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The effects of maltodextrins on gluten-free dough and quality of bread

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ABSTRACT

The aim of the study was to check if maltodextrins of various dextrose equivalents (DE) could be used to improve stability and quality of gluten-free bakery products, and effectively reduce starch retrogradation. The maltodextrins, which were used for partial replacement of starch in the recipe for gluten-free dough, were characterised by DE 3.6, 15.3, 18.0 and 21.8. Basing on the obtained results it was concluded, that the addition of applied maltodextrins significantly influences starch gelatinisation, by increasing pasting temperature and reducing viscosity of the obtained pastes. Rheological properties of the obtained dough are also modified by maltodextrins, which weaken its structure and increase deformation sensitivity. The addition of maltodextrins with low DE (3.6) diminishes loaf volume and causes deterioration of bread quality. Maltodextrins with higher DE, especially 18.0 and 21.8, positively influence bread volume and have a beneficial influence on crumb hardening during storage. Maltodextrin with the highest DE is also an effective factor reducing recrystallisation enthalpy of amylopectin.

1. Introduction

Celiac sprue is a disease related to malfunction of small intestine in the presence of gliadin-like proteins. The only effective way to avoid its symptoms is to apply a diet completely free of proteins present in wheat, rye, barley and several other cereals, which may damage intestinal mucosa (Fasano and Catassi, 2001; Holtmeier and Caspary, 2006). Technology of gluten-free bakery is based on starches of different botanical origin, as well as corn, rice, soy and buckwheat flours (Pruska-Kędzior et al., 2008; Renzetti et al., 2008; Ribotta et al., 2004; Sivaramakrishnan et al., 2004). Polysaccharide hydrocolloids, such as xanthan, cellulose, pectins, beta-glucans, guar gum, and their mixtures are often used as structure and texture forming components of gluten-free formulations (Ahlborn et al., 2005; Korus et al., 2009; Pruska-Kędzior et al., 2008; Ribotta et al., 2004; Sivaramakrishnan et al., 2004). Emulsifiers were successfully used to improve quality and rheological properties of gluten-free bakery products (Nunes et al., 2009). Due to the composition of gluten-free products, they have lower nutritional value as compared to traditional. This is the basis for the studies on the use of nutritional and dietary supplements in its production (Gallagher et al., 2003; Korus et al., 2006, 2009).

Ageing of bread crumb is a complicated and not fully examined process (Karaoglu, 2006). Starch glucans – amylose and amylopectin significantly impact crumb hardening due to their retrogradation (Gray and BeMiller, 2003). Another important issue affecting bread ageing is water migration from crumb to crust. Water content and activity determine recrystallisation of starch polymers, as it was demonstrated by Ostella et al. (2005). Starch retrogradation is especially important in gluten-free bread based on starch, where the content of other components is relatively low (Holtmeier and Caspary 2006; Ribotta and Bail, 2007). Because aggregation of amylose is a rapid process, which starts during bread cooling, the main factor for crumb staling is aggregation of amylopectin (Sahlaström and Bråthen, 1997). Although, according to Gray and BeMiller (2003) protein content influences crumb hardening, because of the interactions between starch and gluten, it cannot be applied to gluten-free products, where the protein content is low, and protein–starch interactions could be neglected. Retrogradation of starch in traditional bakery products were extensively studied (Ahlborn et al., 2005; Defloor and Delcour, 1999; Gujral et al., 2003; Miyazaki et al., 2004; Sahlaström and Bråthen, 1997), and low-molecular dextrins, as well as alpha-amylases were suggested to prevent unwanted textural changes of bread during storage. Both these additives retard bread staling (Gray and BeMiller, 2003; Gujral et al., 2003), but their mechanism is slightly different. Addition of alpha-amylases results not only in the formation of low-molecular weight dextrins, but also modifies the structure of existing starch glucans, and in the case of wheat bread, the interactions between starch and gluten. Miyazaki et al. (2004) reported that the addition of low-molecular weight dextrins to wheat bread retards retrogradation of starch, which was not directly connected with a decrease of crumb hardness, as compared to control bread.

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In model studies on starch gels with the addition of low-molecular weight dextrins it was observed, that they restrict starch gelatinisation and reduce the values of retrogradation enthalpy (Durán et al., 2001), as well as reduce gel firmness both after preparation and during storage (Rojas et al., 2001). Basing on these results it was concluded that low-molecular weight dextrins with a degree of polymerisation 2–7, could be an effective factor preventing bread staling. The use of maltodextrins with a strictly set DP is however impractical on the industrial scale, because commercially available starch hydrolysates are described by dextrose equivalent (DE), which may be the same for products with different ranges of DP, and in general it cannot be assumed that the simple calculation DP = 111.11/DE (Dokic et al., 2004) would give a reasonable result. The application of maltodextrins as antistaling agents for wheat bread was already studied by a few authors (Defloor and Delcour, 1999; Miyazaki et al., 2004). Miyazaki et al. (2004) concluded that the retrogradation of starch in crumb during storage was significantly retarded, if lower molecular weight dextrins were used as compared with high molecular weight dextrins. Defloor and Delcour (1999) observed that different concentrations of maltodextrin preparations with average degree of polymerisation varying between 4 and 66 reduced DSC staling endotherm in baked and stored bread doughs. There are however no data about the impact of maltodextrins on quality and ageing of gluten-free bread.

The aim of the research was to introduce maltodextrins with varying dextrose equivalent as components of gluten-free bread, which would improve its quality and reduce starch retrogradation.

2. Material and methods

2.1. Material

Material used for baking of gluten-free bread consisted of corn starch (Roquette, France), potato starch (Pepees S.A., Poland), guar gum (Lotus Gums and Chemicals, India), pectin (Pektowin, Poland), lyophylized yeast Saf-instant (S.I. Lesaffre, France), sucrose, salt, plant oil and water. Part of these constituents was acquired from local supermarkets. The maltodextrins used in the studies were obtained from company Cargill (Poland): C*Dry MD 01904 with DE 3.6, C*Dry MD 01910 with DE 15.3, C*Dry MD 01914 with DE 18.0 and C*Dry GL 01921 with DE 21.8 (all DEs according to the producer's specification).

Gluten-free batter was prepared according to the following procedure: corn starch 400 g, potato starch 100 g, guar gum 8.3 g, pectin 8.3 g, lyophylized yeast 25 g, sucrose 10 g, salt 8.3 g, plant oil 15 g and water 517 g. Part of starch equivalent to 5%, 10% or 15% (proportionally corn and potato) was replaced with examined preparations. Due to a fact that water content plays an important role in ageing of bread crumb, the amounts of added water was always on the same level. All the ingredients were mixed for 8 min (Laboratory Spiral Mixer SP 12, Diosna, Germany). Similar samples without the addition of yeast were used for rheological studies.

2.2. Methods

2.2.1. Impact of maltodextrins on starch gelatinisation

Pasting characteristics was performed on Micro Visco-Amylo-Graph type 803202 (Brabender, Germany) equipped with a 250 cmg measuring cartridge, run at 75 rpm and operating under Brabender Viscograph ver. 2.4.6 software. Dry mixes based on the recipe (without yeast) were used. Suspensions prepared from 5 g of selected mixes and 95 g distilled water were heated/cooled at a rate 6 °C/min according to the following programme: rising temperature in the range 25–96 °C, constant temperature 96 °C (10 min), cooling in the range 96–40 °C. Pasting temperature, peak viscosity, viscosity after 10 min at 96 °C and after cooling were read from Brabender Viscograph – Data Correlation ver. 2.1.6 software.

2.2.2. Rheological properties of gluten-free dough

Rheological properties of the dough were measured at 25 °C with the use of rheometer MARS II (Thermo-Haake, Germany) equipped with a system of parallel plates (diameter 35 mm and gap 2 mm). Batter samples obtained as described above (without yeast), were put between the plates and left for 15 min in order to obtain relaxation and stabilize temperature.

Mechanical spectra were measured in the range of linear viscoelasticity, at constant strain amplitude ($\gamma = 0.002$) in the range of angular frequency 1–100 rad/s. Experimental data were described by the power-law model (Korus et al., 2009; Sivaramakrishnan et al., 2004):

$$G'(\omega) = K' \cdot \omega^{n'} \quad (1)$$

$$G''(\omega) = K'' \cdot \omega^{n''} \quad (2)$$

where: G' - storage modulus (Pa), G'' – loss modulus (Pa), ω – angular frequency (rad/s), K', K'', n', n'' – experimental constants.

Creep and recovery tests were performed at constant shear stress in creep phase $\sigma_0 = 1$ Pa in the range of strain proportional to stress. Creep stage continued for 150 s, and recovery stage – 300 s. The resulting data of strain as a function of time were expressed in the form of compliance (Steffe, 1996).

Experimental data were described by means of four-parameter Burger's model (Korus et al., 2009; Lazaridou et al., 2007):

$$J(t) = J_0 + \frac{t}{\eta_0} + J_1 \cdot (1 - \exp^{-\frac{t}{\lambda_{ret}}}) \quad \text{for } t \le t_1 \quad (3)$$

$$J(t) = \frac{t_1}{\eta_0} - J_1 \cdot (1 - \exp^{-\frac{t_1}{\lambda_{ret}}}) \cdot \exp^{-\frac{t}{\lambda_{ret}}} \quad \text{for } t > t_1 \quad (4)$$

where: J_0 – instantaneous compliance (1/Pa), J_1 – retardation compliance (1/Pa), η_0 – zero shear viscosity (Pa s), λ_{ret} – retardation time (s), t – time (s), and t_1 – time when stress was applied (s).

The calculations were performed by Marquardt–Levenberg method with the use of software package Statistica 8.0 (StatSoft Inc., USA).

2.2.3. Baking of gluten-free bread

The batter was fermented for 15 min (35 °C, 80% moisture), mixed again for 1 min, and then portions of 250 g were placed into greased metal pans. Final fermentation lasted for 20 min under the conditions described above. Bread was baked for 30 min at 230 °C (electric oven MIWE Condo type CO 2 0608, MIWE GmbH, Germany). Four loaves were baked in two independent trials. After their removal from pans loaves were cooled at ambient temperature and used for further analyses. Three loaves of each batch were used for texture analysis on the following days of storage, while the fourth was utilized for dry mass measurement and DSC analysis.

2.2.4. Volume and texture of gluten-free crumb

After baking and cooling (for approx. 2 h) bread volume of all four loaves, obtained in a batch was assessed by rapeseed replacement. Loaves were packed in polyethylene bags and stored for 48 h at 22 ± 2 °C and relative moisture 64%. After 2, 24 and 48 h after baking texture profile analysis (TPA) of bread crumb of one loaf from each batch was performed, using texture analyser TA-XT2*plus* (Stable Micro Systems, England), according to standard programme, at the compression rate 5 mm/s. Sample of bread crumb, taken from the centre of the loaf with a height 2 cm was pressed to reach 50% deformation by a P/20 aluminium cylinder probe with a diameter 2 cm, in two cycles with a 5 s delay. The resulting