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Dynamic rheological analysis of gluten-free pasta as affected by composition and cooking time

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ABSTRACT

The present work analyzes the effect of cooking times and dough composition on the rheological properties of gluten-free pasta. Gluten-free pasta dough was prepared with corn starch, corn flour, NaCl, dry egg and dry egg-white powders, sunflower oil, xanthan and locust bean gums. Small amplitude oscillatory data was used to obtain the relaxation spectrum. For all the formulations assayed G' was always greater than G'' in the frequency range measured and the increase of both moduli with frequency was small. Oscillatory spectra were satisfactorily predicted using the Maxwell Generalized model. Cooking time had a stronger effect on the mechanical spectra than protein and water contents. Hydrothermal treatment produced a significant microstructural change within the network entanglements. The analysis of the rheological behavior showed that water uptake by the matrix, partial gelatinization of the starch, and aggregation of denatured egg proteins led to chemical and morphological changes of the cooked pasta.

1. Introduction

Celiac disease is characterized by immune-mediated damage to the gut mucosa which is caused by intolerance to gluten, a protein found in wheat, rye and barley (Duggan, 2004). Lifelong gluten withdrawal from diet is now considered as the sole main effective therapy. In recent years, significant studies have been carried out on gluten-free products involving diverse approaches which have included the use of additives such as starches, hydrocolloids, dairy products, gums and other non-gluten proteins, prebiotics and combinations, as alternatives to gluten, to improve the structure, texture, acceptability and shelf-life of gluten-free products (Cureton and Fasano, 2009). However, most studies focus on gluten-free breads and there are only a few works related with other type of gluten-free doughs like pasta (Cappa et al., 2013; Gallagher et al., 2004; Lazaridou et al., 2007; Mahmoud et al., 2013; Sozer, 2009; Sozer et al., 2007).

Pasta cooking is an important step in pasta processing. Pasta is traditionally cooked in an excess of water (recommended pasta:water ratio is 1:10) at 100 °C for different immersion times depending on the desired texture of the final product. Hydration of the product occurs by a diffusion-controlled process, and the temperature – moisture conditions induce the gelatinization of starch. Gelatinization is accompanied by an increase in viscoelasticity and starch solubilization. Regarding the changes at the macroscopic level, starch gelatinization proceeds toward the center of the pasta strand as the cooking time increases (Cunin et al., 1995). Thus, starch morphological changes range from strong swelling and partial disintegration in the outer layer of the strand to slight swelling in the center. Additionally, water uptake by the matrix, promotes a significant softening of the pasta (Cafieri et al., 2008; Sozer et al., 2007). The hydrothermal treatment also affects the proteins present in the dough. Particularly, when egg proteins are included in a gluten-free pasta formulation, their rheological properties change considerably. When albumen is heated to about 65 °C, a weak gel is formed and the strength of the gel increases at higher temperatures. In the case of yolk, the viscosity begins to increase appreciably at about 65 °C, and at 70 °C, fluidity is lost completely with the formation of a semisolid crumbly mass (Powrie and Nakai, 1985).

During cooking pasta, structure changes from elastic to a more plastic state. Textural attributes are usually correlated to rheological parameters obtained by mechanical measurements, which are very important in understanding the structure of food and biological materials (Nouviaire et al., 2008).

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Many rheological methods have been used to predict the quality of cereal food products. Edwards et al. (1996) investigated the rheological properties of noodle dough prepared from three types of Canadian wheat flour and its relationship to water absorption, formulation and work input during dough sheeting. Hatcher et al. (1999) showed the influence of water absorption on the processing characteristics such as raw thickness, sheet length, cooking time and cooked thickness and total work required, color and textural properties (recovery, resistance to compression, maximum cutting stress and surface firmness) of alkaline and white salted noodles prepared from three types of Canadian wheat flour. Furthermore, Yeh and Shiau (1999) and Shiau and Yeh (2001) studied the effects of oxidoreductants and alkali-acids on rheological properties of wheat flour dough; results showed that dough rheology significantly correlated with the quality characteristics of extruded noodles.

In previous works, Larrosa et al. (2013) optimized a formulation for gluten-free pasta containing a mixture of corn flour and corn starch based on rheological parameters of uncooked dough. However, little is known about changes in rheological properties that occur during the cooking stage of gluten-free pasta. Therefore, the aim of the present work was to analyze the microstructural and viscoelastic changes of gluten-free pasta as affected by dough composition and cooking time.

2. Materials and methods

2.1. Materials

Corn starch (12.5% moisture, 0.3% protein) was obtained from Droguería Saporiti (Buenos Aires, Argentina); corn flour (7% moisture and 8% protein) from Herboeste (Buenos Aires, Argentina). Dry egg (2% moisture, 42% proteins) and dry egg-white (3.3% moisture, 95% proteins) from Tecnovo SA (Entre Ríos, Argentina), food-grade commercial xanthan (XG), and locust been gums (LBG) (Sigma Chemical Co., St. Louis, MO), analytical grade NaCl, sunflower oil (Molinos Río de La Plata SACIFI, Buenos Aires, Argentina), and cold distilled water were used.

Moisture content of flour and starch was determined according to the method 44-40 (AACC, 2000); dry matter of dry egg and dry egg-white was analyzed according to AOAC 17-006 (AOAC, 1984). Protein contents were analyzed by Kjeldahl using a conversion factor of 6.25.

2.2. Pasta dough sample preparation

The protocol of Larrosa et al. (2013) and Lorenzo et al. (2008, 2009) was followed to prepare the gluten-free dough. Dry ingredients were premixed and then the sunflower oil and water were added with the processor still running. The dough was sheeted on a noodle machine (Pastalinda, Pastalinda S.A., Argentina, rollers diameter: 35 mm) until a pasta of approximately 2 mm thick was obtained. Subsamples were cut from these sheets and kept in airtight polystyrene containers to avoid moisture loss. Ambient temperature was kept at 20 °C throughout dough preparation.

2.3. Experimental design

To analyze the effect of composition on cooked gluten free pasta, the formulation previously optimized by Larrosa et al. (2013) was chosen as the basic initial formula. All composition was given as percentage of the total pasta dough (g/100 g of dough). Samples consisted in a mixture of corn starch and corn flour in a 4:1 ratio, water, egg proteins, and fixed amounts of NaCl (1%), sunflower oil (2.8%), and a mixture of xanthan and locust bean gums in a 2:1 ratio (2.5%). The content of water plus egg proteins (dry whole-egg + dry egg-white) ranged between 37.5% and 44.1%, thus the corn starch and corn flour mixture varied from 56.2% to 49.6%, accordingly, to complete 100 g of dough.

To determine the levels of water and proteins analyzed, preliminary experiments were carried out. Results showed that outside the water content range it was impossible to laminate the dough. Higher water contents produced a sticky dough, and when lower water contents were used the dough tended to crumble and it was not possible to obtain a homogeneous sheet. Therefore, three levels for moisture content (34.8%, 36.13%, and 37.5%) and two for egg proteins (2.7% and 6.6%) were adopted to analyze the effect of water and protein content on the quality of cooked pasta (Table 1). Additional central point was included (formulation W2EP2, Table 1) to better evaluate curvature in the mathematical models. This central formulation was replicated three times.

Table 1
Composition of the tested formulations and coded levels for water and protein contents.

Formulation	Composition (%)			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

2.4. Cooking procedure

Cooking procedure was carried out for dough disk samples (40 mm diameter, 1.6 mm thick), which were cooked in 250 mL boiling deionized water. Boiling was kept at this level for the entire cooking period. Cooking properties of samples were measured at different cooking times, i.e. 0, 5, 10 and 15 min for all formulations. Previously, pasta optimum cooking time for each sample was determined according to the method 66-50 (AACC, 2000); noodles were deemed to be optimally cooked when the noodle strands did not display a clear visible opaque core (Edwards et al., 1995; Khouryieh et al., 2006). In all formulations the optimum cooking time was 10 min, thus, 5 and 15 min were included to evaluate the undercooking and overcooking effect on the rheological characteristics of gluten-free (GF) pasta. After cooking, samples were cooled by soaking in cold water for 60 s and excess water was removed by lightly patting between paper towels. The samples were immediately used for analytical and instrumental measurements.

2.5. Water absorption

For each gluten-free (GF) formulation pasta strands were immersed into test tubes, one for each tube, containing about 9 mL of distilled water and equilibrated at 100 ± 0.5 °C in a thermostatic bath (Haake L, Haake Buchler Instruments, Karlsruhe, Germany). Each subsample was weighed using an electrobalance (AB204, Mettler Toledo, Switzerland) before the sorption tests were conducted. All pasta samples were 40 mm long, had a width of 6 mm and 2 mm thickness. At given times, the samples were removed from the tube and rapidly blotted. Subsequently, the weight of the samples was determined. The weight of water absorbed at each hydration time has been obtained by subtracting