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Influence of barley non-starchy polysaccharides on selected quality attributes of sponge cakes

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In this study, the suitability of refined flours from different hulless barley cultivars for making sponge cakes was investigated and was compared with refined wheat flour cake in terms of selected quality attributes like mixolab properties, batter viscosity, crumb image characteristics, cake volume, texture and sensory acceptability. The content of total β-glucan and arabinoxylans ranged between 3.4 to 4.4% and 0.7–1.1% for refined barley flours and it significantly increased the viscosity, slurry consistency and gelatinization time ($p \leq 0.05$) of cake batters. Lower protein (6.9–10.3%) and higher non-starchy polysaccharide contents of barley flours promoted formation of small sized air cells in cakes which impacted the crumb characteristics significantly. In terms of end product acceptability, the barley cakes displayed higher cake volumes and exhibited springiness and cohesiveness values significantly similar ($p \leq 0.05$) to wheat cake. It was revealed that batters showing a higher mixolab peak viscosity displayed greater cake hardness ($R = 0.74$, $p \leq 0.05$) and chewiness ($R = 0.71$, $p \leq 0.05$) values upon texture analysis. Altogether, hulless barley refined flours displayed good cake making performance and could be used to make sponge cakes which are equivalent in quality to wheat flour cake but at the same time deliver high levels of bioactive compounds.

1. Introduction

Unlike bread, cakes do not require high gluten flours and are made by baking of flour based batters rather than a viscoelastic dough. Cake structure depends largely on egg protein denaturation and starch gelatinization. Eggs help in giving cake its unique aerated structure owing to their functional properties like emulsification, heat coagulation and foaming (Yang & Baldwin, 1995). Wheat has been reported to be a nutritionally poor grain (Sharma and Gujral, 2013; Holtekjølen, Bævre, Rødbotten, Berg and Knutsen, 2008) and hence, replacement of refined wheat flour with flour from grains like hulless barley may be required to produce value added foods in order to cater to changing consumer requirements. Moreover, since, soft wheat flours are recommended for cake making; therefore, there is a good possibility of using flours from grains such as barley that are known to contain bioactive compounds like β-glucans, arabinoxylans, phenolic compounds and antioxidants (Bhatty, 1999; Izydorczyk, Storsley, Labossiere, MacGregor, & Rossnagel, 2000; Moza & Gujral, 2016) which may exert beneficial effects in diabetes, obesity, hypertension and cardiovascular problems (Moza & Gujral, 2017; Zhang, Xu, & Li, 2014; Shahidi & Ambigaipalan, 2015). The nutritional superiority of this grain is also evident from the lesser occurrence of hyperlipidemia and diabetes cases in Tibetan population who consume hulless barley as a part of daily diet (Gou, Li, & Guo, 2005).

High quality cakes demonstrate attributes like superior volume, softness, even crumb structure, good sensory acceptability and anti-staling properties (Gomez, Ronda, Caballero, Blanco, & Rosell, 2007). Refined barley flour has significantly lower polyphenol oxidase activity as compared to whole barley flour (Sharma & Gujral, 2010); therefore, the products prepared from refined barley flour may suffer less colour deterioration (Newman & Newman, 2008). Gomez et al (Gómez, Moraleja, Oliete, Ruiz, & Caballero, 2010). have also utilized refined flours from wheat, rye, triticale, hulless barley and tritordeum to produce layer cakes having good sensory acceptability and have reported that the composition of hulless barley flours may significantly impact the quality of cakes. So, it is important to expand the opportunities for utilization of this nutritious grain by incorporating it into different convenience foods. Hence, this study was aimed at understanding the cake

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making performance of hulless barley refined flours and exploring the effect of non-starchy polysaccharides on the sponge cake quality attributes.

2. Material and methods

2.1. Materials

Nine hulless barley cultivars and one wheat cultivar was procured from different locations in India. Hulless barley cultivars, Geetanjali and Upasana (NDB-943) were procured from Chandra Shekhar Azad University of Agriculture and Technology (Kanpur, 126 m) and Narendra Dev University of Agriculture and Technology (Faizabad, 97 m), Dolma and HBL-276 from Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (Bajaura, 1219 m), BHS-352 from Indian Agricultural Research Institute (Shimla, 2200 m), Sindhu, Nurboo, SBL-8 and SBL-9 from High Mountain Arid Agriculture Research Institute (Leh-Ladakh, 3500 m). HD-2967 (wheat) was procured from Punjab Agricultural University (Ludhiana). The grains were manually cleaned and stored in PET (Poly-ethylene Terephthalate) jars at 4 °C in a refrigerator for further processing. Milli-Q (Millipore, France) water was used for all the experiments.

2.2. Chemicals

Mixed Linkage β-Glucan kit (K-BGLU) was obtained from Megazyme (Megazyme International Ireland Ltd., Wicklow, Ireland). Phloroglucinol, D (+) xylose, D-glucose, Sodium hydroxide, boric acid, sodium sulphate, selenium dioxide, methyl red and bromocresol green were procured from HiMedia Laboratories Pvt. Ltd. (Mumbai, India). Sulphuric acid, Hydrochloric acid, petroleum ether and acetic acid were procured from Merck. All chemicals were of analytical grade. Milli-Q (Millipore, France) water was used for all the experiments.

2.3. Preparation of barley and wheat refined flours

The hulless barley cultivars and wheat were milled according to the method described by Moza and Gujral (Moza & Gujral, 2017) after conditioning at 14% moisture content (overnight), followed by roller milling in Brabender Quadrumat® Junior mill (Brabender, Germany). The flour obtained after roller milling was passed through a 60 BSS (British Standard Sieve) (250 μm) sieve and the yield ranged between 29 and 43% (Moza & Gujral, 2017) for barley cultivars and 67% for wheat cultivar.

2.4. Proximate analysis of refined flours

Carbohydrates, crude fat, crude protein (N × 6.25), crude fiber and ash were determined according to the methods of Association of American Chemists (AOAC, 1990). All the analyses were conducted in triplicates.

2.5. Quantification of total β-glucan in refined flours

The total β-glucan was estimated according to the method of Mc Cleary and Glennie-Holmes (Mc Cleary and Glennie-Holmes, 1985) as reported by Moza and Gujral (Moza & Gujral, 2017) using β-glucan assay kit' (Megazyme International Ireland Ltd., Wicklow, Ireland). Sample (0.5 g on dry weight basis) was weighed in polypropylene tubes and 1 mL of ethanol (50% v/v) was added followed by sodium phosphate buffer (pH 6.5) and stirred on vortex mixer. The tubes were then incubated in boiling water bath, after which they were cooled to 40 °C. Enzyme, lichenase (10 U) was added, tubes were incubated for 1 h at 40 °C with intermediate mixing. Tubes were centrifuged and aliquot (0.1 mL) was transferred in three test tubes. Sodium acetate buffer (pH 4.0) was added to one of these tubes (reaction blank) and 0.2 U β-glucosidase was added in rest two tubes after which they were incubated at 40 °C for 15 min. After incubation, glucose oxidase peroxidase reagent was added to all tubes and incubated at 40 °C for 20 min. The absorbance was taken at 510 nm on spectrophotometer (Shimadzu, UV-1800, Kyoto, Japan). The test was performed in triplicates. Amount of β-glucan in sample was calculated as:

$$\beta - \text{glucan}\ (\%\text{w/w}) = \varDelta A \times F \times 300 \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180}$$

where,

ΔA = Absorbance after β-glucosidase treatment (reaction) minus reaction blank absorbance.

F = Factor for the conversion of absorbance values to μg.

=100 (μg of D-glucose)/absorbance of 100 μg D-glucose.

300 = volume correction (i.e. 0.1 mL taken from 30.0 mL).

1/1000 = Conversion of μg to mg.

100/W = Factor to express β-glucan content as a percent of dry flour weight.

W = Calculated dry weight of the sample analyzed in milligram.

162/180 = Factor to convert from free D-glucose as determined, to anhydro-D glucose, as present in β-glucan.

2.6. Quantification of arabinoxylans in refined flours

Colorimetric method described by Finnie, Bettge and Morris (Finnie, Bettge and Morris, 2006) and reported by Moza and Gujral (Moza & Gujral, 2017) was used for estimating total and soluble arabinoxylan contents of refined flours. Sample (125 mg) was weighed in polypropylene tubes and water was added to the tubes after which they were shaken vigorously. Aliquot were immediately pippetted out, transferred to polypropylene tubes and were used to estimate total arabinoxylan content of the flours. The original suspension was then shaken in the orbital shaker (Narang Scientific Works, India) at 25 °C for 30 min. After which it was centrifuged at 2500 × g and the supernatant was collected. Aliquot (1 mL) was again pippetted out from the supernatant and was used to determine the water soluble arabinoxylans.

Water (1 mL) was added to all the tubes. Further, an extracting solution containing acetic acid, hydrochloric acid, Phloroglucinol and glucose (aqueous solution) was added to the tubes, and tubes were allowed to boil in a boiling water bath (100 °C) (Narang Scientific Works, India) for 25 min. Tubes were then taken out, cooled and absorbance of the samples was measured at 552 and 510 nm using a spectrophotometer (Douglas, 1981). D-(+)-xylose (X-1500, Sigma) was used for preparation of standard curve, which was used to determine the content of total and soluble arabinoxylans. Insoluble arabinoxylans were calculated by difference. The tests were performed in quadruplets.

2.7. Mixolab of cake batter

Mixolab 2 (Chopin Technologies, France) was used for studying the rheological behavior of cake batters using a standard protocol (1 min Chopin +) mentioned in the Mixolab Application Handbook (Page 64) with slight modifications (Mixolab Application Handbook, 2012). According to the protocol, pasta flours can be tested for their rheological behavior at a constant hydration of 100%, however, we have modified the protocol and used it for studying the rheology of cake batters at a constant hydration rate of 140% (since the ratio of refined flour to water was found to be 1:1.4