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Impact of flour particle size and hydrothermal treatment on dough rheology and quality of barley rusks

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ABSTRACT

Barley rusks are traditional baked products of the Cretan-Mediterranean diet, a naturally β-glucan-containing food item. The impact of flour particle size and autoclaving on dough thermomechanical properties and rusk quality features was evaluated. Rusks were made using a coarse and a fine barley flour stream without or with prior autoclaving at two different moisture levels. Calorimetry showed that autoclaving and decreased particle size of the flour reduce the gelatinization enthalpy values. Small and large deformation mechanical tests revealed that flour autoclaving increased the resistance to deformation and flow, elasticity and hardness of the barley doughs; these trends were more pronounced for coarse flours. The reduction of particle size in thermally untreated flours decreased rusk hardness and increased loaf volume and resulted in finer crumb structure; however, autoclaving of fine flour nullified these quality attribute trends. Nevertheless, these changes are not detrimental for consumer acceptability of this bakery product which traditionally is manufactured with low loaf volume, compact macrostructure and hard texture. Moreover, the hydrothermal pretreatment of barley flour can be an appropriate processing step of making naturally containing β-glucan rusks with polysaccharide molecular characteristics that are more effective in promoting the health benefits of these fibers (high molecular weight).

1. Introduction

Barley rusks, known in Greece as 'Dakos', are a food staple of the Cretan diet and can be an important natural source of β-glucans since they are made from 40 to 60% whole barley flour. For barley β-glucans, the European Commission has issued health claims associating their ingestion with the reduction of blood serum cholesterol and postprandial glucose levels as well as with increase of faecal bulk (E.C., 2012a, b); the recommended daily consumption for reduction of coronary heart disease risk is 3 g β-glucans (E.C., 2012a).

The physiological actions of these polysaccharides on blood cholesterol and glucose levels have been related with viscosity enhancement properties which in turn, are controlled by the amount and molecular weight of the solubilised β-glucans in the gastro-intestinal tract (Tosh, 2013; Wolever et al., 2010). In our previous study, it was shown that the manufacturing process of Cretan barley rusks leads to a significant reduction of β-glucan molecular size, attributed to the activity of endogenous flour β-glucanases during the mixing and fermentation stages (Lazaridou, Marinopoulou, Matsoukas, & Biliaderis, 2014); therefore, autoclaving of barley flour was employed to limit β-glucan degradation, and thus maximize the physiological action of β-glucans in barley rusks. In the latter study, flour particle size and autoclaving as well as tempering of the flour to increase the moisture level prior to the hydrothermal treatment were found to have a significant impact on the potential health benefits of barley rusks; i.e., hydrothermal treatment of tempered barley eliminated β-glucan degradation during rusk making. However, the impact of barley flour particle size and autoclaving on dough thermomechanical behavior and the quality parameters of rusks that could affect consumer acceptability of such products have not been studied yet.

Previous investigations on breadmaking have shown that particle size of wheat, durum wheat, sorghum and oat flours or brans can have a large impact on dough rheological behavior and quality properties of breads (Doblado-Maldonado, Pike, Sweley, & Rose, 2012; Huttner, dal Bello, & Arendt, 2010; Konopka & Drzewiecki, 2004; Sapirstein, David, Preston, & Dexter, 2007; Trappey, Khouryieh, Aramouni, & Herald, 2015; Wang, Hou, & Dubat, 2017; Zhang & Moore, 1997). However, there is limiting information in the literature on the influence of thermal treatment of tempered flours from cereal grains on baking quality (Cetiner, Kahraman, Sanal, & Koksel, 2017; Perez-Quirce, Ronda, Lazaridou, & Biliaderis, 2017).

In the present study, the effect of autoclaving and barley flour particle size on starch gelatinization and dough rheological properties as well as quality attributes of the rusks was examined.

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2. Experimental

2.1. Barley rusk making

Six different rusk preparations from barley flour (85%) – wheat gluten (15%) mixtures were made using a coarse (Co, d_{50} 350 μm) and a fine (Fi, d_{50} 200 μm) barley flour stream (Mills of Crete S.A., Souda, Chania, Greece) without (CTR, control flours, i.e. non-autoclaved) or with prior autoclaving at two different moisture levels (autoclaved flours). The first level was similar to the initial moisture content of the two control flours; i.e. about 12 and 11% for the coarse and fine flour, respectively (LM, non-tempered autoclaved flours). The second flour moisture level was at 14 and 13% for the coarse and fine flour stream (HM, tempered autoclaved flours), respectively, reached by tempering the flours prior autoclaving. Hydrothermal treatment was conducted by placing thin (< 2 mm) layers of the flours in aluminium containers and covered with aluminium foil and then treated in a steam sterilizer (Secfroio, VST 500, Switzerland) at 121 °C and 1.1 atm for 20min. The fine flour was a fraction of the coarse sample prepared by mechanical sieving.

The rusk making procedure was presented in detail in a previous study (Lazaridou et al., 2014). Shortly, for rusk making, the addition of gluten and other improvers, such as commercial enzymes (xylanase, fungal α-amylase, transglutaminase and glucose oxidase), DATEM, salt, glucose, cysteine and ascorbic acid as well as leavening agents (yeast and baking soda) was adopted. After mixing (26.5 min) all ingredients with the optimum water amount, estimated by farinography (Brabender, Duisburg, Germany) at 83 and 87 g water/100 g of barley flour-gluten mixture for the coarse and fine flour streams, respectively, the doughs were fermented (30 °C × 30 min), hand-moulded, re-fermented (30 °C × 10 min), divided into 500 g portions, put in pans and then fully proofed (38 °C × 55 min) and baked in a convection Oven, Fratelli Galli MD-2100 (Italy) at 220 °C for 50–70 min, depending on the formulation and number of loaves baked, till the dough centre assumed a desired crumb structure. After cooling for 1 h, the barley breads weighed, and their loaf volume was measured with a home-made plexi-glass bread volumeter using the rapeseed displacement method. The bread loaves were then cut into slices (2 cm thickness) and dried at 130 °C up to 4–6% moisture level in the final products (barley rusks). Rusk making for each barley flour preparation was repeated three times.

The moisture content of barley flours and rusks and the concentration of β-glucans in rusks were determined using the ICC-Standard method (ICC-Standards, 1976) and the mixed-linkage (1 → 3),(1 → 4)-β-D-glucan assay kit purchased from Megazyme International Ltd., respectively.

2.2. Dough functional properties

Doughs were prepared by mixing the six different barley flour--gluten mixtures with 2% (dry basis, d.b.) salt and water (flour-gluten mixture:water 53:47) for 9 min at 250 rpm speed using a home mixer (Kenwood Chef Electronic). Dough preparation for each flour mixture was performed in triplicate.

2.2.1. Starch gelatinization properties

The dough preparations (~40 mg dry matter) were hermetically sealed into stainless steel crucibles (Mettler, ME-29990, SS) and Differential Scanning Calorimetry (DSC) measurements were carried out with a PL DSC – Gold calorimeter (Polymer Labs. Ltd, Epsom, UK). The onset (To) and peak (Tp) temperatures as well as the apparent enthalpy (ΔH) of starch gelatinization were calculated from thermal scans at a heating rate of 5 °C/min. Three dough specimens were tested from each dough preparation.

The effect of flour autoclaving on starch gelatinization was also evaluated by cross polarized light microscopy using the Olympus BX51 microscope equipped with a digital camera Olympus DP70 (Japan).

2.2.2. Dough rheological properties

The doughs were wrapped with plastic membrane to avoid moisture loss and rested for 20 min at room temperature before any rheological testing.

Oscillatory measurements and creep-recovery tests were performed on a rotational Physica MCR 300 rheometer (Physica Messtechnic GmbH, Stuttgart, Germany) using a parallel plate geometry (50 mm diameter and 2 mm gap) with a solvent trap to avoid moisture loss during measurements; the plate had a sanded surface to prevent slippage. The temperature was regulated at 25(± 0.1)°C by a Paar Physica circulating bath and a controlled peltier system (TEZ 150P/MCR). After dough loading on the rheometer, the specimen was left to rest for 15 min prior to any measurement.

Strain sweep tests in the range of 0.001–100% at 1 Hz frequency were carried out to determine the linear viscoelastic region (LVR) and then, small deformation oscillatory measurements of G' (storage of elastic modulus), G'' (loss or viscous modulus), and tanδ (G''/G') were performed on doughs at 0.1% strain and over the frequency range 0.1–10 Hz.

Furthermore, creep-recovery tests were carried out using the rheometer and by applying constant stress (50 Pa) for 60 s on the dough and allowing strain recovery for 180 s after removal of load. Using the supporting software (US200 V2.21) of the rheometer the compliance curve data from the creep-recovery tests were analyzed and fitted to the Burgers model as described elsewhere (Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007).

Large deformation mechanical properties of the doughs were examined by Texture Profile Analysis (TPA) and compression - stress relaxation tests using a texture analyser (TA-XT2i, Stable Micro systems, Godalming, Surrey, UK) with a 75 mm diameter plunger; cylindrical dough specimens (25 mm diameter x 20 mm height) obtained with a circular shape cutter were tested. For TPA testing the dough specimens were compressed uniaxially in two consecutive cycles up to 60% deformation at a crosshead speed of 0.8 mm s^{-1}. The dough specimens were also subjected to a lubricated squeezing flow (LSF) test under uniaxial compression, followed by a stress relaxation test using the texture analyser. The dough disks were lubricated with paraffin oil to prevent drying of the dough and adhesion to the probe for the LSF test; the test was performed at a crosshead speed of 0.3 mm s^{-1} and 40% deformation in a 26 s period. After stopping the cross-head, the decay of the compression (force) was followed during 180 s. The force at the start of the relaxation (F_{max}) expressed as the dough hardness. As half relaxation time (Tla) was the time required for the force to decrease to a value $F_{max}/2$. The relaxation curve data after LSF were fitted to a modified non-linear Maxwell model as proposed by Bartolucci and Launay (1996):

$$\sigma(t) = \sigma_0 \cdot [1 + k\cdot((1/n)-1)\cdot t]^{n/(n-1)}$$

Where σ is the stress at time t, σ_0 is the stress at $t = 0$, k is the relaxation rate and n is the flow behavior index. For data fitting to this equation the TableCurve 2D software (Jandel Scientific) was used.

Additionally, stress relaxation data were fitted to the Peleg model (Peleg, 1979):

$$t/Y(t) = 1/(a\cdot b) + t/a$$

Where Y(t) is the normalized relaxation stress (i.e. $(\sigma_0-\sigma)/\sigma_0$), a is the asymptotic or equilibrium residual values of Y(t) when $t\rightarrow\infty$ and b is the rate at which the stress relaxes; from this model, the parameters of $k_1 = 1/(a\cdot b)$ and $k_2 = 1/a$ were calculated from the dough stress relaxation curves.

Each rheological test on rheometer and texture analyser was performed on three and five different specimens from each dough preparation, respectively.