Journal of Cereal Science 57 (2013) 520–526

Contents lists available at SciVerse ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Optimization of rheological properties of gluten-free pasta dough using mixture design

Virginia Larrosa [a], Gabriel Lorenzo [a,b,*], Noemi Zaritzky [a,b], Alicia Califano [a]

[a] Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Facultad de Cs. Exactas, UNLP-CONICET. 47 y 116, La Plata 1900, Argentina
[b] Depto. Ingeniería Química, Facultad de Ingeniería, UNLP, Argentina

ARTICLE INFO

Article history:
Received 7 June 2012
Received in revised form
27 February 2013
Accepted 1 March 2013

Keywords:
Gluten-free pasta dough
Rheology
Mixture design
Optimization

ABSTRACT

The rising demand of gluten-free products for celiac people has led to important technological research on the replacement of the gluten matrix in the production of high quality gluten-free foods. The objective of this work was to evaluate the effect of composition (hydrocolloids, water, and proteins) on the rheological and textural properties of gluten-free dough used for producing pasta based on corn-starch and corn flour. Extensibility and rheological properties of gluten-free pasta dough were studied. Rising protein or gum contents produced a marked increase of deformation at break. However protein content was negatively correlated with breaking force. The increase in gums content produced an increase in storage and loss moduli (G', G''). G' was always larger than G'' with a small increase of both moduli with frequency. The mechanical relaxation spectrum was predicted from dynamic oscillatory data using the broadened Baumgaertel–Schausberger–Winter model. Application of a mixture design allowed finding the optimal composition to achieve the desirable textural properties using response surface methodology. A formulation containing 35.5% water, 2.5% gums, 4.7% proteins, 42.8% corn-starch, 10.7% corn flour, 1% NaCl, and 2.8% sunflower oil led to the highest values of G', breaking force, and extensibility according to the optimization analysis performed.

1. Introduction

Celiac disease is a form of enteropathy affecting the (small) intestine in genetically predisposed children and adults, precipitated by the ingestion of gluten-containing foods (Hall et al., 2009). When people with celiac disease consume gluten, their immune system generates antibodies against this protein, causing damage to the tiny hair-like projections in the small intestine. Therefore, this can lead to the inability to absorb nutrients and inadequate nutrition. The mainstay of treatment for celiac disease is life-long adherence to a gluten-free (GF) diet. For the majority of patients, the introduction of a GF diet results in full clinical and histological remission and has been associated with improvements in quality of life. Specifically the storage proteins (prolamins) in wheat (gliadin), rye (secalin) and barley (hordein) have to be avoided (Hall et al., 2009).

Rising demands for GF products parallels the apparent or real increase in celiac disease, or other allergic reactions/intolerances to gluten consumption (Lazaridou et al., 2007). Consequently, there is still a need to find substances that could improve the quality of this type of product. Replacement of the gluten network to produce GF products is a major technological challenge, gluten being the essential structure-building protein. Thus, substances that imitate the viscoelastic properties of gluten are always required in GF products (Mariotti et al., 2011).

Noodles prepared from rice flour are the most popular Asian pasta, widely consumed in Southeast Asian countries. Gluten-free pasta studies mainly involved rice flour alone or in combination with other non-gluten cereals and/or additives (Huang et al., 2001; Marti et al., 2010; Sozer, 2009). In order to produce GF pasta with similar appearance and texture as conventional pasta obtained from wheat flour, it is a usual methodology to obtain pregelatinized starch through heat and cool stages, thus forming a rigid network based on the retrograded starch (Cabrera-Chávez et al., 2012; Mariotti et al., 2011).

Development of fresh gluten-free pasta could also be possible including hydrocolloids in the formulation. It has been observed that the film-forming properties act as a lubricant inside the batter and protect the other formulation ingredients from being damaged by mixing, particularly starch granules (Alamprese et al., 2007, 2009; Yu and Ngadi, 2004).

* Corresponding author. Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Facultad de Cs. Exactas, UNLP-CONICET. 47 y 116, La Plata 1900, Argentina. Tel./fax: +54 221 4254853.
E-mail address: lorenzogabriel@gmail.com (G. Lorenzo).

0733-5210/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jcs.2013.03.003

Xanthan gum, locust bean gum, alginates and carboxymethyl cellulose (CMC) are common stabilizers used in food technology to provide viscosity, improve firmness, giving body and mouthfeel to the end product. Through their ability to bind water, gums can increase the rehydration rate of pasta upon cooking or soaking (Yu and Ngadi, 2004). Nonstarch polysaccharides such as xanthan gum (XG) and locust bean gum (LBG) have very significant viscoelastic properties and might be used to mimic the properties of gluten to form the elastic texture of pasta. The synergistic interaction between these two polysaccharides in solutions often leads to an increase in solution viscosity or the formation of gels. This subject has attracted the interest of many researchers during the last two decades due to its effectiveness in reducing production costs and enhancing rheological properties (Mao and Rwei, 2006). It is known that xanthan in aqueous solutions adopts a rigid, ordered conformation as a double-stranded helix. On heating, it undergoes an order-disorder transition from helix to random coil. At moderate concentrations, xanthan undergoes self-association to form a "weak gel", which flows under a steady stress. When mixed LBG, XG forms a true gel via the cross-links between segments of LBG and XG (Mao and Rwei, 2006).

Even when gluten-free bread formulations containing hydrocolloids and proteins have been investigated for several decades (Anton and Artfield, 2008; Gallagher et al., 2003; Mezaize et al., 2009), there are few works related with other types of gluten-free dough production (Huang et al., 2001; Lorenzo et al., 2008, 2009; Sozer, 2009).

Response surface methodology (RSM), as an effective tool for development and optimizing processes, is usually employed when many factors and interactions affect the desired response and provides an adequate representation of most continuous response surfaces over a relatively broad factor domain (Myers and Montgomery, 2002). Designing an experiment to fit a response surface model typically involves selecting among several candidate designs. A particular group of designs corresponds to experiments with mixtures, very commonly involved in product development whenever a multicomponent system is concerned. In a mixture experiment, the independent factors are proportions of different components of a blend where the proportions of the different factors must sum to 100% (Cornell, 2002). When a mixture design is employed, the purpose of the experiment is to model the blending surface either to predict the response for any combination of the ingredients or to determine the influence on the response of each component individually and in combination with the other components (Cornell, 2002).

The rheological characterization of pasta dough provides important information for food technologists, allowing ingredient selection strategies to design, improve, and optimize the final product. Rheological studies become particularly useful when predictive relationships for rheological properties of foods can be developed, starting from the molecular architecture of the constituent species. When conducted in the linear range, dynamic tests allow the specific expression of well-defined rheological parameters, such as the storage modulus (G') and the loss modulus (G''). In the case of gluten-free doughs, when frequency sweep tests were conducted in the linear domain, G' was greater than G'' and a rather low dependence of both moduli on frequency has been observed by several authors (Lazaridou et al., 2007; Moreira et al., 2011; Sivaramakrishnan et al., 2004).

The objectives of this work were: a) to evaluate the effect of the addition of mixtures of xanthan/locust bean gums, dry egg/dry egg-white, and water, on the linear viscoelastic and textural properties of gluten-free dough used for pasta production using corn starch and corn flour as the main ingredients, b) to obtain and model the relaxation mechanical spectrum from small amplitude oscillatory data to interpret structural features of the material and c) to predict the optimum formulation of fresh pasta dough in terms of the industrial handling requirements considering as the target conditions the characteristics of a wheat dough.

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), and cold distilled water were used.

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

A dough pasta (control sample) formulated with 300 g commercial wheat flour (14% moisture and 9% protein (Molino Cañuelas, Buenos Aires, Argentina) and 149.5 g of fresh egg was prepared in order to obtain a reference rheological behavior.

2.2. Pasta dough sample preparation

Basic pasta dough formula consisted in 42.8% of corn starch, 10.7% corn flour, 1% NaCl, and 2.8% sunflower oil (Barron, 2006), with different amounts of water, egg proteins, and gums added.

The protocol of Lorenzo et al. (2008, 2009) was followed to prepare the gluten-free dough. Dry ingredients were premixed for 1 min in a commercial food processor (Universo, Rowenta, Germany) at 400 rpm (setting #2). With the processor still running, the lipid phase was added and mixed for one more min. Finally, water was added and the dough was mixed for 5 more min. to combine the ingredients. The dough was placed in a tightly sealed container and kept at 4 °C for 24 h to let the starches hydrate. The dough was sheeted on a noodle machine (Pastalinda, Pastalinda S.A., Argentina, rollers diameter: 35 mm) at the minimum setting to smooth and firm it, and fed another four times between the rollers, decreasing the gap between rollers each time, until reaching the maximum setting to give the pasta a good shape and texture (Alamprese et al., 2009). This procedure is similar to the lamination process employed by commercial noodle manufacturers. Finally, the pasta thus obtained was rolled into sheets approximately 2 mm thick. Representative subsamples were cut from these sheets of pasta with an adequate cork borer and kept in airtight polystyrene containers to avoid moisture loss. Ambient temperature was maintained at 20 °C during dough preparation and analysis.

Wheat pasta was prepared following the procedure described above.

2.3. Experimental design

In a mixture experiment, the measured response is assumed to depend only on the relative proportion of ingredients or components present in the mixture, which usually sum to 100%. The present work employed a mixture experiment with seven components: corn starch, corn flour, water, mixture of XG/LBG, and egg proteins (dry egg/dry egg-white mixture), NaCl and sunflower oil. However, corn starch, corn flour, NaCl, and sunflower oil contents were fixed at the relative amounts explained in Section 2.2. The