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Nutritional improvement of corn pasta-like product with broad bean (*Vicia faba*) and quinoa (*Chenopodium quinoa*)

M.A. Giménez [a], S.R. Drago [b], M.N. Bassett [c], M.O. Lobo [a], N.C. Sammán [a,c,*]

[a] Departamento de Agroindustrias, Facultad de Ingeniería, Universidad Nacional de Jujuy, Italo Palanca 10, Jujuy (4600), Argentina
[b] Instituto de Tecnología de Alimentos, Facultad de Ingeniería Química, Universidad Nacional de Litoral, 1 de Mayo 3250, Santa Fe (3000), Argentina
[c] Departamento de Bioquímica de la Nutrición, Instituto Superior de Investigaciones Biológicas (INSIBIO-CONICET), Chacabuco 461, San Miguel de Tucumán (4000), Argentina

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ABSTRACT

In this study, the nutritional quality of pasta-like product (spaghetti-type), made with corn (*Zea mays*) flour enriched with 30% broad bean (*Vicia faba*) flour and 20% of quinoa (*Chenopodium quinoa*) flour, was determined. Proximate chemical composition and iron, zinc and dietary fiber were determined. A biological assay was performed to assess the protein value using net protein utilization (NPU), true digestibility (TD) and protein digestibility-corrected amino acid score (PDCAAS). Iron and zinc availability were estimated by measuring dialyzable mineral fraction (%Da) resulting from *in vitro* gastrointestinal digestion. Nutritionally improved, gluten-free spaghetti (NIS) showed significantly increased NPU and decreased TD compared with a non-enriched control sample. One NIS-portion supplied 10–20% of recommended fiber daily intake. Addition of quinoa flour had a positive effect on the FeDa% as did broad bean flour on ZnDa%. EDTA increased Fe- and ZnDa% in all NIS-products, but it also impaired sensorial quality.

1. Introduction

Pasta is a traditional product produced mainly by mixing durum wheat semolina and water. In pasta processing, gluten is mainly responsible for structure formation, the most significant factor related to its cooked quality. In recent decades, gluten has received attention due to the increasing numbers of patients diagnosed with intolerance, ca. 0.3–1% of the world's population (Stojceska, Ainsworth, Plunkett, & İbanoğlu, 2010).

Pasta is one of the most widely demanded products by those who are gluten-intolerant (Zandonadi et al., 2012). According to Demirkesen, Mert, Sumnu, and Sahin (2010), gluten-free pasta and baked products currently available on the market are often made with refined flours. The most commonly used gluten-free flours are made from rice (*Oryza sativa*), Sorghum (*Sorghum bicolour*) and corn (*Zea mays*). Even though corn flour supplies many micro- and macronutrients, amounts of some essential nutrients are inadequate. Therefore, consumption of these products contributes only small amounts of protein, minerals and dietary fiber, which could increase the risk of nutritional deficiencies associated with celiac disease. For this reason, the nutritional value of gluten-free products should be improved.

In the development of gluten-free baked product, research has focused on substitution of gluten with mixtures of starches, emulsifiers, hydrocolloids, and enzymes (Sciarini, Ribotta, Leon, & Perez, 2012). There have been several studies concerning the changes in functional properties of gluten-free flours, especially hydrothermal treatment (Giménez et al., 2013). With respect to nutritional value, Matos Segura & Rosell, 2011 found considerable variation in the nutrient content of gluten-free products available on the market. They suggested products had low protein content as well as high fat and carbohydrate contents, while dietary fiber content was only adequate, compared with nutritional recommendations. According to Stojceska et al. (2010) and Kiskini et al. (2007), a lack of iron and dietary fiber are among the most frequent deficiencies in a free-gluten diet. For this reason, attempts to improve gluten-free products have increased with the incorporation of nutrient-rich flours or protein isolates, such as those from amaranth (*Amaranthus* spp.) (Cabrera-Chávez et al., 2012), quinoa (*Chenopodium quinoa*) (Schoenlechner, Drausinger, Ottenschlaeger, Jurackova, & Berghofer, 2010), chickpea (*Cicer arietinum*) (Demirkesen et al., 2010), lupine (*Lupinus* spp.) and other leguminous flours (Mahmoud, Nassef, & Basuny, 2012).

In Argentina, wheat (*Triticum aestivum* L.) and corn (*Z. mays* L.) are the most important cereals. More than 70% of both commodities are exported. In the last decade, domestic corn consumption

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* Corresponding author at: Departamento de Agroindustrias. Facultad de Ingeniería, Universidad Nacional de Jujuy, Italo Palanca 10, Jujuy (4600), Argentina.
E-mail address: nsamman@fi.unju.edu.ar (N.C. Sammán).

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has increased, promoted by factors such as increased poultry production, increasing use of fodder, and ethanol production (Pieragostini, Aguirre, & Musssati, 2014). Thus, it would be interesting to develop new products from these sources for human consumption. In the Andean region of the province of Jujuy (Argentina) production of crops such as quinoa (*C. quinoa*) and broad bean (*Vicia faba*) is increasing as an income source for people (farmers) of the region. Due to their nutritional properties, such as wide range of minerals and vitamins, high protein and lysine contents, these gluten-free crops are ideal for enriching corn-based products that may be eaten by the celiac population or those wishing to reduce gluten consumption. These unconventional raw materials also are good ingredients for the development of functional foods due to a high fiber content and other associated components, including polyphenols (Alvarez-Jubete, Arendt, & Gallagher, 2010; Luo & Xie, 2012), which are recognized for their health benefits and prebiotic properties. Unfortunately, the presence of components such as phytic acid, tannin, saponins, limits the utilization of cereal-based products. They are often described as anti-nutritional factors, which decrease bioavailability of starch, protein and, especially, minerals. In order to counteract these negative effects, co-fortifiers, such as ascorbic and organic acids as well as ethylenediminetetraacetic (EDTA), are also added to these foodstuffs. EDTA is used in flours to increase the bioavailability of Fe and Zn (Tripathi, Platel, & Srinivasan, 2012).

Iron deficiency is a major public health problem in developing countries that affects up to half of infants, children and women of childbearing age in poorer populations of Africa, Asia and Latin America (Tripathi et al., 2012). In recent years, zinc deficiency has also being recognized as a global health problem. It is estimated that coeliac disease may account for 3–5% of prevalence of iron deficiency (Kiskini et al., 2007). Therefore, it is important to assess the contribution of macro- and micro-nutrients provided by gluten-free foods. There is a lack of information regarding the bioavailability of both proteins and minerals from gluten-free products.

The nutritional value of protein in foods is usually determined by net protein utilization (NPU) and protein digestibility-corrected amino acid score (PDCAAS) indexes. NPU is a biological method that assesses the efficiency of protein utilization using rats (Oliveira-Souza, Canuto-Fernandes, Medeiros-Alves, Borges de Frias, & Meloso Naves, 2011). This method often under-estimates the protein quality of plant foods since growing rats require greater amounts of certain essential amino acids than humans. PDCAAS is the method recommended by FAO to evaluate protein quality, which considers both essential amino acid profile (in comparison with the human requirement pattern) and protein digestibility (Oliveira-Souza et al., 2011). Several approaches have been used to estimate iron bioavailability, including *in vitro* digestion to measure iron solubility or dialysability, and animal studies. *In vitro* estimation of the bioavailability of minerals and trace elements from foods involves the simulation of gastrointestinal digestion and measurement of the mineral soluble fraction or the mineral fraction that dialyses across a semi-permeable membrane of a certain pore size. The method of Miller, Schricker, Rasmussen, and Van-Campen (1981), in particular, has been shown to provide availability measurements that correlate well with studies *in vivo*. It is one of the most extensively used methods for predicting many inhibitors/enhancing dietary factors. For example, it has been used to examine the influence of processing on mineral availability from foods (Dyner et al., 2007).

The aim of this study was to evaluate the nutritional contribution of gluten-free pasta-like products made with corn flour, and nutritionally improved with 30% broad bean and 20% quinoa flours using EDTA as a co-fortifier.

2. Materials and methods

2.1. Raw materials

Corn flour was provided by Molinos Puerto Reconquista (Santa Fe, Argentina). Size was reduced by using a Buhler-Miag roller mill. Quinoa seeds and broad beans (*V. faba*), obtained from a Cooperative of producers (CAUQUEVA – Tilcara, Jujuy, Argentina), were hulled manually and dried in solar dryer before being ground with a fixed hammer mill (Retsch, Germany) to obtain flour with a particle size between 0.191 and 0.490 mm.

2.2. Elaboration of spaghetti-type pasta (NIS)

NISs were prepared in duplicate, as follows:

Blends of flours were prepared by substituting corn flour with broad bean flour (C/BB) and quinoa flour (C/Q) as 30 g and 20 g/100 g (db), respectively; substitutions were selected to obtain a product of acceptable quality (Giménez et al., 2013). Homogenized blends were mixed with water up to a moisture content of 28% using a planetary mixer (Brabender).

The extrusion process was carried out in a Brabender 10 DN single screw extruder (100 °C) using a 3:1 compression ratio screw, a 1.5 mm × 3 (diameter × n° of holes) die and at a screw speed of 60 rpm. The products were dried at 40 °C and 40% relative humidity for 16 h. Na_2EDTA ($C_{10}H_{14}N_2O_8Na_2{\cdot}2H_2O$; PM: 372,24) was added to the mixture before extruding it at a molar ratio of 1:1 EDTA:Fe to determine its effect on the availability of Fe and Zn.

2.3. Cooking loss (CL)

NIS samples (10 g, 10 cm long) were placed in a 500 mL beaker with 200 mL of boiling distilled water. After required cooking time, the cooked product was drained for 3 min. The cooking water was collected in an aluminum vessel, placed in an air oven (105 °C) and evaporated to dryness. The residue was weighed and reported as a percentage of the starting material.

2.4. Global Sensorial score (GSS)

A trained panel of three persons was used to evaluate firmness and stickiness. A global score was obtained by consensus using two replicates. For each attribute a 0–5 scale was used where 0 was firm and not sticky and 5 soft and very sticky respectively. A global score (firmness plus stickiness) of less than or equal to 5 was considered acceptable.

2.5. Compositional analysis

Raw materials and NIS were analyzed for protein, fat, ash, and moisture using AOAC (1995). Moisture was determined in a vacuum oven (SHE-LAB 1410) using AOAC 925.09. Lipid content was determined according to the acid hydrolysis method AOAC 922.06. Total protein content was determined using the method of Kjeldahl (BUCHI DIGESTIÓN UNIT K-435) with a nitrogen-to-protein conversion factor of 6.25 (AOAC 984.13). Ash analysis carbonized samples at 550 °C (Mufle furnace) (AOAC 923.03). Total iron and zinc content were analyzed using an atomic absorption spectrometer. Calibration of the measurements was performed using commercial standards. Dietary fiber was determined using the enzymatic–gravimetric method, AOAC 985.19. Fatty acid profile was determined by gas chromatography, following the methylation acid process.