DEVELOPMENT AND EVALUATION OF A LOW-COST AMARANTH *(Amaranthus cruentus)* CONTAINING FOOD FOR PRESCHOOL CHILDREN

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SUMMARY

A powdered blend for feeding preschool children was prepared from whole amaranth *(Amaranthus cruentus)* seeds, pearled oats, soybeans, sucrose and vegetable oil. The blend was similar in proximal chemical analysis and total caloric content, and identical in calorie distribution and vitamin and mineral patterns to a soy/oats infant formula previously developed. The amaranth blend equalled the FAO/WHO 1973 children's pattern in tryptophan and exceeded this pattern, as well as the soy/oats formula in all other essential amino acids; it reflected higher PER than casein and the soy/oats formula.

In feeding trials with children 1- 3 years of age, no significant difference in weight gain was observed when either product was fed. The anticipated cost of the amaranth blend is 6%/o lower than that of the soy/oats formula.

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INTRODUCTION

Amaranth seed is a traditional food which has been known in Mexico since Aztec times, and which has been increasingly cultivated in that country as a possible means for improving diets. Although it possesses a high-quality protein, this product is considerably cheaper than other similar vegetable sources including soybeans; indeed, its price nearly equals that of corn (1).

As far as is known, use of amaranth seed flour in child feeding has not occurred up to now, either in clinical trials or through industrial production. In a previous work, Sánchez-Marroquín *et al.* (2) evaluated whole amaranth *(Amaranthus cruentus)* seed flour, either alone or in blends with oats and wheat, as a possible component for infant formulas. They found the 50/50 and 40/60 oats/amaranth blends to be particularly suitable for this purpose.

The development, evaluation and industrial production of a low-cost soy/oats infant formula was described in a previous paper (3). This product has been industrially produced and successfully marketed in Mexico since 1979 (4, 5). Due to its low cost and high nutritive quality, the soy/oats formula has also been successfully utilized by a number of pediatricians as a food for malnourished preschool children (6).

The purpose of this work, therefore, was to develop and evaluate a food for preschool children using the 50/50 oats/whole amaranth blend in combination with soybeans, which would be similar to the soy/oats formula previously mentioned.

Preschool children (ages 1 - 3) were selected for this study because in Mexico they constitute the most malnourished group of the early childhood years. Younger children are usually still being breast-fed, while older children command more attention and hence, obtain more food from their parents (7).

MATERIAL AND METHODS

Development and Processing of the Amaranth/Soy/Oats Blend

Whole amaranth seeds utilized in this research were from a selected line or RRC-1011 *Amaranthus cruentus* (S1-S-1011, Rodale Research Center, Kutztown, PA, USA). The ingredient composition for the amaranth/soy/oats blend was calculated, considering the proximate chemical analyses and amino acid patterns of the raw materials (2, 8), on the following bases: 1) optimum amino acid complementation between the raw materials (amaranth, soy, oats) proteins; 2) proximate chemical composition, calorie distribution and vitamin and mineral patterns to equal those of the soy/oats formula (3).

Basic ingredients utilized in preparing the amaranth/soy/oats blend were whole amaranth seeds, cracked dehulled soybeans, and pearled oat groats, proximate chemical compositions for which are reported in Table 1. Other ingredients used were sucrose, vegetable (safflower) oil, tricalcium phosphate (reagent grade), salt, vitamins, minerals and artificial (cream) flavoring. The amount of each vitamin and mineral required was

TABLE 1

PROXIMATE CHEMICAL ANALYSIS OF BASIC INGREDIENTS FOR PREPARING THE AMARANTH/SOY/OATS FORMULA

Substance	Pearled oat groats[a]	Cracked dehulled soybeans[b]	Whole amaranth seeds[c]
Moisture	8.3		8.8
Protein	13.2		17.0
Ash	1.9		3.1
Fat	7.4		7.4
Crude fiber	1.2		13.1
Carbohydrate	68.0		50.6

a From Sánchez-Marroquín *et al.* (2).
b From Vega (See ref. 23).
c From Sánchez-Marroquín *et al.* (2).

calculated as the difference between levels contained in the soy/oats formula (3) and those calculated to be contained in the amaranth/soy/oats blend, from values reported in the literature for each ingredient (9).

After the ingredient composition had been calculated, the amaranth/soy/oats blend was prepared in the industrial plant of "Productos Alimenticios Delicias, S. A. de C. V." located in the Zona Industrial, Ciudad Delicias, Chihuahua, Mexico (4, 10), applying a process identical to that employed in the production of the soy/oats formula (3). Briefly, this process was as follows. Soybeans were cleaned and dehulled, after which they were mixed in the desired proportion with whole amaranth seeds and pearled oats. The amaranth/soy/oats mixture was cooked by extrusion in a Brady Model 206 extruder (Brady Extruder Corp., Torrance, CA, USA) at 160°C for approximately 90 sec. The product leaving the extruder was cooled and discharged into a 1,000-liter horizontal mixer, to which the required amounts of sucrose, vegetable oil and a premix (prepared in a 100-liter rhomboidal mixer) of vitamins, minerals and artificial flavor, were added. After thorough mixing of the material in the large mixer, it was finely ground in an Alpine Model A-400W pin mill (Alpine American Corp., Natick, MA, USA), after which it was packed in 25-kilo polyethylene bags. Rations to be utilized in the feeding trials were taken from these bags and prepared as noted elsewhere.

Chemical and Nutritional Evaluation of the Amaranth/Soy/Oats Blend

The proximate chemical analysis of the amaranth/soy/oats blend was determined according to the AOAC methods (11), while its calorie distribution pattern was calculated from the results obtained. The amino acid analysis of the formula was obtained according to the methods of Spackman *et al.* (12), and also of Kohler and Palter (13).

Protein efficiency ratio (PER) was determined by the methods of Munro and Allison (14), and that of Miller (15). These were as follows. Five male weanling rats, 22 - 23 days old and weighing 27 - 28 g were used in each of two determinations, one with the amaranth/soy/oats blend, and the other using casein as a reference protein. Before initiation of feeding, all animals were standardized by starving for 24 hr. Protein levels in both diets were adjusted to 10%, and the feeding period was 28 days. Rat weights and amount of food consumed by each rat were recorded daily along the duration of the test period. All diets were analyzed by the Kjeldahl method (11) in order to determine the protein and nitrogen contents. Average PER values, with their corresponding standard deviations, were calculated for each group of animals fed the same diet.

Trypsin inhibitor activity of the amaranth/soy/oats blend was also determined (15).

Microbiological Assay

Total plate count, coliform bacteria as well as yeasts and molds were determined (17) to demonstrate the wholesomeness of the product.

Feeding Trials

Feeding trials with the amaranth/soy/oats formula were conducted with 13 malnourished preschool children (ages 1 - 3 years) from a low-income section of Chihuahua City, Mexico, who were supervised by a pediatrician. Children were medically examined before beginning the trials, and the following information recorded: age, weight, height, and clinical history. Each child was submitted to the following feeding regimens, in sequence, each lasting four weeks (28 days), with weekly-weight measurements and recordings: 1) a stabilization period with the amaranth/soy/oats blend to allow those children who were underweight from malnutrition, to attain normal weight; 2) a test period with the amaranth/soy/oats blend; 3) a test period with the soy/oats formula (3); and 4) a final control period during which children were no longer fed any formula, but were allowed to consume their usual diets. Although the researchers knew which product was being used in any given period, mothers did not; this was, therefore, a single-blind study.

Mothers were supplied weekly with daily rations of the product being utilized, and were taught to prepare it at home as a gruel ("atole"). The daily ration to be consumed by each child was calculated to supply 80% of the child's protein requirement (2.0 g/kg/day for children of the range utilized in this study) (9). The exact amount of amaranth/soy/oats blend and soy/oats formula fed to each child is given in Table 2. Daily rations were preweighed and packed in polyethylene bags; they were then distributed to mothers who were instructed to insure that their children consumed one ration each day. Mothers were not checked daily to ascertain that they had fulfilled the latter commitment; however, those participating in the study were selected on the basis of their motivation and interest in the research, so that it is fairly certain that the instructions were followed. Besides the amaranth/soy/oats blend or soy/oats formula, mothers were told to feed their children their usual diet, *ad libitum*.

TABLE 2

DATA ON CHILDREN WHO PARTICIPATED IN FEEDING TRIALS

Child No.	Initial age Years	Months	Initial weight, kg	Initial height, cm	Amount amaranth/soy/oats blend fed, g/day[a]	Amount soy/oats formula fed, g/day[a]
1	2	3	10.0	79	116	118
2	1	0	7.0	67	81	83
3	2	6	10.0	82	116	118
4	2	1	10.0	78	116	118
5	2	1	9.0	74	104	106
6	2	0	10.0	75	116	118
7	2	5	8.0	73	93	94
8	2	11	11.0	83	128	130
9	2	6	11.0	85	128	130
10	2	10	10.5	78	122	124
11	2	2	9.5	87	110	112
12	3	2	12.0	92	139	142
13	1	5	9.0	77	104	106

a Amount of amaranth/soy/oats blend and soy/oats formula fed was calculated so as to provide the equivalent of 2.0 g/kg/day of protein, which is 80% of the protein requirement for children of age range utilized in this study, according to Hernandez *et al.* (9).

Weight gains resulting from each four-week test period (28 days) (i.e., amaranth/soy/oats blend, soy/oats formula and control) were calculated, expressed as per cent gains with respect to initial weight, and recorded. Results were then analyzed by analysis of variance and the Student's "t"-test techniques (18).

Cost Evaluation

Because of currency fluctuations, cost of the amaranth/soy/oats blend was calculated relative to the cost of soybeans (= 100), and compared with that of the soy/oats formula (3) expressed on the same basis. Ingredient costs are current market prices in the Chihuahua, Delicias, Mexico area.

RESULTS AND DISCUSSION

Development and Processing of the Formula

Table 3 reports the ingredient composition for both the amaranth/soy/oats blend and the soy/oats formula (3). Unlike the latter, the

TABLE 3

COMPOSITION OF THE AMARANTH/SOY/OATS BLEND AND THE SOY/OATS FORMULA

Ingredient	Amaranth/soy/oats blend, %	Soy/oats formula[a], %
Whole amaranth seeds	28.8	—
Dehulled soybeans	16.1	32.1
Pearled oats	28.7	25.6
Sucrose	18.3	34.1
Vegetable oil	5.9	5.8
Tricalcium phosphate	1.2	1.2
Sodium chloride	0.5	0.5
DL-methionine	—	0.2
Vitamins and minerals.	0.4	0.4
Flavoring	0.1	0.1

a Del Valle *et al.* (3).

amaranth blend did not require addition of methionine because whole amaranth protein, which is high in sulfur-containing amino acids (2), made up for all deficiencies of these substances in the other two components. Table 3 also shows that the amaranth blend was lower in soybeans and sucrose than the soy/oats formula (16.1% vs 25.6% and 18.3% vs 34.1%, respectively). Both products, however, were similar in their contents of pearled oats (28.7% vs 25.6%).

The calculated vitamin and mineral contents of the amaranth/soy/oats blend are presented in Table 4. As noted previously, these contents were made identical to those of the soy/oats formula (3).

No processing or manufacturing difficulties were experienced when applying the process developed for the soy/oats formula (3) to the product containing amaranth.

Chemical and Nutritional Evaluation

As Table 5 shows, the amaranth/soy/oats blend and the soy/oats formula closely resembled each other in protein (17.2% vs 17.0%), fat (15.2% vs 14.5%) and carbohydrate (61.1% vs 61.1%). The calorie distribution patterns for the two products were identical (15%, 30% and 55% of total calories in protein, fat and carbohydrate, respectively, as observed in Table 6), while the total calories per 100 g product were very similar (450 vs 443, respectively). Results in Tables 5 and 6 are not surprising, since the amaranth/soy/oats blend was tailored to equal the soy/oats formula in proximate chemical analysis and calorie distribution pattern.

Table 7 compares the amino acid pattern of the amaranth blend with that of the soy/oats formula and the FAO/WHO 1973 (19) pattern for

TABLE 4

VITAMIN AND MINERAL CONTENT OF THE AMARANTH/SOY/OATS BLEND

Substance	Total content per 100 g blend
Vitamin A	1,800 I. U.
Thiamine	0.45 mg
Riboflavin	0.70 mg
Ascorbic acid	35 mg
Vitamin D	330 I. U.
Folic acid	25 mcg
Pantothenic acid	2 mg
Pyridoxine	0.30 mg
Niacin	5 mg
Vitamin E	4 I. U.
Vitamin B_{12}	1 mcg
Copper	0.30 mg
Calcium	425 mg
Phosphorus	345 mg
Iron	12.6 mg
Zinc	3 mg
Iodine	53.4 mcg
Potassium	526 mg
Chloride	367 mg
Sodium	115 mg
Magnesium	50 mg

TABLE 5

PROXIMAL ANALYSIS OF AMARANTH/SOY/OATS BLEND AND SOY/OATS FORMULA

Substance	Amaranth/soy/oats blend, o/o	Soy/oats formula[a], o/o
Protein[b]	17.2	17.0
Fat	15.2	14.5
Carbohydrate	61.1	61.1
Crude fiber	1.9	1.0
Ash	2.6	2.2
Moisture	1.7	4.0

a Del Valle *et al.* (3).
b N x 6.25.

TABLE 6

CALORIE DISTRIBUTION FOR AMARANTH/SOY/OATS BLEND AND SOY/OATS FORMULA

Product	Percent of calories[a] in			Total calories per 100 g
	Protein	Fat	Carbohydrate	
Amaranth/soy/oats formula	15	30	55	450
Soy/oats formula[b]	15	30	55	443

a Calculated from proximal analysis, Table 5.
b Del Valle *et al.* (3).

TABLE 7

AMINO ACID ANALYSIS OF AMARANTH/SOY/OATS BLEND

Amino acid	Grams amino acid per 100 g protein		
	Amaranth/soy/oats blend	Soy/oats formula[a]	FAO/WHO (1973) children's pattern
Isoleucine	4.8	4.2	4.0
Leucine	8.2	7.6	7.0
Lysine	6.3	5.6	5.5
Total sulfur amino acids	4.0	4.2	3.5
Total aromatic amino acids	9.8	8.4	6.0
Threonine	4.1	3.5	4.0
Tryptophan	1.0	1.3	1.0
Valine	5.7	5.5	5.0

a Del Valle *et al.* (3).

children. The amaranth blend pattern exceeded both of the other two patterns in all essential amino acids, except tryptophan, in some cases by appreciable margins. Quite striking were the values observed in the amaranth blend for lysine, threonine and valine (6.3, 4.1 and 5.7 g/100 g protein, respectively). In the case of tryptophan, the amaranth product equalled the FAO/WHO (19) pattern.

Results of the PER determinations are shown in Table 8, which includes corrected PER (casein PER = 2.5) values for the soy/oats formula (3). Most interestingly, the amaranth blend (PER = 2.9) exceeded the soy/oats formula (PER = 2.4) and casein (PER = 2.5) by appreciable margins. These results are consistent with the excellent amino acid pattern reported for the amaranth blend in Table 7. As noted previously, the latter product equalled the FAO/WHO (19) pattern in tryptophan, and exceeded both the soy/oats formula and the FAO/WHO (19) pattern in all other amino acids.

TABLE 8

PROTEIN EFFICIENCY RATIO (PER) AND NET PROTEIN UTILIZATION (NPU) VALUES FOR AMARANTH/SOY/OATS BLEND AND SOY/OATS FORMULA

System	Absolute PER	Corrected PER	Absolute NPU	Relative NPU
Amaranth/soy/oats blend	3.7 ± 0.4	2.9	34.8 ± 10.6	111
Casein	3.2 ± 0.3	2.5	31.3 ± 14.0	100
Soy/oats formula[a]		2.4		87

a Del Valle *et al.* (3).

Trypsin inhibitor activity in the amaranth/soy/oats blend was found to be 5.7 TIU (trypsin inhibitor units) per milligram, which is approximately half that of the soy/oats formula (11.5 TIU/mg) (3). These levels were not considered to be nutritionally significant (20, 21).

Microbiological Assay

The product containing amaranth, as Table 9 shows, was considerably lower in total plate count (50 vs 5,000 per gram) and appreciably lower in yeasts and molds (20 vs 50 per gram) than the soy/oats formula (3). Neither product contained coliform bacteria. Both products fell within the limits established by the Mexican Government for the microbiological assay of infant formulas (10,000 per gram for total plate count and 100 per gram for yeasts and molds (22).

Feeding Trials

Height, weight and age data for children participating in the feeding trials are listed in Table 2, which also includes the amounts of amaranth/soy/oats blend and soy/oats formula fed to each child per day during the trials. Results of the feeding trials are summarized in Table 10, in the form of per cent weight gained (with respect to initial weight) when the different products were fed, as well as during the control period when children were allowed to consume their usual diets and no blend or formula was fed at all. Missing data in Table 10 (i.e., per cent weight gains for children 9 through 13 with all formulated products, and also for children 6 through 8 with the soy/oats formula) refer to subjects who, for different reasons (illness, moving to another location, or mother's loss of interest) were removed from the study.

Table 11, which details results of analysis of variance calculations performed on the data of Table 10, clearly shows that a significant difference did exist between type of feeding regimen ($p < 0.05$) but not, as might have been expected, between children. Application of "t"-tests to

TABLE 9

MICROBIOLOGICAL ASSAY OF AMARANTH/SOY/OATS BLEND AND SOY/OATS FORMULA

Organism	Amaranth/soy/oats blend	Soy/oats formula[a]	Limits by Mex. Dept. Public Health[b]
Total plate count	50	5,000	10,000
Coliforms	Negative	Negative	Negative
Yeasts and molds	20	50	100

a Del Valle *et al.* (3).
b Mex. Dept. Public Health (22).

TABLE 10

WEIGHT GAIN DATA FOR FEEDING TESTS WITH CHILDREN

Child No.	Per cent weight gain in 28 days[a]			
	Amaranth/soy/oats blend, stabilization period	Amaranth/soy/oats blend, test period	Soy/oats formula[b] test period	Control: no formula utilized; children fed usual diet
1	10.0	0.0	0.0	5.0
2	14.3	0.0	14.3	0.0
3	5.0	5.0	0.0	0.0
4	10.0	0.0	5.0	0.0
5	11.1	5.6	0.0	0.0
6	0.0	5.0	—	-10.0
7	0.0	12.5	—	0.0
8	10.5	4.8	—	4.5
9	—[c]	—	—	0.0
10	—	—	—	4.8
11	—	—	—	0.0
12	—	—	—	0.0
13	—	—	—	0.0
Average	7.6	4.1	3.9	0.3

a Per cent weight gain in 28 days = weight increase during each 28-day test period, divided by initial weight and multiplied by 100.
b Del Valle *et al.* (3).
c No data.

individual average weight gain values between feeding regimens revealed that no significant difference existed between the products with and without amaranth during the test periods (4.1o/o vs 3.9o/o, respectively)

TABLE 11

RESULTS OF ANALYSIS OF VARIANCE FOR WEIGHT GAIN DATA*

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value, experimental
Between feeding regimens	269.45	3	89.62	3.61[a]
Between children	198.93	12	16.51	0.67[b]
Random or residual	447.62	18	24.87	—
Total	916.00	33	—	—

* See Table 8.
a Significant at $p < 0.05$ level.
b Not significant.

but that significantly greater weight gains were obtained ($p < 0.01$) when either product was fed (4.1o/o vs 3.9o/o) than when no product was fed at all (control period, 0.3o/o).

Interestingly, a significant difference ($p < 0.01$) was obtained in weight gain values between the stabilization and test periods when the formula containing amaranth was utilized: values were greater in the former than in the latter (7.6o/o vs 4.1o/o). This difference may best be explained by noting that children entering the feeding trials were fairly underweight due to malnutrition; weight gains obtained during the stabilization period, therefore, were probably due more to recovery from malnutrition than to normal growth. After the children had recovered during the stabilization period, weight gains obtained during the test period were then probably due to normal growth. This was, indeed, the reason for including the stabilization period prior to the test periods.

An explanation of why analysis of variance calculations were performed utilizing weight gain data for all children reported in Table 10 —including those who did not participate in all four feeding trials— and not only for those who did participate in all trials (children Nos. 1 through 5) is as follows: 1) valid analysis of variance calculations may be performed, even if the number of subjects per dietary regimen is different (18); and 2) utilizing a greater number of subjects gives a better estimate of experimental error, with more degrees of freedom; as a result, significant effects are more easily detected by the F-test (18).

Cost Evaluation

As Table 12 reveals, the anticipated cost of the amaranth/soy/oats blend (155.74) was approximately 94o/o that of the soy/oats formula.

TABLE 12

RELATIVE COST CALCULATION FOR AMARANTH/SOY/OATS BLEND AND SOY/OATS FORMULA

Ingredient or operation	Relative cost per kilo of ingredient[a]	Relative cost per kilo of amaranth/soy/oats blend	Relative cost per kilo of soy/oats formula[b]
Whole soybeans	100.00	—	—
Cracked dehulled soybeans	118.26[c]	19.51	37.96
Amaranth seed[d]	60.23	17.71	—
Pearled oats	147.73	34.18	29.86
Sugar	88.64	16.67	30.23
Vegetable oil	293.18	17.59	17.00
Mixing of raw materials	4.14[c]	4.14	4.14
Extrusion	14.95[c]	14.95	14.95
Grinding	30.99[c]	30.99	30.99
Total		155.74	165.13

a Soybean, oats, sugar and vegetable oil prices from Vega (23).
b Del Valle *et al.* (3).
c Value calculated from Ponce (24).
d Amaranth seed prices from Sánchez-Marroquín (2).

CONCLUSIONS

A food for preschool children, which utilizes whole amaranth *(Amaranthus cruentus)* seed, pearled oats and soybeans as proteinaceous raw materials, was developed. The product contained lower proportions of soybeans and sucrose, but was similar to a soy/oats formula previously developed in its proximal chemical analysis, calorie distribution, as well as vitamin and mineral content; it exceeded the soy/oats formula in all essential amino acids except tryptophan. The product containing amaranth reflected a higher corrected PER than the soy/oats formula. In feeding trials carried out in children 1 - 3 years of age, no significant difference in weight gain was observed between test periods when children were fed the amaranth blend vs the soy/oats formula, although both products produced significantly greater weight gains than when no product was fed at all, and children were allowed to consume their usual diets. The anticipated cost of the amaranth blend was approximately 6% less than that of the soy/oats formula.

The amaranth product reflected a number of important advantages over the soy/oats formula: 1) its cost was somewhat lower; 2) it required a lower proportion of soybeans, which meant that a more expensive imported commodity would be replaced by a domestically grown product; and 3) a heretofore underutilized raw material of high nutritional quality (amaranth) could be exploited.

RESUMEN

DESARROLLO Y EVALUACION DE UN ALIMENTO DE BAJO COSTO ELABORADO CON AMARANTO *(Amaranthus cruentus)*, PARA NIÑOS PREESCOLARES

Se elaboró una mezcla en polvo para la alimentación de niños preescolares, partiendo de semilla integral de amaranto *(Amaranthus cruentus)*, avena perlada, frijol de soya, sacarosa y aceite vegetal. Se encontró que la mezcla era semejante en análisis químico proximal y contenido calórico total, e idéntica en patrón de distribución de calorías y contenido de vitaminas y minerales, a una fórmula infantil de soya y avena previamente desarrollada. La mezcla de amaranto igualó al patrón FAO/OMS 1973 para niños en su contenido de triptofano, y excedió a este patrón y a la fórmula de soya y avena en todos los otros aminoácidos esenciales; la misma mezcla reflejó un PER corregido mayor que los de la caseína, y la fórmula de soya y avena.

En pruebas de alimentación con niños de 1 - 3 años de edad, no se detectó diferencia significativa en aumento de peso, obtenido por los dos productos. El costo anticipado de la mezcla de amaranto es 6% menor que el de la fórmula de soya y avena.

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