POPPED AMARANTH GRAIN AND ITS PRODUCTS BREAKFAST CEREAL AND CRUNCHY BARS: POPPING PROCESS, NUTRITIVE VALUE AND SHELF LIFE

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INTRODUCTION

Amaranth grain (*Amaranthus spp*) is a pseudocereal and a good potential source of nutrients. The interest in amaranth grain is based on its popping capacity (Zapotoczny et al., 2006; Iyota et al., 2005; Lara and Ruales 2002; Tovar et al., 1994), the characteristics of the starch (González et al., 2007; Gamel et al., 2005; Lara and Ruales1999a), the nutritional value (Gamel et al., 2006a; Gamel et al., 2006b; Gamel et al., 2004; Lara and Ruales 1999b) and the potential use of popped grain as an ingredient in snack foods (Lara, 1999). Popping amaranth grain is the most common mean of amaranth processing to produce snacks foods such as: "alegrías" from México, "turrones from Perú", "nigua" and "alboroto" from Guatemala, and "laddoos" from India. In such products, popped grain is agglomerated with honey and molasses syrups (Schenetzler and Breene 1994). Products based on popped grain fulfil the sensory characteristics requested by the consumers for cereal breakfast and snacks (Lara 1999). The importance of offering a good source of protein and energy in cereal and snack foods is why the children and teenagers have preference for this kind of products. However, as occurs in many snack foods, the lipid oxidation and loss of crunchiness are the main aspects that reduce the shelf life of popped amaranth grain and its products (Lara and Cangás 2004; Lara and Mejía 2004a). The objectives of these studies were to evaluate some aspects related to the popped amaranth grain and its two products: breakfast cereal and crunchy bars.

MATERIALS AND METHODS

Popping process

INIAP-Alegría (*Amaranthus caudatus*), an Ecuadorian variety, was used. A dry hot air popcorn popper was used to study the effect of temperature (200, 220, 240°C), airflow (0.013, 0.014, 0.015 m^3/s), load (14, 18, 22g) and moisture content (12, 14, 16%) on the natural popping capacity of amaranth grain (Lara and Ruales 2002).

Characterization of popped amaranth grain and its use as an ingredient in foods

A comparative study between raw and popped grain was made to evaluate the effect of popping process on the amaranth starch (Lara and Ruales 1999a) and the nutritive content of amaranth grain (Lara and Ruales 1999b). A sequential procedure of research and development was followed to obtain breakfast cereal and crunchy bars (Lara 1999). Content and nutritive quality was determined in amaranth products (Lara and Mejia 2004b).

Shelf life

Samples of popped amaranth grain, breakfast cereal and crunchy bars, packaged in polypropylene metal film and polyester polyethylene (PET) bags, were stored at normal (25°C/50% rh), accelerated (30°C/75% rh) and extreme (35°C/100% rh) conditions (Lara and Mejía 2004a). Peroxide value and maximum force of compression (TA-XT2i) were measured during 90 days. Sensorial scales of five categories were used for rancidity detection (1 not rancid, 2 a little rancid, 3 rancid, 4 quite rancid, 5 extremely rancid) and crunchiness intensity (1 not crunchy, 2 a little crunchy, 3 crunchy, 4 quite crunchy, 5 extremely crunchy).

RESULTS AND DISSCUSION

Popping process

All treatments combinations derived from three levels of temperature, load, airflow and moisture content were effective to reach yields of amaranth grain above 75%, expansion volumes near to 5 times higher than the raw grain volume, densities as low as 0.178 g/cm^3 and residence times no longer than 31.6 seconds. Furthermore, when the levels with the lowest popping capacity were not considered, the yield of popped grain increased to 83.5%, the expansion volume was above 5 times higher than the raw grain volume and the density decreased to 0.173 g/cm^3. The highest yield and expansion volume and the lowest density of popped grain were obtained at 240°C, 22g load, 0.013m^3/s airflow and 12% grain moisture (Lara and Ruales 2002). The result showed that the corn popper model can be operated at the selected condition to pop amaranth grain whereas specific experimental apparatus and other studies are being developed (Zapotoczny et al., 2006; Iyota, et al., 2005).

Characterization of popped amaranth grain and its use as an ingredient in foods

By scanning electron microscopy (SEM), the granules of native starch showed polygonal shape (Figure 1a) whereas a section of popped grain showed irregular cavities (Figure 1b) resulting from the swelling and disruption of starch granules (Lara and Ruales 1999a).

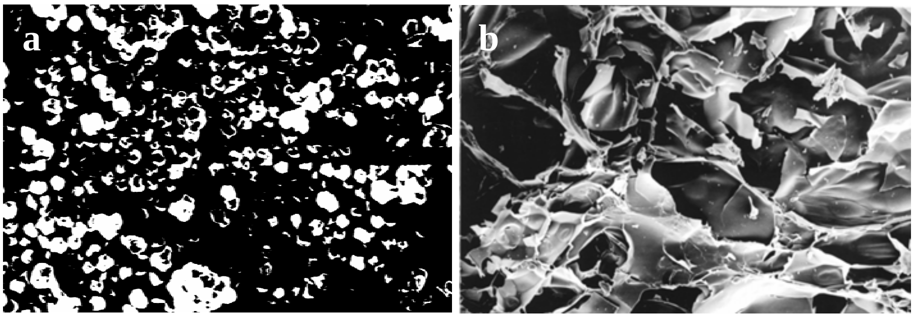


Figure 1. Microphotographs of amaranth starch: a) from raw grain, b) in popped grain.

Amaranth starch was completely gelatinized by effect of popping process under the selected condition. Onset, peak, and final temperatures of 57.09°C ± 0.17, 63.42°C ± 0.12 and 70.10°C ± 0.1, respectively, were detected only in raw grain. The pasting temperature, by rapid visco analyzer, was 67.95°C ± 0.48 in raw grain. The peak viscosity, the swelling power and the water absorption capacity were statistically increased ($\alpha < 0.05$) by the popping process. The final viscosity, available starch and resistant starch were not subjected to statistical variation (Table 1).

Table 1. Starch properties and nutritional components in raw and popped amaranth grain.

Starch properties	Raw	Popped	Nutrients	Raw	Popped
ΔH (J/g)	5.51	ND	TDF (%)*	10.7	10
Peak viscosity (RVU)	33.22b	26.10a	IDF (%)*	7.4	8.2
Final viscosity (RVU)	39.11	33.22	Lysine (g/16g N)	5.0	4.6
Swelling power (%)	2.5 a	7.16b	Leucin (g/16g N)	4.3	4.0
WAC (g/g)	2.16a	6.93b	Thiamine (mg/100g)	0.93	0.73
Available starch (%)	59.8	61.4	Riboflavin (mg/100g)	0.10	0.04
Resistant starch (%)	0.59	0.51	Phytate mg/g	14.4	14.4

Average (n=3), Values in the line with different letter are significantly different ($\alpha < 0.05$), Nutrients reported in db, ΔH = Gelatinization enthalpy, WAC = Water absorption capacity, TDF = Total dietetic fibre, IDF = Insoluble dietetic fibre, ND = No detected. * One determination.

Amongst nutritional compounds, thiamine and riboflavin diminished by the popping process whereas insoluble dietetic fibre increased. Leucin was the limiting amino acid in both, raw and popped grain (Lara and Ruales 1999b) and lysine content was higher (Table 1). In concordance with Chávez et al., (2000), amaranth is a potential source of nutrients for breakfast cereal or crunchy bars. A comparative study showed the nutritional and antinutritional factors of raw grain (Lara and Ruales 1999b), popped grain, breakfast cereal and crunchy bars (Lara and Mejía 2004b), (Table 2).

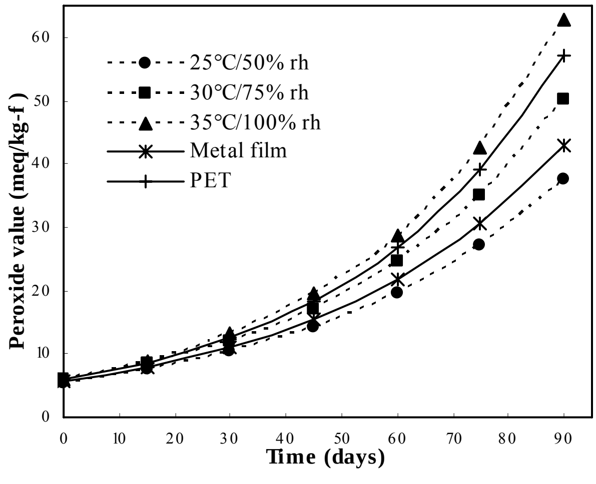
Table 2. Nutritional and antinutritional factors of the amaranth grain.

Nutritive quality	Raw grain	Popped grain	B. cereal	C. Bars
Protein (%)	17.8 (0.1)	15.5 (0.1)	8.4 (0.1)	8.5 (0.1)
Fat (%)	8.3 (0.1)	8.6 (0.1)	8.3 (0.2)	8.2 (0.1)
Total sugar (%)	0.7 (0.1)	1.3 (0.1)	33.2 (0.3)	39.0 (0.4)
Phosphorous (mg/g)	5.4 (0.1)	5.4 (0.1)	3.4 (0.3)	2.5 (0.7)
Potassium (mg/g)	5.0 (0.1)	5.7 (0.3)	7.6 (0.5)	8.4 (0.1)
Iron (μ/g)	75 (2)	69 (3)	51.8 (3.1)	50.7(0.4)
Protein digestibility (%)	79.8 (0.2)	84.4 (0.9)	80.1 (0.3)	81.7 (0.1)
Available lysine (g/100g P)	1.9 (0.1)	3.3 (0.6)	2.7 (0.5)	2.3 (0.5)
Iron availability (%)	**	8.5 (0.8)	11.4 (0.5)	16,9 (0.8)
Energy (kJ/g)	18.46(2.05)	18.11 (2.39)	17.29 (2.64)	18.05 (2.43)
Tannins (mg/100g)	1.60 (0.03)	0.90 (0.01)	0.84 (0.03)	0.62 (0.01)
Trypsin inhibitor (UTI/ml)	1.26 (0.01)	0.63 (0.01)	1.10 (0.01)	1.20 (0.01)

Nutritive quality based on macro and micronutrients, availability and antinutritional factors, Raw grain (*Amaranthus caudatus*), Popped grain at 240°C, 22g load, 0.013m^3/s airflow and 12% grain moisture, Breakfast cereal (45% popped grain, 15% raisings, 9% grated coconut, less than 1% amaranth starch , brow sugar honey 62°Brix and honey 65°Brix), Crunchy bars (60% popped grain, 1.5 amaranth starch , brow sugar honey 62°Brix and honey 65°Brix), Average (n=3), Values in parentheses indicate standard deviation. ** No determined.

Shelf life

The peroxide value of popped amaranth grain and its products showed exponential increase by effect of storing conditions and packaging material (Figure 2a). After 75 days, the level of peroxide value was significant ($p < 0.05$) amongst all treatments, and higher than the maximum level accepted of 20 m-equivalents of oxygen per kilogram of fat. Plotting rancidity sensory score against peroxide value (Figure 2b), was validated the peroxide value as a control parameter in shelf live testing for amaranth products (Lara and Mejía 2004a)



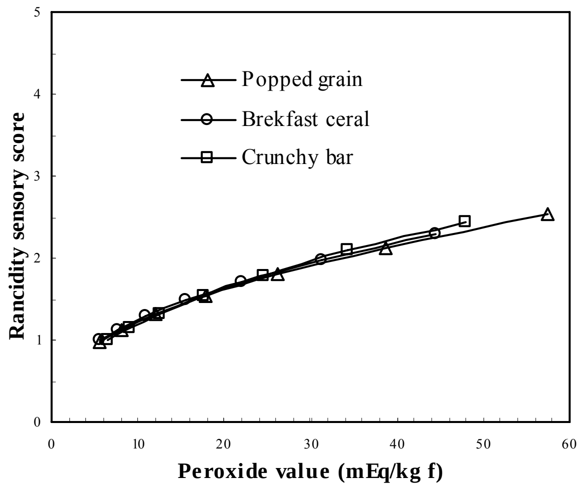


Figure 2. a) Increase of peroxide value during storing period of amaranth products, b) Correlation (r of 0.94 to 0.97) between rancidity sensory score and peroxide value.

The correlation (*r*) and regression (R^2) between sensory crunch intensity and maximum force by compression were from – 0.90 to 0.95 and from 80 to 90%, respectively. The negative sign indicate the inverse relationship of the variables. While the product was crunchier, the maximum force of fracture was lower (Lara and Mejía 2004a).

CONCLUSIONS

The popping process at 240°C, 22g load, 0.013m^3/s airflow and 12% grain moisture reaches yields over 80% of popped amaranth grain which, as main ingredient of breakfast cereal and crunchy bars, is a good source of nutrients, being relevant digestible protein and available lysine. Instead of sensory attributes, peroxide value and the maximum force of compression can be used to control the shelf life testing and basic stability of popped amaranth grain-based products. According to sensorial rancidity, the maximum limit of peroxide value for amaranth products must be lower than 20 m-equivalents of oxygen per kilogram of fat.

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