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Modelling the effects of psyllium and water in gluten-free bread: An approach to improve the bread quality and glycemic response

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ABSTRACT

A 2^2 factorial design with three centre points was used to study psyllium (P) and water (W) addition level effects on gluten-free bread (GFB) physical properties and sensory acceptability. The P levels ranged from 2.86 to 17.14% and W levels from 82.14 to 117.86% on a flour basis. The results show that the P and W interactions improve the bread quality by yielding a better loaf volume, softer crumbs, and improved bread appearance and enhancing the sensory acceptability scores. The optimum formulation (desirability of 0.89) was prepared with 2.86% P and 82.14% W, increasing the dietary fibre content from 2.5% in the control formulation to 4.0%. The results also show that it is possible to add 17.14% P and 117.86% W to obtain an acceptable GFB with nearly a four-fold increase in the fibre content and a 33% decrease in the glycemic response compared to that of the control formulation.

1. Introduction

This study aims to show how psyllium can potentially be used to improve the dietary fibre content and glycemic response of gluten-free bread (GFB) while not compromising its physical properties and sensory acceptability.

Despite the considerable advances in research and development and the growth of the gluten-free market, many GFBs available on the market have high prices and lack the sensory properties and nutritional content of their wheat counterparts (do Nascimento, Fiates, dos Anjos, & Teixeira, 2014; do Nascimento, Fiates, & Teixeira, 2017; Singh & Whelan, 2011). GFBs frequently presents lower levels of dietary fibre because they are frequently made using refined gluten-free flours or starches (do Nascimento, Fiates, dos Anjos, & Teixeira, 2013; Kinsey, Burden, & Bannerman, 2008; Thompson, 2000; Thompson, Dennis, Higgins, Lee, & Sharrett, 2005). Thus, increasing the variety of better-tasting and healthier gluten-free products is still an open challenge. The use of dietary fibre-rich ingredients has been suggested to improve the physical properties, sensory acceptance and nutritional content of GFB and to reduce the glycemic response of such foods (Capriles, dos Santos, & Arêas, 2016).

The bioactive polysaccharide from psyllium seed husks (*Plantago ovata* Forsk) is a type of arabinoxylan, which is also known as a psyllium husk, psyllium mucilage, Ispaghula or Isabgol. Psyllium husk is a source of natural, viscous dietary fibre that has beneficial health properties, such as gut regulation and blood glucose and cholesterol control (Singh, 2007).

Previous research on the use of low amounts of psyllium (1–4 g/100 g flour basis), alone or in combination with hydroxypropylmethylcellulose (HPMC), in gluten-free bread making has shown promising results concerning the physical properties, appearance, and acceptability of GFB (Cappa, Lucisano, & Mariotti, 2013; Haque & Morris, 1994; Mancebo, San Miguel, Martínez, & Gómez, 2015; Mariotti, Lucisano, Pagani, & Ng, 2009). Interesting results were obtained by Zandonadi, Botelho, and Araujo (2009), who developed a psyllium-added GFB that was well-accepted by celiac and non-celiac suffers. Korus and Achremowicz (2004) reported an increase in the GFB dietary fibre content (2.1–2.9%, compared to 1.1% in the control formulation) using 5–10% psyllium instead of a similar starch level. The authors emphasized the importance of the increase in the water content to obtain psyllium-added GFB with a proper crumb structure and texture (Cappa et al., 2013; Haque & Morris, 1994; Mancebo et al., 2015).

As far as the authors are aware, the effects of the psyllium levels on GFB physical properties and sensory acceptability and on the definition of psyllium levels in formulations to obtain a well-accepted, fibre-enriched GFB have not been researched. Furthermore, the addition of viscous dietary fibre, like psyllium, could be a successful way to reduce the glycemic response, which is an important aspect that must be considered in gluten-free product development because celiac disease is frequently related to type I diabetes mellitus. Therefore, increasing the variety of GFB with a low glycemic response is important for helping those individuals who must face the daily challenges imposed by a strict

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gluten-free diet treatment with additional restrictions related to diabetes (Capriles & Arêas, 2016). No investigations have evaluated the impact of psyllium on the GFB post-prandial glycemic response.

The main objectives of this study were to evaluate and optimize the applications of psyllium in a gluten-free bread formulation. With this aim, a 2^2 factorial design with 3 centre points was used to identify the psyllium (P) and water (W) levels in a GFB formulation to achieve the best physical properties and acceptability. Subsequently, the proximate composition and in vivo glycemic response of the best formulations were compared with those of the white GFB and wheat bread counterparts.

2. Materials and methods

The experimental protocol was approved by the Human Research Ethics Committee of the Federal University of São Paulo according to the rules of the National Committee for Ethical Research of the Brazilian Health Ministry (CONEP/MS). The participants were recruited from staff, students, and lecturers at the university to voluntarily participate in the sensory evaluation and glycemic response analysis. All subjects signed informed consent to participate forms.

2.1. Materials

The psyllium husk powder (VITACEL® Psyllium P95) was supplied by JRS Latinoamericana Ltd. (São Paulo, Brazil). This is a light brownish dietary fibre concentrate from milled psyllium husks with a 95% purity, an average particle size of 250 µm, and approximately an 80% dietary fibre content according to the suppliers' specifications and the dietary fibre analysis. The other ingredients used in the bread-making process were obtained from a local market, and they were rice flour (Urbano Agroindustrial Ltda, Santa Catarina, Brazil), cassava starch (Yoki Alimentos S.A., São Paulo, Brazil), egg (Avícola Ito, São Paulo, Brazil), whole milk powder (Nestlé Brasil Ltda, São Paulo, Brazil), white cane sugar (Camil Alimentos S.A., Rio Grande do Sul, Brazil), soy oil (Cargil Agrícola S.A., Minas Gerais, Brazil), salt (Refinaria Nacional de Sal S.A., Rio de Janeiro, Brazil), and dry yeast (Dr. Oetker, São Paulo, Brazil).

2.2. Methods

2.2.1. Gluten-free bread preparation

The GFB formulation consisted, on a flour basis (f.b.), of the following: 75% rice flour, 25% cassava starch, 25% whole egg, 10.5% whole milk powder, 6% white cane sugar, 6% soy oil, 2% salt and 0.8% dry yeast. The psyllium (P) levels ranged from 2.86 to 17.14% and water (W) from 82.14 to 117.96% f.b. according to the experimental design. A control GFB, without P or another hydrocolloid, was also analysed.

A straight dough process was performed using a stand mixer (BPS-05-NSkymsen, Metalúrgica Siemsen Ltd., Brazil) with a dough hook attachment. All the ingredients were mixed at speed 4 (on a 1–10 mixer scale) for 7 min. The resulting dough (400 g) was placed into aluminum pans (19 × 7.5 × 5 cm) and allowed to sit at 40 °C and 85% relative humidity for 90 min (CFK-10, Klimaquip S/A – Tecnologia do Frio, Brazil). Subsequently, baking was performed in an electric oven at 140 °C for 45 min (HPE-80, Prática Produtos S.A., Brazil). After baking, the loaves were removed from the pan and cooled for 2 h on cooling racks at room temperature. The loaves were then stored in polyethylene bags to prevent moisture loss at room temperature (approximately 25 °C). All analyses were performed within 3 h.

Six loaves were prepared from two batches for each of the GFB trials. Three random loaves were used for the weight loss, specific volume and crumb moisture analyses, and three random loaves were used for the crumb texture evaluation and photographs. An extra six loaves were produced for the sensory evaluation.

2.2.2. Bread quality evaluation

The bread physical properties analysis consisted of bake loss, loaf-specific volume, crumb moisture and firmness. The bake loss was calculated as the difference between the weight of the loaf before and after baking. The loaf-specific volume was determined as a ratio of the volume and weight according to AACC method 10-05.01 (AACC International, 2010). The moisture in the bread crumbs was determined according to AACC method 44-15.02 (AACC International, 2010). The values obtained were the mean of three replicates. The crumb firmness was determined according to AACC method 74-09.01 (AACC International, 2010) using a texture analyser (TA.XT*plus*, Stable Micro Systems, Surrey, UK). Texture measurements (six values) were performed on two bread slices that were taken from the centres of three different loaves. A 25-mm thick slice was compressed up to 40% deformation, using a 36 mm diameter cylindrical aluminum probe at 1.7 mm/s speed. Crumb firmness was taken as the force required for compression of the bread sample by 25%.

The sensory acceptability of the breads was evaluated by 53 untrained panellists recruited from the campus via internal announcements. All the panellists agreed to taste the samples before the tests occurred, and they attested that they consumed bread and did not have any allergies or intolerances to any of the ingredients present in the products. They had no gluten-related diseases and were made aware that they were tasting GFBs. The panellists scored the appearance, colour, aroma, texture, taste and overall acceptability of the formulations on a 10-cm hybrid hedonic scale (Villanueva, Petenate, & Da Silva, 2005). The bread slices (12.5 mm thick) were separately offered in a random sequence in polyethylene bags coded with 3-digit numbers. The evaluation was conducted in a climate-controlled (20–25 °C) sensory evaluation laboratory equipped with separate booths. The panellists rinsed their mouths with water between samples to minimize any residual effects.

2.3. Experimental design

A 2^2 factorial design with centre points was used to study the main and interaction effects of the P and W addition levels on the GFB physical properties and acceptability. After preliminary trial-and-error baking tests, the upper and lower limits for these variables were established. The P levels ranged from 2.86 to 17.14% and W from 82.14 to 117.96% f.b. A total of 7 trials were performed with four for the factorial and three as the centre points and were prepared using a previously randomized execution sequence. Assessment of the error was derived from three central point replicates. Model selection (mean = no model, linear or interaction) for each response was determined by the R^2 value and model significance ($P < .05$).

2.4. Optimization of the GFB formulation and quality verification

The fitted models for the loaf volume, crumb firmness and acceptability scores were used to optimize the GFB formulations by applying the technique of the desirability function of Derringer and Suich (1980). For each response, Y_i, a desirability function, d_i, assigns numbers between 0 and 1 to the possible values of Y_i; $d_i = 0$ represents a completely undesirable response value, and $d_i = 1$ represents a completely desirable or ideal response value. The individual desirability values are then combined by applying the geometric mean, which gives the composite desirability (D). The levels of P and W for the optimum formulation were obtained using the maximum D value. The exhaustive computer imposition of the exact grid points from the overlaid acceptability score contour plots was also applied to determine the experimental regions to select the P and W levels for obtaining fibre-enriched and acceptable GFB. These GFBs were prepared and experimentally analysed, and the results were statistically compared to the predicted values from the fitted models.