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Effect of formulation on rice noodle quality: Selection of functional ingredients and optimization by mixture design

María A. Loubes [a, b], Silvia K. Flores [a, b], Marcela P. Tolaba [a, *]

[a] Industry Department, Faculty of Exact and Natural Sciences, University of Buenos Aires (FCEyN-UBA), Buenos Aires, Argentina
[b] National Council of Scientific and Technical Research (CONICET), Buenos Aires, Argentina

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ABSTRACT

The aptitude of seven functional ingredients was evaluated by applying the tensile strength test on cooked noodles. Each formulation included the functional ingredient; modified rice flour obtained by planetary ball milling; and water. Gelatinized rice flour and its blends with gelatinized corn starch; xanthan gum; and guar gum provided a satisfactory mechanical behavior. Pasta formulation was optimized by mixture design, which included seven combinations of gelatinized corn starch, xanthan gum and guar gum. Each combination (8.5%) was blended with modified rice starch (86.7%) and gelatinized rice flour (4.8%) as dry ingredients. Synergistic effects between gums could be detected. Optimum mixture (7.8% gelatinized corn starch, 0.7% guar gum without xanthan gum) obtained by maximizing strain at break (17.9%) and simultaneously minimizing cooking loss (13%) also showed satisfactory values of water absorption (58.7%) and stress at break (31.5 kPa). The capacity of gelatinized rice flour and gelatinized corn starch to induce starch network formation was enhanced by the pre-gelatinized character of modified rice flour. The use of gums in pasta formulated with thermo-mechanical modified rice flour could be significantly reduced by substituting them partially with gelatinized corn starch, without reduction of noodle quality.

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1. Introduction

Rice flour is a convenient ingredient to perform gluten-free foods due to its organoleptic and hypoallergenic characteristics (Molina-Rosell, 2013; Osella, de la Torre, & Sánchez, 2014). Rice noodles based on rice starch or rice flour obtained by wet-milling are a popular food in Asia. In a traditional process, a milk layer (aqueous dispersion of flour or starch) is cooked by steam to obtain gelatinized sheets which are then partially dried and cut to noodle strips. The procedure is similar to that of edible rice paper (Cham & Suwannaporn, 2010; Yeh, 2004). However, Western consumers prefer noodles which emulate those obtained by lamination or extrusion of wheat flour (Molina-Rosell, 2013).

Production of gluten-free pasta requires a uniform and cohesive matrix able to withstand the cooking process and to provide good quality attributes to cooked pasta, such as good water absorption capacity, low stickiness, low cooking losses and high extensibility, among others (Huang, Knight, & Goad, 2001; Mariotti, Iametti, Cappa, Rasmussen, & Lucisano, 2011). Therefore, in order to confer appropriate viscoelastic properties to the gluten-free dough, different hydrocolloids, gums, emulsifiers, enzymes have been used (Heo, Lee, Shim, Yoo, & Lee, 2013; Kim, Kee, Lee, & Yoo, 2014; Susanna & Prabhasankar, 2013).

Several authors have also reported that the gelatinization increases the binding capacity of flour particles, improving the noodle quality (Cham & Suwannaporn, 2010; Hormdok & Noomhorm, 2007; Lorlowhakarn & Naivikul, 2006). In fact, different hydrothermal treatments have been successfully applied to enhance the functionality of rice flours (Sozer, 2009).

In recent studies, pre-gelatinized flours of amaranth and rice were obtained by planetary ball milling (Loubes & Tolaba, 2014; Roa, Santagapita, Buera, & Tolaba, 2014). High impact milling of polished rice produced rice flours of variable granulometry (D50 among 96 μm and 262 μm) which presented a gelatinization degree (36–88%) dependent on milling conditions (Loubes & Tolaba,

* Corresponding author. Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Intendente Güiraldes 2160, Ciudad Universitaria, C1428EGA, Ciudad Autónoma de Buenos Aires, Argentina.
E-mail address: mtolaba@di.fcen.uba.ar (M.P. Tolaba).

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2014). The particle size of rice flour plays a key role in the flour properties; the fine fraction (<150 μm) is traditionally used for rice noodles (Yeh, 2004). Rice flour obtained by planetary ball milling could be useful to produce rice noodle with suitable stability and texture upon cooking, due to its particle size. Nevertheless, this has not been studied yet.

Several studies have been reported on the selection of functional ingredients, optimization of formulations and methods to produce gluten-free food with a high sensorial and textural quality (Cappa, Lucisano, & Mariotti, 2013; Gallagher, Gormley, & Arendt, 2004; Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007; Rosell, Moita Brites, Pérez, & Gularte, 2007; Sánchez, Gonzalez, Osella, Torres, & de la Torre, 2008; Velázquez, Sánchez, Osella, & Santiago, 2012). In comparison to bakery products, however, little information exists in literature concerning rice-based pasta (Lai, 2002; Marti, Caramanico, Bottega, & Pagani, 2013; Marti, Seetharaman, & Pagani, 2010). There is even less information about laminated rice noodles designed to match preferences of Western consumers.

The objectives of this work were a) to produce laminated rice noodles from blends of modified rice flour (obtained by planetary ball milling) and different hydrocolloids. Several formulations based on xanthan gum, guar gum, espina corona gum, HPMC, cassava starch, corn starch and gelatinized rice flour were evaluated; b) to select the best hydrocolloids based on tensile strength tests of cooked rice noodles; c) to perform a mixture design including the selected functional ingredients in order to optimize pasta formulation based on mechanical and cooking attributes of cooked rice noodles. Synergistic effect between hydrocolloids was also investigated.

2. Materials and methods

2.1. Materials

A local variety of long-grain polished rice with 23.7 g/100 g amylose content (dry basis) was milled 20 min in a planetary ball mill (model PM100, Retsch GmbH, Haan, Germany) at 550 rpm to obtain modified rice flour, using the method described by Loubes and Tolaba (2014). Grain composition was determined in duplicate by standard methods (AOAC, 1995), the results expressed in wet basis were: moisture (11.7 g/100 g), starch (79.5 g/100 g), fat (0.5 g/100 g), protein (7.8 g/100 g; N × 5.75), and ash (0.4 g/100 g).

Durum wheat semolina (Carrefour, Buenos Aires, Argentina) was purchased from a local market and it was adopted to prepare the control sample. Flour samples were kept in tightly sealed package, protected from light and moisture, and stored at room temperature for a few weeks prior to being tested.

Xanthan gum, guar gum, cassava starch and corn starch, were purchased from a local market (Doña Clara, Buenos Aires, Argentina), hydroxy propyl methyl cellulose (HPMC) was provided by Sigma–Aldrich (St. Louis, USA) and espina corona gum (hydrocolloid from *Gleditsia amorphoides* seed) was donated by Nature Gum Co. (Chaco, Argentina).

2.2. Pasta formulations

Seven formulations which included modified rice flour, distilled water and the functional ingredient were prepared according to Table 1. The ingredients evaluated were gelatinized corn and cassava starches, gelatinized rice flour and binary blends of gelatinized rice flour and one of the following hydrocolloids: HPMC, xanthan gum, guar gum, espina corona gum. Pasta based on durum wheat semolina and water was adopted as control. Each formulation was conducted in duplicate.

2.3. Preparation of fresh noodles

Rice noodles were prepared according to the procedure of Kim et al. (2014) with modifications. Prior to the preparation of dough, gelatinized fractions of rice flour, corn starch or cassava starch were obtained by heating the corresponding aqueous dispersion (11.1 g/100 ml) in a water bath with stirring at 90 °C for 30 min. The complete starch gelatinization was verified by DSC calorimetry. The total amount of water was added in this step which was determined for each formulation (Table 1) from preliminary experiments in order to achieve an optimum lamination of dough.

Gelatinized fraction was joined on the screened and blended dry ingredients (MRF, MRF and gums or MRF and HPMC), and kneaded by hand for 5 min. The dough (80 g) was placed in a tightly sealed container and kept at 25 °C for 30 min to let the starches hydrate. The dough was sheeted on a noodle machine (rollers diameter: 35 mm, Shule, Changzhou, China) at the minimum setting to smooth and firm it, and fed another five times between the rollers, decreasing the gap between rollers each time. Finally, noodles were cut manually into strips (20 mm × 50 mm) and were stored in hermetically sealed containers at 4 °C until used, to prevent moisture loss.

Wheat pasta (F8) adopted as control, was prepared following the procedure described above.

2.4. Cooking of noodles

Rice noodles were cooked in boiling water using pasta to water ratio of 1 g: 10 ml (distilled water without salt added). The optimum cooking time of rice pasta was evaluated as the time required for disappearance of the dry central core when gently squeezed between two glass plates (AACC, 1995).

2.5. Mechanical properties of cooked noodles

Uniaxial tensile strength tests were performed according to Arismendi, Chillo, Conte, Del Nobile, Flores, and Gerschenson (2013) with slight modifications. Mechanical behavior was determined by using a universal testing machine (Instron 3345, Norwood, USA), calibrated for a load cell of 100 N. The average value of at least ten specimens per sample was reported. Each cooked noodle strip (20 mm × 50 mm × 1.65 mm) was mounted between grips (cat 2710-105 Instron, USA). Initial grip separation and crosshead speed were 30 mm and 10 mm/min respectively. The stress σ (F/A, being F the force and A = 33 mm^2 the area of the specimen; kPa) and the strain ε ($\Delta L/L_0$, being ΔL the crosshead displacement occurred and $L_0 = 30$ mm the initial effective length of the sample; %) were recorded. The stress (σ_b) and strain (ε_b) at break were evaluated. For strains lower than 10% the σ–ε curves were fitted to a linear model and the Young's modulus (YM, kPa) was evaluated from the slope.

2.6. Cooking quality

Cooking loss (CL) was evaluated by following the AACC (16-50) standard method (AACC, 1995). Five strips of pasta (4 g) were cooked in 150 ml of boiling water for 8 min. Cooking water was dried to constant weight at 100 °C in order to determine dry matter. The residue was weighed and CL was reported as percentage of the uncooked product (% w/w, dry basis). Water absorption (WA) was evaluated by weighing pasta before and after cooking (Tudoricâ, Kuri, & Brennan, 2002). WA was expressed as the ratio percentage among the weight increase and the weight of uncooked pasta. The average value of at least three replicates for each sample was reported.

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