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Physicochemical and technological properties of highly enriched wheat breads with wholegrain non wheat flours

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ABSTRACT

The effects on dough and bread properties were investigated after replacing 60% of refined wheat flour with wholegrain rye flour, wholegrain barley flour, and oat flakes meal. Nutritional quality of the composite breads was improved since they are richer in β-glucan, dietary fibers, and total phenolic content than their wheat counterpart. These beneficial components seem to withstand the baking procedure although in the case of dietary fibers, a redistribution between the water soluble and the water insoluble fraction is observed. Incorporation of wholegrain cereals increased farinograph water absorption and dough development time but lowered resistance to extensibility and stretching energy compared to the control. Composite breads showed similar or lighter crust but darker crumb with less small (<4 mm^2) gas cells, and significantly smaller specific loaf volume. Substituted breads, although exhibiting greater rate of moisture loss, had similar or higher moisture content than the control. Incorporation of high amounts of wholegrain cereals in the bread formula increased crumb firmness and degree of amylopectin retrogradation, and produced breads with good overall acceptability score (>5.5), rich in functional components.

1. Introduction

The increasing interest in cereals other than wheat is pertinent to several reports found in the literature that relate their consumption with low levels of glucose and adequate postprandial insulin responses (Cavallero et al., 2002), low levels of serum cholesterol as well as reduction of chronic diseases such as cardiovascular disease, certain forms of cancer and constipation (Rodríguez et al., 2006). The consumer demand for healthier products leads towards production of bread with high content of dietary fiber and other bioactive/functional constituents. Those statements have raised consumer awareness about the healthy role of dietary fiber intake; therefore, fiber enriched cereal based products gained popularity. For adults, a daily intake of 25 g of dietary fiber, was set as a Dietary Reference Value, because it is adequate for normal laxation, while a higher consumption may reduce risk of coronary heart disease and type 2 diabetes and may improve weight maintenance (EFSA, 2010a).

The flour from whole grains is nutritionally preferable to the flour that has been refined. A common practice is the production of wheat breads with incorporation of whole grain flour from other cereals that are rich in dietary fiber and their functional components. Beta-glucan, a polysaccharide from cell walls present in cereals, has received considerable research attention due to its health benefits deriving from its capacity to increase the viscosity of intestinal fluid and thereby reduce the rate of sugar/starch absorption. The European Food Safety Authority (EFSA) supports the claim that oat β-glucan lowers blood cholesterol and reduces risk of (coronary) heart disease in the case of at least 3 g of oat β-glucan daily intake (EFSA, 2010b). In general, non-starch polysaccharides, derived from cereal cell walls, are important functional ingredients in dough and bread systems due to their ability to bind large quantities of water. As a result, they significantly influence water partitioning and rheological properties of bread dough, as well as retrogradation of starch. Resistant starch (RS) is the starch fraction remaining undigested in the human small intestine and is considered to contribute to the maintenance of colonic health and to the reduction of postprandial glucose and insulin responses (Granfeldt et al., 1995).

Abbreviations: RS, resistant starch; SS, soluble starch; TDF, total dietary fiber; TPC, total phenolic content; WISDF, water insoluble dietary fiber; WSDF, water soluble dietary fiber.

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Besides, cereal grains contain other essential components such as phenolic compounds, that as natural antioxidants, inhibit lipid peroxidation in food and improve food quality (Shahidi and Naczk, 1995).

Rye shows the highest dietary fiber content among common cereals and a typical rye bread contains about three times more fiber than white wheat bread. Besides fiber, rye contains other bioactive components, such as B-complex vitamins, cinnamic acids, alkylresorcinols, lignans, sterols, and minerals. On the other hand, oat and barley are recognized for their high β-glucan content. In conventional bread making, the addition of β-glucan in wheat flour disturbs the starch–gluten matrix, affects the viscoelastic behavior of the dough and the expansion of gas cells (Skendi et al., 2010, 2009). The concentration and the molecular weight of the polysaccharide as well as the flour quality are important factors that influence functional properties of the dough and the bread (Skendi et al., 2009).

Despite the increasing awareness of fiber intake from bakery products, there is scarce literature on the impact of wholegrain incorporation, at high levels, on dough rheology and on bread technological quality.

The aim of the present research was to evaluate the effect of high level incorporation (60%) of whole grain cereals such as rye, barley and oat and of their mixtures on the rheological properties of the dough as well as on the technological properties and staling process of the resulting breads, prepared to meet preferences of individuals who wish to follow a healthy diet. The current study was also intended to monitor the fate of beneficial health ingredients such as dietary fiber, β-glucan, RS, TPC from the raw flours to the bread, following baking.

2. Experimental

Commercial bread wheat flour (W), of 70% extraction rate (control) and oat flakes (Walker snack foods, Uthrogle mills, Cupar, Fife, UK) were purchased from the local market, whereas the rye (*Rye secale cereale* L.) and barley seeds (*Hordeum vulgare* L., cv. Ippolytos) were Greek cultivars, generously provided by the Hellenic Agricultural Organization – Demeter, Cereal Institute, Thessaloniki, Greece. Barley seeds, were previously hulled and pearled using a SATAKE (TM05C, Satake Corporation, Japan) equipment. Wholegrain rye flour (R), oat flakes meal (O) and wholegrain barley flour (B) were produced using a laboratory mill (Retch, model ZM 1000, Germany) with a 0.75 mm screen.

The enzyme α-amylase of fungal origin was a product of Sigma–Aldrich (Steinheim, Switzerland) and dry gluten was obtained from Roquette Freres Company (Lestrem, France). Salt and baker's yeast (compressed, wet form) were purchased from the local market. All other reagents and chemicals used were of analytical reagent grade.

2.1. Chemical analyses

The moisture and fat content of flours and breads were determined according to the official methods (44-15A and 30–10 respectively, AACC 2000). The total nitrogen and ash content as well as gluten quantity and quality were determined according to the official methods (ICC 105/2, 104/1 and 155, respectively; ICC-Standards 1994) and the protein content was calculated adopting 5.7 as a conversion factor for wheat and 6.25 for all the other cereal flours. Characteristics of commercial wheat flour were: % moisture 11.92, wet gluten 30.20%, falling number 550 s and gluten index 90. The moisture contents (%) for rye, barley and oat meals were 11.67, 11.70, and 12.20 respectively. All determinations were made at least in duplicate and shown as average. Total dietary fiber, β-glucan content, resistant and total starch contents were determined using the "Total dietary fiber assay" (AACC Method 32-07.01), "Mixed-linkage β-glucan assay" (AACC Method 32-23) and "Resistant starch assay" (AACC Method 32-40.01) procedures provided by Megazyme International Ireland Ltd (Wicklow, Ireland) with their respective test kits.

2.2. Preparation of the blends

Based on preliminary studies, apart from 100% wheat flour (W-control), seven different dry mixtures of composite flours were prepared, comprising 40% of the control and up to 60% in total of the other three whole meal flours, i.e. whole grain rye flour (R), whole grain barley flour (B) and oat flakes meal (O). More specifically, in the order W, R, B, O, the percentage composition of the eight tested samples were as follows: 100:0:0:0 (W control), 40:60:0:0 (W/R), 40:0:60:0 (W/B), 40:0:0:60 (W/O), 40:30:30:0 (W/R/B), 40:30:0:30 (W/R/O), 40:0:30:30 (W/B/O) and 40:20:20:20 (W/R/B/O).

2.3. Farinograph and extensograph tests

Water absorption, dough development time, dough stability and degree of softening (12 min after maximum) were determined by a Brabender farinograph equipped with 300 g mixing bowl (Brabender, Duisburg, Germany) according to the ICC standards, method 115/1. Extensiograph tests were performed using a Brabender extensiograph (Brabender, Duisburg, Germany) following the ICC standard 114/1 after 45, 90, and 135 min of resting time. The stretching force was recorded as a function of time, and the resistance to constant deformation after 50 mm stretching (R_{50}), the extensibility (E), and the energy (A) expressed as the area (cm^2) under the Extensiograph curve, were obtained.

2.4. Breadmaking procedure

The basic recipe for bread production (300 g flour) consisted of the blends of Section 2.2 and other ingredients added at a fixed quantity: α-amylase (0.03 g), salt (6 g), and fresh yeast (9.6 g); dry gluten (16 g) was added in all recipes except the control. The water in each formulation was the required water for the dough to reach 500 BU of consistency in the farinograph (W-150 ml, W/R-192 ml, W/B-208 ml, W/O-193 ml, W/R/B-192 ml, W/R/O-192 ml, W/B/O-196 ml, and W/R/B/O-195 ml). The quantities of α-amylase and dry gluten used in the recipe were chosen based on preliminary tests (data not shown) which aimed at the production of breads with maximum volume. The dough samples were prepared in the farinograph bowl by mixing all ingredients for 10 min; the mixing time was chosen based on preliminary tests (data not shown). Two-step bulk fermentation and proofing was used. During the first step, doughs were proofed for 30 min at 32 °C at 60–70% relative humidity. Following that, the fermented doughs were hand-molded and put into tin pans for proofing at 32 °C for other 60 min at 60–70% relative humidity and then baked at 220 °C for 25 min. All bread loaves were allowed to cool at room temperature before further testing. Following cooling, breads were weighted, their volume was measured by rapeseed displacement and their crumb and crust color measured. Next, the bread loaves were sealed in polyethylene bags and stored at 4 °C. At least six breads for each recipe were prepared.

2.5. Color and image acquisition analysis

Crumb and crust color (CIE L*, a* and b* color system) were evaluated using a HunterLab colorimeter, model MiniScan XE Plus