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Influence of inulin on physical characteristics and staling rate of gluten-free bread

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ABSTRACT

Inulin preparations with different degree of polymerization (HSI with a DP < 10, GR – DP ⩾ 10 and HPX – DP > 23) were used for the production of gluten-free bread. It was found that an addition of investigated compounds resulted in an increase of loaf volume and reduction of crumb hardness. However, internal structure of the obtained loaves was less uniform and more open than in control bread. Generally, inulin preparations with lower degree of polymerization had stronger effect on all analyzed parameters than that with higher DP. A decrease in staling was observed (measured as the rate of crumb hardening), which was caused by the presence of inulin. The highest content of retrograded amylopectin was found for crumb with HSI, and the lowest for samples with HPX.

1. Introduction

Bakery products are important constituents of a daily diet, and supply consumers with many important nutrients and health-related compounds (Dewettinck et al., 2008; Isserliyska et al., 2001; Gül et al., 2003. One of them is dietary fiber, and especially its soluble fraction, which is known to reduce prevalence of cardiovascular diseases, type II diabetes and many digestive dysfunctions, limit blood cholesterol level and body weight gain (Anderson et al., 2009; Gunness and Gidley, 2010). The content of dietary fiber in traditional types of bread ranges from about 2–8%, depending on a flour extraction rate (Poinot et al., 2010; Dewettinck et al., 2008; Mialon et al., 2002; Li et al., 2002). Because of its non-typical composition, gluten-free bakery usually contains less nutrients than wheat flour products, while it displays elevated fat level and calorie value (Matos Segura and Rosell, 2011; Pruska-Kędzior et al., 2008). The content of dietary fiber in starch-based bread is about 1% (Korus and Achremowicz, 2004).

Some fractions of dietary fiber, including inulin, act as prebiotics in human organism. Because of the presence of β(2,1) glycosidic bonds, it could not be digested in human gastrointestinal tract, while it could be utilized by colonic micro-flora (Barclay et al., 2010). A diet with sufficient amounts of prebiotics could stimulate growth of microorganisms residing in guts, which composition and function is essential for human health (Venter, 2007; Fahey, 2010). Inulin is mainly responsible for growth of bifidobacteria and lactic acid bacteria (Fahey, 2010; Figueroa-González et al., 2011). Regular intake of prebiotics decreases prevalence of inflammatory bowel disease, reduces the risk of colon carcinogenesis, improves serum lipid profiles and calcium absorption etc. (Roberfroid, 2007; Ranawana, 2010; Fahey, 2010).

In the production of food, inulin is utilized to replace fat or sugar, and as a thickener or gelling agent (Glibowski, 2010; Tárrega et al., 2011). Inulin is a linear fructan with a degree of polymerization (DP) in a wide range 2–60. The length of molecules is important for technological and prebiotic properties of inulin (Stewart et al., 2008; Glibowski, 2010; Tárrega et al., 2011). The research on the application of different levels of (1–10%) inulin in bakery products were mostly focused on wheat bread, while there is a limited number of studies concerning gluten-free products (Poinot et al., 2010; Morris and Morris, 2012). In our earlier studies it was shown, that starch-based bread could be supplemented with Frutafit inulin up to 8%, which resulted in an increase in volume and retardation of crumb staling (Korus et al., 2006). The aim of the study was to evaluate the influence of a degree of polymerization of inulin on the quality of gluten-free bread and its staling rate.

2. Material and methods

2.1. Materials

Gluten free bread was baked, on the basis of following raw materials: corn starch (Bezgluten, Poland), potato starch (Pepees S.A., Poland), guar gum (Lotus Gums & Chemicals, India), pectin

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(Pektowin, Poland), freeze-dried yeast Saf-instant (S.I. Lesaffre, France) and commercially available: sucrose, salt, rapeseed oil. Three types of inulin differing in a degree of polymerization (DP): HSI with a DP < 10, GR (DP ⩾ 10) and HPX (DP > 23) were obtained from BENEO-Orafti (Belgium).

2.2. Methods

2.2.1. Breadmaking

Bread making procedure followed the method described earlier (Korus et al., 2009). Control formulation contained a mixture of corn starch and potato starch (4:1 w/w). Other ingredients (basis on starch weight) were: guar gum 1.7%, pectin 1.7%, freeze dried yeast 5%, sucrose 2%, salt 1.7%, rapeseed oil 3% and water 103%. In the recipes with inulin 4, 8 or 12% starch bases were replaced with the analyzed preparations. Due to the important differences in water binding ability of inulin, the content of water was adjusted individually for each modified recipe (Table 1), with the use of texture analyzer TA-XT+ equipped with back extrusion rig (A/BE-d 35) (Stable Micro Systems, England), in such a way that the maximum force during back extrusion was comparable (400 G, at compression rate 0.83 mm/s). The addition of HSI and GR preparations diminished water absorption of the dough (by 1.6–4.0% in comparison to amount in control), and HPX – increased it (by 1.6–4.8%). All ingredients were mixed for 8 min (Laboratory Spiral Mixer SP 12, Diosna, Germany) and prefermented in bulk for 15 min (35 °C, 80% moisture), then the dough was re-mixed and its portions (250 g) were put into greased baking pans. Final proofing continued for 20 min at the above mentioned temperature. Loaves were baked in an electric oven MIWE Condo type CO 2 0608 (MIWE GmbH, Germany) for 30 min at 230 °C. Two batches of 6 loaves were baked separately. The loaves were removed from the pans and cooled at ambient temperature. Their volume was evaluated by rapeseed displacement.

2.2.2. Evaluation of crumb hardness of gluten-free bread

The loaves were stored for 3 days in polyethylene bags at ambient temperature. During this time hardness of bread crumb was performed, using texture analyzer TA-XT2plus (Stable Micro Systems, England), according to standard program, at the compression rate 5 mm/s. Bread crumb, cut with cork borer with a diameter 2 cm from the center of the slice with a height 2 cm was pressed to reach 50% deformation by a P/35 aluminum cylinder probe, in two cycles with a 5 s delay. The resulting hardness was used as indicator of textural changes during storage. The calculations were performed using the attached software Texture Exponent (Stable Micro Systems, England).

2.2.3. Image analysis

Slices from the internal part of each loaf (thickness – 1 cm) were scanned by Plustek S-12 desktop scanner (Plustek, Taipei, Taiwan). The registered images were analyzed with the help of ImageJ software v. 1.44c (NIH, Bethesda, USA) (Abramoff et al., 2004), evaluating number of pores, cell area, total crumb area, porosity (cell/total area ratio) cell density (number per 1 cm^2), and number of pores with area larger than 5 mm^2.

2.2.4. Thermal analysis of bread crumb

Thermal properties of gluten-free bread crumb were characterised by means of differential scanning calorimeter DSC 204F1 Phoenix (Netzsch, Germany). The calorimeter was calibrated by indium standard. Crumb samples (approx 15 mg), 2, 10, 22, 34 and 46 h after baking were closed hermetically in aluminium pans and heated in the calorimeter from 25 to 100 °C at a rate of 10 °C/min. Empty aluminium pan was used as reference. Temperatures and enthalpy of thermal transitions were determined with the use of instrument's software Proteus Analysis (Netzsch, Germany). Enthalpy values were expressed as J/g d.b. The changes of enthalpy during storage were described by Avrami equation:

$$\Theta = \frac{\Delta H_\infty - \Delta H_t}{\Delta H_\infty - \Delta H_0} = e^{-k \cdot t^n} \quad (1)$$

where Θ is the fraction of unrecrystallized sample; ΔH_0 (J), ΔH_∞ (J), and ΔH_t (J), are retrogradation enthalpy at zero time, ∞ and t time, respectively, k (s^{-n}) is a rate constant, and n is the Avrami exponent (Armero and Collar, 1998; Sanz-Penella et al., 2010). To reduce the number of evaluated parameters it was assumed that $\Delta H_0 = 0$, which is justified if starch was fully gelatinized during baking. After simplifying and transforming the equation takes the form:

$$\Delta H_t = \Delta H_\infty \cdot (1 - e^{-k \cdot t^n}) \quad (2)$$

Calculations were performed using Marquardt–Levenberg method with the use of Statistica 9.0 (StatSoft Inc., USA).

2.2.5. Statistical analyses

In order to establish the statistical differences between means the date were treated by one-factor analysis of variance, and the least significant difference (LSD) using Fisher test at significance level 0.05 was calculated. The influence of selected factors was analyzed with the use of two- (type of inulin, and the applied addition level) or three factorial (type of inulin, addition level and time of storage) analysis of variance. In order to show the differences between analyzed sample Principal Component Analysis (PCA) was performed, taking into account the followibg parameters: V – bread volume, NP – number of pores, AA – average area, NP5 – number of pores > 5mm, TA – total area, P – porosity, CD – cell density, PP5 – percentage of pores > 5mm, ΔH – retrogradation enthalpy after 2, 24 and 48 h, H – hardness after 2, 24 and 48 h. Additionally the values of Pearson's correlation coefficients between selected parameters characterizing sample properties were calculated. All calculations were performed with statistical software package Statistica 9.0 (StatSoft Inc., USA).

Table 1
Components of gluten-free bread used at variable amounts.

Sample		Corn starch (g)	Potato starch (g)	Inulin type			Water (g)
				HSI (g)	GR (g)	HPX (g)	
Control		480.0	120.0	–	–	–	620
HSI	4%	460.8	115.2	24	–	–	610
	8%	441.6	110.4	48	–	–	600
	12%	422.4	105.6	72	–	–	595
GR	4%	460.8	115.2	–	24	–	610
	8%	441.6	110.4	–	48	–	600
	12%	422.4	105.6	–	72	–	595
HPX	4%	460.8	115.2	–	–	24	630
	8%	4.416	110.4	–	–	48	640
	12%	422.4	105.6	–	–	72	650