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Comparison of homo- and heterofermentative lactic acid bacteria for implementation of fermented wheat bran in bread

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ABSTRACT

Despite its potential health benefits, the integration of wheat bran into the food sector is difficult due to several adverse technological and sensory properties such as bitterness and grittiness.

Sourdough fermentation is a promising strategy to improve the sensory quality of bran without inducing severe changes to the bran matrix. Therefore, identification of species/strains with potential for industrial sourdough fermentations is important. We compared the effects of different representatives of species of lactic acid bacteria (LAB) on wheat bran. *Lactobacillus plantarum*, *Lactobacillus pentosus*, *Lactobacillus brevis*, *Lactobacillus sanfranciscensis* and *Fructobacillus fructosus* produced highly individual fermentation patterns as judged from carbohydrate consumption and organic acid production. Interestingly, fructose was released during all bran fermentations and possibly influenced the fermentation profiles of obligately heterofermentative species to varying degrees. Except for the reduction of ferulic acid by *L. plantarum* and *L. pentosus*, analyses of phenolic compounds and alkylresorcinols suggested that only minor changes thereof were induced by the LAB metabolism. Sensory analysis of breads baked with fermented bran did not reveal significant differences regarding perceived bitterness and aftertaste.

We conclude that in addition to more traditionally used sourdough species such as *L. sanfranciscensis* and *L. brevis*, also facultatively heterofermentative species such as *L. plantarum* and *L. pentosus* possess potential for industrial wheat bran fermentations and should be considered in further investigations.

1. Introduction

In the course of milling, wheat is separated into flour, the germ and bran. The bran fraction contains the outer layers (aleurone and pericarp) of the wheat kernel and on average accounts for 15% of the grain mass (Hemery et al., 2007). Bran is regarded as an unavoidable by-product of the milling industry with little commercial value and so far found its main use as a supplement for animal feed. This is unfortunate because wheat bran has a high content of valuable secondary plant metabolites and is an excellent source of dietary fibre (Brouns et al., 2012; Prückler et al., 2014). Dietary fibre lowers the glycaemic index (Jensen et al., 2006), which reduces the risk of developing type 2 diabetes (Vogel et al., 2012) and also

Abbreviations: AACC, American Association of Cereal Chemists; DM, dry matter; DSMZ, Deutsche Sammlung von Mikroorganismen und Zellkulturen; HQ, high quality; LAB, lactic acid bacteria; OD, optical density; HPLC, high pressure liquid chromatography; PKP, phosphoketolase pathway; RP-HPLC, reversed phase high pressure liquid chromatography; TTA, total titratable acid; W700, Austrian wheat flour quality corresponding DIN10355 Type 550.

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improves the insulin/glucose metabolism in type 2 diabetes patients (Brennan, 2005). Currently, the average intake of dietary fibre in the EU and the USA is below the daily intake recommended for adults (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2010; Trumbo et al., 2005).

Reintegration of wheat bran into the food chain is currently much debated as a strategy to motivate consumers to increase their regular uptake of dietary fibre. Especially the baked goods sector offers ample opportunities to benefit from the health beneficial qualities of bran in food commodities. As such, addition of wheat bran is not only regarded as a means to improve public health but also meets the economic interests of the milling industry to increase the value of the bran fraction. However, poor baking performance and most severely, several unpleasant sensory properties are the major drawbacks in the production of bran containing food commodities (Challacombe et al., 2012; Savolainen et al., 2014).

While the strawy or sandy mouth feeling caused by bran can readily be reduced by particle size reduction, the major challenge for the incorporation of wheat bran in food products is its unpleasant bitter taste accompanied by a long lasting bitter/astringent aftertaste. This circumstance finally leads the majority of consumers to reject whole meal products or products containing higher amounts of bran. These undesirable sensory properties are caused by a complex array of constituents and the exact chemical nature of this phenomenon has not been completely resolved to date. Plant secondary metabolites such as phenolic compounds and alkylresorcinols have been made responsible for bitterness and aftertaste of cereals (Bin et al., 2012; Heiniö et al., 2008). However, despite their adverse sensory effects, these metabolites are also of nutritional value due to several potential health benefits (Parikka et al., 2006). These include their antioxidant activities (Kozubek and Nienartowicz, 1995) and a possible influence on lowering the glycaemic index (Poutanen et al., 2009).

Several processes on the market promise a debittering of wheat bran. The debittering is done by acidification and oxidation of bitter constituents with ozone (Monsalve-Gonzalez and Prakash, 2011) or a combination of hydrothermal treatment and fine grinding (Farigel process, Westhove, Limagrain). Extrusion, a process combining hydrothermal treatment, high shear force and drying has been reported to improve the taste of wheat pasta containing bran (Wójtowicz and Mościcki, 2011). However, such processes are economically challenging due to the technological requirements and high energy demands. Furthermore, they possibly reduce the activity of health beneficial plant metabolites.

A relatively simple, though effective, method to improve dough rheology and to modify bread taste is sourdough fermentation. Traditional Type I sourdoughs stem from spontaneous fermentations and contain complex cultures of symbiotic yeasts and lactic acid bacteria (LAB) that are continuously propagated by backslopping. Most of the LAB strains isolated from sourdough belong to the genus *Lactobacillus*. *Lactobacillus sanfranciscensis*, *Lactobacillus brevis* and *Lactobacillus plantarum* are among the key species of the sourdough microflora (Gänzle et al., 2007). Isolated LAB species are also crucial for industrial Type II and Type III sourdough technologies (Corsetti and Settanni, 2007).

Increased CO_2 retention of the dough is among the technological benefits of sourdough fermentations is thereby contributing to improved loaf volume, firmness and shelf life. Reduction of lipase activity retards fat hydrolysis and thus reduces rancid flavour (Gobbetti et al., 2014). Furthermore, lactic acid fermentation offers several health related benefits through the reduction of antinutritive factors such as phytic acid and improved bioavailability of antioxidants (Gobbetti et al., 2005). Reduced starch digestion through lactic acid and a prolonged gastric emptying rate through acetic acid were reported to reduce the glycaemic index (Novotni et al., 2011; Poutanen et al., 2009).

Fermentation of wheat bran with *L. brevis* was reported to improve the technological and sensory quality of the resulting breads (Katina, Salmenkallio-Marttila et al., 2006; Salmenkallio-Marttila et al., 2001). It was further shown that acidification partially masks or reduces the unpleasant bran flavour. However, a detailed study comparing the effect of metabolically distinct LAB species on wheat bran has, to our awareness, not been performed. Therefore, the aim of this study was to investigate the effect of different LAB (i.e., *Lactobacillus*) species on the complex matrix of wheat bran and to determine which species may be of interest for industrial bran fermentations. This paper reports the effect of the LAB metabolism on carbohydrate, organic acid and phenol/alkylresorcinol profiles of wheat bran. These investigations were accompanied by a sensory evaluation as to whether a correlation of chemical changes with sensory characteristics can be made.

2. Materials and methods

2.1. Raw materials

Fine wheat bran (food grade, from mechanically cleaned and peeled wheat) and wheat flour (W700/Type 550) (basic analytics see Table 1) were provided by GoodMills Group (Schwechat, Austria). The fine bran fraction was taken from the 500 μm sieve deck with 80% of the particles smaller than 250 μm. The ingredients for dough preparation, with exception for yeast (saf instant, S.I. Lesaffre, France), were obtained from a local supermarket (sunflower oil, Osana, Austria; fine sugar, Agrana, Austria; fine salt, iodized, Salinen Austria, Austria).

2.2. Fermentation of wheat bran

All *Lactobacillus* strains used for fermentation (Table 2) were obtained from Deutsche Sammlung von Mikroorganismen and Zellkulturen GmbH (DSMZ, Braunschweig, Germany). *Fructobacillus fructosus* FF14-1 strain isolated from a flower was also included because of its specific metabolic characteristics (Endo and Salminen, 2013).

Pre-cultures of each strain were prepared in De Man, Rogosa & Sharpe (MRS, DSMZ Medium 11) broth with 1% (w/v) glucose and incubated overnight at the optimal growth temperatures (30/37 °C). For propagation of *F. fructosus*, fructose (1% w/v) was added in addition to glucose. The overnight cultures were suspended in sterile NaCl (0.9% w/v). Per kg of dry bran (91.6% dry matter), 37 mL of cell suspensions with $OD_{600} = 1$ were added. This resembles a 2% (v/w) inoculum, taking into account that the water content was finally adjusted to 50%. The mixtures were homogenised for 10 min and compressed in plastic barrels. The barrels were filled to the top, closed and incubated for 18 h at 30 °C. All fermentations were

Table 1
Basic analytics of food grade wheat bran and wheat flour. All values are means of triplicate determination and refer to dry matter.

Material	Food grade bran fine	W700/high gluten flour
Dry matter [%]	91.6	87.3
Ash [%]	5.8	0.8
Crude fat [%]	5.7	1.3
Crude protein [%]	15.5	13.9
Starch [%]	19.3	65.1
β-Glucan [%]	2.7	0.3
Soluble dietary fibre [%]	3.4	1.1
Insoluble dietary fibre [%]	40.5	3.4