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Improved functional properties of pasta: Enrichment with amaranth seed flour and dried amaranth leaves

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ABSTRACT

The present investigation evaluated the effects of dried amaranth leaves (DAL) and amaranth seed flour (AF) as ingredients for pasta production and their contribution to antioxidant activity. Cooking quality, proximal and aroma analysis, antioxidant capacity and sensory evaluations were performed. The results demonstrated that pastas with amaranth ingredients had decreased cooking time, increased cooking loss percentage, and decreased luminosity values compared with semolina control pasta. Pastas with both AF and DAL demonstrated the highest protein, crude fiber and ash contents. The addition of DAL resulted in higher contents of iron, zinc, magnesium and potassium compared with the control pasta. TC, FRAP and ORAC assays showed that the pastas exhibited an important reduction in antioxidant capacity by cooking process. Formulas with DAL showed the higher antioxidant capacity values after cooking. The addition of AF and DAL has proved to increase the functional benefits of the pasta.

1. Introduction

Amaranth is a pseudocereal that belongs to a very versatile crop, which can supply grains and tasty leafy vegetables. Nowadays, three amaranth species are mainly used for seed production; these are *Amaranthus cruentus* L., *A. caudatus* L., and *A. hypochondriacus* L. These species produce big inflorescences full of seeds, therefore, consumers can take advantage of them for different uses, such as flour from seeds, salads from fresh leaves, inflorescences as source of natural red dye, or waste products as animal foodstuff (López-Mejía et al., 2014). Amaranth is currently gaining popularity due to its excellent nutritional value. The grains have contents of 15 g/100 g of protein, 60 g/100 g starch and 8 g/100 g fat in addition to being a source of thiamine, niacin, riboflavin, and folate, and dietary minerals including calcium, iron, magnesium, phosphorus, zinc, copper, and manganese (Chauhan et al., 2015; Inglett et al., 2015). Both, grains and leaves from *A. hypochondriacus* contained nutraceutical ingredients. The protein in the grain after the digestion process produces peptides with anti-hypertensive, anti-oxidant, antithrombotic, anti-proliferative, and anti-inflammatory activities among others (Montoya-Rodríguez and González de Mejía, 2015; Moronta et al., 2016). On other hand, amaranth leaves are a good source of antioxidant compounds such as phenolic acids, flavonoids and carotenoids (López-Mejía et al., 2014). Antioxidants may play an important role in inhibiting free radical and oxidative chain-reactions within tissues and membranes (Chauhan et al., 2015) and the consumption of food products rich in antioxidants has been related to a decrease in the risk to develop diseases related to oxidative stress (Pisoschi and Pop, 2015).

The popularity of this crop is not only because of its nutritional and nutraceutical value but also to its ease of adaptation to adverse conditions like poor soils and a shortage of water (Rezaei et al., 2015). The amaranth grain can be toasted, popped, extruded or milled into flour and it can therefore be consumed as such or included in other cereal products such as bread, cakes, muffins, pancakes, cookies, dumplings, crepes, noodles, pastas and crackers.

Abbreviations: ABTS, 2,2-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid); AF, amaranth flour; CL, cooking loss; CMC, carboxymethylcellulose; CW, cooking weight; DAL, dried amaranth leaves; DPPH, 1,1-diphenyl-2-picrylhydrazyl; FRAP, ferric reducing antioxidant power; ORAC, oxygen radical absorbance capacity; PCA, Principal Component Analysis; S, semolina; TE, trolox equivalent; TPC, total phenolic content; Trolox, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid.

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The nutritional quality of amaranth seed is higher than that of most cereal grains, owing to its high protein content and balanced essential amino acid composition. The amaranth grain protein is especially rich in lysine, which is usually deficient in cereal grains (Salcedo-Chávez et al., 2002; Sanz-Penella et al., 2013).

Pasta products are made from wheat semolina, although more recently other grains have been used to partially replace it, presenting a higher nutritional value, such as essential amino acids, minerals, vitamins and phenolic compounds. In addition, composite flours have been used to prepare gluten-free or low glycemic index pastas for special nutrition. Total replacement of wheat flour is not always advantageous because vegetable pasta made with alternative flours can break down and have high loss of solid content during cooking in water and an undesirable texture due to high adhesiveness (Louise et al., 2016). Interest in amaranth flour has grown since studies have shown that it can contribute to the improvement of the structure and the cooking quality of pasta as well as enrichment of the essential mineral content in the case of gluten-free products (Fiorda et al., 2013; Hidalgo et al., 2015).

Despite the scientific knowledge on the functional properties of amaranth, there is a dearth of amaranth food products available on the market. The present investigation aimed to evaluate the effects of amaranth leaves and seed flour as ingredients for pasta production and their contribution to antioxidant activity.

2. Material and methods

2.1. Materials

Commercial amaranth flour (AF), semolina (S) and fresh egg were procured from a local market in Winnipeg (Manitoba, Canada). Fresh amaranth leaves were obtained from local farmers in Querétaro (Querétaro, México), blanched, dried in an air convention oven (50 °C for 5 h) and milled. As structuring agent, commercial carboxymethylcellulose (CMC) was used (TIC Gums, Nealanders International Inc., Delta, B.C.). 2,2-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 1,1-diphenyl-2-picrylhydrazyl (DPPH), Folin Ciocalteu reagent, potassium persulfate and methanol were supplied by Sigma Aldrich Co. (St. Louis, MO,USA). Sodium hydroxide, hydrochloric acid, sodium bicarbonate and sulfuric acid were purchased from JT Baker (Mallinckrodt Baker, Inc., Phillipsburg, NJ, USA).

2.2. Experimental design

For the main experiment, a mixture design was conducted with variable proportions of semolina, amaranth seed flour (AF), dried amaranth leaves (DAL), fresh egg and carboxymethylcellulose (CMC) with the following restrictions: semolina 21.25–50.97%, AF 25.45–49.57%, egg 15.06–15.31%, DAL 0–5.61%, CMC 8.52–14.13%, and semolina + AF = 70.8–84.85%. The experimental design was built to allow the estimation of main effects and double interactions, giving a total of 16 experimental formulations, which were carried out in duplicate in a random order (Table 1). After statistical analysis of the experimental results, seven formulations were chosen for further characterization.

2.3. Pasta production

According to the experimental design and after calculating the amount of water required to obtain a 34% moisture content in the dough (the moisture content of all ingredients was considered in the calculation), the dry ingredients for each formula were weighed and mixed together (Kitchen Aid® Professional Mixer, Model 4KV25HOXWH, USA – speed 2). The water and egg were then slowly added, kneading for 5 min (speed 2) to obtain homogenous dough, which was extruded using a pasta press (Kitchen Aid® attachment Model 4SNFGA, USA). The elbow-type pasta produced was placed on sieves and dried in an air convection oven for 4 h at 80 °C. Then the pasta was cooled and packaged in plastic containers and stored at room temperature until further use. All formulations were produced in duplicate.

2.4. Cooking quality of pasta

The cooking quality of the pasta produced was evaluated according to official method 66–50.01 of AACC which defines the cooking conditions and procedures for the determination of the cooking quality of noodles. Briefly, for *cooking time*: Twenty-five grams of pasta were placed into 300 ml of boiling water. Every 30 s a piece of pasta was taken out and pressed between two glass or perspex plates. The cooking time was reached at the time when a white core could no longer be seen. The *cooking loss* (CL) was determined gravimetrically by weighing the residues after evaporating the cooking water and the *cooking weight* (CW) was obtained by weighing the cooked pasta. All measurements were determined by duplicate.

2.5. Color analysis

Color analyses were carried out on pasta samples using a color spectrophotometer (CM-3500d Konica Minolta, Osaka, Japan). Color was expressed in L*, a*, b* Hunter scale parameters. At least eight measurements were carried out on each sample and the coefficients of variation, expressed, as the percentage ratio between the standard deviation and the mean value, were less than 8%.

2.6. Proximal analysis

Moisture, ash, crude fat and crude fiber were determinate in accordance with AOAC (1997). The values of carbohydrates were estimated by difference and the caloric value was calculated considering the following energy conversion factors: carbohydrate 4 kcal/g (17 kJ/g), protein 4 kcal/g (17 kJ/g) and lipid 9 kcal/g (37 kJ/g).

2.7. Mineral analysis

1 g of milled pasta was added to an Erlenmeyer flask and covered with HNO_3. The sample was heated under the hood until brown fumes disappeared. Then 5 ml of $HClO_4$ were added to continue digestion. The mineral solution was transferred into 100 ml volumetric flask by filtration through Whatman No. 42 filter paper. This solution was used to determine Fe, Zn, Mg, Ca and K by atomic absorption spectrophotometry (3110 Perkin Elmer, Norwalk, CT, U.S.A). Results were expressed as mg of mineral/Kg pasta.

2.8. Antioxidant analysis

2.8.1. Sample preparation

Raw and cooked pasta samples of each formulation were prepared. For cooked samples, 15 g of pasta were placed into 300 ml of boiling water containing 5 g of salt and cooked according to the predetermined cooking time. The pasta was then drained, cooled and frozen prior to freeze-drying (Thermo Electron Corporation, Waltham, MA.). A mill (Black and Decker, Hunt Valley, MD) was used to grind raw and cooked pasta samples.