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# Barley flour exploitation in sourdough bread-making: A technological, nutritional and sensory evaluation

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ABSTRACT

Consumption of whole grain barley foods reduces blood cholesterol and glycemic index, and promotes weight loss by increasing satiety. However, barley has only been marginally exploited by the baking industry, due to its deteriorating effect on bread quality. The use of sourdough can be a strategy to improve the quality of barley bread. In this study, two sourdoughs, made with sole hull-less barley flour or with a mixture of 50 g/100 g barley and 50 g/100 g wheat flours, were characterized from a microbiological and technological point of view, in comparison with a sole wheat flour sourdough. Chemical-physical and sensory analyses of the resulting breads were carried out during 6 days storage. The total titratable acidity, phytate and β-glucan content of the different types of flour, sourdough, dough and bread were also evaluated. Overall, the results showed that the barley sourdoughs investigated could be used to obtain barley bread with enhanced nutritional value. Furthermore, despite the lower specific volume and denser crumb of barley breads with respect to wheat bread, no significant differences were seen in the degree of liking among the three breads after baking and during shelf-life, thus confirming the possibility for successful exploitation of barley flour in the baking industry.



## 1. Introduction

The ever growing consumer demand for high quality and healthy foods is a challenge for the baking industry to develop breads with improved sensory and nutritional properties. Increasing the dietary fiber content of bread could be one of the strategies to promote health benefits (Rieder, Holtekjølen, Sahlstrøm, & Moldestad, 2012; Sullivan, Arendt, & Gallagher, 2013). Barley β-glucans are known to prevent or reduce some pathologies, such as diverticular and heart disease, colon cancer, and type-2 diabetes, to improve lipid metabolism and to promote weight loss by increasing a sense of satiety (Baik & Ullrich, 2008; EFSA, 2011a, 2011b; FDA, 2006; Izydorczyk & Dexter, 2008). However, the integration of wheat flour with barley flours generally reduces the bread-making potential of the resulting blends, and hence bread features, particularly loaf volume (lower) and texture (denser); for this reason, barley flour is typically incorporated into wheat bread at low levels (Baik & Ullrich, 2008; Izydorczyk & Dexter, 2008; Sullivan et al., 2013). On the other hand, the incorporation of barley flours into wheat doughs has a positive effect on bread quality by delaying staling (Gujral, Gaur, & Rosell, 2003).

A further strategy to improve the quality of bread is the use of sourdough. Sourdough is a mixture of flour and water spontaneously fermented by (or inoculated with) a mixed community of lactic acid bacteria (LAB) and yeasts and propagated by back-

*Abbreviations:* ANOVA, analysis of variance; db, dry basis; *breads*: $B_B$, bread obtained from $S_B$ and $F_B$; $B_W$, bread obtained from $S_W$ and $F_W$; $B_{WB}$, bread obtained from $S_{WB}$ and $F_{WB}$; *bread doughs*: $D_B$, bread dough obtained from $S_B$ and $F_B$; $D_W$, bread dough obtained from $S_W$ and $F_W$; $D_{WB}$, bread dough obtained from $S_{WB}$ and $F_{WB}$; *farinographic test*: BU, Brabender Unit; WA, water absorption; *flours*: $F_B$, barley flour; $F_W$, wheat flour; $F_{WB}$, mixture composed of 50 g/100 g wheat flour plus 50 g/100 g barley flour; LAB, lactic acid bacteria; *rheofermentographic test*: Hm, maximum dough height; H'm, maximum height of gaseous production; Tx, time of dough porosity appearance; $CO_{2\ TOT}$, total $CO_2$ production; $CO_{2\ RET}$, $CO_2$ retained; RC, $CO_2$ retention coefficient; *sourdoughs*: $S_B$, sourdough obtained from $F_B$; $S_W$, sourdough obtained from $F_W$; $S_{WB}$, sourdough obtained from $F_{WB}$; TTA, total titratable acidity; DSMZ, *Deutsche Sammlung von Mikrorganismen und Zellkulturen* (Braunschweig, Germany); DBVPG, Industrial Yeasts Collection of Department of Agricultural, Food and Environmental Science, University of Perugia (Perugia, Italy); CBS, *Centraalbureau voor Schimmelcultures* Fungal and Yeast Collection (Utrecht, The Netherlands).

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slopping (De Vuyst et al., 2014). Sourdough is traditionally used as a fermentation/leavening agent in the production of many baked products (Garofalo, Aquilanti, & Clementi, 2011) since it improves their volume, texture, flavor, nutritional and sensorial features, as well as their shelf-life by slowing down the staling process and inhibiting mold growth (Arendt, Ryan, & Dal Bello, 2007; Garofalo et al., 2012; Gobbetti, Rizzello, Di Cagno, & De Angelis, 2014). However, to date, few investigations have explored the use of sourdough to improve the baking and sensory properties of barley bread (Marklinder, Haglund, & Johansson, 1996; Marklinder, Johansson, Haglund, Nagel-Held, & Seibel, 1996; Rieder et al., 2012). In a previous study (Zannini et al., 2009), three different sourdoughs were made on a laboratory scale by introducing a defined multi-strain starter culture (LAB and yeasts) into three doughs made of (i) 100 g/100 g wheat flour, (ii) 50 g/100 g wheat flour plus 50 g/100 g hull-less barley flour, and (iii) 100 g/100 g hull-less barley flour, respectively. The microbial composition of the three sourdoughs, as well as their organic acid profiles and leavening ability, were investigated. The objective of the present study was to explore the potential use of these three sourdoughs in barley-flour-based bread-making. The sourdoughs were characterized from a microbiological, technological and nutritional point of view; the resulting breads were comparatively evaluated for TTA (total titratable acidity) and nutritional properties 5 h after baking and for chemical–physical properties as well as overall consumer acceptance, during 6 days storage.

## 2. Materials and methods

### 2.1. Flours

Hull-less barley (*Hordeum vulgare*) flour ($F_B$; 11.1 g/100 g water, 10.6 g/100 g proteins, 1.7 g/100 g lipids, 66.7 g/100 g carbohydrates, 1.5 g/100 g ash), from a mixture of barley varieties, was purchased from a local bakery. Wheat (*Triticum aestivum* L.) flour ($F_W$; 14.0 g/100 g water, 13.5 g/100 g proteins, 1.1 g/100 g lipids, 73 g/100 g carbohydrates, 0.5 g/100 g ash) was purchased from a local milling plant.

The TTA of $F_W$, $F_B$ and their mixture ($F_{WB}$, containing 50 g/100 g of each) was determined (Zannini et al., 2009), and results ($n = 3$) were expressed as the amount of NaOH used (mL).

$F_W$, $F_{WB}$ and $F_B$ were also analyzed for phytate and β-glucan content as described at § 2.2.2, except for the freezing and freeze-drying steps.

### 2.2. Sourdoughs

#### 2.2.1. Sourdough production

Three sourdoughs ($S_W$, $S_{WB}$ and $S_B$), were obtained from $F_W$, $F_{WB}$, and $F_B$ respectively, as reported by Zannini et al. (2009). Briefly, the three types of sourdough were made up by mixing 120 mL of tap water and 250 g of the different flours ($F_W$, $F_{WB}$, and $F_B$). These doughs were inoculated with 40 mL of a multi-strain starter culture (LAB and yeasts) and incubated at 30 °C for 24 h. At the end of this fermentation step, 200 g of each sourdough were further added with 120 mL tap water and 200 g of the same flour blend previously used, and then fermented daily at 30 °C for two months. For long-term storage the three sourdoughs were kept at −20 °C in sterile polycarbonate bags. Before use, they were thawed at room temperature, and subsequently refreshed with the back-slopping technique for 7 days at 30 °C in order to reach stability, that was verified by daily pH measurements (Minervini, De Angelis, Di Cagno, & Gobbetti, 2014). Mixing was performed by a Brabender Farinograph (mod. SEW; Brabender OHG, Duisburg, Germania) to constantly monitor the consistency of the different sourdoughs. At each refreshment, each sourdough was added with flour and tap water, generally adopting the following ratios (sourdough:flour:water): 1:1:0.5 for $S_W$, 1:1:0.6 for $S_{WB}$, and 1:1:0.7 for $S_B$. Adjustments in terms of water were carried out when necessary, to maintain each sourdough at its original farinographic consistency (Brabender Unit, BU): $S_W = 580$ BU, $S_{WB} = 350$ BU, $S_B = 300$ BU.

#### 2.2.2. Sourdough characterization

After the 7 days of refreshment, the three mature sourdoughs ($S_W$, $S_B$, and $S_{WB}$) were subjected to: i) LAB and yeast viable counting (Zannini et al., 2009); ii) PCR-DGGE analyses performed on the DNA directly extracted from the three sourdoughs, as reported by Zannini et al. (2009); iii) pH measurement ($n = 3$) by means of a pH-meter equipped with a solid electrode (HI2031, Hanna Instruments, Padova, Italy) which was directly inserted into each sample; iv) TTA measurement (§ 2.1); v) β-glucan and phytate analyses and samples were frozen, freeze-dried and ground using a mortar and pestle.

For the determination of β-glucans, simple sugars were removed from the sample by incubating 1 g of sample in 10 mL of aqueous ethanol (50:50 v/v) for 5 min at room temperature. After centrifugation, the pellets were re-suspended in 5 mL of sodium phosphate buffer (0.02 mol/L, pH 6.5), added with 1 mL of aqueous ethanol (50:50 v/v), and analyzed using the *"Mixed Linkage Beta-Glucan Assay Procedure"* (Megazyme International Ireland, Bray, Co. Wicklow, Ireland). Results ($n \geq 3$) were expressed as β-glucan (g/100 g, db).

Phytic acid was measured as the amount of phosphorus released by phytase and alkaline phosphatase, using the *"Phytic Acid Assay Procedure"* (Megazyme International Ireland, Bray, Co. Wicklow, Ireland). Results ($n \geq 3$) were expressed as phytic acid (g/100 g, db).

### 2.3. Bread doughs

#### 2.3.1. Preparation

The three mature sourdoughs $S_W$, $S_B$, and $S_{WB}$ were used for bread dough production. Very simple formulations were adopted (g/100 g of dough), based on those reported by Zannini et al. (2009) with some modifications:

i) $D_W$: 49.8 $F_W$ + 24.9 $S_W$ + 25.3$H_2O$;
ii) $D_{WB}$: 49.3 $F_{WB}$ + 24.6 $S_{WB}$ + 26.1$H_2O$;
iii) $D_B$: 48.6 $F_B$ + 24.3 $S_B$ + 27.1$H_2O$.

The flour:sourdough ratio was kept constant and equal to 2:1, while water was added in order to reach almost the same farinographic consistency as $D_W$ after 15 min of mixing (§ 2.3.2).

#### 2.3.2. Mixing properties

The mixing properties of the different bread doughs were examined with the Brabender Farinograph. First, 400 g of a mass composed of 49.8 g/100 g $F_W$, 24.9 g/100 g $S_W$ and 25.3 g/100 g $H_2O$ was mixed in the farinographic bowl for 15 min at 30 °C. The consistency reached at the end of the mixing period was considered as the reference, and water was added to the other doughs ($D_B$ and $D_{WB}$) to reach roughly the same final value. Results ($n \geq 3$) were expressed as the amount of water added to each dough and as dough final consistency (BU).

#### 2.3.3. Leavening properties

Bread dough development during leavening, as well as gas production and retention, were measured by a Rheofermentometer F3 (Chopin, Tripette & Renaud, Villeneuve La Garenne, Cedex, France). The rheofermentographic test was performed for 4 h at 30 °C on a 300 g portion of each bread dough, placing the weight