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Influence of *Psyllium*, sugar beet fibre and water on gluten-free dough properties and bread quality

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ABSTRACT

Celiac patients generally have a low intake of protein and fibre attributed to their gluten-free (GF) diet. To satisfy the increasing demand for healthier products, this research focused on the effects of the supplementation of *Psyllium* (P) and sugar beet fibre (SB) on the mixing and leavening behaviour of gluten-free doughs. Four doughs, having different consistencies that made them suitable to be poured into moulds or to be shaped, and their corresponding breads were evaluated. The results obtained suggested that a lower consistency is preferred to assure good dough performances during leavening, in particular when ingredients having a high water affinity are included into the recipe. Both P and SB improved the workability of the doughs, but P played a central role on GF bread development, thanks to its film forming ability, and evidenced a more effective antistaling effect, thanks to its high water binding capacity.

1. Introduction

Celiac disease (CD) is one of the most common lifelong disorders on a worldwide basis. It is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. At present, the only available treatment for celiac people is the strict adherence to a gluten-free (GF) diet, which means a permanent withdrawal of gluten from daily foods. With the increasing incidence of CD, a rising demand for GF goods broke out; at the same time, a higher quality and a prolonged shelf-life of GF products are expected by the consumers. In fact, nowadays, the quality of the GF products available on the market does not fulfil consumers' expectations, being these products often characterized by a low nutritional value and an unsatisfactory sensory quality, particularly when compared to their wheat counterparts. Therefore, even if many studies have been performed in the last decades on this topic, more investigations are necessary.

Bread is the most challenging among GF foods. When compared to their wheat based counterparts, GF breads are characterized by a heterogeneous recipe, usually made of a combination of rice (Arendt, Morrissey, Moore, & Dal Bello, 2008; Gujral & Rosell, 2004; Marco & Rosell, 2008) and corn (Brites, Trigo, Santos, Collar, & Rosell, 2010; Renzetti, Dal Bello, & Arendt, 2008) starch and flour, as well as proteins, fibres, fats, hydrocolloids, and eventually specific enzymes. In GF bread production, the first crucial point is to supply for the absence of the viscoelastic gluten network that makes the whole breadmaking process problematic, and penalizes the sensorial quality of the final product. Doughs lacking in gluten, in fact, show limited abilities of gas expansion and retention during leavening, that inevitably lead to bread with a reduced volume and a low crumb softness (Gallagher, Gormley, & Arendt, 2004; Mariotti, Lucisano, Pagani, & Ng, 2009).

Nowadays, to provide for the lack of gluten and to simulate its viscoelastic behaviour, the addition of hydrocolloids having a strategic role in making the GF dough workable and improving

Abbreviations: A, formulation containing 2.5% *Psyllium* and 0.5% sugar beet fibre; AMY, maltogenic amylase; ANOVA, analysis of variance; B, formulation containing 1.5% *Psyllium* and 1.5% sugar beet fibre; BD, breakdown; BU, Brabender Unit; B_{A200}, bread obtained from D_{A200}; B_{A500}, bread obtained from D_{A500}; B_{B200}, bread obtained from D_{B200}; B_{B500}, bread obtained from D_{B500}; CD, celiac disease; $CO_{2\text{-}RET}$, CO_2 retained by the dough; $CO_{2\text{-}REL}$, CO_2 released by the dough; $CO_{2\text{-}TOT}$, total CO_2 production; CS, corn starch; D_{A200}, dough obtained from M_A, with a consistency of 200BU; D_{A500}, dough obtained from M_A, with a consistency of 500BU; D_{B200}, dough obtained from M_B, with a consistency of 200BU; D_{B500}, dough obtained from M_B, with a consistency of 500BU; DS, damaged starch; FV, final viscosity; GF, gluten-free; GG, guar gum; Hf, final dough height; Hm, maximum dough development; HPMC, hydroxypropylmethylcellulose; LB, locust bean gum; LSD, least significant differences; M, GF baking mixtures: M_0 (CS + RS + RF + RP), M_1 (M_0 + HPMC + LB + GG), M_A (M_1 + 2.5%P + 0.5%SB), M_B (M_1 + 1.5%P + 1.5%SB); MVA, Brabender® Micro-Visco-Amylograph; PT, pasting temperature; PV, peak viscosity; P, *Psyllium* fibre; Rc, gas retention coefficient; RF, rice flour; RP, rice protein; RS, rice starch; Sb, setback; SB, sugar beet fibre; TS, total starch; Tx, time of dough porosity appearance; WA, amount of water required to reach the desired dough consistency; WBC, water binding capacity.

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at the same time the texture of the final GF product (Guarda, Rosell, Benedito, & Galotto, 2004; Kobylañski, Perez, & Pilosof, 2004; Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007), has become quite common. The most effective gums and hydrocolloids have been identified with hydroxypropylmethylcellulose (HPMC), locust bean gum, guar gum, carrageenan and xanthan gum (Gallagher et al., 2004; Lazaridou et al., 2007). Mariotti et al. (2009) investigated the role of *Psyllium* flour – differently combined with corn starch, amaranth flour and pea isolate – on the rheological properties and the ultrastructure of GF doughs. The same authors evidenced how *Psyllium* generally enhanced the physical properties of the doughs, due to the film-like structure formed during kneading, and how it appeared promising in terms of final bread technological and nutritional quality. *Psyllium* seed husks have the highest known level (about 70%) of soluble fibre, and this fibre is a polymer of arabinose, galactose, galacturonic acid, and rhamnose (Nelson, 2001).

Since celiac patients generally have a low intake of protein and fibre (Thompson, 2000), the enrichment of GF bread with vegetal and animal proteins, as well as with dietary fibre, is a winning way to increase the nutritional and sensorial quality of the final product. In wheat bread, the main source of fibrous materials is generally wheat bran. Nevertheless, the design of fibre-enriched traditional baked goods has always come up against consumers resistance to accept breads with reduced loaf volume and hard crumb accompanied by particular flavours (Rosell, Santos, & Collar, 2010). Filipovic, Djuric, and Gyura (2007) thus suggested to incorporate other fibres, such as sugar beet fibre, characterized by low phytate content and by a better water retention capacity in comparison to wheat bran. Sugar beet fibre is the beet pulp remaining after water extraction of the sugar from the sliced beet tuber; the isolated fibre is about 73% total dietary fibre, about one-third of which is soluble fibre, mainly pectin.

Generally, the higher the presence of fibre in a dough the higher the amount of water required to obtain a workable dough (Mariotti et al., 2009). Water and flour are the most significant ingredients in a bread recipe, as they affect texture and crumb the most. Water, in particular, has essential and critical functions: it is necessary for solubilizing other ingredients, for hydrating proteins and carbohydrates, and for developing the protein network (Maache-Rezzoug, Bouvier, Allaf, & Patras, 1998). Water also plays an important role in the changes associated to starch occurring during breadmaking (*e.g.* gelatinization and retrogradation), and in assuring the quality and the shelf-life of the final bread (*e.g.* in terms of crumb softness and crust crispness) (Wagner, Lucas, Le Ray, & Trystram, 2007). In GF bread production the amount of water used to prepare the dough is frequently almost the same as (or higher than) the total amount of the dry ingredients included in the recipe; the aspect and consistency of the resulting dough is generally closer to that of a batter than to that of a conventional wheat flour dough (Mariotti, Pagani, & Lucisano, 2013). Critical is the shelf-life of GF breads, due to the presence into the recipe of a large amount of starches and flours from different origin that inevitably determines an increase of the staling rate of the product. Fibres may play a positive effect on quality parameters related to bread staling (such as crumb softness and springiness) by increasing the water absorption of the dough (Chen, Rubenthaler, Leung, & Baranoski, 1988; Wang, Rosell, & de Barber, 2002).

The aim of this research was the investigation of the effects that different amounts of *Psyllium* fibre (a thickening agent and a source of fibre), sugar beet fibre (a fibre source), and water have on GF dough and bread properties, in order to: (*i*) evaluate the influence of the presence of different fibres on the rheological properties of the dough; (*ii*) study the importance of GF dough consistency for its workability and for the technological quality of the final product; (*iii*) increase the nutritional quality and the shelf-life of the GF breads.

2. Materials and methods

2.1. Raw materials

The raw materials used to prepare the GF mixtures were the followings: corn starch (CS; Roquette Frères, France), rice flour (RF; Beneo-Remy NV, Belgium), rice starch (RS; Beneo-Remy NV, Belgium), rice protein (RP; Beneo-Remy NV, Belgium), *Psyllium* fibre (P; Indian Psyllium seed husk; Roeper GmbH, Germany), sugar beet fibre (SB; Danisco Sugar AB, Sweden), hydroxypropylmethylcellulose (HPMC; UNIVAR S.p.A., Italy), locust bean gum (LB; Caremoli S.p.A., Italy), guar gum (GG; Caremoli S.p.A., Italy), maltogenic amylase (AMY; Novozymes, Switzerland).

2.1.1. Chemical–physical characterization

The chemical-physical properties of the main ingredients (CS, RS, RF, RP, P and SB) were evaluated. The moisture content was determined according to the Official Standard Method AACC 44-15A (2000). The total nitrogen content was evaluated according to the Official Standard Method AOAC 920.87 (1999), and the protein content was calculated adopting 6.25 as conversion factor. The amounts of total starch (TS) and damaged starch (DS) were determined using the “Total Starch Assay Kit” and the “Starch Damage Assay Kit” (Megazyme International Ireland Ltd., Bray Business Park, Bray, Co. Wicklow, Ireland), respectively. All these evaluations were made at least in duplicate ($n \geq 2$).

2.1.2. Pasting properties

The pasting properties of the main ingredients (CS, RS, RF, RP, P and SB) were investigated using a Brabender® Micro-Visco-Amylograph (MVA; Brabender OHG, Duisburg, Germany) (Mariotti, Zardi, Lucisano, & Pagani, 2005; Shuey & Tipples, 1980). Fifteen grams of raw materials were dispersed in 100 mL of distilled water, scaling both flour and water weight on 14% sample moisture basis. The suspensions were subjected (stirring at 250 min^{-1} and using a 300 cm·g_f cartridge) to the following standard temperature profile: heating from 30 °C up to 95 °C, holding at 95 °C for 30 min, cooling from 95 °C to 50 °C, holding at 50 °C for 30 min and cooling to 30 °C. A heating/cooling rate of 3 °C/min was applied. The following indices were considered: pasting temperature (PT, °C; temperature at which an initial increase in viscosity occurs), peak viscosity (PV, Brabender Units, BU; maximum viscosity achieved during the heating cycle), breakdown (BD, BU; index of viscosity decrease during the holding period, corresponding to the peak viscosity minus the minimum viscosity reached after the holding period at 95 °C); final viscosity (FV, BU; paste viscosity achieved at the end of the cooling cycle), and setback (Sb, BU; index of the viscosity increase during cooling, corresponding to the difference between FV and the minimum viscosity reached after the holding period at 95 °C).

The MVA was also used to test the pasting properties of some mixtures (M), paying attention to maintain the same ratios among the different ingredients as those present in the main recipe (see Section 2.2.1). In particular, the followings were tested: M_0 (CS + RS + RF + RP); M_1 (M_0 + HPMC + LB + GG); M_A (M_1 + 2.5%P + 0.5%SB); M_B (M_1 + 1.5%P + 1.5%SB) (Fig. 1). In this case, 10 g of each mixture were dispersed in 100 mL of distilled water, scaling both mixture and water weight on 14% sample moisture basis. The same standard temperature profile described before was applied, and the same indices were considered.

All these determinations were made at least in duplicate ($n \geq 2$).