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Comparison of the rheological and end-product properties of an industrial aleurone-rich wheat flour, whole grain wheat and rye flour

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A B S T R A C T

In our previous work a novel type of wheat milling fraction was developed at industrial scale. The new fraction is rich in aleurone layer; therefore it is a good source of dietary fiber, protein, oil and minerals. This study aimed to characterize this novel fraction in terms of rheological properties and baking quality. The mixing-, viscous rheological and end-product properties of the aleurone-rich flour were investigated and compared to commercial whole grain wheat- and rye (medium, whole grain) flours. In order to examine the effect of blending, the aleurone-rich, the common rye- and wheat flours were added to bread wheat flour in the ratio of 15, 40 75 and 100%. The rheological properties of the aleurone-rich fraction resulted in significant differences compared to those of the studied milling products. It showed significantly longer dough development time, higher mixing and dough stability, and in spite of the reduced starch content it had higher ability for gelling. The end-product quality of the novel fraction was weaker but comparable to that of the commercial white bread. The aleurone-rich flour is a nutritionally valuable milling product that caused smaller reduction in the end-product properties of bread wheat blends than the other common flour types.

1. Introduction

Increasing the amount of functional components in food is a major direction of cereal based product development. Health promoting food components, like dietary fiber (arabinoxylan, β-glucan, arabinogalactan), phenolic components (Kendall et al., 2010), micro components and vitamins are concentrated in the outer layer of the cereal grain (Hemery et al., 2011). Numerous studies reported that dietary fiber intake from bran consumption has many health benefits, such as prebiotic effects, glucose regulation and reduction of the risk of coronary heart diseases, etc (Kendall et al., 2010).

Grain milling fractions containing bran behave differently from the commercial white wheat bread flour in their rheological properties and end-product performance. Comparative study conducted on the effect of blending whole wheat flour or wheat bran into white wheat flour showed that the increase of bran content in the blend caused a linear increase in water absorption (Schmiele et al., 2012). This behavior was explained by the increasing amount of dietary fiber, mainly arabinoxylan that is able to swell in spite of the decreasing gluten protein and starch concentration of the blends. Dough development time and stability values in the 40% bran-bread wheat flour blend was twice as much as the 40% whole wheat-bread flour sample. Due to the decreased starch content, the gelling ability of the blends was inversely proportional to the dosage. Moreover, bran addition resulted in lower viscosity values in the blend than the addition of whole wheat flour at the same level (Schmiele et al., 2012). These results showed that the presence of fibers that do not swell (cellulose, lignin, and hemicellulose) impaired the gelling ability.

In general, baking quality of flours containing bran is affected by the bran constituents. Different components in bran fractions, such as arabinoxylans (AX), β-glucans, arabinogalactans, galactomannans, phytates and lipids can interact with the gluten network. The AX can covalently bind to the gluten proteins via the esterified phenolic components. The non-swelling cellulose fibers delay the formation of the gluten network and reduce gelling process. These structural effects contribute to the decrease of elasticity and stability of the dough and to the reduction of the gelling ability, thereby impairing gas retention, altering dough

Abbreviations: ALF, aleurone-rich fraction; AX, arabinoxylan; BWF, bread wheat flour; DDT, dough development time; TOTAX, total arabinoxylan; RF, rye flour; WEAX, water-extractable arabinoxylan; WWF, whole wheat flour; WRF, whole grain rye flour.

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structure and leading to weakened baking quality. Thus, bread made of whole grain flour shows reduced loaf volume with denser and darker crumb (Noort et al., 2010). Furthermore, the particle size of the applied bran has significant impact on rheological behavior and end-product performance. Bran particles with 5 μm provide larger surface for the interactions than particles with 1000 μm. Therefore, the addition of fine bran fraction causes shorter dough stability and smaller bread loaves than the addition of coarse bran (Noort et al., 2010).

Experiments were also performed with the application of isolated water-extractable arabinoxylans (WEAX). The dosage of WEAX to white wheat flour up to 1.3% increased water absorption and dough development time via the high water binding capacity of the polysaccharides. Furthermore, the increased presence of WEAX (up to 0.9%) improved bread volumes, however a higher dosage resulted in decreased volumes compared to the control white flour breads (Biliaderis et al., 1995). Harasztos et al. (2015) reported that supplementing white wheat flour with 0.5, 1, 1.5 and 2.5% WEAX significantly increased viscosity measured by RVA. AX-induced changes in the dough and end-product properties mainly depended on the molecular weight of AX, the amount of ferulic acid and the arabinose/xylose ratio (Morales-Ortega et al., 2013). The beneficial effects of WEAX on baking performance was described by Gan et al. (1995). The soluble fluid part of the dough is important for gas cell stability. The high viscosity part containing WEAX is able to prevent the escape of the gas from the cells. The water-unextractable AX (WUAX) has adverse effects on the dough and end-product properties by disrupting the cell wall film. A growing body of evidence suggests that breaking down the high molecular weight polymers during processing helps to avoid their negative impact on the technological properties (Biliaderis et al., 1995).

Besides wheat, rye is another rich source of dietary fiber (Nyman et al., 1984). Voicu et al. (2012) have reported that dosing rye flour to white wheat flour up to 40% caused a slight increase in dough development time but reduced dough stability. The increasing amount of rye flour in the mixtures decreased the elasticity of the dough because of its different protein composition and the increased non-starch polysaccharide fiber content that has different properties than white wheat fractions (Voicu et al., 2012).

In order to better exploit the potential of the bran fraction of wheat and other cereal grains, research efforts are shifting towards the peripheral parts of the grain, especially to the aleurone layer. From a morphological point of view, it is part of the endosperm but is separated from the flour alongside the bran during the industrial milling process. As it is situated under the hull it is not exposed to contamination and with the removal of the outer layers the new product poses less food safety risk than the bran or the whole grain fractions. Due to its protector, transporter and mediator functions in the grain, the aleurone layer contains large amounts of cell wall constituents, such as dietary fibers (AX, galactomannan and arabinogalactan in various ratios), healthy lipid components, antioxidants (i.e. phenolic components) and minerals (Hemery et al., 2011). Moreover, the aleurone is abundant in proteins. Thus, novel approaches were developed in laboratory and pilot scale to separate the aleurone tissue layer in order to produce pearled, highly bioactive milling fractions (Blandino et al., 2013; Hemery et al., 2011). Blandino et al. (2013) applied a pearling technique on the intact grain. As a cleaning step the 8% of the grain from the outer layers was removed and an intermediary fraction was produced that formed 16% of the total grain weight. Hemery et al. (2011) provided another approach that was based on the fractionation of the wheat bran followed by electrostatic separation of an aleurone-rich fraction. An aleurone-rich wheat milling fraction was also prepared at industrial scale based on the further separation and fractionation of a bran rich fraction (Bagdi et al., 2016).

The aim of this study was the characterization of the novel aleurone-rich wheat milling fraction: (i) chemical composition (ii) rheological aspect focusing on the mixing and pasting properties and (iii) the end-product quality of the new fraction were examined. Furthermore, besides the novel flour, commercial fiber-rich bread raw materials (whole grain wheat and rye flours) were selected to make a rheological and end-product quality comparison.

2. Materials and methods

2.1. Materials

The novel aleurone-rich wheat flour (ALF) was developed at industrial scale by the Budapest University of Technology and Economics, the Gyermelyi Zrt. Hungary and the Bühler AG, Switzerland (Bagdi et al., 2016) from *Triticum aestivum* wheat. The investigated ALF is an intermediate product of the process development. For the comparative study, whole wheat flour, (WWF, Biopont, Hungary), medium rye flour (RF, standard Hungarian flour with defined ash content: 0.66–0.98% (CODEX, 2007)) and whole grain rye flour (WRF, Gyermelyi Zrt., Hungary) were selected. ALF and the three fiber-rich flours were mixed with conventional bread wheat flour made of *T. aestivum* wheat, (BWF, Gyermelyi Zrt., Hungary) in the ratios of 15%, 40%,75% and 100% (w/w%) in order to gain more information about the effect of the dosage on the rheological and end-product properties. The blending was carried out in a mixer (Classic Plus® Series 4.5-Quart Tilt-Head Stand Mixer, KitchenAid, Benton Harbor, USA) using a mixing speed of 84 rpm (speed 2) in 2 kg final weight. The blends were homogenized for 20 min. In each case, the unmixed bread wheat flour was analyzed as a control (0%) sample.

2.2. Chemical composition and particle size

Ash, moisture, crude protein, crude fat, total and soluble dietary fiber, crude fiber, and wet gluten contents of the unmixed flours and breads were measured according to the standard methods (ICC, 1996a). The particle size distribution of the unmixed flours was determined by sieving 200 g flour for 30 min, at the amplitude of 70 applying sieves with 100, 150, 200, 250, 300, 500 μm diameters (AS 200 basic, Retsch GmbH. Haan, Germany). The flour kept by each sieve was weighed and expressed in mass matter basis (%). The analysis was performed with three replicates. The total β-glucan content was determined by the Megazyme® mixed linkage β-glucan assay kit based with three replicates. Both the extractable (WEAX) and total arabinoxylan (TOTAX) contents were determined according to the Healthgrain method (Gebruers et al., 2009) with three replicates.

2.3. Rheological characterization

2.3.1. Investigation of the mixing and pasting properties by Mixolab

The measurements were carried out according to the method by Rosell et al. (2007). The tests were performed for each sample with the addition of certain amount of water (water absorption) to reach the maximal 1.1 Nm. The Chopin + protocol was applied for studying both the mixing and the pasting behaviors the method was the same as applied by. The obtained parameters are water absorption capacity and dough properties such as dough development time (DDT), dough stability (C1 parameter), protein weakening (C2 parameter), starch gelatinization (C3 parameter), amylase activity (C4 parameter) and starch gelling (C5 parameter) were determined by Mixolab (Chopin, Tripette et Renaud, Paris,