MILLING PROCEDURES AND AIR CLASSIFICATION OF AMARANTH FLOURS[1]

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SUMMARY

The different milling characteristics of *Amaranthus cruentus*, a domestic variety prevailing in Mexico, selected as representative sample, are herein discussed. This was subjected to proximate analysis, which confirmed its good quality.

Milling trials were carried out for the preparation of whole flour by means of conventional mills and by combining some of these with the Raymond and Alpine separators for air classification. Results were then compared to those obtained with a Strong-Scott pearler. Grits and bran contained the highest protein concentration.

After comparing overall results, it may be concluded that the best operating conditions are the following: a) seed pearling using five passes, in a pearler, with variable yields of approximately 22o/o containing 36o/o protein, and b) combining the Miag mill and Raymond air separator, with variable yields of approximately 32o/o and a protein content of 30-36o/o.

Proximate analysis of the fractions as well as farinographic and amylographic characteristics —different from those of whole wheat and amaranth flours— suggest their use in the preparation of nutritionally-enriched food products.

INTRODUCTION

The effect of applying thermic treatment on the quality of amaranth seeds was dealt with in a previous paper (1). *Amaranthus cruentus* 12 was selected as representative sample from a total of 45 domestic species.

Findings revealed a deleterious effect on the protein and lysine con-

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tents, as these diminished when moisture (6.0 to 10o/o), temperature (90-170oC) and time (1-5 minutes) were combined. On the other hand, the nutritional quality apparently improved by previous toasting of the seed, as opposed to the behavior of whole wheat and the starchy fractions, separated by means of a pearler and air classification.

The baking quality of the flour derived from amaranth toasted seeds also denoted improvement in its organoleptic characteristics, since digestibility and efficiency of the protein suffered no alterations.

Nevertheless, in spite of the fact that the Mercado type of *A. hypochondriacus* seemed to be the best choice among Mexican domestic seeds, *A. cruentus* is at present preferred, due to its prevalence as a species and to the satisfactory rheologic characteristics of its flours (1). This species has been formerly studied under diverse aspects (2-6), whereas *A. hypochondriacus* has undergone ample research in recent works (7, 8).

The present paper deals with the milling characteristics of *A. cruentus* seeds, as well as with the protein fractions obtained through the use of a seed pearler and air separation, with regard to their chemical composition and amylographic and farinographic characteristics.

MATERIALS AND METHODS

Seeds and Milling

In the present case, *A. cruentus* seeds came from Huazulco, Morelos, Mexico, and exhibited the characteristics already described (1). Seeds were kept at laboratory temperature without preservation problems; they were cleaned before milling by means of a slightly modified version of the device *ex professo* designed by the Rodale Research Center (9), and by a Mc Gill rice cleaner. The clean seeds were then processed by differential milling, in several mills, and by standard milling for the obtention of whole amaranth flours from raw, toasted and popped seeds, as described elsewhere (1, 2, 9). The mills employed included: Christy & Norris (machine-type desintegrator, 8,000 rpm), Kek (Hurdsfield Industrial State; Cheshire, England), UD Cyclone Sample Mill (UD Corporation), CeCo-Co (type D, No. 21,230; Osaka, Japan), MIAG (971,2771, Braunschweig), Brabender (Duisburg, type 279,001), Bühler MLU-202, Alpine Pin Mill Model 250 CW and Alpine Air Classifier (type 132 MP, Augsburg). Mills were used either individually or combined, depending on the purposes. The particle size, mesh number and yield were determined according to conventional flour classification methods. Fraction separation was performed using a Strong-Scott pearler, in accordance with other researchers (4), while air classification was carried out by a Raymond separator (in one only pass), after being milled in a CeCoCo or Miag, or else by the combination of Kek and Alpine, or Christy and Alpine, in one or several passes, as later indicated. Mesh sifters 20, 32, 45, 60, 6XX, 10XX, 15XX and Plato were employed.

Analysis

Chemical determinations were carried out following the AOAC's methods (10). Amylographic and farinographic values were obtained as already indicated (1).

RESULTS AND DISCUSSION

Table 1 depicts the proximate analysis of samples No. 3, 7 and 8 of *A. hypochondriacus,* and of No. 9, 10 and 12 corresponding to *A. cruentus.* Sample No. 12 of *A. cruentus* was selected from this Table due to its greater protein content. It was then subjected to milling studies.

TABLE 1

PROXIMAL ANALYSIS (o/o) OF SIX SELECTED AMARANTH WHOLE FLOURS*

Samples	Moisture	Protein	Fat	Crude fiber	Ash	Carbohydrates
3	7.6	15.2	4.9	4.7	2.1	65.5
7	9.3	15.9	5.7	5.4	3.0	60.7
8	7.7	14.7	6.3	4.4	2.2	64.7
9	8.1	15.6	5.3	5.5	2.5	63.0
10	7.8	15.8	6.1	4.7	2.8	62.8
12	7.6	16.1	6.2	4.9	3.1	62.1

* Mean values of three determinations.

Milling trials were carried out in Brabender and Bühler mills, with the results shown in Tables 2 and 3. The Brabender mill produced four fractions: a) grits, with a 22o/o yield and 15o/o protein; b) bran, with a 51.0o/o yield and 16.4o/o protein; c) coarse flour, with 8.6o/o protein, and d) fine flour with a 9.5o/o protein content. The yield of both of the latter flours was low (16.4 and 10.1o/o, respectively). As to the content of the remaining components, some differences were displayed by all fractions, particularly in the case of fat. Bran and grits represent the fractions with the highest nutritional value (Table 2) as far as chemical composition is concerned.

Eight fractions (three of rupture, three of reduction, plus grits and bran) were obtained in the Bühler mill. These presented a low yield and a low protein content (Table 3), except for the second reduction fraction which yielded 22.3o/o with 11.6o/o protein. On the other hand, bran displayed a 36.8o/o yield with 12.5o/o protein. The first ruptured fraction showed a high-protein content (14.4o/o) but a low yield (2.9o/o). Grits also presented a high protein content and a satisfactory 17.7o/o yield.

When the appraised results of these two mills are compared, it is evident that grits and bran are acceptable due to their yield and quality, as opposed to flours, the yields of which are low.

TABLE 2

YIELDS IN THE BRABENDER MILL AND PROXIMATE ANALYSIS (%) OF FLOUR FRACTIONS

Fractions	Yield (%)	Moisture	Protein	Fat	Crude fiber	Ash	Carbohydrates
Gross	16.4	10.0	8.6	4.0	0.6	2.1	74.7
Fine	10.1	9.3	9.5	2.8	1.3	3.9	73.2
Grits	22.0	9.5	15.7	5.4	0.4	2.1	66.9
Bran	51.0	8.6	16.4	7.1	1.5	2.0	64.4

TABLE 3

YIELDS IN THE BÜHLER MILL AND PROTEIN CONTENT OF AMARANTH FLOUR*

Fractions	Yield (%)	Protein (%)
Breaking:		
First	2.9	14.4
Second	3.1	8.9
Third	3.4	7.3
Reduction		
First	8.3	10.6
Second	22.3	11.6
Third	9.6	12.5
Bran	36.8	16.1
Broken milled (grits)	17.7	15.6
Loss	0.9	—

* Mean of two determinations.

Table 4 shows the results obtained with the different mills employed for the obtention of whole flour. In accordance with granulometry, all of the mills permit whole flour yield with a mesh larger than No. 60, a great percentage of meshes from 60 to 120, being profitable: 92% in a Miag mill, 85% in a CeCoCo, 94% in a UD, 97% in a Kek and 86.5% in a Christy and Norris (after three passes).

The following meshes were responsible for the highest flour percentage: Miag, 38% with a No. 60 mesh; CeCoCo, 42% with a No. 60 mesh; UD, 54.6% with a No. 70 mesh; Kek, 40% with a 120 mesh, and Christy & Norris, 32% with a 90 mesh.

TABLE 4

MILLING YIELD (%) OF AMARANTH WHOLE FLOUR

Mesh	Kek	Christy & Norris	Miag	CeCoCo	UD Rice mill	White wheat flour
28	–	–	1.0	1.74	–	–
35	0.2	1.15	6.78	12.46	2.65	–
45	1.8	11.35	–	–	–	–
60	9.5	31.6	38.02	42.22	8.84	3.1
70	–	–	14.16	13.32	54.62	5.9
80	–	–	9.10	8.20	2.41	6.36
90	36.0	32.85	–	–	–	–
100	–	–	10.40	7.25	15.93	13.28
120	40.15	15.25	6.61	4.79	5.01	14.85
Plate	11.05	6.75	13.55	9.30	7.51	54.81
Loss	1.3	1.05	0.38	0.72	3.03	1.70

All of the amaranth whole flours which were obtained under such conditions contained from 11.0 to 15.0% protein. Considering the percentage yields, the mills which produced the best results were UD, Kek and Christy & Norris. Table 5 depicts the flour yields and classification by means of different mills and separators. As the figures reveal, both the pearler and the combination of the Miag mill with the Raymond air separator produced the best results.

The milling sequence employed for the obtention of amaranth whole flours, as well as the fractions obtained with the Strong-Scott separator, and those resulting from air classification by combining the Kek and Alpine mills, Brabender and Kek, Christy and Alpine mills, and the Miag mill with the Raymond separator, are diagrammatically presented in Figure 1. Yields associated to the highest protein content were either obtained through the use of the pearler, after five passes (fraction 1-P: 22% yield with 36% protein), or by combining the Miag mill with the Raymond air classifier (fraction 1-R: 32% yield with 29-36% protein). The proximate analysis of these fractions is shown in Table 6. The excellent food quality of both fractions, which display a high protein and reduced carbohydrate content, may be appreciated. The fat content is relatively high at times and tends to occlude the Alpine separators, although it does not affect the pearler's nor the Raymond separator's performance. In both cases, however, results of the proximate analyses were variable, especially when the Miag-Raymond combination was employed, as indicated elsewhere (1).

The results herein presented are similar to those indicated by other researchers in the case of quinoa, under similar circumstances (11), while the characteristics of the pearler's fractions are in agreement with those described by Betschart *et al.* (4). On the other hand, the concentration of nutritious elements in the 1-R protein fraction obtained by combining the Miag mill with the Raymond separator, constitutes one more alternative

TABLE 5

GRINDING YIELD (%) AND CLASSIFICATION OF AMARANTH WHOLE FLOUR BY DIFFERENT MILLS AND SEPARATORS

Mesh	Miag + Raymond		Pearler		Kek +	Christy +	Brabender +
	1-R	2-R	1-P	2-P	Alpine	Alpine	Kek
16	–	–	–	35.36	–	–	–
20	–	–	–	54.11	–	–	–
28	–	1.18	2.41	9.97	–	–	–
35	1.34	18.4	14.14	–	0.15	0.6	–
45	–	–	–	–	1.25	8.1	0.3
50	–	–	–	–	7.15	28.9	–
60	17.73	50.77	24.19	0.23	–	–	5.0
70	23.99	9.41	5.39	–	–	–	–
80	30.77	7.28	6.01	–	–	–	–
90	–	–	–	–	34.3	35.3	35.0
100	11.83	5.95	17.99	–	–	–	–
120	2.1	4.74	12.72	–	43.35	18.8	47.8
Plate	8.69	1.98	16.13	–	10.65	6.45	10.75
Loss	3.55	0.29	1.02	0.33	3.15	1.85	1.15

1-R and 2-R = Protein and starchy fractions, respectively, from the Raymond separator.
1-P and 2-P = Protein and starchy fractions, respectively, from the Pearler.

TABLE 6

PROXIMATE ANALYSIS (%) FLOUR CLASSIFIED FRACTIONS*

Determinations	Pearler		Raymond fractions	
	Bran + Germ (Fraction 1-P)	Perisperm (Fraction 2-P)	1-R	2-R
Moisture	8.5	9.3	9.0	10.3
Protein	34.0	9.4	29.0	7.1
Fat	19.1	5.2	11.1	2.7
Ash	6.0	1.7	4.0	1.1
Crude fiber	9.5	4.6	6.9	1.4
Carbohydrates	20.9	69.8	40.0	77.4

* Mean values in three trials. Pearler, five passes. Raymond (one pass); after, Miag mill (one pass).

FIG. I.- FLOW SHEET OF AMARANTH SEED MILLING (% FLOUR YIELD AND PROTEIN).

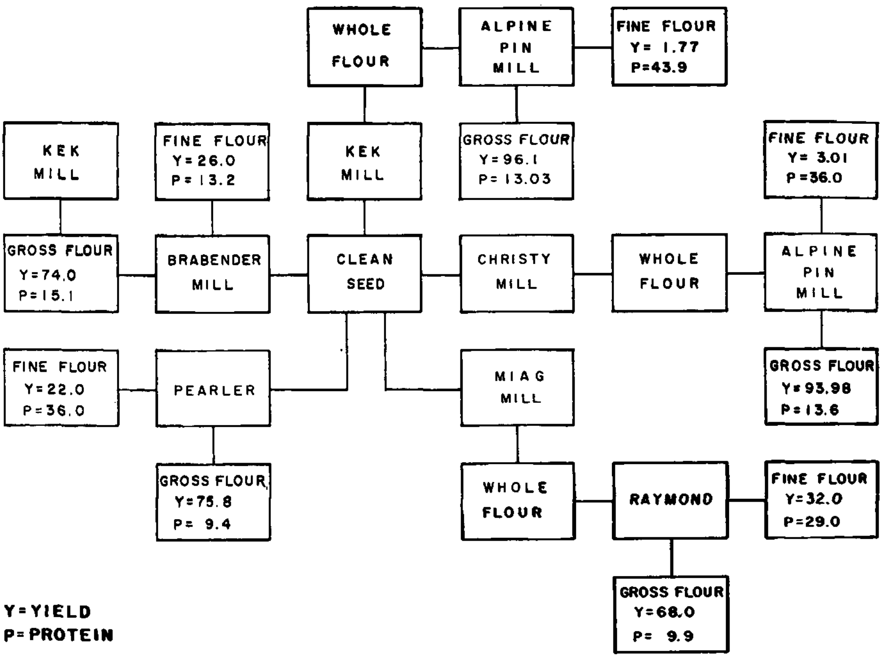

FIGURE 1

Flow sheet of amaranth seed milling (o/o flour yield and protein)

for the best exploitation of the extraordinary qualities of amaranth seeds. This fraction, as well as the pearler's 1-P, also display different amylographic (Table 7) and farinographic characteristics from those of the whole-wheat flour (Figure 2), thus conferring the fraction a special character suggestive of the expansion of its applications for future research.

To conclude, mention should be made of the fact that the nutritional values appraised by the PER tests, concerning the pearler's fractions and their digestibility (4), are worthy of consideration. The same can be said of the corresponding Raymond fractions, a subject to be discussed in a future paper.

TABLE 7

AMYLOGRAPH DATA ON AMARANTH FLOUR AND PROTEIN FRACTIONS

Determinations	Amaranth		1-P	1-R	Wheat
	Whole	Flour*	Fraction	Fraction	whole flour
Viscosity, U. B.					
Peak	650	(598)	560	925	1,620
92°C	540	(598)	550	850	340
92°C, 30 min	520	(442)	>1,000	700	180
35°C		(103)	—	590	470
35°C, 30 min		(320)	—	720	1,720
Gelatinization, °C					
Initial	66	(62)	65	70	58.5
Medium	78	(64)	70	85	—
Final	90	(68)	74	95	—

* Figures in parenthesis correspond to a different sample of another run.

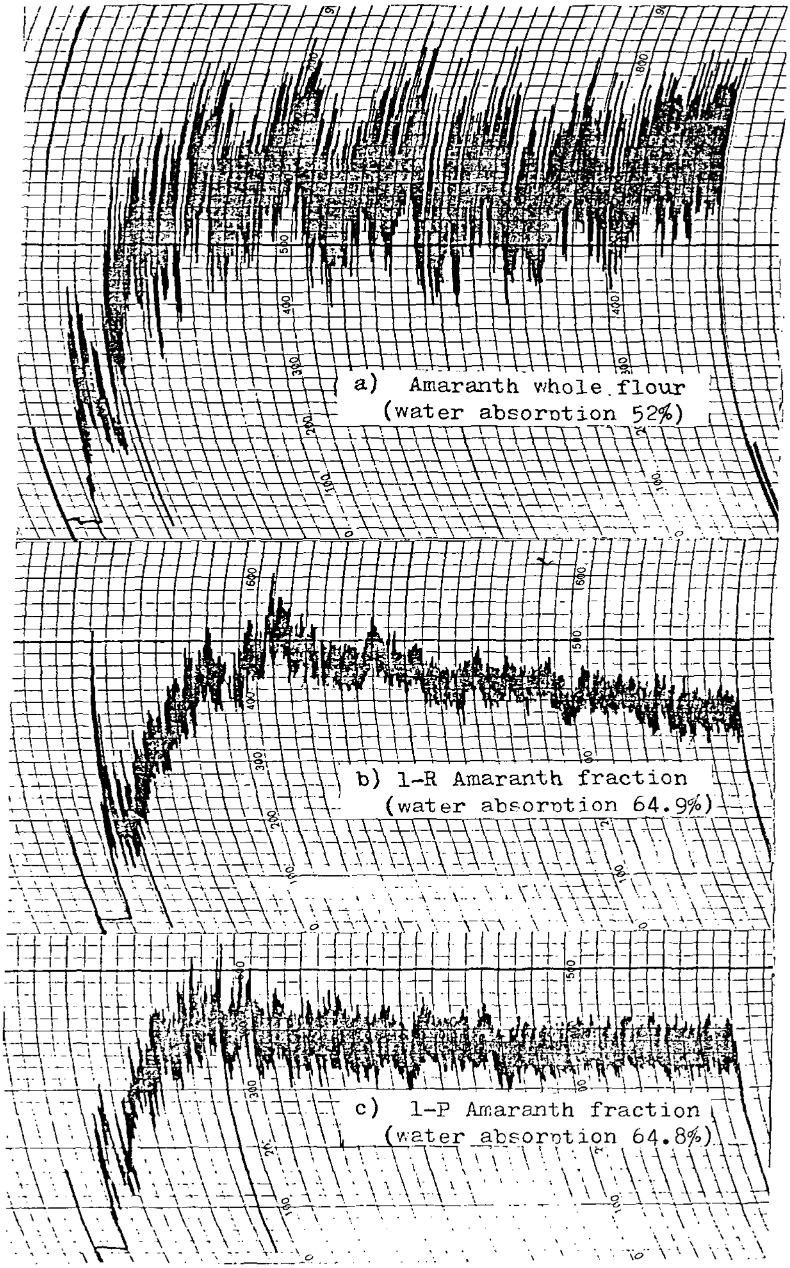

FIGURE 2

Farinographs of amaranth whole flour and protein fractions

RESUMEN

PROCEDIMIENTOS DE MOLIENDA Y CLASIFICACION, POR CORRIENTE DE AIRE, DE PARTICULAS DE HARINAS DE AMARANTO

Se comentan las diferentes características de molienda del *Amaranthus cruentus*, una variedad autóctona que predomina en México, la cual fue seleccionada como muestra representativa. Esta se sometió a análisis proximal, el que confirmó su buena calidad.

Los ensayos de molienda para la preparación de harina integral se llevaron a cabo mediante molinos convencionales, y a través de la combinación de éstos con separadores de partículas por corriente de aire, Raymond y Alpine. Luego se compararon los resultados con los obtenidos con el perlador Strong-Scott, encontrándose que el salvado y el granillo son los que contienen la mayor concentración proteínica.

Después de comparar los resultados globales, se concluye que las mejores condiciones de operación son las siguientes: a) perlado de la semilla mediante cinco pases en el perlador, con rendimientos variables en torno de 22o/o y un contenido proteínico de 36o/o, y b) combinación del molino Miag y del separador de partículas por aire, Raymond, con rendimientos variables de 32o/o, con un contenido proteínico de 30 a 36o/o, aproximadamente.

El análisis proximal de las fracciones así como las características farinográficas y amilográficas de las mismas —diferentes a las de harinas integrales de trigo y amaranto— sugieren la conveniencia de su uso en la elaboración de productos alimenticios enriquecidos nutricionalmente.

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