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The comparison of the effect of sodium caseinate, calcium caseinate, carboxymethyl cellulose and xanthan gum on rice-buckwheat dough rheological characteristics and textural and sensory quality of bread

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A B S T R A C T

The effect of calcium and sodium caseinate supplements (2 g/100 g) on the behavior of rice-buckwheat dough and bread quality was compared to the effect of xanthan gum and carboxymethyl cellulose. The addition of caseinates significantly ($P < 0.01$) increased dough weakening, which became similar to dough with xanthan gum. During heating, the gelatinization rate became similar to dough with carboxymethyl cellulose. Moreover, peak complex viscosity was decreased by $0.4 \cdot 10^5$ Pa s. Additionally, hydrocolloid supplements impacted bread crumb characteristics. An open structure was found in crumb with added calcium caseinate, carboxymethyl cellulose as well as xanthan gum. The hardness of rice-buckwheat crumb without hydrocolloids (12.2 N) was decreased by calcium caseinate (4.3 N), xanthan gum (9.1 N) and carboxymethyl cellulose (9.3 N), however, no significant effect of sodium caseinate was recorded (11.5 N). The overall sensory acceptability of rice-buckwheat bread (7.1) was increased by sodium caseinate (7.5), calcium caseinate (7.7) and carboxymethyl cellulose (7.8). The acceptability of bread with xanthan gum (5.9) was negatively impacted by dry, coarse crust and extremely sticky crumb. It can be concluded caseinates may be alternative substances with satisfactory impact on the rheological characteristics of rice-buckwheat dough, as well as bread quality.

1. Introduction

The absence of structure-forming protein network (gluten) in gluten-free (GF) dough results in the leakage of leavening gas during proofing and baking, resulting in insufficient bread quality. Many substances (enzymes, proteins and hydrocolloids) were tested for the ability to mimic wheat gluten potential to trap leavening gas by preventing the collapse of the thin dough film surrounding gas bubbles (Fidantsi & Doxastakis, 2001; Singh & MacRitchie, 2001). Hydrocolloids most often used in GF bread-making are xanthan gum, carboxymethyl cellulose, etc. Xanthan gum (XG) is an extracellular polysaccharide produced by the microorganism *Xanthomonas campestris*. Xanthan gum does not form gels, but its pseudoplastic behavior affects rheological characteristics of GF dough (Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007; Moreira, Chenlo, & Torres, 2011; Sworn, 2009), which makes it able to mimic gluten properties (Anton & Artfield, 2007; Lazaridou et al., 2007). XG high water-holding capacity is attributed to the presence of hydroxyl groups, allowing more water interactions through hydrogen bonding (Guarda, Rosell, Benedito, & Galotto, 2004). XG addition improves volume, texture, moisture retention and sensory acceptability of bread (Rosell, Rojas, & Benedito de Barber, 2001; Shittu, Aminu, & Abulude, 2009).

Similarly, carboxymethyl cellulose (CMC) increases dough water absorption and is also used as an anti-sticking agent. CMC increases dough viscosity, has a positive effect on dough extensibility and elasticity and improves the structure and volume of bread (Collar, Martinez, & Rosell, 2001; Lazaridou et al., 2007).

GF products are often made from refined flour or starch, resulting in a lower amount of nutrients, particularly calcium, iron, etc. (Anton & Artfield, 2007; Gallagher, Gormley, & Arendt, 2004; Thompson, Dennis, Higgins, Lee, & Sharrett, 2005). The consumption of traditional sources of calcium (milk and dairy products) may be harmful for people initially diagnosed with celiac disease, since they may have a secondary form of lactose intolerance. The fortification with various calcium salts and milk powders with high

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protein and low lactose contents (calcium caseinate) can affect not only the nutritional and sensory quality of GF bread, but impact the behavior of GF dough during heating as well (Krupa-Kozak, Altamirano-Fortoul, Wronkowska, & Rosell, 2012; Krupa-Kozak, Bączek, & Adamowicz, 2014; Krupa-Kozak, Bączek, & Rosell, 2013; Krupa-Kozak, Troszyńska, Bączek, & Soral-Śmietana, 2011). Additionally, the milk proteins are able to form a thin tenacious film at gas–liquid interface, making the incorporation and stabilization of a large amount of leavening gas in GF dough possible (O'Regan, Ennis, & Mulvihill, 2009). Moreover, to a certain extent, Ca^{+} bonds can replace disulphide bridges, affecting gluten rheological characteristics (Stathopoulos & O'Kennedy, 2008).

Gallagher, Gormley, and Arendt (2003) and Sadrabadi, Ardakani, and Azizi (2013) found the improving effect of sodium caseinate supplement on GF bread shape, volume, crumb and crust. However, the consumption of bread with added sodium caseinate can increase the already high sodium intake which is often associated with a rise in blood pressure and the risk of cardiovascular disease (He & MacGregor, 2009). Calcium caseinate can be a nutritionally more valuable alternative to sodium caseinate. A certain stabilizing effect of calcium caseinate on GF dough can be expected, even if its foaming properties are known to be weaker (Abascal & Gracia-Fadrique, 2009). Additionally, the impact of different hydrocolloids on the characteristics of dough and bread crumb is known to be highly dependent on raw materials, the nature and quantity of hydrocolloids and water availability (Sciarini, Ribotta, León, & Pérez, 2012). It is therefore very difficult to predict the real effect of hydrocolloid on the formulation. Hence the aim of the research was to investigate the impact of calcium and sodium caseinate addition on thermally-induced changes in GF dough, crumb characteristics and sensory evaluation of composite rice-buckwheat bread. The effect of both caseinates was compared to the effect of hydrocolloids used in GF breadmaking (XG, CMC). Moreover, the applicability of caseinates in GF breadmaking was evaluated.

2. Material and methods

2.1. Flours and hydrocolloids

Buckwheat and rice flours were kindly provided by Extrudo Bečice, s.r.o., Czech Republic. Rice flour is usually preferred in GF products because of its colorlessness, nutritional characteristics, bland taste and low hypoallergenic properties (Gujral & Rosell, 2004). Buckwheat flour is a good source of polyphenol compounds and is used to improve the nutritional quality of GF breads (Alvarez-Jubete, Wijngaard, Arendt, & Gallagher, 2010). A blend containing 30 g of buckwheat and 70 g of rice flour per 100 g of dry blend was used in this study. The effect of sodium caseinate, calcium caseinate (Moravia Lacto, a.s., Czech Republic), CMC and XG (Sigma Aldrich, Czech Republic) additions (2 g/100 g) on thermally-induced changes of dough rheological characteristics and the quality of GF bread was compared.

2.2. Rheological characterization of dough during heating

The effect of hydrocolloid additions on the rheological characteristics of dough was studied at 30–90 °C temperature ramp simulating dough baking. Rheological measurements were performed using HAAKE RheoStress 1 (Thermo Scientific, Czech Republic). The dough samples were prepared according the formulation used in breadmaking (see 2.3), excluding yeast and ascorbic acid. After mixing, the dough sample was rested at 30 °C for 5 min in a sealed bowl to allow relaxation of stresses generated during the sample preparation. The measurements were performed using 35 mm P35 Ti L parallel plates. The dough sample was placed between the parallel plates and compressed to reach a gap of 1.5 mm. Dough edges were afterwards trimmed with a spatula. The exposed side of the dough was coated with methyl silicone oil M15 (Lučební závody a.s. Kolín, Czech Republic) to prevent the dough from drying out during the measurement. After a 5-min rest between the plates the temperature dependence of dough rheological characteristics was measured using temperature sweep test, increasing the temperature from 30 °C to 90 °C at 0.058 °C/s. Stress sweep test at the frequency of 1 Hz was previously performed at temperatures of 30, 40, 50, 60, 70, 80 and 90 °C to determine the linear viscoelastic region (0.01–1%). Temperature sweep test was performed at strain of 0.1% and frequency 1 Hz. The values of elastic modulus G', viscous modulus G'', complex viscosity η^* and loss factor tan δ were obtained. Each test was performed on dough samples prepared at least in three replicates. The given results are represented as mean values.

If the thermally-induced changes of dough behavior are measured by empirical mixolab, parameters α, β, γ are calculated as the slopes (angles) between the ascending and descending parts of curve and defined as protein breakdown α, gelatinization rate β and cooking stability rate γ (Collar, Bollain, & Rosell, 2007). The thermally-induced processes in dough can be measured by fundamental dynamic rheometry as well. The main advantage of dynamic rheometry is its ability to differentiate between the elastic behavior of dough (elastic modulus G') and viscous behavior (viscous modulus G''). This differentiation allows greater precision and objectivity in the description of dough properties (Weipert, 1990). Moreira, Chenlo, and Torres (2011) previously reported the acceptable agreement between the results obtained by mixolab and rheometry, hence the applicability of the mixolab evaluation method on dynamic rheology can be expected. Thus, $\alpha_{G'}$, $\beta_{G'}$ and $\gamma_{G'}$ were used to characterize the angles between the ascending and descending parts of the elastic modulus curve, $\alpha_{G''}$, $\beta_{G''}$ and $\gamma_{G''}$ were used to characterize the viscous modulus curve and finally, α_{η^*}, β_{η^*} and γ_{η^*} were used to characterize the complex viscosity curve.

2.3. Bread preparation

The dough was made from flours blend (300 g), saccharose (1.86 g/100 g), active dry yeast (1.80 g/100 g), salt (1.50 g/100 g), the hydrocolloid (2.00 g/100 g) and water (80 g/100 g); these weights were related on the dry flour basis. The amount of added water was adequate to form a consistent dough.

Dry yeast was reactivated for 10 ± 1 min in a sugar solution (35 ± 1 °C). The dough ingredients were placed in the Spar mixer bowl (Spar Food Machinery MFG, Co., Ltd. Taiwan) and mixed for 6 min. The prepared dough was scaled into three bread pans and placed into a proofer for 20 min at 30 °C and 85% relative air humidity. The loaves were baked for 20 min at 180 ± 5 °C in a steamy oven. After baking, the breads were stored at room temperature for 2 h, then analyzed. Each test was performed on different dough samples, prepared at least in three replicates. The given results are represented as mean values.

Dough formulation and baking conditions were selected in agreement with Gujral and Rosell (2004), Krupa-Kozak et al. (2012), Lazaridou et al. (2007), Moore, Schober, Dockery, and Arendt (2004) and Rosell et al. (2001), who reported 90–130 g of water per 100 g of flour and baking at 175–190 °C.

2.4. Loaf specific volume

Loaf volume was determined in triplicate using plastic granulates of rape-seed size. Loaf weight was measured using top-pan balance. Loaf specific volume (ml/g) was obtained by dividing the