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Rheology and breadmaking performance of rice-buckwheat batters supplemented with hydrocolloids

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ABSTRACT

The aim of this work was to investigate the effects of hydrocolloid addition on rheological properties and breadmaking performance of rice-buckwheat batter at different water levels. Xanthan gum (XG) and propylene glycol alginate (PGA) were added to rice-buckwheat blend (60:40) at levels of 0.5–1.5%. Batter rheological properties were investigated using dynamic measurements in the linear viscoelastic range (frequency sweep and time cure tests). The addition of both hydrocolloids significantly enhanced the storage modulus (G′) of batter. XG exerted greater effect on G′ than PGA. Different effects on starch gelatinisation were observed for the two hydrocolloids. PGA breads showed higher improvement in terms of increased specific volume (V_s), decreased crumb firmness and crumb structure than XG breads. Different technological behaviours were explained on the basis of batter rheological properties.

1. Introduction

Buckwheat is a traditional crop in Asia and Europe. Common buckwheat (*Fagopyrum esculentum*) is the most widely grown species. From a botanical point of view buckwheat is a dicotyledonous plant in contrast to the monocotyledonous cereals, but since it is usually processed into flour it is called a pseudocereal. In recent years, buckwheat has received increasing attention from scientists for prevention of chronic diseases due to its functional properties and as a potential raw material in a gluten-free diet (Alamprese, Casiraghi, & Pagani, 2007; Li & Zhang, 2001; Moore, Schober, Dockery, & Arendt, 2004; Renzetti, Dal Bello, & Arendt, 2008). According to Ikeda, Sakaguchi, Kusano, and Yasumoto (1991) and Radovic, Maksimovic, Brkljacic, Varkonji Gasic, and Savic (1999) the protein fractions in common buckwheat consist of 64.5% globulin, 12.5% albumin, 8% glutelin and a small percentage of prolamins. Since buckwheat does not contain any prolamins toxic to people with celiac disease, it can be integrated into gluten-free diets.

Gluten is the major protein in wheat dough, responsible for its unique viscoelastic behaviour. Gluten largely consists of monomeric gliadin proteins and polymer forming glutenin proteins (Wrigley & Békés, 1999). The glutenin fraction is also polydisperse, since different glutenin monomers can combine into oligomers and even higher aggregated protein structures (Hamer & van Vliet, 2000). It is well accepted that the higher aggregated glutenin fraction is especially related to dough properties (Hoseney & Rogers, 1990; MacRitchie, 1992).

Nowadays, gluten replacement is one of the most challenging issues for food science and technology since a gluten-free diet is essential for patients having celiac disease. Currently, many of the gluten-free baked products that are available in the marketplace are of low quality, exhibiting poor mouth-feel and flavour. The production of gluten-free breads mainly involves the incorporation of starches, protein-based ingredients and hydrocolloids into a gluten-free base flour that could mimic the viscoelastic properties of gluten (Gallagher, Gormley, & Arendt, 2004).

Xanthan gum (XG) is a branched, anionic polysaccharide produced by aerobic fermentation of the bacterium *Xanthomonas campestris*. The primary structure consists of a cellulosic backbone having a charged trisaccharide side chain attached to alternate glucose residues (Lapasin & Pricl, 1995). The molecular weight of xanthan is usually in the range $2\text{–}5.5 \times 10^6$ (Lapasin & Pricl, 1995). Aqueous xanthan dispersions are thixotropic. The weak gel structure formed results in an unusually high “low shear-rate” viscosity at low polymer concentrations, which can be used to thicken aqueous samples and permits stabilization of emulsions, foams and particulate suspensions (Morris, 1995). This behaviour results from the ability of xanthan molecules, in solution, to form aggregates through hydrogen bonding and polymer entanglement. This highly

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Abbreviations: tan δ, loss tangent; G′, storage modulus; G″, loss modulus; XG, xanthan gum; PGA, propylene glycol alginate; CR, commercial reference; d.b., dry basis; RH, relative humidity; V_s, specific volume; YM, Young’s modulus; ESEM, environmental scanning electron microscopy.

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ordered network of entangled, stiff molecules results in high viscosity at low shear rates, and in practical terms, accounts for the outstanding suspending properties of XG solutions (Sworn, 2000). This polymer has many advantages such as high solubility in cold or hot water, high solution viscosity at low concentrations, no discernable change in viscosity over a wide temperature range, excellent stability in acid conditions, and thermal or freeze-thaw stability (Dreher, 1999). A synergistic interaction occurs between XG and galactomannans such as guar gum, locust bean gum and cassia gum and glucomannans such as konjac mannan. This interaction results in enhanced viscosity or gelation (Sworn, 2000). XG was used as a gluten replacement in the development of gluten-free bread improving dough elasticity (Demirkesen, Mert, Sumnu, & Sahin, 2010; Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007). Several studies have been carried out showing the effects of XG on gluten-free breads (Lazaridou et al., 2007; Moore et al., 2004; Schober, Messerchmidt, Bean, Park, & Arendt, 2005).

“Alginate” is a collective term for a family of polysaccharides produced by brown seaweeds (*Phaeophyceae*) and some bacterial species (*Azotobacter* and *Pseudomonas*). They can be described as linear binary copolymers of 1–4-linked β-D-mannuronic acid (M) and α-L-guluronic acid (G) residues (Moe, Draget, Skjåk-Bræk, & Smidsrød, 1995). A common feature of mannuronic acid and guluronic acid residues is that they both bear a carboxyl group that, at neutral pH, renders alginate an anionic polymer. Alginate gels form when salts of alginic acid are mixed with cations (Draget, 2000). Calcium alginate gels are formed by ionic bridging between two carboxyl groups on adjacent polymer chains with calcium ions, giving rise to junctions as cross-links in the gel network. Important properties of alginates include viscosity enhancement, gel-forming ability and stabilization of aqueous mixtures, dispersions and emulsions (Moe et al., 1995). Rosell, Rojas, and Benedito de Barber (2001) showed that an improvement in wheat dough stability during proofing can be obtained by the addition of sodium alginate or xanthan gum.

Several attempts to chemically modify alginate to vary its physicochemical properties have been reported. Propylene glycol alginate (PGA) is produced by partial esterification of the carboxyl groups on the uronic acid residues by reaction with propylene oxide (Moe et al., 1995). Increasing the degree of esterification reduces the overall hydrophilic character of the molecules and imparts surface-active properties (Baeza, Carrera Sanchez, Pilosof, & Rodríguez Patino, 2004). PGA is largely used as a thickener and stabilizer in several food applications mainly because of its solubility in acidic conditions and low sensitivity to the presence of divalent ions. In addition, the hydrophobic character introduced by the propylene glycol moiety allows this modified polysaccharide to function as a surfactant and emulsifier (Baeza et al., 2004; Yilmazer, Carrillo, & Kokini, 1991). PGA is used to stabilize beer foams, acid emulsions and acid fruit drinks and juices (Moe et al., 1995). However, there are no data in the literature related to the use of PGA in the baking industry.

The various mechanisms, which contribute to the positive effects of hydrocolloids on gluten-free breads, are not fully understood. Studying the influence of hydrocolloids with large differences in their functional properties on bread could contribute to increase knowledge in this field. PGA is a hydrocolloid that has at the same time surface-active properties due to chemical modification of alginate (Baeza et al., 2004). Thus, it might influence the dough and bread by its thickening ability, but also by its amphiphilic nature increasing interfacial activity within the dough system during proofing. XG does not possess surface-active properties, but has much higher water binding capacity, thickening properties and tendency for aggregation than PGA (Morris, 1995; Sánchez, Bartholomai, & Pilosof, 1995).

The aim of this work was to investigate the effects of hydrocolloid addition on rheological properties and breadmaking performance of rice-buckwheat batter. Only a limited number of studies have addressed wheat-free buckwheat breads, which are particularly interesting for their functional properties (Moore et al., 2004; Renzetti et al., 2008). PGA and XG were selected for this investigation. To date, no systematic study has been reported on the effect of PGA on the rheological properties of gluten-free batter and bread quality.

2. Materials and methods

2.1. Materials

Common buckwheat (*F. esculentum*) flour was supplied by an Italian company (Nadalutti, Reana del Rojale, UD, Italy). Buckwheat flour (14.18% d.b. protein, 2.05% d.b. ash) was obtained by grinding the achenes with a millstone and then sifting. The particle size of the flour was lower than 200 μm. Commercial rice flour (7.67% d.b. protein, 0.30% d.b. ash) was purchased from Pasini-Riso e Derivati (Castel D’Ario, MN, Italy). A commercial gluten-free flour mix containing rice flour, potato starch, sugar, salt, hydroxypropylmethylcellulose, locust bean gum, mono- and diglycerides of fatty acids, was used as a commercial reference (CR). Xanthan gum and propylene glycol alginate (70% degree of esterification) were donated by Chimab Food Ingredients (Campodarsego, PD, Italy).

2.2. Batter formulation

The bread batter formula contained rice flour (300 g, 14% moisture basis), buckwheat flour (200 g, 14% moisture basis), salt (7.5 g), oil (22 g), compressed yeast (26.5 g) and variable amounts of water and XG or PGA. Three water levels and three hydrocolloid levels were used. Water levels were 80, 90 and 100% on flour weight basis (fwb). XG or PGA levels were 0.5, 1.0 and 1.5% on fwb. The sum of rice flour and buckwheat flour was established as fwb. Control samples were prepared without hydrocolloids. Twelve different formulations were studied. CR bread batter contained commercial gluten-free flour mix (500 g), water (400 g), salt, oil and yeast as reported above.

2.3. Baking procedure

Rice and buckwheat flour, hydrocolloid and salt were mixed at speed 1 for 5 min in a Hobart N50 mixer at 30 °C. The yeast was dissolved in a portion of water at 30 °C and was added with the remaining water and oil during mixing at speed 1 for a further 2 min. All ingredients were mixed at speed 2 for 5 min. The batters were measured into 250 g portions and placed in three baking pans, proofed at 30 °C and 80% relative humidity (RH) for 45 min and baked at 200 °C for 50 min. The CR bread was prepared using the same procedure as the rice-buckwheat bread. Bread quality was evaluated 1 h after baking.

2.4. Loaf volume

Loaf volume (mL) was obtained by rapeseed displacement according to Approved Method 10-05 (AACC, 2000).

2.5. Moisture content of bread crumb

Moisture content of the bread crumb was determined by oven drying for 12 h at 105 °C. Three bread slices (25 mm thickness) were cut from the central portion of the loaf and a crumb cylinder (40 mm diameter) was taken from the centre of each slice and used for moisture determination.