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Dietary fiber obtained from amaranth (*Amaranthus cruentus*) grain by differential milling

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Abstract

Specific differential milling of amaranth (*Amaranthus* spp.) yields three different granulometric fractions, which are classified according to their composition and properties. They are a high-fiber fraction, a high-protein fraction and a high-starch semolina. The high-fiber fraction can be improved by pneumatic classification until a product with 63.9% insoluble fiber and 6.86 soluble fiber contents is obtained.

Keywords: Dietary fiber; Amaranth; Differential milling

1. Introduction

The importance of food fiber, particularly in special diets, has encouraged the search for new fiber sources. Amaranth (*Amaranthus* spp.), a dicotyledoneous plant of great importance in pre-Columbian American diets, has now been re-discovered. Its tiny grain, about 1 mm in diameter, has remarkable nutritional properties. Some authors consider it as a pseudocereal (Breene, 1991); it contains between 15 and 22% protein with 0.34 g Lys/g N; protein efficency ratio values range between 1.5 and 2.1. It also contains between 58 and 66% starch, with low gelitinization temperature and varying granule size, (between 1 and 3.5 μm, according to the variety). It has from 9 to 16% dietary fiber, and the bran is thinner and softer than that of wheat. Lipid contents range between 3.1 and 11.5% (Betschart, Irving, Shepherd & Saunders, 1981; Pedersen, Hallgreen, Hansen & Eggum, 1987). High concentrations of calcium, phosphorus, iron, potassium, zinc, vitamin E and B complex, as well as low levels of antinutritional factors, make this grain a product of high interest for food formulation. The very low glyadine content, less than 0.01% in some varieties (*Amaranthus cruentus, A. mantegazzianus*), makes useful for those who suffer from celiac disease.

Due to the amaranth grain structure and morphology (Irving, Betschart & Saunders, 1981), it is possible to separate its parts and thus obtain milling fractions with different nutritive and dietary features. Betschart et al. (1981) treated the amaranth grain in a Strong-Scott equipment for barley and obtained a flour with a higher protein content than whole flour. Taking this into account, a differential milling technique, which separates anatomically different grain pieces of different composition by intensive friction in a selective way, was developed at the CIDTA (Centro de Investigación y Desarrollo en Tecnología de Alimentos, Facultad Regional Rosario, Universidad Tecnológica Nacional; Tosi, Ré, Masciarelli & Ciappini, 1996). Differential milling, operated in a continuous stream, produces two milling fractions and yields, after a sieve classification, a high-protein fraction and a high-starch fraction. As a consequence of the milling stream separation, two intermediate fractions are obtained. Most of the bran (with some protein) is found in one of them.

The processes of differential milling and classification by physical methods, which do not need reagents nor produce liquid effluents, constitute an advantage over wet-enrichment methods.

The purpose of this work is to obtain and characterize the dietary fiber fraction of the amaranth grain separated by differential milling.

2. Materials and methods

Amaranth grain (*A. cruentus*) air-dried for its preservation, was provided by the Facultad de Ciencias Agrarias of the Universidad Nacional de Río Cuarto,

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Table 1
Fractions, yield, and insoluble, soluble and total dietary fiber content of whole amaranth grain after differential milling

Fraction	Denomination[a]	Yield (%)	Fiber[b] (%)		
			Insoluble	Soluble	Total
Whole grain	–	–	8.1	6.1	14.2
R18	–	22.8/24.4	6.4	6.1	12.5
P18/R20	–	6.7/5.6	4.3	3.3	7.6
P20/R30	HSS	47.6/46.2	1.4	3.3	4.7
P30/R50	HFF	6.5/7.1	31.8	5.4	37.2
P50	HPF	16.4/16.7	14.6	8.2	21.7

[a] HSS, high-starch semolina; HFF, high-fiber fraction; HPF, high-protein fiber.
[b] Includes the non-hydrolyzed protein

Argentine. Grains retained by the 18 ASTM mesh sieve with 11.5% moisture, 18.9% proteins, 2.8% ash, 10.2% ethereal extract and 56.6% carbohydrates, with 14.2% dietary fiber content, were used to carry out the tests.

Differential milling was performed on conditioned grains (Tosi & Ré, 1999) in a pilot-scale prototype mill developed by the CIDTA. Two output streams were obtained. These streams were granulometrically classified by sieving and by pneumatic separation, by 18, 20, 30, 40, 50, 80 and 100 ASTM meshes. Four fractions were obtained: (1) a fraction which passes through 50 mesh (P50), named high-protein flour (HPF); (2) a fraction which passes through 20/rejects 30 mesh (P20/R30), named high-starch semolina (HSS); and (3) an intermediate fraction which passes 30/rejects 50, (P30/R50) named high-fiber fraction (HFF), which contains most of the fiber with some protein and (4) a fraction which rejects 20 mesh (R20) and is returned to the mill. By further pneumatic separation of the high-fiber fraction, previously classified by sieving, in cyclonic separation equipment built at the CIDTA, the bran was separated from high-protein flour and fractions C_1 and C_2 were obtained. The air-blast speed was set between 4.3 and 5.5 m s^{-1} values.

Moisture, protein, ether-soluble material, ash, starch and dietary fiber determinations were carried out on conditioned grains, HPF, HSS and HFF, using whole flour of the same conditioned amaranth grains as control.

Moisture content was determined according to the ISO 711:1985 Standard (ISO, 1995), protein content by AACC 46-11 Official Method, ether-soluble material by the AOAC 920.85 (1995) Official Method, ash by the AACC 08-16 (1982) Official Method, starch by the method proposed by Dekker and Richards (1971), dietary fiber determinations, soluble and insoluble fiber were carried out by the AOAC 985.29 (1983) Official Method, digestibility by the AACC Ba 10-85 Official Method, urease index by the AACC 22-90 Official Method, water-binding capacity by Robertson and Eastwood (1981) method, water-holding capacity by the Mongeau and Brassard (1982) method, cationic-exchange capacity by Robertson, Eastwood and Yeoman (1980) method and organic molecule absorption capacity by the Mc Conell, Eastwood and Mitchel (1974) method. The same determinations were carried out on two high-fiber commercial products.

3. Results and discussion

Table 1 includes the performance and fiber content of all milling fractions obtained by sieving the products from differential milling of the amaranth grain. Table 2 shows the compositions of the most important fractions obtained.

Protein separation from the high-fiber fraction by pneumatic classification yields a high-fiber product. Table 3 shows fiber contents and properties of whole amaranth grain, milling fractions, pneumatically separated

Table 2
Compositions of whole flour and high protein flour, high fiber fraction and high starch semolina obtained by the differential milling of conditioned amaranth grain and their standard deviations (fraction P18/R20 is not included)

Components (% wb)	Differential milling conditioned grain							
Denomination	IF	σ[a]	HPF	σ[a]	HFF	σ[a]	HSS	σ[a]
Granulometric fraction	–	–	P50	–	P30/R50	–	P20/R30	–
Proteins (N×6.25)	18.8	2.62	40.1	2.72	23.1	2.13	5.81	1.73
Ether-soluble material	10.27	1.80	20.10	2.11	12.7	1.90	3.31	1.38
Moisture	9.82	0.93	7.70	0.62	8.78	0.95	11.30	0.98
Carbohydrates [b]	57.3	–	24.50	–	47.6	–	78.4	–
Ash	3.84	0.92	7.60	0.81	7.8	0.31	1.20	0.11
Starch	–	–	–	–	–	–	73.7	2.11
Soluble dietary fiber	6.25	1.36	8.20	1.16	5.4	2.01	3.3	2.1
Insoluble dietary fiber	8.19	1.72	14.60	1.71	31.8	1.32	1.4	1.9

[a] Standard deviation.
[b] Includes starch, soluble and insoluble dietary fiber (obtained by difference).

Table 3
Insoluble and soluble fiber contents and properties of high fiber fractions obtained from the amaranth grain after differential milling, followed by mechanical and pneumatic classification[a]

Fraction	IF	SF	TF	FI/FS	Digestib.	UI	WBC	WHC	CEC	OMAC
Whole grain	8.1	6.1	14.2	1.32	80.3	0.83	132.8	127.5	0.5	132
P30/R50	31.8	5.4	37.2	5.9	80.1	–	220	340	0.52	180
C1	63.9	6.86	70.8	9.3	62.1	0.03	599	810	0.78	645
C2	60.5	6.5	67	9.3	63.9	0.03	551.2	821	0.70	640
Commercial prod. 1	27.1	2.2	29.3	12.35	–	–	304.6	353.4	0.88	201
Commercial prod. 2	15.3	7.8	23.1	1.96	–	–	332.6	294.3	0.304	172

[a] UI, urease index; WBC, water binding capacity (g water/g product); WNC, water holding capacity (g water/g product); CEC, cationic exchange capacity (meq/g product); OMAC, Organic molecules absorption capacity.

fractions C_1, C_2 (both of high fiber content), and two commercial high-fiber content products. The FI/FS relationship, although high, does not exceed that of a common high-fiber dietary commercial product.

Fiber yield ranges between 6.5 and 7.1% by weight of the total. It is not high but it must be pointed out that it is a by-product of the high-protein flour (between 16.4 and 16.7% weight basis), and a high starch semolina fraction, all of these obtained simultaneously from the same milling and classification operation.

A high-fiber product of excellent quality and properties may be obtained from the amaranth grain by exclusive physical means of low or no environmental impact, which comprises a differential milling, specific for this grain, followed by a sieve and pneumatic classification.

The characterization of the obtained fractions by soluble and insoluble contents and physico-chemical properties of physiological interest shows that the amaranth fiber is a useful contributor to the food fiber market.

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