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Effect of high pressure processing on the baking aptitude of corn starch and rice flour

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A B S T R A C T

The effectiveness of high pressure treated ingredients in slowing down the staling kinetic of gluten-free breads, in comparison with their untreated counterparts, was investigated. In terms of high pressure processing, both corn starch (CS) and rice flour (RF) were treated (CSt; RFt) at 600 MPa for 5 min at 40 °C; a very high sample-to-water concentration level was used. Four different bread recipes were then tested, starting from the following mixtures: CS + RF for the control sample, CSt + RFt, CSt + RF and CS + RFt. The properties of the doughs during mixing and leavening were investigated, as well as the GF breads characteristics during storage. In regard to crumb softness, similar results were evidenced among the four recipes just after baking, while during 3 days of storage at controlled conditions, the presence of high pressure treated corn starch or rice flour was effective in slowing down the staling rate of bread crumb. High pressure treatment applied to raw materials could therefore be successfully used to improve gluten-free bread shelf-life, and these results could assist in advancing the quality of gluten-free bread for the celiac consumer.

1. Introduction

Today, there is an increasing interest in gluten-free (GF) products, as the prevalence of celiac people is estimated to be 0.5–2.0% of the population in most European countries and in the United States (Fasano & Catassi, 2001; Reilly & Green, 2012; Rewers, 2005). Furthermore, at present, the only treatment for celiac disease is a total lifelong avoidance of gluten ingestion, so celiacs must strictly follow a GF diet.

In the last decades, many studies have been carried out to improve GF bread quality, in terms of nutritional properties and consumer acceptability (Alvarez-Jubete, Auty, Arendt, & Gallagher, 2010; Cappa, Lucisano, & Mariotti, 2013; Gallagher, Gormley, & Arendt, 2004; Gallagher, Polenghi, & Gormley, 2002; Gambus, Gambus, & Sabat, 2002; Guarda, Rosell, Benedito, & Galotto, 2004; Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007; Mariotti, Lucisano, & Pagani, 2006; Mariotti, Lucisano, Pagani, & Ng, 2009; Moore, Schober, Dockery, & Arendt, 2004) and to increase the number of products available for celiacs (Arendt, Morrissey, Moore, & Dal Bello, 2008; Dreher, 1987; Sharma, 1981). However, because of the complexity of the GF formulations, further studies are required for developing GF bread with satisfactory structure, acceptability, shelf-life and cost. Particularly, critical is the GF bread texture, as the absence of the viscoelastic gluten network makes the breadmaking process problematic. The rheological properties of a GF dough are poor, with limited ability to retain gas during leavening, factor that inevitably lead to breads with a reduced volume and a low crumb softness (Mariotti et al., 2006). Besides, as GF bread contains a large amount of starch, the onset of staling is more rapid than in gluten-containing baked products (Arendt et al., 2008).

A comprehensive overview about the possibilities to increase the quality of GF bread and enhance its shelf-life has been published by Houben, Höchstötter, and Becker (2012). Actually, many approaches have been tested, as reported in the literature. Hydrocolloids are generally used as gluten replacer for their thickening abilities, high water binding capacity and gel forming

Abbreviations: a*, redness; −a, greenness; AI, dough area increase; ANOVA, analysis of variance; b*, yellowness; −b*, blueness; BU, Brabender® unit; CS, corn starch; CSt, CS treated at 600 MPa for 5 min at 40 °C; G′, storage modulus; G″, loss modulus; GF, gluten-free; HP, high pressure; HPMC, hydroxypropylmethylcellulose; L*, lightness; LSD, least significant differences; MVA, Brabender® micro-visco-amylograph; RF, rice flour; RFt, rice flour treated at 600 MPa for 5 min at 40 °C; tanδ, ratio between G″ and G′; WA, dough water absorption.

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characteristics. The use of whole flours or fibers is also a common way to enhance dough and bread water binding capacity and slow down hardening phenomena (Arendt et al., 2008; Cappa et al., 2013; Korus, Grzelak, Achremowicz, & Sabat, 2006; Mariotti et al., 2009). Starch hydrolyzing enzymes have been also tested to decrease amylopectin retrogradation during storage, thus reducing the staling of the end product (Gujral, Haros, & Rosell, 2003). Puffed flours were also found to be useful in limiting the diffusion and the loss of water from bread crumb and the interactions between starch and protein macromolecules, resulting in softer GF bread crumb and reduced staling kinetics during storage (Mariotti, Pagani, & Lucisano, 2013). A positive influence has been also proved by the use of sourdough in GF bread-making, a traditional bakery procedure satisfactory applied to the conventional baked products (Moroni, Dal Bello, & Arendt, 2009).

In recent years, also high pressure (HP) processing was investigated as a novel tool to improve gluten-free foods quality. It is well known that HP acts on most of the foods components such as water, proteins and starch and it can be used to modify the functional properties of proteins and inactivate enzymes that are mainly responsible for shortening the products shelf-life (Barba, Terefe, Buckow, Knorr, & Orlien, 2015; Estrada-Girón, Swanson, & Barbosa-Cánovas, 2005). Some researchers applied HP also on cereal doughs and batters, such as wheat (Bárcenas, Altamirano-Fortoul, & Rosell, 2010; Vallons & Arendt, 2010), sorghum (Vallons & Arendt, 2009b; Vallons, Ryan, Koehler, & Arendt, 2010), buckwheat (Vallons & Arendt, 2009a) and oat (Hüttner, Dal Bello, & Arendt, 2010). However often HP treated doughs and batters gave unsatisfactory results in terms of bread volume and texture due to high starch gelatinization occurring during pressure application. HP effects differ not only as a function of the cereal tested, time, temperature and pressure applied but also of slurry concentration, as reported by Alvarez, Fuentes, Olivares, and Canet (2014). These authors studied chickpea slurries and found that only those slurries containing a sample-to-water ratio of 1:5 were totally gelatinized after HP-treatment at 600 MPa; but in more concentrated chickpea slurries (1:4, 1:3 and 1:2) HP-induced gelatinization was only partial. Cappa, Lucisano, Barbosa-Cánovas, and Mariotti (2016) performed a study on rice flours and corn starch pre-conditioned in order to have a sample-to-water ratio of 1:0.5, and even at this very high sample-to-water concentration HP processing were effective in modifying the native organization of starch, and consequently, its pasting behavior, in addition to other chemical-physical properties of the samples.

The objective of this study was to evaluate the effectiveness of HP treated ingredients in slowing down the staling kinetics of GF breads. Rice flour and corn starch treated at 600 MPa for 5 min at a processing temperature of 40 °C were employed as unconventional ingredients of a GF bread recipe. Comparisons with the untreated raw materials were performed to evaluate the uniqueness of the applied processes. The rheological properties of the untreated and treated raw materials, the mixing and leavening behavior of the various GF bread recipes containing the HP treated ingredients, as well as the quality of the related end products (both fresh and stored up to 72 h at controlled conditions) were investigated.

2. Materials and methods

2.1. Materials

Corn starch (CS) was obtained from Roquette America Inc. (Iowa, USA) and rice flour (RF) was provided by Beneo-Remy NV (Leuven-Wijgmaal, Belgium). CS and RF were mixed with water (sample-to-water ratios of 1:0.5), and submitted to HP processing at 600 MPa for 5 min at a processing temperature of 40 °C (CSt and RFt, respectively), as reported by Cappa et al. (2016).

In order to produce the GF breads, the following ingredients were used in addition to CS and RF: pea proteins (IPP-F9 Cosucra, Warcoing, Belgium), *Psyllium* fibre (Roeper GmbH, Germany), hydroxypropylmethylcellulose (HPMC; UNIVAR S.p.A., Italy), extra virgin olive oil (Monini S.p.A., Spoleto, Italy), sugar (Pellicano-Comprabene S.p.A., Italy), sodium chloride (Carrefour Italia S.p.A), and compressed yeast (Lesaffre Italia S.p.A., Italy).

2.2. Rheology of the starchy gels

The fundamental rheological behavior of the gels obtained from CS, RF, CSt, and RFt was studied by dynamic oscillatory measurements performed on a Physica MCR300 Rheometer (Anton Paar GmbH, Graz, Austria), supported by the Universal Software US200 (version 2.5) (Anton Paar, Ostfildern, Germany). The gels were produced by means of a Brabender® Micro-Visco-Amylograph (MVA; Brabender® OHG, Duisburg, Germany), as previously reported by Cappa et al. (2013), and evaluated after 30 min at 25 °C and after 1, 2, 3, 4, and 7 days of storage at 4 °C. Before each trial, gels were conditioned at 25 °C for 30 min and aliquots (2.5–3 g) were taken from the containers by means of a cylindrical corer, thus avoiding any further perturbation and disruption of the system.

Dynamic oscillatory rheological measurements were carried out at 25 °C, using a corrugated parallel plate system (diameter: 2.5 cm) at a gap of 1 mm, and a special humidity cover (H-PTD 150) with a water trap and wet pads designed to saturate the water vapor inside, to prevent moisture loss during measurements. After loading the gels between the parallel plates, the excess was trimmed off and the sample was allowed to rest at 25 °C for 5 min to relax stresses, before starting the test. Dynamic shear data were determined within the linear viscoelastic region, as defined by preliminary amplitude sweep tests performed in the range of 0.01–300% strain, at a constant frequency of 1 Hz. Frequency sweep tests were performed over the range 0.1–10 Hz at 1% strain. From each trial, storage modulus (G', Pa), loss modulus (G'', Pa) and $\tan\delta$ (ratio between G'' and G') were computed. All the measurements were performed in triplicate ($n = 3$) with highly reproducible results (relative standard deviation < 8%) for each sample.

2.3. Rheology of the gluten-free doughs

To determine the effects of HP processing on the bread making properties of CS and RF, four mixtures were produced: a) CF + RF; b) CSt + RFt; c) CSt + RF; d) CS + RFt. The complete GF bread formulations were made up as follows: 38% CS (or CSt), 38% RF (or RFt), 6% pea proteins, 1.5% *Psyllium* fibre, 1.5% HPMC, 6% olive oil, 4% sugar, 2% sodium chloride, and 3% compressed yeast. Percentages are expressed on the total recipe weight basis. The rheological properties of the resulting doughs were evaluated as follows.

2.3.1. Mixing properties

The mixing properties of the various doughs were examined with a Brabender Farinograph (Brabender® OHG, Duisburg, Germany), setting the temperature at 30 °C. The dry ingredients (273 g) were pre-mixed for 5 min, before adding the yeast (previously suspended in a part of the recipe water), oil, and of the remaining amount of water up to a 200 Brabender® Unit (BU) consistency. This value is considered as a suitable farinographic consistency in order to assure good leavening performances and workability at the GF dough (Cappa et al., 2013; Mariotti et al., 2009). Kneading was carried out for 15 min. For each formulation, the water absorption (WA; %), intended as the amount of water required to reach the desired consistency, was determined.