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Effect of water content and flour particle size on gluten-free bread quality and digestibility

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ABSTRACT

The impact of dough hydration level and particle size distribution of the rice flour on the gluten free bread quality and *in vitro* starch hydrolysis was studied. Rice flour was fractionated in fine and coarse parts and mixed with different amounts of water (70%, 90% and 110% hydration levels) and the rest of ingredients used for making gluten free bread. A larger bread specific volume was obtained when coarser fraction and great dough hydration (90–110%) were combined. The crumb texture improved when increasing dough hydration, although that effect was more pronounced when breads were obtained from a fine fraction. The estimated glycaemic index was higher in breads with higher hydration (90–110%). Slowly digestible starch (SDS) and resistant starch (RS) increased in the coarse flour breads. The coarse fraction complemented with a great dough hydration (90–110%) was the most suitable combination for developing rice bread when considering the bread volume and crumb texture. However, the lowest dough hydration limited starch gelatinization and hindered the *in vitro* starch digestibility.

1. Introduction

Celiac disease (CD) has become an increasingly recognised autoimmune enteropathy triggered by the ingestion of some cereal prolamines. In Europe, the prevalence of CD is between 0.3% and 2%, depending on the geographic area evaluated (Mustalahti et al., 2010). Along with genetic susceptibility, environmental factors may play a role in the development of celiac disease (Niewinski, 2008). Moreover, timing of the introduction of gluten in infancy was demonstrated to be an important factor (Norris et al., 2005). The individual's intolerance to gluten is lifelong and self-perpetuating, and the only treatment is strict adherence to gluten-free diet (GFD). Despite the benefits of GFD on symptoms, numerous negative sequelae have been reported including lower intakes of essential micronutrients, vitamins and minerals and higher intakes of sugar (Wild, Robins, Burley, & Howdle, 2010).

Given the changes in diet and in the small intestinal absorptive function following the gluten-free diet treatment, significant changes in body mass index may be expected (Dickey & Kearney, 2006; Ukkola et al., 2012). Moreover, CD is usually related to associate diseases such as anaemia and type I diabetes. Nevertheless, type I diabetes is diagnosed first than CD in the 90% of the cases (Holmes, 2001). Since celiac disease is associated with a high incidence of type I diabetes (Cronin & Shanahan, 1997), patients should maintain good glycaemic control whilst adhering to a strict gluten-free diet.

The glycaemic index (GI) defined as "the area under curve of blood glucose after eating a food containing a determined quantity of carbohydrate" provides an indirect measure of the ability of a food to raise blood glucose and a direct one of the absorption of carbohydrates. The glycaemic index classification of foods has been used as a tool to assess prevention strategies for diseases where glycaemic control plays an important role, such as obesity and diabetes. So far, celiac patients were advised only to avoid gluten in their diet but taking into account the nutritional quality of gluten-free products. On this line, Esfahani et al. (2009) compiled some studies showing a significant protective effect against the risk of developing diabetes with the lowest dietary glycaemic index intake.

Enzymatic digestion of starch can be affected by many factors such as granule structure, the presence of lipids, proteins or minerals, amylose:amylopectin ratio, digestion conditions and particle size Al-Rabadi, Gilbert, and Gidley (2009). The presence of proteins or lipids influences starch digestion and reduces glycaemic response by limiting starch accessibility by encapsulating it (Fardet, Leenhardt, Lioger, Scalbert, & Rémésy, 2006). Moreover, the effect of particle size is usually related to the surface area available for enzymatic action. In this regard, Blasel, Hoffman, and Shaver (2006) found the degree of starch access by α-amylase to decrease by 26.8 g/kg starch for each 100 μm increase in particle size in ground corn grain. Regarding bread, Fardet et al. (2006), studying

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gluten containing breads, considered the physical structure as the most important factor influencing GI, stating that the more compact the structure, the lower the glycaemic response. Nevertheless, there is no information about how that could be beneficial when obtaining gluten free breads, and neither if by controlling the process conditions or the raw materials it is possible to modulate the glycaemic index, and therefore the starch hydrolysis, of the gluten free bread.

The aim of this study was to assess the effect of particle size of rice flour (fine and coarse) and dough hydration, one of the most critical parameters in gluten free breadmaking, on the physical quality and starch enzymatic digestion of gluten-free breads.

2. Materials and methods

2.1. Materials

Commercial rice flour supplied by Harinera Castellana (Medina del Campo, Spain) had a moisture and protein of 12.19/100 g and 7.22/100 g, respectively. Salt, sugar, and sunflower oil were purchased from the local market. Dry yeast (Saf-instant, Lesaffre, Lille, France) and hydroxypropyl methylcellulose (HPMC) (Methocel K4M, Dow Chemical, USA) were used.

2.2. Flour obtaining process

Flour was sifted in a Bühler MLI 300B (Bühler AG, Uzwil, Switzerland) with screens of 132 and 200 μm to obtain fine and coarse fractions. The so-called fine flour had particle size lower than 132 μm, and the coarse fraction contained particles with sizes ranging between 132 and 200 μm. Those particle sizes were selected based on authors' previous research (de la Hera, Talegon, Caballero, & Gomez, 2013c) conducted with corn, which studied the influence of the particle size of corn flour on gluten free bread performance, and concluded that coarser flours (>180 μm) provide breads with higher volume and softer crumbs.

Fine and coarse flours were used as raw material for gluten free bread making. Since flour hydration is crucial for gluten free breadmaking performance (Marco & Rosell, 2008), three different hydrations were applied to determine whether they could affect starch features and consequently glycaemic index of the resulting bread.

2.3. Bread making process

A straight dough process was performed using a Kitchen-Aid Professional mixer (KPM5, KitchenAid, St. Joseph, MI, USA) with a dough hook (K45DH). The following ingredients (as% on wet flour basis) were used: sunflower oil (6%), sucrose (5%), salt (1.8%), dry yeast (3%), HPMC (2%) and water (70%, 90% or 110%). The water content or dough hydration was referred to the amount of water used in each recipe. All ingredients were mixed for 8 min at speed 2 (in a scale 1–10 of the mixer). Dough pieces (250 g) were placed into aluminium pans (232 × 108 × 43.5 mm) and fermented in a proofing chamber at 30 °C and 90% relative humidity for 60 min. After proofing, the dough was baked in an electric oven for 40 min at 200 °C. Then the loaves were removed from the pans, cooled for 50 min at room temperature, and packed in sealed polyethylene bags to prevent dehydration. Analytical measurements were made within 24 h. Two batches were made for each sample.

2.4. Analytical methods

The flour protein content was determined following AACC method 46–30, performed with a Leco TruSpec®N nitrogen/protein analyser.

The bread moisture content was determined following AACC method 44-01.01 (AACC, 2000). Weight loss during baking was assessed by weighing the pans before and after baking. Bread volume was determined using a laser sensor with a BVM-L 370 volume analyzer (TexVol Instruments, Viken, Sweden). The bread specific volume was calculated as the ratio between the volume of the bread and its weight. These measurements were carried out in three breads of each batch.

The crumb texture was determined using a TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK) with the "Texture Expert" software. A 25 mm diameter cylindrical aluminium probe was used in a 'Texture Profile Analysis' (TPA) double compression test to penetrate to 50% depth, with a test speed of 2 mm/s, and a 30 s delay between the first and second compressions. Hardness, cohesiveness, springiness and resilience were calculated from the TPA plot. Measurements were made on two central slices (20 mm thickness) from three breads of each batch.

2.5. In vitro starch digestibility and estimated glycaemic index

Two slices were freeze dried for determining the *in vitro* digestibility. Enzymatic hydrolysis of gluten-free bread was determined following the method reported by Gularte and Rosell (2011) using 100 mg of powdered freeze dried breads. According to the hydrolysis rate of starch, three different fractions were quantified as suggested Englyst, Veenstra, and Hudson (1996). Rapidly digestible starch (RDS) was referred to the percentage of total starch that was hydrolysed within 30 min of incubation; slowly digestible starch (SDS) was the percentage of total starch hydrolysed within 30 and 120 min, and resistant starch (RS) was the remnant starch after 16 h of incubation. The percentage of the total starch hydrolysed at 90 min (H90) was also calculated.

The *in vitro* digestion kinetics were calculated in accordance with the procedure established by Goñi, Garcia-Alonso, and Saura-Calixto (1997). A nonlinear model following the equation $[C = C_\infty\ (1 - e^{-kt})]$ was applied to describe the kinetics of starch hydrolysis, where C was the concentration at t time, C_∞ was the equilibrium concentration or maximum hydrolysis extent and k was the kinetic constant. The hydrolysis index (HI) was obtained by dividing the area under the hydrolysis curve (0–180 min) of the sample by the area of a standard material (white bread) over the same period of time. The estimated glycaemic index (eGI) was calculated using the equation described by Granfeldt, Björck, Drews, and Tovar (1992): eGI = 8.198 + 0.862HI.

2.6. Statistical analysis

Data were subjected to a two-way analysis of variance (ANOVA) to study the differences in bread quality induced by particle size and dough hydration. A one-way ANOVA was carried out for analysing the texture parameters of breads individually. Fisher's least significant difference (LSD) test was used to describe means with 95% confidence. A correlation analysis was also carried out to determine possible relationships among parameters. Statgraphics Plus Centurion XVI (Statpoint Technologies, Warrenton, USA) was used as the statistical analysis software.

3. Results and discussion

3.1. Physical characteristics of gluten-free breads

Breads obtained from the two different rice flour fractions were physically characterised (Table 1, Fig. 1). The specific volume significantly increased when coarse flour was used to obtain breads, and also a steady increase of specific volume was also observed