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Effect of barley and oat β-glucan concentrates on gluten-free rice-based doughs and bread characteristics

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ABSTRACT

The impact of commercial oat or barley β-glucan concentrates incorporated at different levels (1.3–3.9 % actual β-glucan concentration, flour basis) into gluten-free (GF) rice-based dough formulations differing in water content (89–141%, flour basis) on dough rheology (empirical and fundamental tests) and breadmaking performance has been investigated. The effect of the baking process on the content and molecular weight of β-glucan in the final bread has been also evaluated. The rheological properties of the dough were dramatically influenced by dough water content; i.e. optimization of dough hydration is indeed of primary importance on improving GF bread quality. The bread specific volume was negatively correlated with the dough elastic modulus (G') and the viscosity (η_0), and positively with the loss tangent. At optimum hydration, the rheological properties of barley β-glucans-enriched doughs and the quality attributes of breads derived therefrom were notably affected by the soluble fibre content; the G' at 1 Hz increased up to ~100% and the bread volume decreased ~32% with respect to the values of the control dough and bread. In contrast, the impact of concentration of the oat-β-glucan preparation in the fortified doughs and bread was much less pronounced. These findings could be explained by the ability of the low molecular weight barley β-glucans to develop a gel network structure at higher concentrations, whereas the preparation of the high molecular weight oat β-glucan exhibits a more viscous-like rheological response. The added β-glucans to doughs were also quantitated in the bread crumbs, and a significant decrease in their molecular weight was noted, most likely due to the β-glucanase activity in the raw materials incorporated in the GF flour mixtures. Consequently, although the EFSA claims are achievable in gluten-free breads enriched with commercial β-glucans concentrates, control of β-glucanase activity in the raw materials may be a critical issue in exerting all the physiological benefits associated with the consumption of these bioactive polysaccharides.

1. Introduction

The impact of dietary fibre on the maintenance and improvement of human health has attracted considerable scientific interest in the last decades (Brennan & Cleary., 2007). However, innovative DF-enriched products have to meet the main quality requirements for food products: nutritional added value, safety, texture-taste, palatability, convenience and easy handling during processing (Angioloni & Collar, 2011). This goal is particularly challenging in gluten-free (GF) breadmaking where the lack of the gluten protein matrix seriously constrains the dough visco-elastic character, leading to a failure in carbon dioxide entrapment during proofing and baking, and thereby a quality decline in the resulting breads. Moreover, a poor nutritional balance frequently characterises multi-ingredient (composite) GF matrices due to the higher content of readily-digestible carbohydrates (Thomson, 2009). The GF baked goods are often low in fibre, both soluble and insoluble; consequently their enrichment with dietary fibre seems to be necessary for nutritional improvement of these products (Sabanis, Lebesi, & Tzia, 2009). Cereal β-glucans (BG) are classified as soluble dietary fibre with well recognized ability for reducing blood serum LDL-cholesterol levels and attenuating the postprandial blood glucose and insulin levels (EFSA, 2011). The beneficial to health effects of cereal β-glucan isolates have been recently reviewed by Wood and

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co-workers (Tosh, 2013; Whitehead, Beck, Tosh, & Wolever, 2014; Wood, 2010), with most of the data derived from studies with oat β-glucans (OBG), followed by barley (BBG) and rye (Kinner et al., 2011). Isolates of cereal BG are hydrocolloids with thickening properties (Doublier & Wood, 1995; Lazaridou & Biliaderis, 2007) that can increase the nutritional value of GF bread in terms of soluble dietary fibre content with proven human health promoting effects. On the other hand, it has been reported that a high concentration of BG decreases the water availability for the protein-starch network and thus impairs the quality of wheat breads (Gill, Vasanthan, Ooraikul, & Rossnagel, 2002). In this context, it must be noted that, as for all hydrocolloids, the fine structure, the molecular mass - chain length, the solution conformation and any chemical modification, the concentration added, the nature of raw materials and process parameters would be all important determinants of BG functionality during breadmaking (Houben, Hoechstoetter, & Becker, 2012).

Previous studies have shown a great variability in the effect of BG on the viscoelastic behaviour and bread quality of rice flour-based GF bakery products, depending on dough water and BG contents (Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007; Pérez-Quirce, Collar, & Ronda, 2014; Ronda, Perez-Quirce, Angioloni, & Collar, 2013). Therefore, a systematic study to quantify the effect of water content in order to optimize the hydration level in the dough formulation depending on BG content and source is needed to evaluate and compare the effect of different BG preparations on dough and bread properties. It should be also noted that farinographic tests, universally accepted to establish dough water requirements in wheat bread making, are not well adapted to GF dough formulations (Hager et al., 2011).

The potentially beneficial physiological activities of β-glucans have been largely attributed to their ability to increase the viscosity of the gut content and thereby modification of the absorption rates of nutrients and bile acids (Wood, 2010). In this respect, the importance of BG molecular weight (MW) on its nutritional and health-related benefits is well known (Wood, 2010). The technological effects of BG on wheat doughs and breads, also dependent on their molecular weight and concentration, have been recently studied (Cleary, Andersson, & Brennan, 2007; Sabanis et al., 2009; Skendi, Biliaderis, Papageorgiou, & Izydorczyk, 2010). However, as far as we know, the impact of β-glucan MW on GF dough rheology and the resultant bread quality has not been explored yet. It is also important to explore the influence of the baking process on the content and molecular weight of the β-glucan present in the final GF product.

The aim of the present work was to study the effect of enrichment of GF flour formulation with commercial concentrates of β-glucans (BGs), derived from barley and oat, on dough rheology and bread quality characteristics; the water content of the dough was also varied to optimize the hydration level of the BG fortified systems to maximize the bread quality. The impact of the GF bread making process on the content and MW of BG, was also examined in order to assess the nutritional implications of the fortification on the final baked product.

2. Materials and methods

2.1. Materials

Rice flour (12.5% moisture, 0.43% ash, 7.5% protein, 0.47% fat and 79.1% starch) was supplied by Herba Ricemills S.L.U (Tarragona, Spain). Salt, sugar and sunflower oil were purchased from the local market. Hydroxy-propyl-methyl-cellulose (HPMC) 4 KM was a gift from Dow Chemical (Midland, EEUU). Barley (1 → 3) (1 → 4)-β-D-glucan (BBG) (Glucagel™) a preparation of low/medium molecular weight was given as a free sample from DKSH (Hamburg, Germany). The oat (1 → 3) (1 → 4)-β-D-glucan concentrate (OBG) (Promoat™) which was a high molecular weight β-glucan preparation, was supplied by Biovelop AB (Kimstad, Sweden). The proximate composition of these materials as given by the suppliers was: 2.52% moisture, 4.75% soluble protein, 1.43% ash, 1.32% fat, >85% total carbohydrates, and >72% β-glucan for the BBG concentrate, and 6% moisture, 54–56% carbohydrates (dextrin), <4.5% protein, 1–3 % ash and 0.5–1 % fat, and 33–36 % β-glucan for the OBG preparation. The gluten content of the commercial oat and barley BG samples was analysed by the ELISA test based on the R5 antibody; i.e. the gluten content in OBG was under the detection limit (<6.2 mg/kg), while the gluten concentration of BBG was found 1.76 g/kg that rendered this commercial β-glucan concentrate not gluten-free. Nevertheless, the BBG was also included in this study for evaluation of the effect of BG MW on the rice flour-based gluten-free dough formulation since it is technically feasible to obtain a gluten-free barley β-glucan preparation (Ronda et al., 2013).

2.2. Dough preparation and breadmaking

A straight dough process was performed using the following formulation on a 100 g rice flour basis: 78% water, 6% oil, 5% sucrose, 2% HPMC, 1.8% salt and 3% dried yeast. Table 1 summarizes the amounts of β-glucan concentrates and the amount of water added to the dough mixture, following an experimental design of 32 elaborations (2 BG types × 4 BG levels × 4 water levels). The dough water content, established with preliminary tests, was adapted to the BG content as it is well known the high water absorption capacity of these hydrocolloids (Ronda et al., 2013). The GF dough- and bread-making procedures are described in detail elsewhere (Pérez-Quirce et al., 2014; Ronda et al., 2013). After baking, breads (around 200 g) were removed from the pans and left for 1 h at room temperature before any analysis.

2.3. Evaluation of dough properties

2.3.1. Large deformation mechanical test: forward extrusion test

Forward extrusion assays were performed in a TA-XTplus texture analyser (Stable Micro Systems) equipped with a 25 kg-load cell and operating at 10 mm/s head speed as described in detail elsewhere (Ronda et al., 2013). This test measures the compression

Table 1
Experimental design: amounts of commercial β-glucan concentrates from oat (OBG) and barley (BBG) dose and water contents in each elaboration.

Run	BBG (% rfb)	Run	OBG (% rfb)	WATER[a](% rfb)
1	0	17	0	78
2	0	18	0	85
3	0	19	0	92
4	0	20	0	99
5	1.8	21	3.9	89
6	1.8	22	3.9	97
7	1.8	23	3.9	105
8	1.8	24	3.9	113
9	3.6	25	7.9	100
10	3.6	26	7.9	109
11	3.6	27	7.9	118
12	3.6	28	7.9	127
13	5.4	29	11.8	111
14	5.4	30	11.8	121
15	5.4	31	11.8	131
16	5.4	32	11.8	141

[a] The amount of water added for both the OBG and BBG fortified dough formulations on each row, as specified by the respective run numbers, is common for the two concentrates.