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Influence of dextran-producing *Weissella cibaria* on baking properties and sensory profile of gluten-free and wheat breads

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ABSTRACT

Breads based on gluten-free buckwheat, quinoa, sorghum and teff flours were produced with addition of 20% sourdough fermented with exopolysaccharide (EPS) producing *Weissella cibaria* MG1. Wheat bread was baked as a reference. Dough rheology, bread quality parameters and sensory properties of the sourdough-containing breads were compared to sourdough non-containing control breads of the respective flour. The specific volume remained unaffected by sourdough application. In buckwheat, sorghum, teff and wheat sourdough breads acidification increased crumb porosity compared to control breads. Crumb hardness was significantly reduced in buckwheat (−122%), teff (−29%), quinoa (−21%) and wheat sourdough breads (−122%). The staling rate was significantly reduced in buckwheat, teff and wheat sourdough breads. Water activity of the sourdough containing bread crumb was not influenced by the presence of EPS. Due to the presence of exopolysaccharides (EPS) and influence of acidification, the dough strength, A_F, as measured by oscillation tests decreased significantly in sourdough-containing buckwheat, sorghum and wheat dough, but increased in sourdough-containing quinoa and teff dough. Microbial shelf-life was significantly prolonged neither for gluten-free sourdough nor for wheat sourdough breads. Scanning electron microscopy of control and sourdough bread crumbs did not show differences concerning structural starch features. In addition, the aroma of most bread was not improved by sourdough addition.

1. Introduction

Cereal products are important staple foods of the human diet (EUFIC, 2013). However, the digestion of the storage protein gluten (present in wheat and related grains like barley, rye and triticale) releases a peptide from the α-gliadin fraction which induces a systemic immune-mediated disorder, called coeliac disease, in genetically susceptible persons (Fasano and Catassi, 2012; Green and Cellier, 2007). Worldwide, 0.6–1.0% of the population is affected by this auto-immune disease which damages the intestinal mucosa through inflammation of the micro-villi and thereby deteriorates the ability to absorb nutrients (Fasano and Catassi, 2012; Green and Cellier, 2007). Currently, the only available treatment is the complete avoidance of gluten containing cereals (Arendt et al., 2011). A wide range of gluten-free flours is available as alternative. Breads produced thereof are often of low nutritional quality and show poor sensory characteristics such as dry crumb, poor mouth feel and off-flavours (Gallagher, 2009; Hager et al., 2011). Most gluten-free formulations include gluten-free starches, protein-based ingredients and hydrocolloids which mimic the viscoelastic properties of gluten (Gallagher et al., 2004b). Hydrocolloids are commonly used ingredients to improve crumb structure of gluten-free breads, reviewed by Hager and Arendt (2013) and Anton and Artfield (2008). The synthesis of exopolysaccharides (EPS) by lactic acid bacteria has gained increasing interest to improve textural properties of fermented foods in general and bread quality especially. EPS can be divided into homo- (made of one sugar moiety) and heteropolysaccharides (made of two to three different monosaccharides) (Monchois et al., 1999). They have the potential to replace hydrocolloids (Di Cagno et al., 2006) and to improve textural properties as well as shelf-life of conventional (Decock and Cappelle, 2005; Lacaze et al., 2007; Tieking and Gänzle, 2005) and gluten-free breads (Galle et al., 2012; Ruehmkorf et al., 2012; Schwab et al., 2008). *Weissella* was among the dominant strains in previous gluten-free fermentations (Galle et al., 2010; Schwab et al., 2008). We have previously isolated and identified the strain *Weissella cibaria* MG1 that dominates and produces a glucan during sucrose supplemented sourdough fermentations (Galle et al., 2010; Wolter et al., 2014). Dextran (an α-1,6-linked glucan) with a molecular weight of $5 \cdot 10^6$–$4 \cdot 10^7$ kDa was produced with yields of 4 g and 3 g/kg buckwheat and quinoa sourdough (Wolter et al., 2014). Although, improvement of rheological behaviour (Galle et al., 2012; Wolter et al., 2014) and baking properties by in situ formed dextran was previously demonstrated in breads made from buckwheat, sorghum and teff flours (Galle et al., 2012; Ruehmkorf et al., 2012; Schwab et al., 2008), it is not known

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how this strain influences crumb structure and sensory profile of gluten-free breads. Investigations on the aroma potential of lactic acid bacteria have demonstrated that specific strains are able to generate individual aroma profiles and odorant compositions due to their metabolic properties (Czerny et al., 2005). Consequently, the application of *W. cibaria* can be especially promising regarding improvement of adverse crumb structure aroma and of gluten-free breads. Therefore, *W. cibaria* started sourdough supplemented with sucrose (Wolter et al., 2014) is utilised for gluten-free bread baking to evaluate the influence on quality and flavour profile using a basic recipe based on buckwheat, quinoa, sorghum and teff flours and compare to wheat counterparts as reference.

2. Materials and methods

2.1. Ingredients

The ingredients used in this study were buckwheat flour (Doves Farm Foods Ltd., UK; moisture 12.6%, protein 12.2%, fat 4.2%), quinoa flour (Ziegler Naturprodukte, Germany; moisture 12.3%, protein 13.8%, fat 8.6%), sorghum flour (Twin Valley Mills, Nebraska, USA; moisture 11.1%, protein 4.7%, fat 3.5%), teff flour (Trouw, The Netherlands; moisture 9.5%, protein 12.8%, fat 4.4%), wheat flour (baker's flour, Odlums, Ireland; moisture 12.7%, protein 11.5%, fat 1.8%), yeast (Puratos, Belgium), sugar (Siúcra, Ireland) and salt (Glacia British Salt Limited, UK).

2.2. Sourdough preparation

Sourdough was prepared using *W. cibaria* MG1 as previously described by Wolter et al. (2014). To ensure exopolysaccharide (EPS) production, 10% flour was replaced with sucrose. Flour, sterile tap water and cell culture solution containing 10^9 CFU LAB/ml broth were mixed to gain a final inoculum size of 10^8 CFU/ml dough and a dough yield of 190. Fermentations were carried out in triplicates at 30 °C for 24 h.

2.3. Cell counts, pH and total titratable acidity after sourdough fermentation

Viable cell counts were determined in sourdough by serially diluting samples in triplicates in Ringer solution and plating on mMRS5 agar supplemented with 0.05 g/l bromocresol green. The identity of fermentation microbiota with the inoculum was assessed by comparing the colony morphology to the morphology of *W. cibaria* MG1, and by measuring pH and total titratable acidity (TTA) before and after fermentation. The TTA of sourdough was determined as the amount of 0.1 N sodium hydroxide solution which is necessary to adjust the pH of 10 g sample in 90 ml distilled water to 8.5 as described by Katina et al. (2006b).

2.4. Dough rheology

A controlled stress and strain rheometer (Anton Paar MCR 301, Ostfildern, Germany) was used to evaluate the influence of exopolysaccharides (EPS) and acid production on rheological properties of sourdough samples. All bread batters were prepared without yeast addition to ensure reproducibility of measurements. Sourdough-containing bread batters were prepared replacing 20% of flour by the equivalent amount of fermented flour in the form of sourdough (SD). Bread batters prepared without sourdough served as controls (ctrl). The sourdoughs for rheological trials were prepared using sifted flours (mesh size 0.05 mm). Measurements were carried out as previously described by Galle et al. (2011). For sorghum and wheat samples a parallel plate geometry (PP50/P2-SN13968; gap d = 1 mm) was used, consisting of a 50 mm diameter corrugated probe and plate. Excess sample was trimmed off after loading and a thin layer of paraffin oil was applied to the edges of the sample to avoid moisture loss. For buckwheat, quinoa and teff samples a 25 mm cylinder fitted in a 27 mm cup (CC27-SN8085; d = 0 mm) was applied. Samples were allowed to rest for 5 min prior to analysis. Initially, the linear viscoelastic region was determined for all samples during amplitude sweeps with the strain (γ) ranging from 0.001 to 100%. Frequency sweeps were performed at 30 °C with an angular frequency (ω) ranging from 0 to 9.63 Hz and a target strain (γ) of 0.05%. Complex modulus values (G^*) obtained from the frequency sweeps were matched to the power law equation $G^*(\omega) = A_F \cdot \omega^{1/z}$ for weak gel model (Gabriele et al., 2001). Two parameters were extracted from the power law equation: A_F, subsequently referred to as the dough strength, and z, the network connectivity (Gabriele et al., 2001). All results are averages of at least two measurements of at least three individual fermentations.

2.5. Bread production

Non-sourdough-containing breads (control breads) from four different gluten-free flours and wheat flour were produced as previously described by Hager et al. (2012a) using 100% flour, 2% salt, 2% sugar and 3% dry-yeast (based on flour, BF). The optimal water addition level (WL) based on flour (BF) was determined through preliminary baking trials for gluten-free flours (85% BF for buckwheat, 95% BF for quinoa, sorghum and teff breads) and with the farinograph method 54-21 (AACC, 2000) for wheat flour (63% BF) (Hager et al., 2012a). Sourdough breads were prepared replacing 20% of flour with the equivalent quantity of flour in the form of sourdough. Gluten-free breads were baked at 190 °C for 45 min and wheat breads for 30 min at 220 °C top and 235 °C bottom heat. Three batch replicas were prepared. Bread loaves were cooled at room temperature for 2 h prior to analysis.

2.6. Bread characteristics

Bake loss was determined by weight determination of dough before and bread after baking. The influence of various water levels applied in the different gluten-free formulations was taken into account by division of bake loss by water addition level. The moisture of bread crumb on the day of baking (day zero) was determined using the two stage air-oven method 44-15.02 (AACC, 2000). Water activity of the fresh bread crumb was determined using an AquaLab 4TE water activity meter (Decagon Devices Inc., Pullman, Washington, USA). The specific volume of three breads from each baking batch was determined using a laser scanning system (Volscan Profiler, Stable Micro Systems, UK). The instrumental textural crumb evaluation of three slices from three different loaves per batch was conducted according to AACC method 74-09 (AACC, 2000) using a Universal Testing Machine (TA-XT2i texture analyser, Stable Micro Systems, Surrey, UK) on day zero, two and five of storage compressing the slice to 40% of its initial height with a 35 mm (buckwheat, sorghum, teff and wheat breads). Due to smaller sample dimension a 12 mm aluminium cylindrical probe was used for quinoa bread. The staling rate was calculated as increase in hardness within five days of storage (staling rate = [hardness (day 5 − day 0) / days of storage]). The crumb structure was analysed from three middle slices of three breads per batch in terms of slice area, number of cells, porosity (ratio pore area/slice area) and crumb brightness (mean grey level of pixels, value 0–255) using a C-cell Bread Imaging system (Calibre Control International Ltd., UK).

2.7. Sensory evaluation

Sensory analyses were performed with a trained panel (n = 22) under the conditions described by Hager et al. (2012a) and briefly described below.