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Comparison of Gluten-Free Dough Ability to Produce Leavening Gas During Baking and its Impact on Crumb Characteristics

Porovnání schopnosti bezlepkového těsta produkovat kypřící plyn během pečení a jeho vliv na kvalitu pečiva

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Burešová, I., Bureš, D., Čurečková, K., 2017: Comparison of Gluten-Free Dough Ability to Produce Leavening Gas During Baking and its Impact on Crumb Characteristics. Kvasny Prum. 63, No. 1, pp. 8–10

Dough ability to produce leavening gas and its impact on bread crumb characteristics was evaluated on wheat, buckwheat and rice dough. The ability to produce leavening gas was recorded as thermally-dependent changes of dough volume; curve gradient, area under curve and the temperature range of leavening gas production were evaluated. Wheat dough reached the highest curve gradient α ($28 \cdot 10^{-3}$ $mm \cdot s^{-1}$), contributing to the large area under curve (7,169 mm·s). Significantly lower curve increase ($10 \cdot 10^{-3}$ $mm \cdot s^{-1}$; $5 \cdot 10^{-3}$ $mm \cdot s^{-1}$) as well as area under curve (6,291 mm·s; 53 mm·s) were obtained in buckwheat and rice doughs. The rising values of curve characteristics increased crumb quality. Even if gas retention ability was not evaluated, gas production ability significantly impacted crumb quality.

Burešová, I., Bureš, D., Čurečková, K., 2017: Porovnání schopnosti bezlepkového těsta produkovat kypřící plyn během pečení a jeho vliv na kvalitu pečiva. Kvasny Prum. 63, č. 1, s. 8–10

Schopnost těsta tvořit kypřicí plyn a jeho vazba na kvalitu pečiva byla sledována u pšeničného, pohankového a rýžového těsta. Schopnost produkovat kypřicí plyn byla sledována jako změny objemu těsta vyvolané změnami teploty. Nejstrmější nárůst křivky byl zjištěn u pšeničného těsta α ($28 \cdot 10^{-3}$ $mm \cdot s^{-1}$), což přispělo také k větší ploše pod křivkou (7 169 mm·s). Průkazně nižší nárůst křivky ($10 \cdot 10^{-3}$ $mm \cdot s^{-1}$; $5 \cdot 10^{-3}$ $mm \cdot s^{-1}$), stejně jako plochy pod křivkou (6 291 mm·s; 53 mm·s) byly zaznamenány u pohankového a rýžového těsta. Vzrůstající hodnoty byly v těsné vazbě s kvalitou pečiva. Přestože schopnost těsta zadržovat plyn nebyla stanovována, schopnost těsta produkovat kypřicí plyn průkazně ovlivnila kvalitu pečiva.

Burešová, I., Bureš, D., Čurečková, K., 2017: Die Vergleichung der Fähigkeit des glutenfreien Teiges einen Gärgas zu bilden und den Gaseinfluss auf Qualität des Gebäcks zu untersuchen. Kvasny Prum. 63, Nr. 1, S. 8–10

Die Teigfähigkeit den Gärgas zu bilden wurde beim Weizen-, Buch- und Reisteig mit der Bindung auf die Gebäckqualität verfolgt. Die Teigfähigkeit den Gärgas zu bilden wurde durch die Temperaturänderung verursachte eine gemessene Teigvolumenänderung festgestellt. Der steilste Kurve anstieg wurde beim Weizenteig festgestellt α ($28 \cdot 10^{-3}$ $mm \cdot s^{-1}$), was auch zu der größeren Fläche unter der Kurve beigebracht hatte (7 169 mm·s). Der deutlich niedrigere Kurvenanstieg ($10 \cdot 10^{-3}$ $mm \cdot s^{-1}$; $5 \cdot 10^{-3}$ $mm \cdot s^{-1}$), wie auch kleinere Fläche unter der Kurve wurden beim Buch- und Reisteig (6 291 mm·s; 53 mm·s) festgestellt. Die zunehmenden Werte wurden in enger Bindung mit der Teigqualität. Trotzdem dass die Teigfähigkeit den Gärungsgas aufzuhalten nicht geprüft wurde, die Teigfähigkeit den Gärgas zu bilden, hat diese Eigenschaft endgültig beeinflusst.

Keywords: *dough, wheat, gluten-free, leavening gas*
Klíčová slova: *těsto, pšenice, bezlepkový, kypřicí plyn*

1 INTRODUCTION

Dough is a multiphase and multicomponent system composed of water, polysaccharides, proteins, salt, lipids, and other minor substances. Starch polysaccharides are hydrolyzed by the action of natural flour enzymes and produced sugars are fermented by the microorganism *Saccharomyces cerevisiae* present in the yeast. Sugars are converted into water and carbon dioxide CO_2 during fermentation (Mondal and Datta, 2008). CO_2 goes into the solution in dough aqueous phase until saturation is achieved. Continued fermentation thereafter causes dough expansion as the gas is retained within the dough structure (Cauvain, 2001). The amount of produced leavening gas is impacted by many factors including dough temperature, yeast content, availability of fermentable sugars, method of dough preparation, etc. (Chiotellis and Campbell, 2003). Yeast activity is the highest at 35 to 40 °C, decrease occurs after reaching temperature of 43° C and is ceased when the temperature is above 55 °C (Cauvain, 2001). The quantity of yeast used in breadmaking is inversely related to the duration of fermentation; longer fermentation generally required lower levels of yeast. Moreover, fermentation takes place under lower temperatures. Thus, 1% (w/w) of yeast on flour weight is used for 3 h straight dough system at 27 °C, whereas 2–3% is required for a no-time dough at 27–30 °C (Kent and Evers, 1994).

The leavening process can be divided into three stages: the lag stage, the positive acceleration stage and the negative acceleration stage (Romano et al., 2007). It is important to distinguish between gas production and gas retention. Gas production is attributed to the generation of CO_2 as a natural consequence of yeast fermentation. Provided the yeast cells in the dough remain viable and sufficient substrate for the yeast is available, gas production will continue but expansion of the dough can only occur if that carbon dioxide gas is retained in the dough. Not all of the gas generated during processing, proofing and baking will be retained within the dough. The proportion depends on the development of a suitable gluten matrix within which the expanding gas can be held. Gas retention in doughs is therefore closely linked with the level of dough development (Cauvain, 2001). The absence of gluten network in gluten-free (GF) dough is known to significantly decrease GF dough gas retention (Ranken et al., 1997; Sivaramakrishnan et al., 2004, Goesaert el al., 2005), hence gas accumulation during baking has a more significant impact on bread porosity than proofing (Arendt and Dal Bello, 2008). Gas production ability of GF dough, however, has not been described yet. Hence the aim of the study was to compare gas production ability of GF doughs commonly used in breadmaking with wheat dough. The relation between the gas produced during baking and quality of yeast-leavened bread was also investigated.

2 MATERIAL AND METHODS

2.1 Material

The study was performed on buckwheat and rice flour kindly provided by Extrudo Bečice, s.r.o., Týn nad Vltavou, Czech Republic. Wheat flour (Penam a.s. Czech Republic) and yeast (SAF-Instant, Lesaffre Česko, Ltd. Czech Republic) were bought in a local supermarket. Saccharose p.a. and natrium chlorid p.a. were bought from PENTA s.r.o., Czech Republic.

2.2 Gas production

Gas production measurement was performed using the TA.XT plus (Stable Micro System Ltd., UK) texture analyzer equipped with an Dough Pot (A/DP) with extending lid. Dough was prepared according to the formula used in breadmaking. Immediately after kneading, 100 g ball of the dough was placed into an oiled Dough Pot (A/DP). Dough was flattened by placing the extending lid into the pot cavity and gently pressing down. The pot was placed into temperature water bath adjusted to 30 °C. A 50mm cylinder probe (P/50) was put on the lid center. Once trigger force of 300 g was reached, the probe then proceeded to compress the sample until a force of 301 g was attained. The plot started to increase at the same time as the dough began to proof. The rise in the sample was indicated by a change in the distance caused by the force of the sample pushing the probe upwards while maintaining the specified constant force. The temperature of water was increased by 0.05 °C/s. The dough temperature was measured by the thermometer with the temperature probe stuck into the centre of dough. The values of curve gradient α, area under the curve, time at which gas production was started t_1 and ended t_2 were evaluated by Exponent Lite software (*Fig. 1*). The temperature range of leavening gas production (T_1, T_2) was calculated from t_1 and t_2.

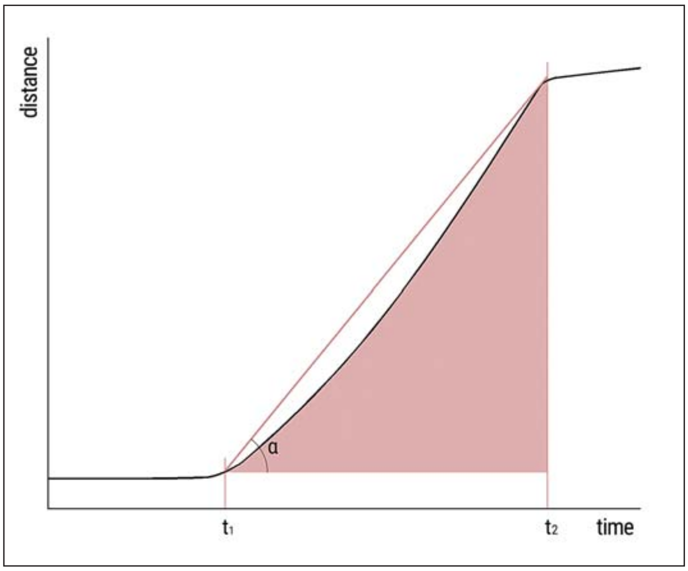

Fig.1 Curve obtained by measuring of leavening gas production in dough during heating

2.3 Bread preparation

Dough was prepared by mixing water, saccharose (1.86%), active dry yeast (1.80%) and salt (1.50%). The amount of added water varied among wheat and GF dough. Wheat flour was mixed with 56.5% of water to obtain optimal consistency of 500 FU. High dough hydration (90–110%) is essential for producing GF bread with improving loaf volume and crumb texture (de la Hera et al., 2013a,b), hence 100% of water was used in buckwheat and rice dough. Dry yeast was reactivated for 10 ± 1 min in a sugar solution (35 ± 1 °C). The dough ingredients were placed into an Eta Exclusive Gratus mixer bowl (Eta, a.s., Czech Republic) and mixed for 6 min. The prepared dough was divided into three bread pans and placed into a proofer for 20 ± 2 min. at 30 ± 1 °C and 85% relative air humidity. The loaves were baked for 20 ± 2 min. at 180 ± 5 °C in an oven (MIWE cube, Pekass s.r.o. Plzeň, Czech Republic). After baking, the breads were stored at room temperature for 2 h, then analyzed. Baking loss was determined by weighing breads before and 2 h after baking. Textural properties of bread crumb were measured using texture profile analysis (TPA) using the TA.XT plus (Stable Micro Systems Ltd., UK) texture analyzer. The TPA tests were performed on samples 35 mm in diameter and 10 mm in height obtained from the center of each loaf. Each sample was placed on the analyzer base and squeezed twice to 4 mm with the 36.0 mm diameter cylinder probe P/36R. Crumb parameters (hardness, springiness, cohesiveness, resilience and chewiness) were determined. Bread porosity was evaluated by a semi-consumer panel of 58 members (department staff and students), both male and female between the ages of 25–55 years.

2.4 Statistical analysis

The results were statistically analyzed using analysis of variance (ANOVA). The differences were tested on α = 0.05 significance level using Fisher LSD test. Statistical analysis was performed using Statistica CZ9.1 software (StatSoft, CR, Ltd).

3 RESULTS AND DISCUSSION

3.1 Gas production ability

Dough ability to produce leavening gas is a key factor affecting final crumb porosity. Gas released during test simulating baking was characterized by curve gradient α which is closely related to the rate of gas production and by area under curve expressing the total amount of released gas. The typical curve is displayed in *Fig. 1*.

The dough temperature was held at 30 °C during the initial phase of measurement ($t < t_1$). A similar pattern of yeast growth associated with low gas production (Romano et al., 2007), followed by the beginning of gas production were recorded in all tested doughs. Increasing dough temperature initiated a rapid increase of curve gradient α in the middle phase of measurement ($t_1 < t < t_2$), which may be associated with rising yeast activity and gas releasing. The highest curve gradient α was reached in wheat dough ($28 \cdot 10^{-3}$ mm·s^{-1}), while significantly lower increase was obtained in buckwheat ($10 \cdot 10^{-3}$ mm·s^{-1}) and rice ($5 \cdot 10^{-3}$ mm·s^{-1}) doughs. The increase of wheat and buckwheat dough curve prolonged since reaching the temperature of about 60–62 °C (*Table 1*). The temperature range is in the general agreement with known temperature-dependent yeast activity, which is the highest at 35 to 40 °C and is ceased when the temperature of more than 55 °C is reached (Cauvain, 2001). The changes of doughs observed above 55 °C may be related to the gas produced by the microorganism naturally present in dough together with water evaporation, both impacting crumb porosity (Fan et al., 1999; Cauvain, 2001).The rapid increase of wheat dough curve, moreover, contributed to reaching large area under curve (7,169 mm·s). A significantly lower area under buckwheat curve (6,291 mm·s) may be related to lower curve gradient α, since the temperature range of leavening gas production was similar in wheat and buckwheat dough. The increase of rice dough curve continued above 60 °C and ended at the temperature of about 80 °C. The changes of rice dough observed above 60 °C may be related to gas produced by the microorganisms naturally present in dough and water evaporation, which rates seemed to be a more extensive than recorded in wheat and buckwheat dough. Disregarding prolonged increase in rice dough, the lowest curve gradient had deteriorating impact on area under curve (53 mm·s). And finally, a plateau was reached during a final phase of measurement ($t > t_2$) in all tested doughs.

Curve characteristics, especially the areas under them, may be expected to be in close relation with the amount of leavening gas released by the yeast, hence better gas production ability may be expected in wheat and buckwheat dough than in rice dough.

Table 1 The ability of buckwheat, rice and wheat dough to produce leavening gas

Flour	Area (mm·s)	α 10^{-3} (mm·s^{-1})	T_1 (°C)	T_2 (°C)
Buckwheat	6,291 ± 4^{b}	10 ± 1^{b}	30 ± 1^{a}	60 ± 1^{a}
Rice	53 ± 5^{a}	5 ± 1^{a}	30 ± 1^{a}	80 ± 1^{b}
Wheat	7,169 ± 9^{c}	28 ± 2^{c}	30 ± 1^{a}	62 ± 1^{a}

Mean values ± standard deviation followed by different letters in the column differ significantly ($P < 0.05$).

3.2 Bread crumb characteristics

Hardness, springiness, cohesiveness, resilience and chewiness of bread crumb were evaluated by texture profile analysis (TPA), while crumb porosity by the panelists. The crumb ability to spring back after it was deformed during the first compression (springiness), as well as crumb ability to regain its original shape and size (resilience) together with ability to withstand compressive or tensile stress (cohesiveness) reached the highest values in wheat crumb (92%; 117%; 53%). The obtained high values characterizing wheat crumb are typical for high quality bread. Significantly lower values recorded in buckwheat (85%; 75%; 49%) and rice (75%; 63%; 41%) crumb indicated lower quality of these breads (*Table 2*). Since springiness, resilience and cohesiveness may be related to crumb structure, high porosity of wheat crumb (8.7); together with significantly poor poros-

Table 2 Characteristics of wheat, buckwheat and rice bread crumb. Mean values ± standard deviation followed by different letters in the column differ significantly (P < 0.05).

Flour	Hardness (N)	Springiness (%)	Cohesiveness (%)	Resilience (%)	Chewiness (-)	Crumb porosity
Buckwheat	30 ± 4[c]	85 ± 1[b]	75 ± 1[b]	49 ± 1[b]	1,900 ± 200[c]	7.7[b]
Rice	21 ± 1[b]	75 ± 2[a]	63 ± 4[a]	41 ± 3[a]	1,000 ± 100[a]	6.5[a]
Wheat	13 ± 4[a]	92 ± 1[c]	117 ± 5[c]	53 ± 1[c]	1,627 ± 100[b]	8.7[c]

Porosity score range: 1: dislike extremely; 9: like very much.

ity of buckwheat (7.7) and rice (6.5) crumb were expected results. The differences in bread crumb structure are evident from *Fig. 2.* Large-sized open pores were present in wheat crumb. This structure is often found in softer crumb (Burešová et al., 2016), explaining the low hardness of wheat crumb (13 N). Smaller-sized enclosed pores prevailed in the buckwheat and rice crumb. Better scores of buckwheat crumb may, however, be attributed to a thinner dough surrounding pores. The presence of enclosed smaller-sized pores in buckwheat and rice bread increased crumb hardness. The crumb of buckwheat bread was significantly harder (30 N) than rice crumb (21 N), which is not clearly consistent with buckwheat better porosity and thinner dough surrounding pores, indicating softer crumb. The prolonged evaporation observed in rice dough during measurement of gas-releasing ability probably led to the creation of a crunchier rice dough surrounding pores. Disregarding its thickness, crunchy rice crumb required lower power to be squeezed during TPA, resulting in low values of hardness as well as chewiness. Prolonged evaporation was not observed in buckwheat dough, hence why dough surrounding pores was firm, increasing the recorded values of hardness and chewiness.

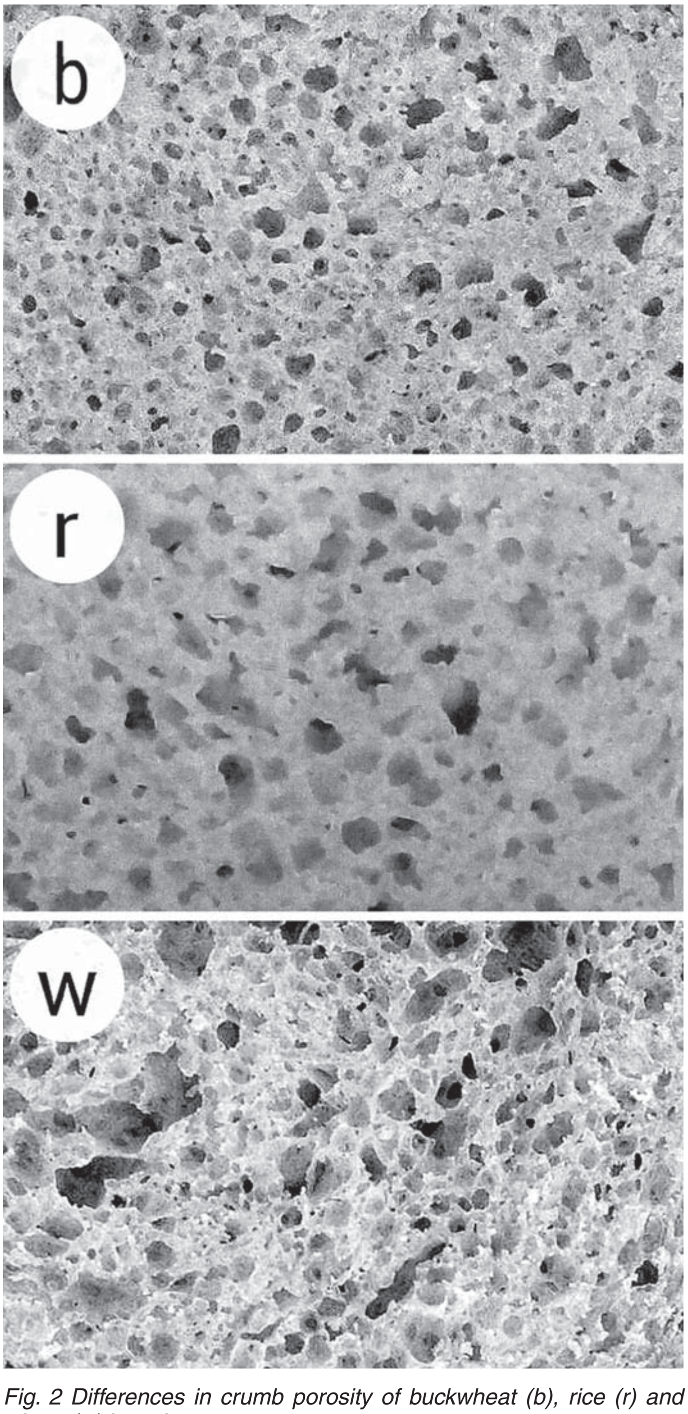

Fig. 2 Differences in crumb porosity of buckwheat (b), rice (r) and wheat (w) bread

4 CONCLUSIONS

The gas production ability, characterized by slope of curve and area under the curve significantly differed among wheat, buckwheat and rice dough. The bread crumb characteristics were significantly improved in doughs with rapid increase of curve slope and higher area under the curve. Even if slow, prolonged rise of curve slope positively decreased rice crumb hardness and chewiness, the other crumb characteristics (springiness, cohesiveness, resilience and porosity) were significantly weaker than in wheat and buckwheat crumb.

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