orthophosphate	0.6000	0.048000
Vitamin A -250-SD	0.0313	0.002504
Corn starch	0.1327	0.010616
Total	100.0000	8.000000

1/ Nutritional Improvement of Maize, 1972.

Table 9 summarizes the improvement in protein quality of corn supplemented with amino acids or protein and the values are compared to those from Opaque-2 corn. The results show Opaque-2 corn to be somewhat superior in quality to the supplemented corn and definitely superior to common corn.

TABLE 9

PROTEIN QUALITY OF SOYBEAN FLOUR SUPPLEMENTED TORTILLA IN RATS

Food	Protein %	PER	Utilizable protein, %
Lime-treated corn	7.9	1.26	2.7
Lime-treated corn + Lys + Tryp	8.0	2.78	6.0
Lime-treated corn + 8% soybean flour + 0.1% Lys	9.7	2.43	6.3
Casein	9.8	2.80	7.3
Opaque-2 corn	10.1	2.66	7.2

A batch of lime-treated corn supplemented with soybean and lysine was also tested in children using the nitrogen balance methodology (13). The results of the nutritional evaluation is shown in Table 10. At equal nitrogen intake the soybean supplemented corn gave nitrogen retention values expressed as percentage of the intake similar to those resulting from milk protein.

TABLE 10

PROTEIN QUALITY OF SOYBEAN FLOUR SUPPLEMENTED TORTILLA IN CHILDREN

	Nitrogen Balance			Nitrogen	
	Intake	Absorbed	Retained	Absorbed	Retained
	mg/kg/day			%	
Lime-treated corn	192	144	30	75	16
Lime-treated corn + 8% soybean flour + 0.1% Lys	197	154	63	78	32
Milk	195	157	75	80	38
Lime-treated corn (87%) + beans (13%)	207	150	36	72	17

III. Physical and Biological Characteristics of Tortillas with and without Supplements

The nutritional improvement of the supplemented corn is only one of the aspects in the solutions of the protein problem. From the chemical and biological points of view, the supplement increases protein content and also increases the content of limiting amino acids, which results in higher protein quality. Other added nutrients, such as vitamins, increase the overall nutritive value of the food. Physical and organoleptic characteristics of the supplemented food are also very important points to be taken into consideration, from the industrial and the consumer's points of view. The addition of synthetic amino acids is not expected to change those characteristics; however, the use of a protein supplement may have an effect on the rheological and organoleptic properties of the corn dough used in the preparation of tortillas. Unfortunately, only limited research has been carried out on the rheological characteristics of the corn dough itself, mainly because tortilla preparation is a homemade process with only a very small contribution from the industry, at least in some countries. It is expected, however, that as industrialization progresses, convenient corn-based products will have their place in the market of corn-eating countries, and those properties have to be studied. Table 11 summarizes the effect of adding corn masa, soybean flour, with different nitrogen solubility (7).

TABLE 11

IMPROVEMENT OF THE PROTEIN QUALITY OF LIME-TREATED CORN SUPPLEMENTED WITH SOYBEAN FLOURS OF DIFFERENT NITROGEN SOLUBILITY

Supplement	Nitrogen solubility of soybean flour, * %	% Protein in the diet	Weight gain g/28 days	Protein Efficiency Ratio
None	-	6.8	31	1.65
8% soybean flour - 1	99.7	9.6	78	2.20
8% soybean flour - 2	96.7	9.4	73	2.26
8% soybean flour - 3	82.3	9.3	89	2.50
15% whole soybeans**	-	11.7	106	2.46
8% soybean textured protein	-	10.7	96	2.31

* Nitrogen solubility in NaOH 0,02 N.
** Lime-treated with 85% corn.

The results show the improvement obtained in the protein quality of corn masa and a tendency to obtain a better response with the soybean flour with less nitrogen solubility. It is also of interest to note that the best preparation, in terms of weight gain, was presented by the addition of whole soybeans. Acceptability trials using "The Rank Method" at laboratory level were carried out on various food preparations using the type of corn normally consumed in the Central American countries. Although no significant differences were found among the tortillas, those prepared from corn and whole soybeans were consistently ranked first. Water retention capacities of the supplemented and unsupplemented tortillas were also carried out, by weighing the different preparations over a period of three days (5, 7). The results obtained are shown in Figure 2 indicating that over a 72-hour period, at room temperature, water retention was similar for the different preparations. This is an important aspect from the consumers' points of view, since the tortillas consumed at breakfast are those prepared the previous day; in a sense, water holding characteristics are a measure of the texture stability of the product through a definite period of time.

WATER HOLDING CAPACITY OF TORTILLAS MADE FROM CORN AND CORN SUPPLEMENTED WITH VARIOUS TYPES OF SOYBEAN PROTEIN

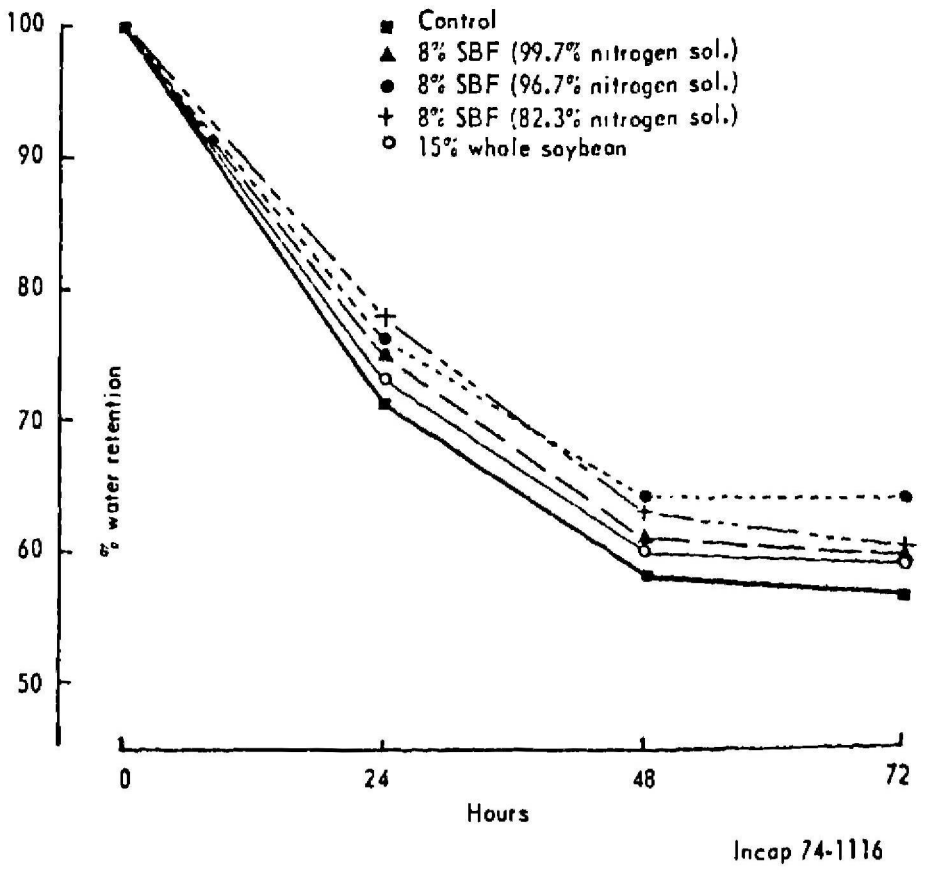

FIGURE 2

Other physical measurements were determined in the corn dough as well as in the corn dough supplemented with soy flours and whole soybeans. Table 12 shows the farinogram values obtained with the different preparations (7).

TABLE 12

FARINOGRAPHIC CHARACTERISTICS OF CORN DOUGH CONTAINING 8% SOYBEAN FLOUR

Supplement	Water absorption	Time required for the development of maximum dough stiffness (B), min	Resistance of the dough to break down (CD), min	pH
Control	136.0	14.0	8.5	7.05
8% soybean flour - 1	135.0	16.0	4.5	6.95
8% soybean flour - 2	136.0	16.5	6.0	6.95
8% soybean flour - 3	134.0	22.5	7.5	6.95
15% whole soybeans	131.0	23.5	stable	8.70

It may be observed that water absorption by the various preparations during mixing is very similar, although there is a slight tendency to decrease with the addition of soy flour, being more pronounced in the case of whole soybeans. Since water absorption is related in some way to dough consistency, the time required for the development of maximum dough stiffness is longer for the supplemented corn dough as compared to the corn dough alone. Again the corn-whole soybean sample took a longer time to reach the maximum stiffness. The data also shows that the stability or the resistance of the dough to break down is higher for unsupplemented corn as compared to the supplemented samples except in the case of the corn-whole soybeans sample. In summary, these results show that the addition of soybean tends to decrease the resistance of the corn dough to break down, probably due to the smaller amount of starch in these mixtures, in which corn proteins were replaced by soy proteins. It is known that soy globulins do not possess the same rheological properties as cereal proteins. The different behavior of the sample with whole soybean is probably due to the mild wet heat treatment given to it in comparison to the heat treatment generally applied in the preparation of some soy flours, which have been shown to have an adverse effect on the bread making potential.

These observations are confirmed on the amilogram values obtained on those samples (7), as shown in Table 13.

TABLE 13

AMILOGRAPHIC CHARACTERISTICS OF CORN DOUGH CONTAINING 8% SOYBEAN FLOUR

Supplement soybean flour 1/	Time for maximum viscosity, min	Temperature for maximum viscosity B.U.	Maximum viscosity B.U.	Viscosity at 94°C	Temperature for 500 B.U.
Control*	44.0	91.0	1030	996	81.2
No. 1	43.0	89.5	760	708	82.0
No. 2	43.0	89.5	860	770	83.5
No. 3	44.0	91.0	880	840	83.5
No. 4*	43.3	89.9	1130	1050	82.0

1/ Lime-treated corn samples contained 8% soybean flour of different nitrogen solubility except No. 4, which contained 15% whole soybeans.

* Were subjected to an additional tension of 125 g.

Again it can be observed that maximum viscosities were obtained with the unsupplemented corn dough and the corn-whole soybeans dough. In the case of the latter sample it is possible that its more alkaline pH has influenced the higher viscosity since it has been demonstrated that there is an effect of pH on the gelatinization and breakdown of corn starch.

From the results obtained it can be said that the use of whole soybeans as a supplement to corn protein has not only nutritional advantages but also maintains the physical characteristics of the dough used in the preparation of tortillas.

Although the results obtained with the amilograph and the farinograph, showed some differences in the physical characteristics of the supplemented dough, it seems that they are not significant from the practical point of view, since the taste panel test, carried out with the tortillas prepared with the supplemented corn, showed no statistically significant differences as compared to the tortillas made with the normal corn. However, it is important to indicate that the data obtained suggest that the addition of higher levels of soy flour to corn flour could affect the consistency of the corn dough used to prepare the tortillas more drastically. With the present level of soy flour additions, it seems that the only possible practical problem is a small increase in the time required to reach the "normal consistency" usually obtained with the normal corn dough. The addition of soybean flour, furthermore, does not change the appearance of the tortilla, or its color, and it can be used to prepare other food preparations as shown in Figures 3 and 4. The first shows the common tortilla, while the second shows taco preparations and fried tortillas (7).

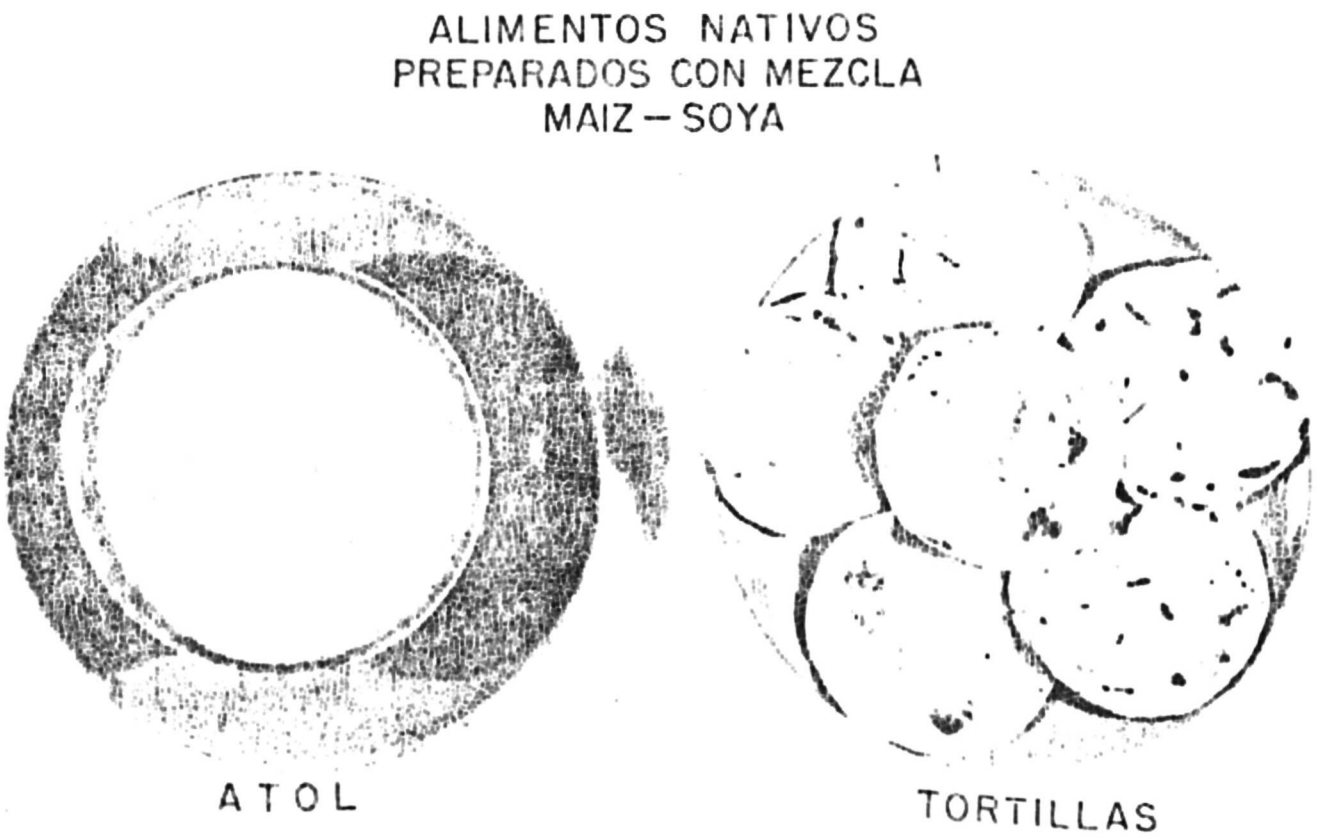

FIGURE 3

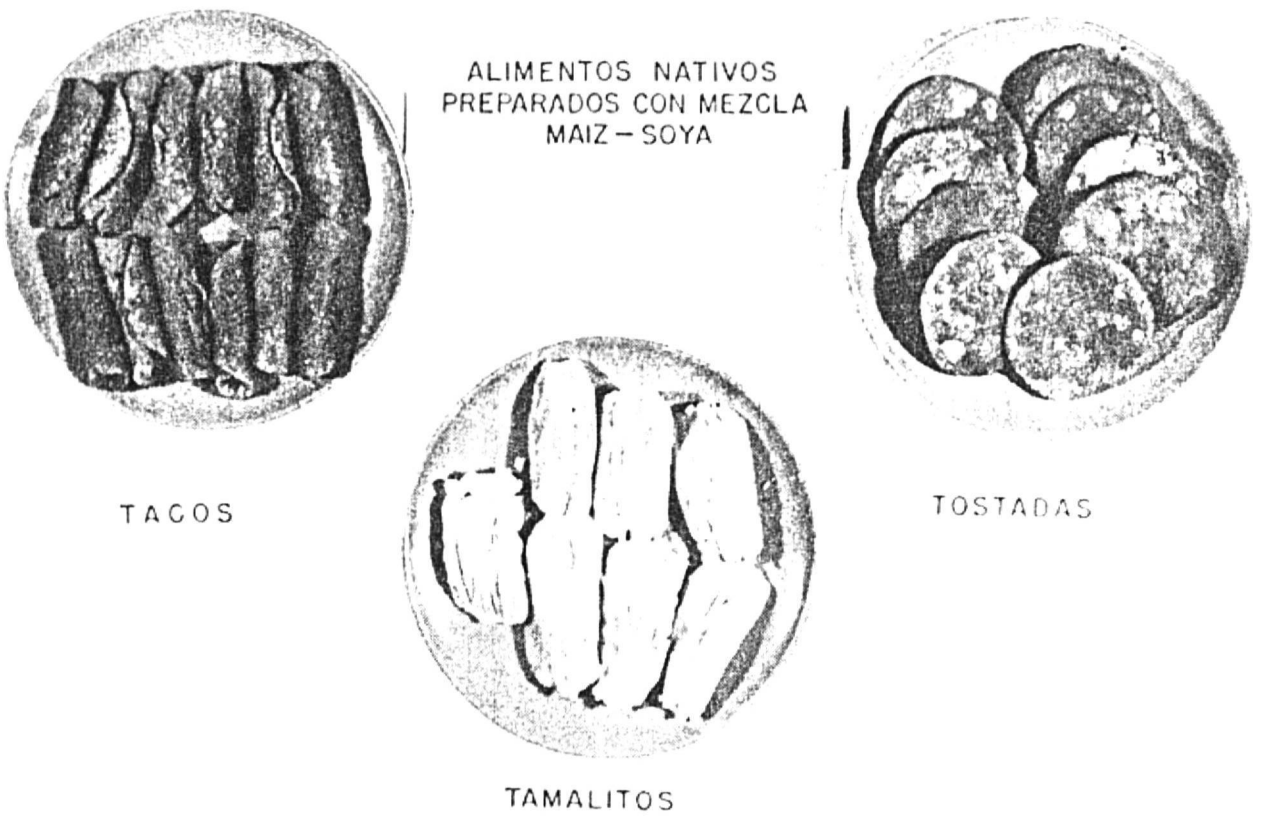

FIGURE 4

Stability trials

The preparation of tortillas uses a process involving wet and dry heat cooking. On the other hand, it is well-known that high temperature cooking decreases protein quality by amino acid inactivation. Since the "supplement" is added to the dried or wet corn flour, just before the dry heat step, it was important to find out the stability of the nutrients added in the final cooked product.

Table 14 shows the effect of processing on the chemical stability of amino acids added to corn dough and to tortillas baked for three and six minutes (6). The percentage of lysine and tryptophan recovery shown in the last column indicates that these amino acids were not significantly affected, even at the maximum time of heating (six minutes).

Table 15 shows the determination of lysine and tryptophan in the tortillas supplemented with Torula as the protein concentrate, and the protein concentrate plus lysine (6). The results again show that the amount of lysine from the Torula yeast, as well as from the Torula yeast plus lysine, were not significantly altered.

TABLE 14

EFFECT OF PROCESSING ON THE STABILITY OF AMINO ACID ADDED TO THE DIFFERENT PREPARATIONS

Preparation	Cooking time min	Content g/lys/g N	Content g /Tryp/ g N	Recovery Lys %	Recovery Tryp %
Masa	0	0.198	0.053	-	-
Tortilla	3	0.205	0.057	-	-
Tortilla	6	0.199	0.055	-	-
Masa + 0.30% Lys + 0.10% Tryp*	0	0.370	0.080	106.3	95.2
Tortilla + 0.30% Lys + 0.10% Tryp	3	0.359	0.080	103.2	94.0
Tortilla + 0.30% Lys + 0.10% Tryp	6	0.344	0.099	98.8	117.8

* L-Lys HCl; DL-Tryp.

TABLE 15

EFFECT OF PROCESSING ON THE STABILITY OF AMINO ACID ADDED TO THE DIFFERENT PREPARATIONS

Preparation	Cooking time	Content		Recovery	
		g/lys/g N	g/tryp/g N	Lys %	Tryp %
Masa + 3% Torula**	0	0.255	0.056	105.8	94.9
Masa + 3% Torula	3	0.259	0.055	107.5	93.2
Masa + 3% Torula	6	0.247	0.056	102.5	94.9
Masa + 3% Torula + 0.10% Lys*	0	0.302	0.057	96.5	96.6
Tortilla + 3% Torula + 0.10% Lys	3	0.319	0.058	101.9	98.3
Tortilla + 3% Torula + 0.10% Lys	6	0.228	0.064	72.8	108.5

* L-Lys HCl; DL-Tryp.
** 3 g of Torula = 0.118 g Lysine; 0.021 g Tryptophan.

TABLE 16

PROTEIN QUALITY OF THE CORN DOUGH AND TORTILLAS WITH VARIOUS SUPPLEMENTS

Diet	Treatment	Ave. Weight gain, g *	Protein Efficiency Ratio
Masa	-	25 ± 2.0**	1.28 ± 0.6**
Tortilla	-	23 ± 3.5	1.25 ± 0.5
Masa	3% Torula	52 ± 3.6	1.86 ± 0.8
Tortilla	3% Torula	47 ± 3.5	1.76 ± 0.6
Masa	3% Torula + 0.15% Lys***	64 ± 3.0	2.29 ± 0.7
Tortilla	3% Torula + 0.15% Lys***	64 ± 4.7	2.17 ± 0.5
Masa	0.30% Lys + 0.10% Tryp	59 ± 4.6	2.42 ± 1.0
Tortilla	0.30% Lys + 0.10% Tryp	61 ± 7.3	2.53 ± 1.0
Casein		101 ± 8.6	3.06 ± 0.8

* Initial weight: 47 g.
** Standard error.
*** L-Lys HCl; DL-Tryp.

The biological evidence which is summarized in Table 16 indicates that the availability of the nutritional components provided by the supplements added was not affected by the heat treatment applied (6).

This conclusion can be inferred from the weight gain and PER obtained with the different preparations. This is indeed a fortunate finding which is due to the characteristics of the process used to prepare the tortillas as shown in Table 17.

TABLE 17

CHARACTERISTICS OF THE COOKING PROCESS OF CORN MASA FOR THE PREPARATION OF TORTILLAS

Measures	
Temperature of the surface	150 - 200°C
Average time of cooking	3 - 4 min
Average weight of tortilla before the thermic treatment	55 grams
Average weight of tortilla after the thermic treatment	44 grams
Moisture content of tortilla before the thermic treatment	54.6%
Moisture content of tortilla after the thermic treatment	34.6%
Water lose during thermic treatment	20%

The well-known Maillard reaction responsible for the destruction or inactivation of the amino acids during the heat treatment requires nitrogen compounds and reducing groups as well as other factors such as temperature, time, moisture, and adequate pH. In this particular process the temperature is high (150-200°C), the cooking time is short, and the moisture content is high (54.6%). These conditions associated with the low content of free sugars in the corn dough (1.52%) explains in part the absence of this reaction during the preparation of tortillas (6).

IV. Systems for Addition

It is obvious that improvement of the nutritional value of tortillas can be achieved at laboratory level with the basic information already presented. However, the transference of this technology to a large scale is a real problem in part because tortilla preparation is almost entirely a homemade process with a very small but a growing participation from industry (9). It will be helpful to introduce at this point the method of preparing tortillas in Guatemala in order to discuss the possibilities of incorporating the supplement at the industrial and village level. The traditional (2) method is shown in Figure 5.

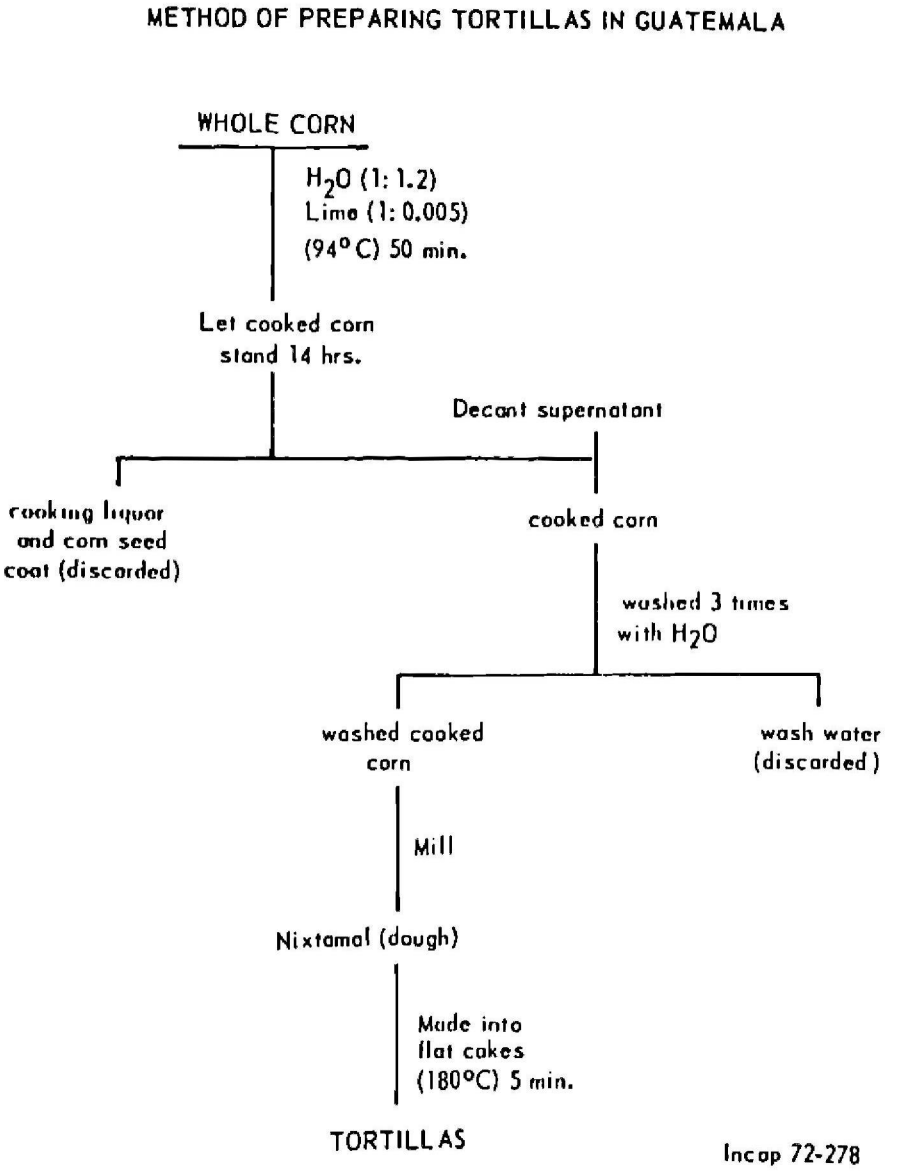

FIGURE 5

It consists in cooking the corn for one hour, using a calcium hydroxide solution. After cooking and cooling, the corn is washed with water, an operation which removes the seed coat and eliminates excess calcium hydroxide. The cooked maize is called nixtamal. It is then ground, an operation which was done by hand with a grinding stone. However, the grinding stone is no longer used; it has been replaced by a corn mill shown in Figure 6 which is distributed in many places, both in urban and rural areas.

NIXTAMAL MILL

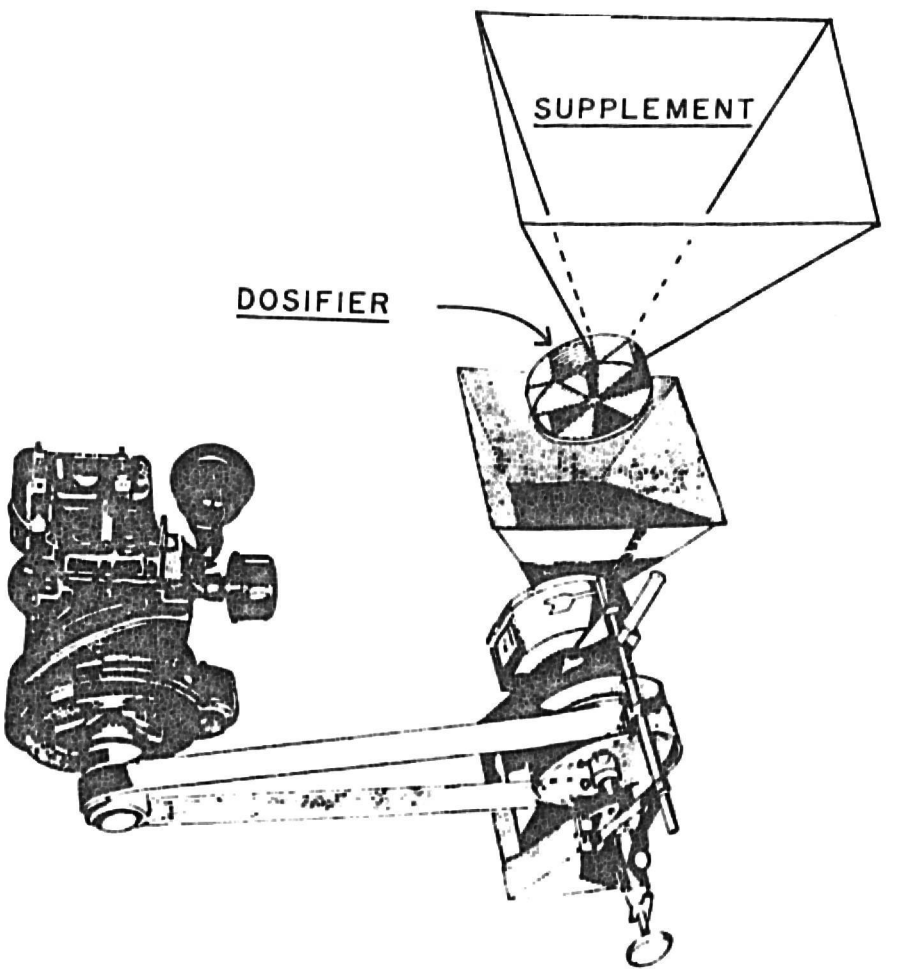

FIGURE 6

a. Industrial Level

The sequence of steps for the industrial preparation of precooked corn flours is basically the same as the one used at the home level when the alkaline treatment is included in the process. The main differences consist in the cooking time, which is around 1.5 hours, and the omission of the soaking step after cooking. After grinding, the nixtamal (dough) is dehydrated to give a precooked flour as a final product.

In this method of processing, the best stage to add the supplement is after grinding, which would include a mixing operation before packaging. Addition of the supplement before this stage would result in significant losses of nutrients because of the washing procedure used after cooking. Experimental data have shown that, for an efficient, homogenous distribution, addition of the supplement as a powder is better than in any other form.

b. Village Level

There are two possibilities of adding the supplement to corn in the rural areas - at home and at the mill used to grind the cooked corn (9, 11, 12). It is clear that the first procedure is very difficult since this mechanism will create numerous problems from the practical point of view. The second alternative is more feasible when carried out under controlled conditions, but still very difficult to be applied as a general procedure, due to the low educational level of the rural population. At the present time, the addition of 15% whole soybeans is being recommended.

c. Advantages and Disadvantages

The addition of the supplement either at the industrial or village level presents advantages and drawbacks. From the industrial point of view, the main advantage is the uniformity of the product and its constant availability in different convenient forms. However, the main problem consists in the fact that in developing countries food industries are generally located in the urban areas, the supplemented food will not reach the rural areas where undernutrition is more prevalent; of course, those problems can be solved either by locating the food industries in the rural area or by recommending adequate methods of transportation. However, the last alternative implies economic factors which are also important from the consumer's point of view.

V. Evaluation of the Supplemented Corn and of Opaque-2 Corn in Diets of Cereal Grain and Legume Foods

Results demonstrating the improvement of protein quality of lime-treated corn have already been shown in the preceding sections of this document. In this section, selected results will be shown to

indicate that the superior quality of supplemented corn and of Opaque-2 corn in comparison with common corn is also evident in mixed diets (8). Some biological results obtained are shown in Table 18.

TABLE 18

IMPROVEMENT OF THE PROTEIN QUALITY OF A CORN-BEAN DIET THROUGH AMINO ACID OR PROTEIN SUPPLEMENTATION

Supplement	Average wt. gain, g	PER	Utilizable protein, %
None	52 ± 4.4	1.75 ± 0.12	4.4
Corn + Lys + Tryp	80 ± 3.6	2.48 ± 0.06	6.3
Corn + 8% soy flour + 0.15% Lys	120 ± 5.4	2.50 ± 0.06	8.2
Corn + 8% skim milk + 0.10% Lys	111 ± 6.1	2.63 ± 0.07	7.7
Corn + 3% Torula + 0.10% Lys	85 ± 5.2	2.24 ± 0.08	6.2

In: Nutritional Improvement of Maize, 1972.

The data clearly indicate that the protein quality of the diet, in terms of protein efficiency and utilizable protein, is increased by various supplements added including that of the soybean flour. In all cases, small amounts of lysine were included with the protein supplement added because it was not able to meet all of the lysine needed in corn as shown by previous results (6). A second example is shown in Table 19.

Table 19

COMPARATIVE PROTEIN QUALITY OF CORN WITH AND WITHOUT SUPPLEMENTS AND OF OPAQUE-2 CORN

Protein	Protein %	PER	Relative Nutritive Value*, %	Utilizable Protein ** %
Corn***	7.9	1.26	33.7	2.66
Corn*** + 0.3% Lys + 0.1% Tryp	8.0	2.78	74.5	5.96
Corn*** + Soybean flour + 0.1% Lys	9.7	2.43	65.1	6.31
Opaque-2 corn***	10.1	2.66	71.2	7.19
Casein	9.8	2.80	75.0	7.35

* Relative nutritive value to casein
** Protein content x Relative Protein Quality
*** Corn masa.

In this case, the evaluation was done by nitrogen balance, which shows that the replacement of common corn by Opaque-2 corn induces a significant increase in nitrogen retention. This information demonstrates, therefore, that either Opaque-2 corn or protein supplemented corn improves the quality of simple diets based on cereal and beans. It is believed the same sort of improvement is expected in human populations, and reports to this effect will be presented elsewhere in this document.

Prospects

The evidence presented shows that a nutritional intervention such as the one described is of great value in improving the nutritional status of people consuming poor protein quality diets of low protein content. The problem, however, is how to achieve permanent acceptance for a

measure such as the one described, since it has economic implications which might not be possible for these low-income people and because they produce the corn they consume. If the lime-treated corn were industrially produced and consumed by all, not only by urban populations, the problem would have a simple solution. But, as it was indicated, this is not the case. There are no easy solutions to the above problem. However, one which we are beginning to develop consists in the use of whole soybeans together with corn. In this scheme, 85 parts of corn and 15 parts of whole soybeans are processed together as indicated (5). Material balance of this process averaged 85%. The 15% loss is accounted for by the losses of seed coats and poor quality kernels. Since soybeans are not normally grown in some of these countries, the success of this possibility would involve agricultural extension programs designed to teach soybean cultivation, as well as home economics type of education to show how to use this material together with corn. A small industry could be developed following a flow diagram as shown in Figure 7 which will permit not only the production of soybean fortified tortillas, but other food products of higher protein and energy content with good protein quality.

PROPOSED VILLAGE CORN-SOYBEAN PRODUCTS INDUSTRY

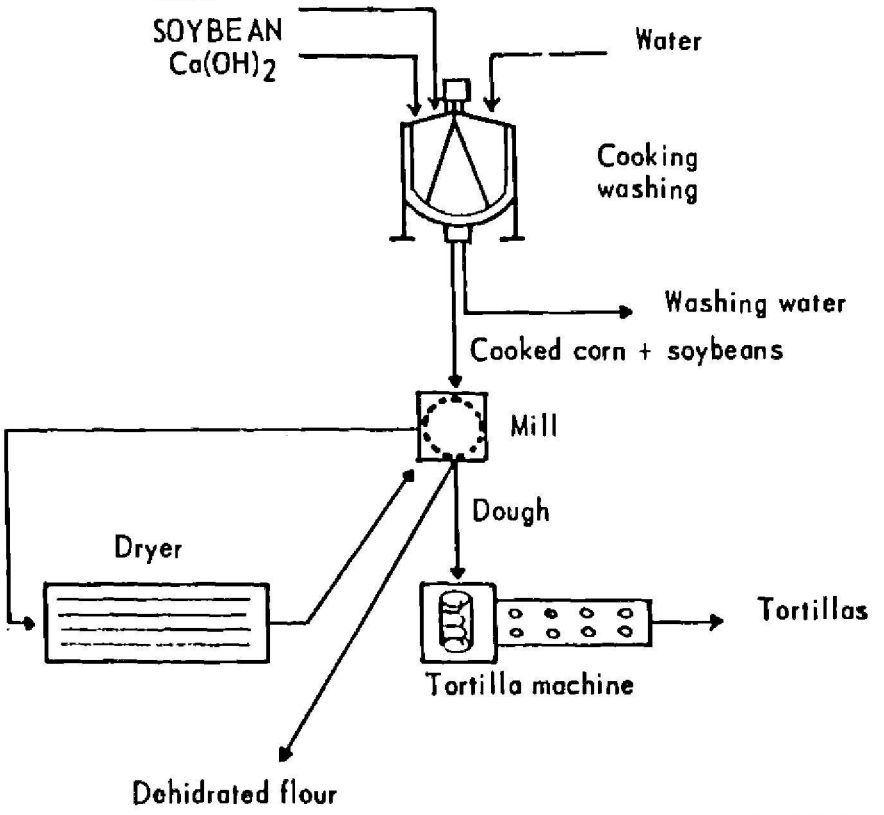

FIGURE 7

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