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Application of bioprocessing techniques (sourdough fermentation and technological aids) for brewer's spent grain breads

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ABSTRACT

A comprehensive study into the potential of bioprocessing techniques (sourdough fermentation and technological aids) for improving the technological, sensory, and nutritional properties of breads made using brewer's spent grain (BSG) was undertaken. Xylanase and dough conditioner altered the mixing and pasting properties of the flours, improved the specific volume and texture of breads and delayed staling in BSG breads when added to both sourdough and non-sourdough BSG breads. The aromatic properties were determined by volatile analysis and were influenced by sourdough fermentation. Ferulic and 4-coumaric acids were the main phenolic acids found in insoluble bound form in BSG flour, while the phenolic profile was different for the free extracts. Sourdough fermentation and the use of enzymes increased the antioxidant capacity of breads.

1. Introduction

Brewer's spent grain is a by-product of the brewing industry and is considered to be agricultural waste, with high volumes being generated globally. It is estimated that the annual production of BSG is approximately 30 million tonnes worldwide (Wilhelmson et al., 2009) and 3.4 million tonnes of spent grain from the brewing industry is produced in the EU every year (Stojceska, Ainsworth, Plunkett, & Ibanoglu, 2008). It has mainly been used for animal feed but according to Stojceska and Ainsworth (2008) there is strong potential for the use of BSG for human consumption as a cheap source of dietary fibre. Incorporating BSG into food products will address the increased consumer need for healthier products and also the current global priority for reducing food waste.

BSG consists of the husk–pericarp–seed coat layers that covered the original barley grain and depending on the brewing practices used, there could also be residues of starchy endosperm and walls of empty aleurone cells present. BSG is rich in fibre with the main components being: arabinoxylan, lignin and cellulose (Mussatto, Dragone, & Roberto, 2006). BSG is also rich in protein and it has been found that 10% BSG addition increased both the fibre and protein content and lowered the caloric content of breads (Hassona, 1993).

Sensory properties and shelf-life of baked products have been widely studied over the years, and it is known that addition of fibre generally results in darker products of lower volume, increased hardness and a denser structure. In our previous study (Ktenioudaki et al., 2013) it was found that addition of 10% BSG in baked snacks increased the fibre content of the snacks by 100% compared to wheat control snacks, without losing its appeal to the consumers.

Sourdough fermentation is a common practice in bread making and has been used to improve the palatability of cereal brans and whole meal flours (Poutanen, Flander, & Katina, 2009; Salmenkallio-Marttila, Katina, & Autio, 2001). The use of a sourdough starter has been shown

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to improve the volume, texture and shelf-life of breads (Katina, Heiniö, Autio, & Poutanen, 2006) while also affecting the levels of several bioactive compounds such as phytate, folates, tocopherols and the bioavailability of phenolic compounds (Katina et al., 2007; Liukkonen et al., 2003; Mateo Anson, Havenaar, Bast, & Haenen, 2010; Michalska et al., 2007).

Additionally, plant cell wall modifying enzymes have been used extensively in various baking applications, aiming at improving shelf life, volume, textural characteristics, crust colour, flavour, and nutritional quality of cereal products. Cellulolytic and hemicellulolytic hydrolases including xylanases act on nonstarch polysaccharides (NSP). They can improve dough handling properties and increase baked product volume (Waters, Murray, Ryan, Arendt, & Tuohy, 2010). Enzymes such as endoxylanases are believed to act during the agglomeration of gluten following the breakdown of gluten structures during mixing, affecting gluten yield and rheological properties (Wang, van Vliet, & Hamer, 2004). Dough conditioners used in the baking industry are commonly a mixture of enzymes, surfactants and oxidising agents. Surfactants such as DATEM can affect gluten development and lead to more disordered protein structures, with an altered gluten network (Gomez, Ferrer, Anon, & Puppo, 2013).

The objectives of this study were:

1. To carry out a comprehensive investigation into the potential of bioprocessing techniques (such as sourdough fermentation and technological aids) on the technological and sensory properties of BSG breads;
2. To evaluate the shelf-life and staling kinetics of BSG breads, including the thermophysical properties;
3. To examine the effect of sourdough fermentation on the aromatic properties of BSG breads;
4. To determine the in vitro antioxidant capacity and phenolic composition of BSG flour and breads.

2. Materials and methods

2.1. Materials

Commercial wheat flour (13.7% moisture, 12.3% protein, 1.4% fat, 0.8% ash, 66.3% total starch, and 3.7% Total Dietary Fibre (TDF)) (Shackleton's Baker's wheat, Shackleton's milling Ltd., Ireland) was used in the study. Dried brewer's spent grain (BSG) (5.6% moisture, 20.8% protein, 4.5% fat, 3.2% ash, 3.3% total starch, and 60.5% TDF) was obtained from the micro-brewery establishment in University College Cork, Ireland. The BSG was dried and milled as described by Ktenioudaki et al. (2013). Dough conditioner (DC) (Fermex® Point 5 W) was kindly donated by Fermex International Ltd. (Worcester, UK). Endo-1,4-xylanase (Xyl) (Pentopan Mono BG) was obtained from Novozymes (Denmark). The activity (according to the manufacturer) was 2500 fungal xylanase units (Wheat)/g). Panistart W01 was donated by Puratos (Belgium) for the fermentation of the BSG. Panistart W01 is a lyophilised lactic acid bacteria (*Lactobacillus brevis*, *Lactobacillus plantarum*) and yeast (*Saccharomyces cerevisiae*). Other ingredients used for sample preparation included: table salt and sugar (purchased locally), emulsified bread fat (Irish Bakels Ltd., Dublin, Ireland), and instant yeast (Pante instant yeast, The Puratos group, Belgium). Barley malt extract (Rayner's Essentials, Sussex, UK) was purchased locally.

2.2. Chemicals

Gallic acid, quinic acid, 3-hydroxycinnamic acid, trans-3-coumaric acid, protocatechuic acid, sinapic acid, vanillic acid, (+)-catechin, epicatechin, chlorogenic acid, p-coumaric acid, procyanidin B1, ferulic acid, HPLC grade acetonitrile and water, formic acid, methanol, sodium hydroxide (NaOH), hydrochloric acid (HCl), ethyl acetate, hexane, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tris(2-pyridyl)-s-triazine (TPTZ), 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) and Folin Ciocalteu Reagent (FCR) were purchased from Sigma-Aldrich Chemical Ltd. (Wicklow, Ireland).

2.3. Sample preparation

2.3.1. BSG sourdough fermentation

BSG flour (75 g) was mixed with water (300 g), 0.25% Panistart W01, and 3% barley malt extract to create a liquid dough. It was placed in a proofing cabinet at 25 °C and 85% relative humidity, for 24 h. The fermented BSG resulting from this process will be henceforth referred to as BSG sourdough starter.

2.3.2. Bread baking

Six samples of bread were prepared, containing 15% BSG (flour basis) either as BSG flour addition (BSG, BSG_{xyl}, and BSG_{DC}) or as BSG sourdough (SD) addition (BSG_{SD}, $BSG_{SD + xyl}$, and $BSG_{SD + DC}$). BSG_{xyl} and $BSG_{SD + xyl}$ contained xylanase (xyl); BSG_{DC} and $BSG_{SD + DC}$ contained dough conditioner (DC). The formulation of the samples is given in Table 1. The bread samples were prepared by mixing all the ingredients in a Kenwood mixer for 4 min. The water absorption used was 71.9% (Mixolab value). After mixing, the dough was allowed to rest for 30 min in a proofing cabinet (30 °C, 80% Relative Humidity) (Koma SDCC-1P/W, Koma Koeltechnische Industrie B.V., The Netherlands). They were then divided into 65 g pieces, moulded into shape and placed in rectangular tins (108 × 64 × 37 mm). A proofing period of 45 min followed and the loaves were baked for 20 min at 220 °C in a deck oven (Compacta, Tom Chandley Ovens, Manchester, UK). Breads were allowed to cool for 2 h before being placed in plastic bags and stored for 15 days at room temperature. Breads from each batch were also frozen and held or freeze dried, vacuum packed and kept frozen, until specific analysis was carried out.

2.4. Compositional analysis of the flours and baked loaves

Ash content was measured in duplicate according to the AOAC method No 923.03 (AOAC, 2000). Total, soluble and insoluble dietary fibre analysis was conducted by Campden BRI (UKAS accredited) according to AOAC Method 985.29 (AOAC, 1985) (Campden Technology Ltd., Gloucestershire, UK). The protein content was determined using a nitrogen analyser (FP-328 Leco Instrument; Leco Corporation, St Joseph, Michigan, USA) based on the Dumas principle (Nx6.25).

2.5. Total titratable acidity (TTA) and pH analysis

Frozen bread samples and BSG sourdough starter samples were thawed and the pH value was measured from an aliquot of 10 g of sample blended with 100 mL of distilled water. TTA was determined by titrating this suspension against 0.1 M NaOH to pH 8.5 (retitrating to pH 8.5, 5 min after it was first reached). TTA was expressed as the amount of NaOH used (mL).

2.6. Mixolab characteristics of each dough formulation

Investigation into the physicochemical properties of the dough samples was performed using Mixolab® (Chopin Technologies, France). Flour-BSG blends (BSG, BSG_{xyl}, and BSG_{DC}) and flour-BSG sourdough blends (BSG_{SD}, $BSG_{SD + xyl}$, and $BSG_{SD + DC}$) were introduced in the mixing bowl and the appropriate amount of water was added following the Chopin + protocol and the method was performed according to ICC method no. 173 (ICC, 2011). The resulting dough was 75 g in all samples. The mixolab curve has been described by many researchers (Rosell, Santos, & Collar, 2010).