

# INDUSTRIAL CORN FLOUR ENRICHMENT WITH WHOLE AMARANTH FLOUR AND MILLING FRACTIONS IN CORN-BASED PRODUCTS<sup>1</sup>

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## SUMMARY

Whole flour and milling fractions of raw amaranth seeds were used in 90:10, 80:20 and 50:50 mixtures with industrialized corn flour (MINSA) to prepare tortillas and arepas, basic nutritional foods in several Latin American countries. The three corn-amaranth mixtures showed a good protein and fat content as well as amino acid profile, and presented adequate physical characteristics for making tortillas.

Amaranth whole flour and commercial corn flour mixtures in the proportion of 80:20 and 50:50 were found suitable for the preparation of arepas. Protein and fat content were substantially improved, with no changes in organoleptic characteristics.

The Mexican type of *Amaranthus cruentus*, selected due to its availability and bromatologic properties, yielded products of excellent nutritional quality, according to their amino acid content and protein efficiency ratio (PER). The protein-rich (1R) and starchy (2-R) fractions obtained by air classification, also yielded good results when substituting amaranth flour. The afore-mentioned flours and air-classified fractions of the 50:50 mixtures proved to be adequate in gruel preparations when used in 1:8 and 1:12 dilutions, as they improved their organoleptic characteristics. Flakes and extrudates were also used, yielding products with a 13.3 – 15% protein content, 1.7-3.7% fat, and 65.2-74.2% carbohydrates. In addition, extrudates were utilized to prepare snacks of better nutritional quality than existing similar commercial products.

Improvement of the tortilla's mineral and fatty acid contents was achieved in every case. Enrichment of this product with whole amaranth flour is, therefore, recommendable for use in programs aimed at improving the nutritional status of the population.

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Manuscrito modificado recibido: 27-5-85.

- 1 Financial support for this research was kindly provided by the U.S. National Academy of Sciences/National Research Council, through a grant-in-aid from the U.S. Agency for International Development.
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## INTRODUCTION

In Central America, Mexico, Venezuela and Colombia, as well as in other countries from the so-called Third World, several products basically prepared from corn, are consumed as a basic staple. Thus, interest in large-scale production of commercial corn flours (dehydrated corn dough) and other similar types, has increased. At the same time, a great number of methods have been amply studied for the enrichment of corn dough with other flours, in order to increase its nutritional value. This fact was recently discussed by Feria-Morales and Pangborn (1) in the case of tortillas, and by Salazar de Buckle, in regard to arepas (2). This goal, however, is not always achieved, as the following observations have been made. First, the organoleptic quality and characteristics of the final products are indeed inferior to those of traditional products. Second, their price is prohibitive for the marginal populations for whom they are intended, or else, due to a number of reasons, they are not accepted by the potential consumers. On the other hand, concomitantly there exist domestic technologies, such as in the case of the Mexican tortilla, as well as in other Central American countries, whose traditional processing has been cited as an example by Bender and Bender (3). One of these technologies, designated commercial "nixtamalization" (alkaline grain treatment and ulterior dough dehydration), has been carried out in large scale in Mexico, Costa Rica and in the United States of America, since it allows easy and fast tortilla preparation, both mechanically in commercial tortillerías, as well as at the domestic level. Likewise, dehydrated flours for domestic or industrial products made from arepas are now regularly obtained in Colombia and Venezuela for greater popular consumption.

Some of these flours were used in the research work herein discussed, to experimentally produce these basic Latin American foods. Other corn-based products from industrially manufactured flours, in combination with whole amaranth and fractions flour mixtures, have also been prepared as described in previous papers (4, 5).

## MATERIALS AND METHODS

The amaranth seeds belonged to the Mexican type of *A. cruentus* and the Mercado Aztec types of *A. hypochondriacus*, according to the terminology of the Rodale Research Center (6). The raw seeds were subjected to grinding in a CeCoCo mill with a No. 40 mesh, so as to obtain whole flour, and to a Simpactor mill (with a 60 mesh) – in combination with a Raymond air separator – for the obtention of two fractions: the first, of high-protein content, which we have labelled 1-R (35% yield), and the other, of starchy nature, the 2-R (65% yield), as indicated elsewhere (7-12).

The amaranth flour used in every case was prepared with raw seeds previously cleaned in a rice cleaner. Flours from amaranth seeds which had been processed through alkaline treatment, as well as those prepared with popped amaranth seeds were also tested through the use of a popper designed by the Rodale Research Center.

Corn and amaranth flours, and the protein and starchy amaranth

milling fractions in 90:10, 80:20 and 50:50 proportions were used for the preparation of tortillas. Corn flour was treated according to the traditional alkaline Mexican procedure (8, 9), or by using the commercial dehydrated flour, Minsa, which is industrially prepared by CONASUPO, National Company of Popular Subsistences of the Mexican Government. The final stage for the preparation of tortillas was carried out in a Celorio device, domestic kind, while arepas were prepared manually.

In the case of the latter (arepas), only three commercial Venezuelan flours were employed. The "Amarilla" type was finally selected, and arepas were prepared according to the procedure indicated by the producing company. The process, however, was adjusted to those described by South American researchers (2, 10). The difference between the procedure used for the preparation of arepas and that accustomed for tortillas, is that the first includes previous separation by mechanical maceration of the corn into germ and endosperm, with elimination of the former. Due to this reason, and because of the avoidance of the calcium hydroxide treatment, the resulting product proves to be inferior in nutritional quality with respect to the tortilla (3, 11). Tortillas and arepas were subjected to an ulterior thermic treatment to "cook" them on both sides, and to improve their taste, by using a metallic sheet electrically heated.

The mixtures of corn flour with either amaranth flour or its fractions (1-R and 2-R) were selected to prepare other products, as done in previous works (4, 7, 12).

Flakes preparation required the use of a Buflovack rotatory drum, and that of the extrudates, a Wenger extruder, X-5 Model, as described in other papers (7, 12, 13). The operation conditions are indicated in the following section (See Tables 12 and 13).

Both staples and final products were subjected to a proximate analysis, according to the usual methods (14); carbohydrates were calculated by difference.

Amino acid determinations and biological tests to determine the protein efficiency ratio (PER), were carried out as described in other articles (4, 7, 12), as well as the rheologic studies (12, 15) and subjective sensory assays (12).

Mineral determination was done by atomic absorption, and that of fatty acids, by gas chromatography. These determinations were carried out according to the Official Methods of Analysis of the AOAC (14).

Physical characteristics of the tortilla prepared with the above-mentioned corn-amaranth mixtures, were determined according to the usual unpublished methods of CONASUPO. Chemical analyses were carried out following the procedures of the AOAC (14).

## RESULTS AND DISCUSSION

Table 1 shows the proximate analysis of the "masa" (corn dough), Minsa and "Amarilla" corn flours, as well as the whole amaranth flour and 1-R and 2-R fractions of the types of amaranth used. The Mercado type is superior in protein content to the Aztec type and the Mexican type of

TABLE 1  
 PROXIMATE ANALYSIS OF STARTING MATERIALS  
 (expressed in %)o

Flour	Moisture	Protein	Fiber	Fat	Ash	Carbohydrates
<b>Corn:</b>						
Masa (corn dough)	10.7	8.6	0.9	2.8	1.9	74.1
Minsa (Mexico)	10.8	8.6	2.3	2.3	1.7	74.3
"Amarilla" (Venezuela)	10.6	7.5	0.6	1.9	1.3	78.1
<b>Amaranth:</b>						
<i>A. hypochondriacus</i>						
Mercado (whole flour)	10.1	17.8	5.1	3.2	2.1	61.7
Mercado 1-R (fraction)	9.0	29.0	6.9	11.1	4.0	40.0
Mercado 2-R (fraction)	10.3	8.1	1.4	2.7	1.1	76.4
Aztec (whole flour)	7.4	15.1	5.9	5.1	3.1	63.4
<i>A. cruentus</i>						
Mexican (whole flour)	6.6	15.3	6.2	6.7	2.9	57.9

*A. cruentus*. Nevertheless, whole amaranth flour and 1-R and 2-R fractions pertaining to the Mexican type of *A. cruentus* were selected for the experiments on account of the availability of seeds, and because *A. hypochondriacus* had been previously studied for the same purpose, as already reported (4). Fraction 1-R has a 29% protein content, 11% fat, and only 40% carbohydrates.

The amylograph curves of the 80:20 mixture of Minsa flour and raw amaranth seeds in contrast to the 50:50 mixture used for the preparation of arepas, as well as the Minsa flour alone and commercial corn flour which did not undergo the nixtamalization process, are shown in Figure 1. As may be appreciated, their rheological behavior was similar to that observed by Ramírez-Velazquez (16). The data also reveal that gelatinization values did not approach a pasting peak, but instead reached a high degree of viscosity. Likewise, viscosity increased in the corn flour which underwent the lime-treatment process when compared to untreated corn flour. This was probably due to a calcium cross-linking which prevented starch granules and protein from swelling and collapsing (17). Also, the temperature for maximum viscosity between both corn flours has a difference of approximately 20°C.

In the 50:50 mixture, viscosity might be higher than 900 B.U. at a 1:8 dilution, but when compared to processing at intermediate moisture (26 to 30%) and constant temperature (90°C), a decrease in viscosity was observed in the experiments performed by Smith (18) and Smith *et al.* (19). It was also present in those assays conducted by Salazar de Buckle (2) in the case of processed corn, for the preparation of arepas. Extrusion processing applied in the preparation of arepas, as well as the characteristics of the flours do not depend only upon the degree of starch

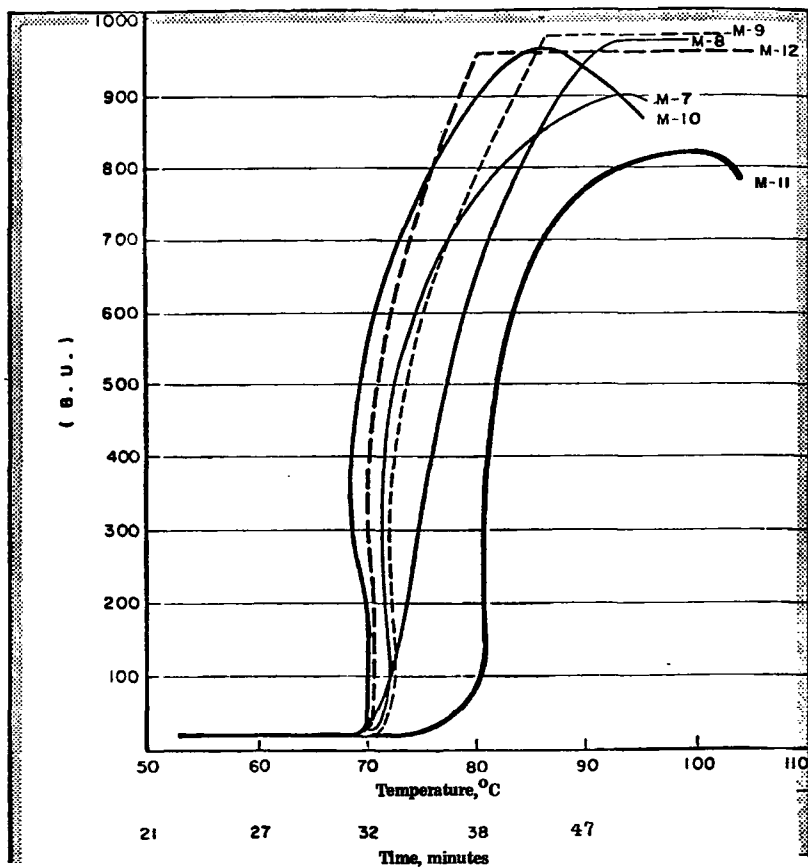


FIGURE 1

Amylograph curves of corn + amaranth mixtures. M-7, "Amarilla" + amaranth whole flour (50:50); M-8, Minsa + 1-R fraction (80:20); M-9, Minsa + 2-R fraction (80:20); M-10, fraction 2-R alone; M-11, corn flour; Minsa flour (lime-treated, dehydrated corn flour).

modification, but also on the type of modification, according to moisture content and temperature (19).

### *Tortillas and Arepas*

Table 2 presents the main data concerning preparation of tortillas when enriched with whole amaranth flour and air-classified fractions (*A. cruentus*, Mexican type), in contrast to the regular processing of Minsa flour. Results were acceptable in every case according to the evaluation methods of the Minsa firm. Table 3, however, shows that only the 90:10 mixtures prepared with whole amaranth flour or with 2-R fractions

TABLE 2

## PROCESSING DATA ON AMARANTH-ENRICHED TORTILLAS

Blends	Formula	Moisture o/o	Water absorption (lt/kg)	Dough yield (kg/kg)	Tortilla yield (kg/kg)	Granulometry yield, o/o	
						Mesh 60-80	Mesh 100
Minsa + amaranth whole flour	80:20	12.1	1.1	2.05	1.48	21-26	37
Minsa + amaranth whole flour	90:10	9.9	1.2	2.14	1.51	20-24	42
Minsa + amaranth 1-R	80:20	11.7	1.1	2.05	1.48	16-29	41
Minsa + amaranth 1-R	90:10	12.5	1.1	2.06	1.47	18-24	30
Minsa + amaranth 2-R	80:20	10.3	1.0	1.95	1.46	22-23	35
Minsa + amaranth 2-R	90:10	11.3	1.1	2.06	1.46	18-20	44
Minsa (blank)	100:0	10-11.3	1.2-1.25	2.1-2.18	1.47-1.50	25*	

\* The 30-60 and 80-100 blending, were ground to 25 mesh.

TABLE 3  
MAIN CHARACTERISTICS AND SELECTED FORMULAS OF AMARANTH-ENRICHED TORTILLA

Blends		Pliability ("correa")	Adhesiveness	Penetrometry	Color <sup>a</sup>	Flavor <sup>b</sup>	Protein o/o	Fat o/o	Selections
M <sup>c</sup> + AWF <sup>d</sup>	80:20	17	15	178	B	T	11.9	2.8	Second
	90:10	20	17	198	Cr	T	11.3	2.9	First
M <sup>c</sup> + Am 1-R	80:20	20	18	184	B	Sd	15.4	4.5	—
	90:10	21	18	186	B	Sd	12.3	3.6	—
M <sup>c</sup> + Am 2-R	80:20	12	11	176	Cr	T	9.1	2.2	Third
	90:10	10	11	145	Cr	T	9.1	2.5	Third
Commercial tortilla (blank)		12-14	13-17	192-200	Y	T	9.5-10.6	2.9	—

<sup>a</sup>B = Brownish; Cr = cream; Y = yellow.

<sup>b</sup>Sd = Slightly different; T = tasteless.

<sup>c</sup>Minsa = Lime-treated corn flour.

<sup>d</sup>AWF = Amaranth whole flour prepared from raw seeds.

display the required characteristics for industrial regulations. Tortillas made with the 1-R fraction have sometimes a slightly different taste from that of traditional tortillas, but this difference disappears when amaranth previously undergoes the nixtamalization process, or when the formula is modified to 95:5.

The main chemical and physical analyses of arepas, depicted in Table 4, indicate that products made with mixtures of commercial corn flour (Minsa or Venezuelan) and whole amaranth flour, are superior in protein and fat content than the corn "masa" and commercial flours (Table 1). Color, texture, shelf life and taste properties, in contrast, are within the traditional values of the Venezuelan arepas (2, 10, 11, 18).

Addition of the 1-R protein fraction to corn flour yields better results in regard to composition; yet, the afore-mentioned slight difference in taste, prevails.

Likewise, substitution of amaranth flour by the protein of the 1-R fraction in the 80:20 formula for the preparation of tortillas and arepas, represents a great advantage; it increases the protein content in a lower product quantity, without altering the main distinctive characteristics, except for the slightly different taste.

Table 5 presents aminograms pertaining to the 80:20 and 50:50 Minsa and raw amaranth whole flour mixtures, as well as those of the tortillas and arepas prepared with them, in comparison to mixtures of corn and amaranth flours alone. The FAO/WHO 1973 values (20) for children and adults are also included. As may be observed, almost all of the registered amino acid values are superior in the amaranth mixtures, considering references such as those from Bressani and Scrimshaw (21), in the case of tortillas, Chávez and Pellet (22), for arepas, and those of corn (23) and for amaranth (23). From a practical point of view, formula 80:20 is commendable for economic reasons. No amino acid determinations were made in the final products. However, the PER values of the 80:20 amaranth-Minsa mixture and of the 1-R-Minsa tortillas, were very close to that of casein.

Sulfur amino acids and total aromatic amino acids (4.8 and 7.5–7.8, respectively) are also higher in amaranth mixtures. As to the FAO/WHO requirements, it may be observed that the mixtures comply with them in all the essential amino acids, except for lysine, insofar as children's requirements. Regardless of the fact that such amino acid might not be available, protein efficiency tests (PER and NPR, Table 6) in general terms agree with our previous statement, bearing in mind that lysine addition does not increase the PER in tortillas prepared with a 3.60/o amaranth protein mixture, in diets which require lysine, this being a limiting factor (25). On the other hand, the value of lysine at 4.3 g/16 g N is comparable to that of 4.04 g/100 g of available lysine in Trejo-Gonzalez, Feria-Morales and Wild-Altamirano's best combination (26): corn + wheat + beans + rice + potatoes. Differences in PER values for corn dough (Table 6), according to Del Valle, Montemayor and Bourges (27), differ from those given in references (5, 17, 29).

The mineral and fatty acid contents (Tables 7 and 8) are also quite acceptable in selected corn + amaranth mixtures, when compared to values given by other researchers (4, 5, 14, 28-31). Calcium, phosphorus, and oleic and linoleic acids, are particularly high.

TABLE 4

MAIN CHEMICAL AND PHYSICAL DATA OF TRADITIONAL AND  
AMARANTH-ENRICHED AREPAS

Blends	Formula	Protein, N x 6.25 o/o	Fat o/o	Color	Texture <sup>b</sup>	Shelf life (days)	Flavor <sup>c</sup>
None (dough)	Traditional	8.6	2.8	White	100	2	9.0
Minsa + AWF <sup>a</sup>	80:20	9.0	2.5	White	85	2-3	8.0
Minsa + AFW <sup>a</sup>	50:50	11.5	2.8	White	80	2-3	8.0
Amarilla (Ven.) + AWF <sup>a</sup>	80:20	10.3	2.2	White	90	2-4	9.0
Amarilla (Ven.) + AWF <sup>a</sup>	50:50	12.0	2.6	White	90	2-4	8.0

<sup>a</sup> Amaranth whole flour.

<sup>b</sup> Texture on 100 score for traditional products.

<sup>c</sup> Flavor score: 9 = like extremely; 1 = dislike extremely.

TABLE 5

## AMINO ACID ANALYSIS OF MINSA + AMARANTH BLENDS, TORTILLA AND AREPA

g/16 g N	Minsa + amaranth		FAO/WHO (1973)		Tortilla <sup>a</sup>	Arepa <sup>b</sup>	Corn <sup>c</sup>	<i>Amaranthus cruentus</i> <sup>d</sup>
	50:50	80:20	Children	Adults				
Aspartic acid	7.6	7.1	—	—	6.2	6.0	5.7	—
Threonine	3.4	3.3	4.0	1.4	3.0	3.3	3.3	3.6
Serine	5.6	5.1	—	—	4.2	5.4	4.4	5.9
Glutamic acid	16.2	16.7	—	—	19.0	21.4	19.9	31.3
Proline	5.7	7.3	—	—	10.1	10.3	8.8	9.7
Glycine	5.7	4.6	—	—	4.8	2.9	3.4	3.9
Alanine	4.9	5.9	—	—	8.8	8.6	7.3	3.3
Cysteine	2.3	2.4	—	—	0.9	1.8	—	2.4
Valine	4.7	4.9	5.0	2.0	4.8	4.8	4.7	4.6
Methionine	2.5	2.5	—	—	1.9	1.5	2.0	2.3
Isoleucine	3.7	3.6	4.0	2.0	4.5	3.6	3.3	4.0
Leucine	8.1	10.1	7.0	2.8	9.6	14.6	12.5	5.7
Tyrosine	3.5	3.6	—	—	3.8	4.5	4.3	3.2
Phenylalanine	4.1	4.3	—	—	3.8	5.1	4.8	4.7
Histidine	2.8	2.9	1.4	—	2.4	3.2	2.8	2.6
Lysine	4.3	3.5	5.5	2.4	2.9	1.9	2.4	5.5
Arginine	7.0	5.7	—	—	4.2	3.8	4.3	4.4
Total sulfur	4.8	4.9	3.5	2.6	2.8	3.4	—	—
Tryptophan	1.1	0.8	1.0	0.7	0.5	0.5	0.7	—

<sup>a</sup> Bressani and Scrimshaw (21).

<sup>b</sup> Chavez and Pellet (22).

<sup>c</sup> Greene *et al.* (23).

<sup>d</sup> Carlson, R. (24).

TABLE 6

**PROTEIN EFFICIENCY RATIO OF TRADITIONAL AND AMARANTH  
OR SOYBEAN FLOUR-ENRICHED TORTILLAS**

Blend, o/o	Formula	PER	Reference
Corn dough	Traditional	1.60	(5)
Corn dough + AWF*	80:20	1.74	(5)
Minsa + amaranth whole flour	80:20	2.14	(5)
Minsa + popped amaranth	80:20	2.40	(5)
Casein	—	2.63	
Minsa + 1-R	80:20	2.2	This paper
Minsa + 2-R	80:20	1.5	This paper
Casein	—	2.5	This paper
Corn dough 100	Traditional	1.56—1.65	(29)
Raw corn	—	1.33	(29)
Casein	—	2.50	(29)
Corn dough + popped amaranth + lysine	Traditional	2.32	(25)
Corn dough 100	Traditional	0.98	(15)
Corn dough + soy flour + methionine + lysine	—	2.80	(15)
Casein	—	2.74	(15)
Minsa + soy flour	90:100	1.45	(27)
Corn dough 100	Traditional	2.62	(27)
Casein	—	3.40	(27)

\* AWF = Amaranth whole flour.

TABLE 7

**MINERAL CONTENT OF MINSA + AMARANTH BLENDS, TORTILLAS**

Minerals mg/100 g	Minsa + AWF		Minsa (blank) 100:0
	90:10	80:20	
Calcium	33.0	40.0	34.2
Copper	0.2	0.2	—
Iron	3.2	3.2	2.4
Phosphorus	283.4	370.5	274.9
Magnesium	26.2	26.6	23.8
Manganese	0.4	0.8	0.2
Potassium	32.0	34.0	28.0
Zinc	1.2	1.4	1.0

AWF = Amaranth whole flour.

TABLE 8  
FATTY ACIDS CONTENT (o/o) OF MINSA + AMARANTH  
BLENDS TORTILLAS

Blends	Formula	Palmitic (C16:0)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)
Minsa + AWF	90:10	15.4	3.5	37.5	43.6
Minsa + AWF	80:20	16.3	3.8	38.8	41.0
Minsa (blank)	100:0	13.5	6.9	42.2	37.3

AWF = Amaranth whole flour.

On the other hand, gruel preparation with the 50:50 mixture of Minsa corn flour and whole amaranth flour, or with the 1-R and 2-R fractions in 1:8 and 1:12 dilutions (Tables 9 and 10, respectively) yield similar and even better results as those of commercial products. The same applies in regard to protein content, when the initial slight sour taste is eliminated by adding small quantities of powdered milk.

TABLE 9  
MAIN CHARACTERISTICS OF MINSA + AWF 50:50 BLENDS FOR  
GRUELS (dil. 1:8)

Blends	<sup>o</sup> Brix	Color	Flavor	Moisture o/o	Protein o/o	Fat o/o	Ash o/o
Minsa + AWF, raw	3.0	White	Corn	87.9	1.3	0.8	0.3
Minsa + AWF, toasted	3.2	Cream	Nutty	87.2	1.3	0.8	0.3
Minsa + fraction 1-R	2.0	Golden	Slightly bitter <sup>a</sup>	83.3	1.9	1.3	0.5
Minsa + fraction 2-R	3.0	White	Tasteless	85.0	1.0	1.7	0.2

a Disappears at dilution 1:12.

### Flakes and Extrusion Cooking

Preparation of flakes and extruded products with the 50:50 mixtures under the conditions indicated in Tables 11 and 12, yielded satisfactory results. Products obtained from toasted amaranth-seed flour (Table 13) displayed a higher protein and fat content. This was also observed when *Amaranthus caudatus* or quinoa flour were employed (13), or when wheat

TABLE 10

## CHEMICAL COMPARISON OF CORN-AMARANTH AND COMMERCIAL GRUELS

Gruels <sup>a</sup>	Moisture o/o	Protein (N x 6.25) o/o	Fat o/o	Ash o/o
Minsa + 1-R (50:50)	85.3	1.4	1.2	0.5
Maizena	92.9	0.7	0.4	—
Soyatole	92.5	0.9	0.4	0.2
Colombian formula <sup>b</sup>	84.8	0.5	0.5	0.2
-----				
Minsa + 1-R + Powdered (50:50)                      milk				
1 + 1	85.5	2.8	1.1	0.5
3 + 1	85.4	2.9	1.4	0.6
5 + 1	84.9	4.6	1.3	0.7

a Dilution 1:8.

b Reference (2).

TABLE 11

## VACUUM DRUM-DRYER OPERATIONS FOR THE PREPARATION OF CORN AND AMARANTH BLENDS

Conditions	Selected operations	
	1	2
Blend, kg	1	1
Water, lt	7	8
Boiling (min)	5	5
Test time (min)	55	30
Rate, kg/hr	8.7	18
Drum speed, rpm	3	3
Steam pressure, kg/cm <sup>2</sup>	1.1	1.8
Pressure, mm Hg	160	160
-----		
Final product, g	340	450
Flakes characteristics	Small, Brittle	Large, Resistant

flour from toasted seeds was used for comparative purposes.

Diverse snack variations and gruels with a 13-15% protein content were prepared with extruded corn plus amaranth 50:50 blends (flour

and milling fractions), with the addition of sugar cane, vegetable oils, salt, chile, pepper, etc., according to the usual resources in food technology. Each of these products exhibited some nutritional qualities (Tables 9 and 13), therefore being recommendable for use as complements in school-feeding programs. Some of those products are mentioned elsewhere (12, 13, 32, 33).

TABLE 12

## EXTRUSION-COOKING OPERATIONS FOR CORN AND AWF 50:50 BLENDS

Conditions	Selected operations	
	1	2
Blend, kg	5	5
Sugar, g	—	250
Salt, g	75	—
Water, ml	625	625
Temperature, °C	25	25
Rate, kg/hr	5	5
Time, min	60	63
Rpm	420	420
Temperature, °C	110	110
Final product, g	5,030	5,400
Expansion	VG <sup>a</sup>	G <sup>b</sup>
Quality	VG	VG

a Very good.

b Good.

In conclusion, the 50:50 mixture of Minsa flour and whole amaranth raw-seed flour approaches the ideal protein established by FAO/WHO in 1973 in regard to amino acid content, as shown in Table 5. Consequently, it is suggested that it be used for preparing arepas, gruels, and snacks.

The use of formula 80:20 (both amaranth whole flour and air-classified fraction mixtures) seems advisable to prepare tortillas (Tables 2 and 6), thus sparing corn in the corresponding proportion, which could then be liberated for other uses. These facts must be seriously taken into consideration, bearing in mind the scarcity conditions of corn and cereals which prevail in the majority of the countries of the so-called Third World.

TABLE 13

**PROXIMATE ANALYSIS OF MINSA AND AWF FLAKES AND EXTRUDED PRODUCTS FROM 50:50 BLENDS**

Products	Moisture o/o	Protein (N x 6.25) o/o	Ash o/o	Fat o/o	Fiber o/o	Carbohydrate o/o
Minsa + AWF (flakes) raw	4.3	13.3	2.1	1.7	1.4	72.2
Minsa + AWF (extruded) raw (50:50)	10.9	13.5	2.1	2.2	2.7	68.6
Wheat flour +AWF (flakes) toasted (50:50)	5.7	15.0	1.8	2.2	1.1	74.2
Wheat flour +AWF (extruded) toasted (50:50)	11.4	14.5	2.0	3.7	3.2	65.2

**ACKNOWLEDGEMENTS**

The authors wish to express their appreciation to Eng. R. Otal, from the MICONSA-CONASUPO Industrial Plant, for performing three of the tests presented in Table 3; to Mary Issa, for some of the data shown in Table 4, and to Miss Melva López, for the data in Tables 9 and 10.

**RESUMEN**

**ENRIQUECIMIENTO INDUSTRIAL DE HARINA DE MAIZ CON HARINA INTEGRAL DE AMARANTO Y FRACCIONES DE MOLIENDA EN PRODUCTOS ELABORADOS A BASE DE MAIZ**

Se utilizó harina integral y fracciones de la molienda de semillas crudas de amaranto, en mezclas de 90:10, 80:20 y 50:50 con harina industrializada de maíz (MINSA), para la elaboración de tortillas y arepas, constituyentes nutricionales básicos de la dieta habitual en varios países latinoamericanos. Las tres mezclas de maíz-amaranto acusaron un buen contenido de proteína y grasa, así como de su perfil de aminoácidos, y presentaron características físicas adecuadas para la confección de tortillas.

Se encontró que las mezclas de harina integral de amaranto y harina de maíz comercial, en la proporción de 80:20 y 50:50, eran adecuadas para la preparación de arepas. La proteína y grasa mejoraron substancialmente, sin que sus características organolépticas sufriesen cambio alguno.

El tipo mexicano de *Amaranthus cruentus*, seleccionado por su disponibilidad y propiedades bromatológicas, rindió productos de calidad nutricional excelente, según

los datos referentes al contenido de aminoácidos e índice de eficiencia proteínica (PER). Las fracciones 1-R (rica en proteína) y 2-R (amilácea), obtenidas mediante clasificación por corriente de aire, también rindieron buenos resultados al sustituir por harina de amaranto. Las harinas mencionadas y las fracciones de las mezclas clasificadas por corriente de aire en la proporción de 50:50, demostraron ser adecuadas para la elaboración de atoles, al utilizarse a las diluciones de 1:8 y 1:12, ya que las características organolépticas mejoraron.

También se usaron hojuelas y extruidos que rindieron productos con un contenido proteínico de 13.3-15.0%; grasa, 1.7-3.70%; y carbohidratos, 65.2-74.20%. Los extruidos se utilizaron además para preparar refrigerios de mejor calidad nutricional que los productos comerciales existentes.

En todos los casos se logró mejorar el contenido de minerales y ácidos grasos de la tortilla. Se recomienda, por consiguiente, el enriquecimiento de este último producto con harina integral de amaranto, para uso en programas orientados a mejorar el estado nutricional de la población.

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