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Improvement of the texture and quality of cooked gluten-free pasta

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ABSTRACT

The effects of egg-proteins and water content on viscoelastic and quality properties of cooked gluten-free pasta were analyzed. Cooking properties included the determination of optimum cooking time (OCT = 10 min), water absorption, cooking loss, and total organic matter. Cutting force and texture profile parameters were also evaluated. Springiness, resilience, and adhesiveness were mainly controlled by the egg-protein content in the dough, while cooked pasta hardness and the plateau modulus were negatively correlated with dough moisture. The obtained results were mathematically modeled, and a multi-response optimization process was performed using individual desirability functions based on target properties of wheat flour pasta. These functions were combined into a single composite response (global desirability) to determine the precise amount of the different components in the formulation to obtain high quality gluten-free cooked pasta. Optimized dough was prepared, cooked, and the predicted properties were experimentally validated.

1. Introduction

Pasta manufacturing industry, like all industries, caters to the wants and needs of their consumers. High quality cooked pasta from durum wheat semolina maintains good texture, resists surface disintegration, does not release an excessive amount of organic matter into the cooking water, retains a firm structure, and does not show surface stickiness (Liu, Shepherd, & Rathjen, 1996). This is clearly related to the fact that gluten in wheat flour is the main structure-forming protein, thus its absence in gluten-free (GF) pasta results in technological and quality problems.

The technological process adopted in GF pasta production has a significant influence on the quality of the final product as well as the raw materials used. One of the usual methodologies to produce GF pasta is to obtain pregelatinized starch through heat and cool stages, thus forming a rigid network based on the retrograded starch (Cabrera-Chávez et al., 2012; Marti, Caramanico, Bottega, & Pagani, 2013; Marti, Seetharaman, & Pagani, 2010).

However, despite the great efforts made in the last few decades to produce GF pasta with sensory characteristics similar to durum-wheat products, the GF pasta currently on the market is still far from what the consumer is looking for (Marti & Pagani, 2013). Basically, in GF pasta, the role of gluten could be replaced by choosing suitable formulations and recipes using the correct amount of proteins, hydrocolloids and moisture to achieve the desirable quality attributes after the traditional hydrothermal treatment, but also making the dough easy to handle under industrial conditions (Larrosa, Lorenzo, Zaritzky, & Califano, 2013).

Starch has to assume a structuring role, which is related to the tendency of its macromolecules to re-associate and interact after gelatinization, resulting in newly organized structures that retard further starch swelling and solubilization during cooking. Protein quantity and quality have received considerable attention as the most important factors affecting both wheat pasta properties (D'Egidio, Mariani, Nardi, Novaro, & Cubadda, 1990), and GF pasta (Marti et al., 2014). In some cases, also low amounts of emulsifiers (Chillo, Laverse, Falcone, & Del Nobile, 2008) and hydrocolloids (Singh, Raina, Bawa, & Saxena, 2004) are added. Nowadays, the most used ingredients in gluten-free pasta production are: rice and corn flours (Arendt, Morrissey, Moore, & Dal Bello, 2008; Larrosa, Lorenzo, Zaritzky, & Califano, 2012), flours from pseudo cereals (Chillo et al., 2008; Fiorda, Soares, da Silva, Grosmann, & Souto, 2013) starches of different origin (Huang, Knight, & Goad, 2001),

Abbreviations: D, overall desirability value; EP, egg-protein content; G′, storage modulus; G″, loss modulus; GF, gluten-free; G_N^0, plateau modulus; LBG, locust bean gum; OCT, Optimum cooking time; SEM, standard error of the mean; TOM, Total organic matter; W, water content; XG, xanthan gum.

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dairy products and vegetable proteins (Marti et al., 2014; Mirhosseini et al., 2015).

The amount of water used in pasta processing should be optimized to achieve pasta color and textural characteristics according to market preferences (Fu, 2008; Hou, Otsubo, Okusu, & Shen, 2010). It has been informed that insufficient water produce streaky and/or flaky dough sheet surfaces (diminishing pasta color), resulting in softer cooked pasta texture (Hou et al., 2010). Using above optimum levels of water in the formulation also has adverse quality effects, as doughs will be stickier to handle and difficult to sheet tending to produce poor quality finished pasta (Fu, 2008; Hatcher, Kruger, & Anderson, 1999; Hou et al., 2010).

In previous works, Larrosa et al. (2013) optimized gluten-free (GF) pasta dough composition to achieve the desirable textural and rheological properties of the uncooked dough, evaluating its handling properties such as extensibility, ease of processing, smoothness, and non-adhesiveness. The aim of the present work was to improve the GF pasta dough formulation previously proposed (Larrosa et al., 2013) by studying cooked quality attributes at the optimal cooking time. To fulfill this global objective three steps were completed: i) the relationship between egg-proteins and water contents and quality features of cooked GF pasta was analyzed; ii) the precise amount of components to obtain a high quality GF cooked pasta was predicted based on the response of those characteristics that were significantly affected by composition; iii) the predicted optimal formulation was prepared and the cooked GF pasta was characterized, to validate the procedure.

2. Materials and methods

2.1. Materials

Corn flour and corn starch were purchase from Herboeste (Bs As, Argentina) and Saporiti (Bs As, Argentina), respectively. Dry egg and dry egg-white were kindly provided by Ovobrand SA (Brandsen, Argentina). Used hydrocolloids were food-grade commercial xanthan (XG) and locust been gums (LBG) obtained from Sigma–Aldrich Co. (St. Louis, MO). Analytical grade NaCl, sunflower oil (AGD, Bs As, Argentina), and cold distilled water were also used.

2.2. Experimental design

A two-way factorial design was employed to analyze the effect of water and protein content on the quality of cooked pasta (Larrosa, Lorenzo, Zaritzky, & Califano, 2015). Three levels for moisture content (34.8 g/100 g, 36.13 g/100 g, and 37.5 g/100 g) and two for egg-proteins (2.7 g/100 g and 6.6 g/100 g) were adopted (Table 1). An additional central point was included and replicated three times to better interpret the interaction of components and evaluate curvature in the mathematical models (W2EP2).

Water plus egg-proteins contents (dry whole-egg + dry egg-white, 10:1) ranged between 37.5 g/100 g and 44.1 g/100 g, thus the corn starch and corn flour mixture varied from 56.2 g/100 g–49.6 g/100 g, accordingly. The ratio between corn starch and corn flour was 4:1 in all formulations.

As a control, wheat pasta formulated with 67 g/100 g of commercial wheat flour (Molino Cañuelas, Bs As, Argentina) and 33 g/100 g fresh eggs was also prepared.

Table 1
Composition of the studied formulations. Protein and water contents are given as percentages of the total fresh dough.

Formulation	Composition (g/100 g)			Coded levels	
	Dry egg	Dry egg-white	Water	Egg-protein (EP)	Water (W)
W1EP1	2.45	0.25	34.8	−1	−1
W2EP1	2.45	0.25	36.13	−1	0
W3EP1	2.45	0.25	37.5	−1	1
W2EP2	4.23	0.42	36.13	0	0
W1EP3	6	0.6	34.8	1	−1
W2EP3	6	0.6	36.13	1	0
W3EP3	6	0.6	37.5	1	1

2.3. Pasta dough sample preparation

The basic formulation of the dough was taken from a previous work where composition was optimized to obtain a good quality uncooked pasta dough (Larrosa et al., 2013): 1 g/100 g NaCl, 2.8 g/100 g sunflower oil, 2.5 g/100 g of a mixture of XG and LBG in a 2:1 ratio.

The mixing protocol adopted to prepare GF dough was previously described by Larrosa et al. (2013). Once the laminated dough was obtained, representative subsamples were cut from these sheets and kept in airtight polystyrene containers to avoid moisture loss until assessment of their functional characteristics. Ambient temperature was kept at 20 °C throughout dough preparation.

Two different geometries were used: band pasta (tagliatelle, 8 × 2 × 150 mm) and lasagna sheet (80 × 80 × 2 mm). Tagliatelle shaped pasta was used to analyze texture and the other quality parameters, while rheological properties were determined using circles (35 mm diameter) cut from the lasagna sheet, to entirely cover the measuring surface of the sensor.

2.4. Cooking properties

2.4.1. Pasta quality evaluation

The optimal cooking time for each formulation was determined using method AACC 66-50 (AACC, 2000). The cooking tests were performed for various cooking times for each pasta sample in order to determine the optimal cooking time (OCT). Briefly 25 g of tagliatelle was cooked in 300 ml of boiling distilled water. OCT was when the white core in the pasta was still present but disappeared after squeezing between two glass slides. Once the OCT was evaluated, the pasta sample was optimally cooked and the solid loss and water absorbed during cooking were determined by triplicate.

Cooking loss (g loss/100 g initial dough) was measured by evaporation of the cooking water to dryness in an oven-tray (100 °C). Absorbed water was measured as the weight increase of tagliatelle before and after cooking, and was expressed as percent weight gain with respect to the weight of uncooked pasta (Bonomi et al., 2012).

2.4.2. Total organic matter (TOM)

Total organic matter (TOM) is the amount of organic matter released from the cooked pasta during exhaustive rinsing. 25 g drained pasta was washed with 500 ml water to remove the substance coating the surface of cooked pasta. Then the washing water was analyzed for TOM (D'Egidio et al., 1982) using a commercial test for Chemical Oxygen Demand analysis (Hach Cat. N° 24159, Hach Co., CO, USA). Water samples digestion (2 h, 150 °C) was performed in a Hach COD Reactor 45600, and absorbance was measured (Hach DR 2000 photometer). TOM value was expressed as g starch/100 g dough. Measurements were done in triplicate.

2.5. Color analysis

The color of raw and cooked pasta was measured using a Minolta Chroma Meter (CR-400, Minolta Co., NJ, USA). CIE color parameters lightness (L*), redness (a*), and yellowness (b*) were determined. At least three different regions of the lasagna sheets