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Quality assessment of gluten-free pasta prepared with a brown rice and corn meal blend via thermoplastic extrusion

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ABSTRACT

The development of gluten-free pastas made with brown rice (BR) and corn meal (CM) was proposed. A 3^2 central composite rotation design was used to evaluate the effects of the extrusion variables, i.e., temperature, feed moisture and CM content, on the pasting properties and cooking quality of the extrudates. Sensory factors, texture and chemical composition were also analysed to determine the best treatments. The pasting properties allowed verification of the transformations/interactions among the components of the dough after the extrusion process. An increase of the feed moisture content (up to 43.4 g/100 g) caused an increase in cooking loss, but for CM flour (up to 46.8 g/100 g), this increase caused an increase in cooking time. The temperature levels did not influence the cooking characteristics. The pasta with the highest BR flour content (87 g/100 g) had higher contents of lipids and fibre, as well as better mineral and amino acid profiles. The pasta produced with a ratio of 40:60 (CM:BR), 30 g/100 g of moisture content, and at 70 °C received better evaluations with respect to texture (sensory and instrumental) compared with pasta made with a ratio of 13.2:86.8 (CM:BR) and 35 g/100 g moisture content at 80 °C.

1. Introduction

Pasta is a starchy staple food widely consumed across the world and is popular with consumers for its ease of transportation, handling and cooking, as well as its storage properties (Foschia, Peressini, Sensidoni, & Brennan, 2013). Pasta products made from wheat are characterized by proteins that form a viscoelastic network and optimal dough properties during the mixing and extrusion steps (Mariotti, Iametti, Cappa, Rasmussen, & Lucisano, 2011), thus producing better strength and stability in the final product. In gluten-free (GF) pasta, the viscoelastic gluten network is absent, and the intensive heating applied during the extrusion process has necessitated important modifications to the starch organisation, leading to the creation of a new structure formed by retrograded or partially gelatinized and retrograded starch (Lucisano, Cappa, Fongaro, & Mariotti, 2012). Thus, the development of a farinaceous GF product is not a simple process because it is necessary to create a matrix that is uniform and sufficiently cohesive to withstand the cooking process and confer quality attributes on the final product (Gimenez et al., 2013). Therefore, the incorporation of alternative (to wheat) ingredients for pasta production requires processing adjustments and additives (Schoenlechner, Drausinger, Ottenschlaeger, Jurackova, & Berghofer, 2010).

The common ingredients in GF pasta are flour and/or starch from corn, rice, potato (or other tubers), with the addition of protein, gums, and emulsifiers which may partially act as substitutes for gluten. The diversity of GF raw materials help to increase the quantity and the quality of products for celiacs. Formulating GF pasta requires, firstly, a thorough knowledge of the component properties of GF flours and starches. Then, appropriate additives may be selected to promote a cohesive mass in the product (Marti & Pagani, 2013).

Rice flour is commonly used as a raw material in preparation of GF products because of its bland taste, high digestibility and

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hypoallergenic properties (Rosell & Marco, 2008). Most of the extruded GF products found in the market include corn and white or polished rice as their main ingredients due to their abundance, low cost and high expansion capacity, as well as their suitability for celiacs (Gimenez et al., 2013). However, white or polished rice is low in fibre and has relatively poor technological properties for interaction and development of a cohesive network.

The extrusion-cooking method is an alternative technology that is suitable for manufacturing of GF pasta-like products because it involves unification of the pre-gelatinisation and formation steps (Amerayo, Gonzalez, Drago, Torres, & De Greef, 2011; Marti, Seetharaman, & Pagani, 2010).

Although the effects of different starch sources have been extensively investigated (Islas-Rubio, Calderón de la Barca, Cabrera-Chávez, Cota-Gastélum, & Beta, 2014; Larrosa, Lorenzo, Zaritzky, & Califano, 2013; Marti et al., 2010), little information is available on the use of brown rice mixed with corn meal flour, its suitability for pasta making, and its cooking behaviour.

The main objectives of this study were (a) to study the effects of such extrusion variables as temperature, feed moisture and corn meal content on the pasting properties and cooking quality of pasta made with brown rice flour, and (b) to analyse the sensory attributes, instrumental texture and chemical composition (proximate composition, mineral profile and amino acids) of the best treatments made with a brown rice and corn meal blend.

2. Materials and methods

2.1. Materials preparation and particle size

Non-parboiled brown rice was donated by the Josapar company (Pelotas, Rio Grande do Sul, Brazil). Corn grits were purchased at a local food market (Rio de Janeiro, RJ, Brazil). Each raw material was milled separately into flour on a knife-hammer mill using a sieve with a 1 mm opening (TREU, São Paulo, Brazil). The particle size distribution of the brown rice flour and the corn meal flour was determined by sifting 100 g of each flour for 10 min through a plan sifter equipped with seven sieves (Ro-Tap RX 29-10, Ohio, USA) with different opening sizes (420, 300, 250, 180, 150, 105 and 75 μm), according to ASAE Standards method S319.2 (1995).

2.2. Amino acid profile and essential amino acids score

In order to characterize the raw materials, the amino acid profiles of the brown rice and corn meal flour were determined in duplicate according to the AOAC (2005) method 994.12, and quantification of amino acids was performed using a high performance liquid chromatograph (HPLC) (Alliance Waters 2695 - Massachusetts, USA) with fluorescence detection (Alliance Waters 2475 - Massachusetts, USA). The essential amino acids score (EAAE) was calculated with reference to the standard recommended by the FAO/WHO for children 2–5 years old, children 10–12 years old, and adults (FAO, 1985). The score calculation and interpretation of results are consistent with the methodology of Pires, Oliveira, Rosa, and Costa (2006) (Equation (1)).

$$\text{EAEE} = \frac{\text{mg amino acids/g of protein}}{\text{FAO} - \text{WHO recommendation(mg amino acids/g of protein)}} \tag{1}$$

2.3. Dough preparation and extrusion processing

Brown rice and corn meal flours were mixed in proportions established by the experimental design (Table 1) to obtain 1 kg of the total mixture. Flour moisture content was determined in order to establish the amount of added water necessary to adjust the moisture content of the blend to the required levels of 26.59–43.41 g/100 g. Additionally, 1.5 g/100 g of an emulsifier was added to each mixture (monoglyceride Nu-Rice - Ribus, Inc., St. Louis, MO, USA), both relative to the total flour. The final blends were held for 18 h under refrigerated conditions (4 °C) in a sealed plastic bag prior to the extrusion process.

The extrusion process was performed in a single-screw extruder Brabender 20DN DSE coupled to a module 330 Food Torque Rheometer (Duisburg, Germany). The feed rate of 2.5 kg/h and screw speed of 80 rpm were held constant throughout the process at a pressure of 9–11 MPa. The screw configuration was L/D 1:2 (compression ratio) and included a laminar die with a 1 mm aperture flat sheet head and a 2 cm width, with temperature regulation performed by a corresponding Brabender® Circulatory System. The extrusion trials were started after the equilibrium temperatures of the feed zone (zone 1 = 50 °C) and transition (zone 2 = 60 °C) zone were reached, and these temperatures remained constant throughout the process. In the third zone, temperature variations were applied according to the experimental design (Table 1). The extrudates were collected 3 min after the start of processing, when the product reached equilibrium with respect to temperature and homogeneous material and was free of bubbles and beads on the surface. After extrusion, the pasta was cut into pieces with lengths of 15–20 cm (using scissors) and dried at 40 °C and 80–85% RH for 1 h in an air circulation oven (Fabbe-Primar – São Paulo, Brazil). After the drying process, the pasta was held inside the oven for another 15 min at 70% RH. The pasta samples were cooled at room temperature until they reached a moisture content of approximately 12 g/100 g. The samples were placed in individual sealed plastic bags and stored at room temperature until analysis. These drying conditions were set in preliminary tests.

2.4. Pasting properties

The pasting properties of the extruded samples were analysed in duplicate using a Rapid Visco Analyzer (RVA Super-4 model, Newport Scientific Pvt. Ltd, Australia). The viscosity profiles were recorded using sample suspensions consisting of 3.0 g (14 g of water/100 g) of a sample milled with a Perten mill model and 25 mL of water. The sample was held at 25 °C for 2 min, heated to 95 °C (held for 3 min) and cooled to 25 °C, and the test was completed within 20 min. The heating and cooling phases were performed with a temperature gradient of 6 °C/min. The values of the peak viscosity (PV), breakdown (BD), final viscosity (FV) and setback (SB) were expressed in Pascal-seconds (Pa.s). For the RVA, samples with particle sizes between 125 and 250 μm were used.

2.5. Cooking quality

The pasta samples were subjected to cooking tests in duplicate according to AACC method 16–50 (AACC, 2000) and were