HIGH PROTEIN QUALITY VEGETABLE MIXTURES FOR HUMAN FEEDING. INCAP

Ricardo Bressani[1]

A number of nutrition and food consumption surveys conducted in the Central American countries in the early 1950's, showed that large segments of the population, particularly children, suffered from calorie protein malnutrition as well as of deficiencies of iodine, vitamin A and iron (Scrimshaw et al., 1955).

The above situation gave rise to various research programs whose objectives were to provide practical solutions to the nutritional problems indicated. The iodozation of salt was the first to be implemented, which time has shown to have been effective, with some problems taking place occasionally manly due to the logistics in iodine addition and its quality control. Vitamin A addition to sugar has also been implemented and is a successful approach to eliminate Vitamin A deficiency in Central America.

In order to provide practical solutions to the protein/calorie problem, a research program was initiated as early as 1950 to develop high quality protein vegetable multipurpose foods mainly for child feeding but useful also to other population groups suffering nutritional deficiencies (Béhar, Bressani & Scrimshaw, 1959).

The food concept established at the time was that the food to be developed had to be presented as a flour; it had to be consumed following dietary habits and practices of the population; had to be formulated from locally available ingredients with a corn-like flavor; it had to have a protein content and quality similar to that of animal proteins; be supplemented with B vitamins as well as

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with vitamin A and iron; be free of antiphysiological factors; it should be stable and have an acceptable shelf-life and it had to be cooked before consumption. The final purpose was to develop a food capable to supplement efficiently the habitual diets of children.

Presently available high quality foods

At the present time there are available in Guatemala from research conducted at INCAP four high quality weaning foods with the commercial names and experimental designation shown in Table 1. Two of them were licensed by INCAP. *Incaparina* and *Bienestarina* and the other two. *Vitatol* and *Innovarina*, produced by the own initiative of the food industry which manufactures *Incaparina*. using information from the literature which was published. This measure was taken in order to continue the production of these foods since Cotton Seed Flour is becoming difficult to obtain in Central America. Table 2 shows the basic main ingredient composition of the formulas (Bressani & Elías, 1966, Bressani et al., 1966,Bressani et al., 1961). All are blended products containing degermed corn flour and variable amounts of oilseed flour. *Incaparina*, the first food to be produced commercially contains human grade cottonseed flour. Lower amounts of this flour are used in *Vitatol*, which also contains soybean flour. The other two foods, *Innovarina* and *Bienestarina*, contain soybean flour as the supplementary protein source. The other product available is a cookie made from one of the above mixtures and wheat flour. This food product is used for school feeding programs.

The four weaning foods are packaged in cellophane polyethylene lined bags holding 454 g. Some products are also sold in 75 g packages. These containers have printed information on ingredients, chemical composition, and instructions for cooking. They also indicate the date of manufacture. The shelf life is around four months, under tropical conditions.

The nutrient content in the label of each of the four weaning foods is shown in Table 3. Protein content varies from around 21 to 23% , while the content of calories varies from 335 to 386 per 100 grams. The table shows the content of other major nutrients as well as the amounts of niacin, thiamin, riboflavine, vitamin A and iron added. These are niacin, 13.62 to 20.50 mg; thiamine, from 1.12 to 2.15 mg, and riboflavin from 1.01 to 2.05 mg/100 g. The vitamin A used is Vitamin A acetate 500 added in amounts to provide 4.500 to 5980 IU per 100 g. The source of iron is ferrous fumarate added to provide 11.2 to 20.0 mg per 100 g. The recommended intake is around one full tablespoon (20 - 25 g) per glass, three times per day. The consumption of 20-25 g/day provides the nutrient levels shown in Table 4. The label also indicate the percentage of the RDA ingested from 20 g of the product. There are 27 - 37 % for vitamin A; 15 - 30 % for thiamine; 15 - 24 % for riboflavin; 15 - 22 % for niacin; 5 - 10 % for calcium and 20 - 36 % of iron.

Experimental Nutritional Quality of Mixtures

The main ingredient composition of the various weaning high protein quality foods shown previously was established from biological protein complementation studies with rats (Bressani et al., 1961; Bressani & Elías, 1966; Bressani et al., 1966) The protein quality of these mixtures is shown in Table 5. For cottonseed flour protein and corn, the highest protein quality resulted when both ingredients were mixed in a 60 to 40 weight ratio for a PER of 1.93. On the other hand, soybean protein and maize gave highest PER (2.24) when blended in a 70 to 30 parts weight ratio. For mixtures with cottonseed and soybean and maize, the blend 70 parts of corn to 15 and 15 each of CSF and SBF was found to be the highest in quality protein (PER 2.20) (Bressani et al., 1972). The protein quality of the cottonseed flour/corn mixture could be improved substantially by adding 0,250% lysine (Bressani & Elías, 1962).

Protein Quality of Mixtures in children

The basic blends indicated above were tested extensively in various experimental animals before conducting feeding tests with children. Some nitrogen balance studies with children fed the mixtures as the sole source of protein (Bressani et al., 1972) are presented in Table 6. As suggested by the results with young growing rats, the protein quality of the four blends are also high for children. As expected they all have a lower true protein digestibility (80 - 92%) than animal protein sources (92 - 95%) but a high biological value of the absorbed nitrogen (66 - 82%).

The Manufacture and Fortification Procedure

The manufacturing process used at least by one manufacturer is shown in Figure 1. While in the past lime treated corn flour was used, at the present time white corn is milled and converted into a flour without the seed coat. This will reduce the level of dietary fiber. The germ is eliminated to increase stability of the flour during storage and marketing. This will also decrease in a significant way the level of phytic acid in corn (O'Dell, Boland & Koirtyohann, 1972). The cottonseed flour is produced from either prepress solvent or solvent extracted cottonseed. This raw material is milled and screened to at least 100 mesh flour with 50% protein and low levels of free gossypol (Bressani & Elías, 1968). The soybean flour used is a solvent extracted product.

These ingredients are mixed in the proportions for each mixture in a horizontal blender to which the vitamins, minerals, flavors and antioxidants are added . To insure an efficient distribution of the nutrients added, a premix is first prepared and then added to the other blended ingredients which should have at least or more than a particle size of 120 mesh. The particle size of each of the four commercials foods is shown in Table 7. As shown, 7.6 - 24.4% is retained above the 80 mesh screen, 11 - 21% is retained by the 120 mesh screen and 63 - 76% passes the 120 mesh screen. The bulk density varies from 0.67 to 0.62 g/ml. To protect the flours and the supplements the antioxidants added include BHA, BHT and TBHQ at a level of 0.005 to 0.010%.

However, shelf life studied to establish the stability of vitamin A or bioavailability of iron have not been conducted.

Processing Effects on Nutrient Content and Protein Quality

The recommendation in the label of the four weaning foods indicate that for consumption the flours should be cooked for at least 15 minutes. A limited number of studies have been conducted to learn if the cooking process decreases nutrient content and quality of the foods.Most of the studies were done with the cottonseed flour containing mixtures because of the possible negative effects which gossypol could induce. In one study with the CSF food, cooking time effects were evaluated with the results shown in Table 8. Thiamine decreased around 32%, while riboflavine showed a decrease of 23%. Available lysine showed a decrease of 18%. It is of interest to point out the significant decrease in free gossypol, probably becoming bound to other chemical compounds during the cooking process (Bressani et al., 1964). As shown in Table 9, protein quality, expressed as nitrogen retained as percentage of nitrogen intake did not change up to 24 minutes of cooking (Bressani et al., 1964). With respect to vitamin A. Table 10 show the effects of a 30 minute cooking time at 92 C on its retention in *Incaparina.* The vitamin A recovery from quality control analysis is 95.5% and the recovery after cooking of 76.7% is equivalent to a loss of around 23.3%.

Monitoring and impact

Quality control.

In order to protect the consumer by guaranteeing the quality of the mixtures licensed by INCAP to qualified industries , INCAP has established licensing requirements as well as a control system for the packaging, identification, advertising and analysis of the quality of the product (INCAP, 1960). The quality includes chemical composition, microbiological quality and with less frequency biological nutritional quality. The analyses are carried out at the intervals and in the manner prescribed in the respective authorization, that is on samples collected at the production level or in the food stores, based on the quantity produced. An example of the quality control scheme is shown in Table 11.

Up to the present time no major problems in this respect have been found with the nutrients as indicated in the label. The problem has been more with the microbiological quality of the various weaning foods, due to inefficient systems of storage of grain or of other raw material.

Impact

As far as it is known, the impact of the weaning food as sources of Vitamin A and Iron have not been evaluated in field studies. On the basis of the suggested daily consumption of 20 g/person/day, these products would provide around 27-37% of the RDA for vitamin A and 20-36% of the RDA for iron. The monthly sales of all weaning foods together is around 1 x 10^6 lb/m. On the basis of an intake of 60 g/day and of the number of 0-4 years old in Guatemala (OPS,1990) these foods may be reaching around 260,000 children 0 - 4 years old. The possible number of children covered is therefore relatively small, about 16% of the existing 0-4 year old population in Guatemala (OPS, 1990). The preparation of these foods for consumption by cooking in water includes the addition of sugar in a weight ratio of about 3 to 7. Therefore, the vitamin A intake by the consumer would come from the multipurpose food and from sugar which in Guatemala is fortified with vitamin A. On the other hand, Fe may not be as readily available because of factors in the weaning foods, such as dietary fiber, phytate, gossypol and other compounds which could interfere with its bioavailability. Oil seed flours, including cottonseed and soybean contain high levels of phytic acid (Erdman, Jr., 1979; Hartman, Jr., 1979) and although the levels can be reduced, the amounts still remaining are relatively high. Refining cottonseed flour by air classification reduced phytic acid about 20% (Wozenski & Woodburn, 1975). Since these flours represent the supplementary protein source in the weaning foods presented, it is of interest to know the extent of interference on Iron bioavailability, which is being added. Likewise, storage conditions could reduce bioavailability even further. This is an area to be studied, even though in biological tests with rats fed *Incaparina*, blood hemoglobin and RBC counts were essentially alike to the control diets fed (Bressani et al., 1964).

Problems Encountered

Up to the present time, no problems have been encountered with respect to the availability of raw materials and other ingredients, and with respect to processing and distribution. However, the cost of the foods have been increasing since the first product, **Incaparina**, was introduced in the market. At the moment, the price of all four mixtures is around 0.50 US$ per pound, which in the 60's and 70's it was around 0.26 US$/lb for **Incaparina**. The cost increase is due to increased in the cost of ingredients, packaging materials, labor, electrical power and other facilities, as well as the cost of distribution. This higher costs probably limits the access of the products to people, particularly in rural areas. The vegetable mixtures were intended for small children, however, they are consumed by elder groups.

With respect to quality control, the activity develops well, however, it could be improved as a means to solve the problems which the foods may have as for example the possible problem of iron bioavailability.

Success

As indicated previously, **Incaparina** was the first product launched by INCAP through a private industry, and its acceptance by the population has steadily been increasing. The fact that there are other three foods of recent introduction in the market suggest that there is a market for them and that people are purchasing such products. Even though the cost has been increasing, it is significantly less than that of milk, meat, or even common beans and of baby cereal grains manufactured by international food companies. It is not possible to indicate that these products have eliminated protein - calorie malnutrition among the child population, however, they are contributing towards that goal and the lives of children even if small has been saved. Finally, their manufacture has contributed to industrial and economic development in the region.

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TABLE 1

COMMERCIAL NAMES OF HIGH PROTEIN QUALITY VEGETABLE FOODS MANUFACTURED BY GUATEMALAN NATIONAL FOOD INDUSTRIES

COMMERCIAL NAME	EXPERIMENTAL FORMULA INCAP No.
INCAPARINA[1,2]	MIXTURE No. 9
VITATOL[2]	MIXTURE No. 15
INNOVARINA[2]	MIXTURE No. 14
BIENESTARINA[1]	MIXTURE No. 14

1 Licenced by INCAP.

2 Produced by the same food industry.

TABLE 2

BASIC QUANTITIES OF MAIN INGREDIENTS IN MULTIPURPOSE HIGH NUTRITIONAL QUALITY FOODS

(%)

	Mixture No.		
	9	14	15
Maize flour	60	70	70
Cottonseed flour	40	-	15
Soybean flour	-	30	15

TABLE 3

NUTRITIONAL INFORMATION OF LABEL IN EACH OF THE FOUR FOODS - PER 100 G

Nutrient	Incaparina	Vitatol	Innovarina	Bienestarina
Moisture, g	8.0	10.0	-	-
Calories, kcal	367	335	360	386
Protein, g	23.0	23.0	21.2	21.0
Fat, g	3.0	3.5	3.10	5.6
Crude fiber, g	3.5	4.0	2.4	2.5
Ash, g	4.0	4.5	-	-
CHO, g	62.0	53.0	62.4	63.0
Vit A, IU	4500	5000	5980	4500
Niacine, mg	13.62	13.62	20.50	14.25
Thiamine, mg	1.70	1.70	2.15	1.12
Riboflavin, mg	1.01	1.01	2.05	1.23
Iron, mg	11.20	11.20	20.00	20.00
Lysine, mg	250	250	-	-

TABLE 4

PERCENTAGE OF THE DAILY DIETARY RECOMMENDATION FROM 20 G/CUP

NUTRIENT	%	20 G/CUP
VITAMIN A	27 - 37	900 - 1195 IU
THIAMINE	15 - 30	0.34 - 0.43 MG
RIBOFLAVINE	15 - 24	0.20 - 0.41 MG
NIACIN	15 - 22	2.7 - 4.1 MG
CALCIUM	5 - 10	61 - 64 MG
IRON	20 - 36	2.2 - 4.0 MG

TABLE 5

PROTEIN QUALITY OF QUALITY PROTEIN VEGETABLE MIXTURES (RATS)

FOOD	COMMERCIAL NAME	P.E.R.
Skimmilk	milk	2.55 ± 0.30
Whole egg	egg	2.90 ± 0.27
V.M. # 9*	*Incaparina*	1.93 ± 0.13
	Innovarina	
V.M. # 14*		2.24 ± 0.23
	Bienestarina	
V.M. # 15*	*Vitatol*	2.20 ± 0.20
Casein	Casein	2.88 ± 0.20

* Experimental formulations.

Bressani et al. , ALAN 22: 227, 1972

TABLE 6

PROTEIN DIGESTIBILITY AND PROTEIN QUALITY OF VEGETABLE MIXTURES IN CHILDREN

FOOD	COMMERCIAL NAME	N INTAKE MG/KG/DAY	TPD*	BV**
Milk	Milk	163	92.0	80.6
Egg	Egg	168	95.2	78.1
V.M.#9	Incaparina	174	80.4	65.7
V.M.#14	Innovarina			
	Bienestarina	158	91.8	78.6
V.M.#15	Vitatol	168	88.7	82.5

* True Protein Digestibility

** Biological Value

Bressani et al. ALAN 22: 227, 1972.

TABLE 7

PARTICLE SIZE DISTRIBUTION OF COMMERCIAL WEANING FOODS IN GUATEMALA (%)

Mesh	*Incaparina*	*Vitatol*	*Innovarina*	*Bienestarina*
Above 40	0.2	0.2	1.9	1.5
Above 80	9.1	7.6	16.4	24.4
Above 120	21.5	16.2	12.6	11.2
Passes 120	69.2	76.0	69.1	62.9
Bulk density, g/ml	0.67	0.65	0.62	0.62

TABLE 8

EFFECT OF COOKING TIME ON CHANGES IN SEVERAL NUTRIENTS IN EXPERIMENTAL *INCAPARINA* (V.M.9)

Cooking time min	Thiamine mg/100g	Riboflavin mg/100g	Free amino groups of lysine mg/100g	Free gossypol mg/100 g
0	2.25	1.12	1.16	7.7
5	1.96	1.07	1.09	5.3
10	2.01	1.05	0.95*	6.4
15	1.99	1.14	1.18	8.4
20	1.75	0.86*	1.19	5.3
25	1.54*	1.18	1.09	2.7*

*32% *23% *18% *62%

Bresani et al. Food Tech. 18: 95, 1964.

TABLE 9

EFFECT OF COOKING TIME OF EXPERIMENTAL INCAPARINA (VM9) ON NITROGEN BALANCE IN YOUNG DOGS

COOKING TIME MIN	NITROGEN BALANCE % OF NITROGEN INTAKE*
0	17.5
8	16.2
16	16.4
24	16.3
0	13.6

* Nitrogen intake: 844-865 mg/kg/day.
Nitrogen absorption: 71.2%

Bressani et al. Food Tech. 18: 95, 1964.

TABLE 10

VITAMIN A RECOVERY IN QUALITY CONTROL AND UPON COOKING

SAMPLE	VITAMIN A RECOVERY (%)
FROM QUALITY CONTROL	95.5
COOKED (30 MIN)	76.7

TABLE 11

QUALITY CONTROL SCHEME

Production	No. of samples
10 MT	1
11-24 MT	2
25-49 MT	3
Each additional 25 MT	1 additional

Samples taken at production site or market place

Chemical analyses:moisture - protein - fat
fiber, ash, and minerals, vitamin B_2, vitamin A, free gossypol (only in foods with CSF), available lysine, trypsin inhibitors (SBF)

Microbiological analyses:total bacterial count and *E. coli*

Biological assays:PER or NPR occasionally or when requested

HIGH PROTEIN QUALITY VEGETABLE MIXTURES FOR HUMAN FEEDING

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As early as 1950, a research program on developing high quality vegetable multi-purpose foods was established at **INCAP** with the objective to support the fight against protein calorie malnutrition, and other nutritional deficiencies in Central America.

The food concept established at the time included the following characteristics: it had to be presented as a flour; it had to be consumed according to dietary habits and practices of the population; it had to be formulated from locally-available ingredients; it had to have a corn flavor; it had to be free of antiphysiological factors; it had to be supplemented with B vitamins and Vitamin A and iron; it had to be stable and have an acceptable shelf life upon storage and it had to be cooked for consumption.

Many options were developed and up to the present time, four are in commercial production. Two of them **Incaparina** and **Bienestarina**, have been licensed by **INCAP**, and the other two, **Vitatol** and **Innovarina**, are produced by the own initiative of the industry which manufactures **Incaparina**. Total production for all is close to 500,000 MT/m with **Incaparina** taking around 70% of the market, since the other three products are relatively new entries. The main protein source in **Incaparina** is human grade cottonseed flour (CSF) while **Vitatol** contains half of the main protein source as CSF and the other half as soybean flour (SBF). The other two foods contain SBF as the main protein source. The other main ingredient in all foods is degermed corn flour.

The vitamin and mineral supplements are added as a premix to the blends of the main ingredients which have been ground so that the largest percentage passes 120 mesh. All mixtures contain from 0.005 to 0.010% of BHO, BHT and TBHQ as antioxidants. The

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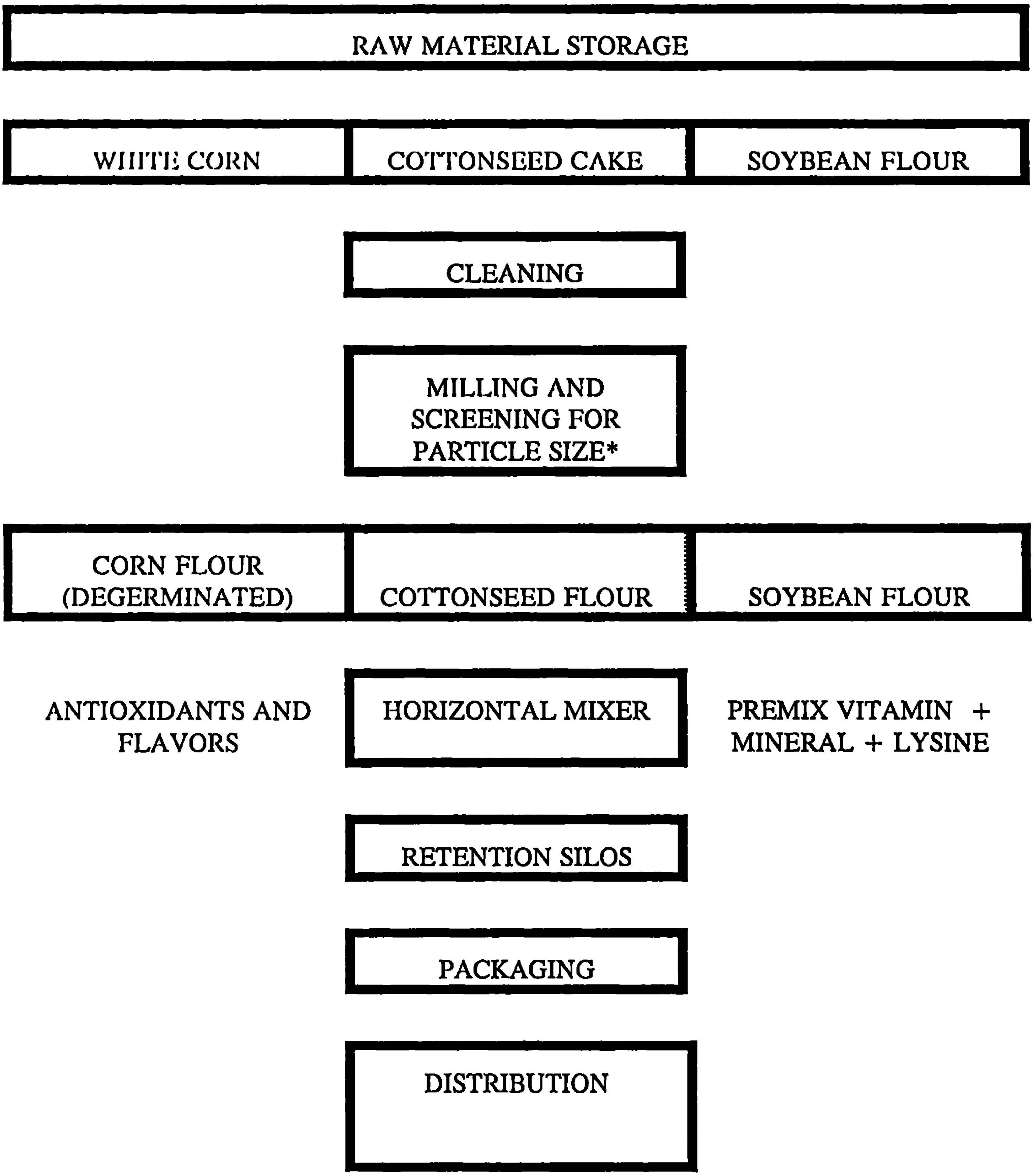
FIGURE 1
FLOW DIAGRAM FOR MANUFACTURE OF INCAPARINA AND OTHER HIGH QUALITY PROTEIN FOODS



* over 100 mesh

products are marketed in one pound or 75 g plastic bags, which have a nutritional label on a per 100 g basis, on a 20 g basis and its contribution to the RDA for the micronutrients. These are 27-37% for vitamin A, 15-30% for B1, 15-24% for B2, 15 to 22% for niacin, 5-10% for calcium and 20-36% for iron. The protein quality of these foods as tested in children varies from a biological value of 66 to 82%, with true protein digestibility of 80-92%. Cooking Incaparina for up to 30 minutes decreases the levels of B1, B2 and of lysine, if this is added. Small decreases around 23% in vitamin A have been obtained upon cooking. No change has been observed in protein quality.

Commercial firms wishing to obtain a license from INCAP to manufacture these foods or wish the backing of INCAP printed in the label must satisfy a number of requirements which include quality control activities payed by the manufacturer on a production basis. The quality control includes chemical and microbiological analysis and biological testing when requested. Although problems in nutrient content have been found, the most common problem is that of microbiological quality.

On the basis of the monthly sales, and on the amounts recommended for consumption the blends are reaching about 16% 0-4 year old children, assuming they are the only consumers. Their impact on reducing vitamin A deficiency has not been evaluated in field studies. Since these foods are consumed with sugar mixed in a ratio of about 3/7, the vitamin A intake is higher since sugar is fortified with this nutrient in Guatemala. Iron bioavailability has not been established and it could be an activity of interest because of the presence in these foods of substances which could reduce the bioavailability of this nutrient. Likewise, it would be desirable to test the stability of vitaminA and iron upon storage and increase the number of observations upon cooking and of other kinds of processing.