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EFFECTS OF STARCHY AND β-GLUCAN ADDITIVES ON FLOUR, DOUGH, AND BREAD PARAMETERS

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Composite flours were formulated from wheat flour and additives containing high amylose starch, resistant starches of RS_2 and RS_3 types, and barley β-glucan. Different parameters of flours, doughs, and final breads were evaluated. Almost all composite flours had significantly worse parameters as flour and dough in comparison to control. Sensory parameters of breads were also lower, though loaves supplemented with up to 15% (w/w) of high amylose starch (Hylon® VII), RS_2 (Hi-maize™ 260), and RS_3 (Novelose® 330) were considered as acceptable, with higher content of RS observed. Loaves with β-glucan (Barliv™ barley betafiber) were not acceptable either in sensory or technological parameters.

Keywords: wheat, flour, dough, bread, resistant starch, β-D-glucan, functional food

Both the sufficiency and quality of food influence the physiological state of the consumer. A relevant trend is the supplementation of foods with compounds uncovered by the daily nutrition and the production of functional foods. Foods are functional when it is possible to evidently demonstrate their beneficial effect in amounts normally consumable in the daily diet. From practical point of view, the functional food could be food with compounds added or replaced to achieve the benefit. Food additives usually change technological parameters, content of nutrients, and final product traits; in wheat it is gluten quality, rheological parameters, and bread acceptability. Attractive additives from nutritional point of view are resistant starches (RS) and β-glucans (BG). RSs are resistant to absorption in the small intestine and provide substrate for microbial fermentation in the large intestine resulting in beneficial short-chain fatty acids. Englyst and co-workers (1992) described RS_1 (unavailable for enzymatic degradation in gastrointestinal tract), RS_2 (naturally resistant to degradation), RS_3 (created by hydrothermal processing), and RS_4 (chemically modified). β-glucan affects human body as an activator of immune processes (Estrada et al., 1997) or an agent reducing the risk of cardio-vascular diseases and gastrointestinal problems (Mälkki & Virtanen, 2001; Keogh et al., 2003).

Different additives supplied to basic wheat flour essentially influence parameters of flour, dough, and the final product. Therefore, the aim of this study was to evaluate the effect of different additives (high amylose starch and resistant starches from maize, barley β-glucan) on parameters of composite flours, dough, and bread.

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1. Materials and methods

The basic component of experimental flours was soft bread wheat flour (type T 650 from the mill Penam a. s., Trnava, Slovakia) containing proteins 11.3%, carbohydrates 73.3%, lipids 1.5%, ash ≤0.78% with wet gluten ≥26% and falling number ≥170 s. Commercial additives were resistant starches Hi-maize™ 260 (RS_2) and Novelose® 330 (RS_3), high amylose (min. 68%) maize starch Hylon® VII (all from National Starch & Chemical Co., Bridgewater, USA), and Barliv™ barley betafiber (concentrated barley β-glucan) (Cargill Inc., Minneapolis, USA). The weight ratios (w/w) of additives in composite flours were 5–20%.

Wet gluten content and gluten swelling (STN, 1988), total ash (STN ISO, 2006a), Zeleny's sedimentation index (STN ISO, 2000), falling number (STN ISO, 2006b), farinographic parameters (ICC, 1992), and final bread, made from flour 250 g, yeasts 12.5 g, sugar 2.5 g, salt 3.75 g, fat 2.5 g, and water, were evaluated. Flour and dough were blended (mixer RM 800 A-B, RM Gastro s.r.o., Veselí n. L., Czech Republic), fermented for 20 min at 32±1 °C, rolled, leavened for 10 min, left rising for 25 min at 32±1 °C, and baked for 20 min at 230 °C (Domino modular oven, Marton, Slovakia). Loaves were evaluated for specific loaf volume and weight. Sensory parameters of breads, crust (colour, thickness, and firmness), crumb (colour, hardness, size, and uniformity of crumb porosity), aroma, and taste were evaluated 2 h after baking by the 5-point hedonic scale (Pokorný, 1997) by seven educated panellists. The moisture content on the 1st and 2nd d after baking was evaluated according to STN (1990) after pre-drying up to 45 °C, melting, and drying at 130 °C for 60 min. The total, soluble, and resistant starch, and β-glucan content were determined by kits K-TSTA, K-RSTAR, K-BGLU (Megazyme Int. Ireland Ltd., Wicklow, Ireland) based on relevant official methods A.A.C.C. (2000; 2002; 2003), A.O.A.C. (1995; 1996; 2002), and ICC Standard (1998), respectively.

Data were evaluated by analysis of variance (ANOVA), multiple comparisons by LSD test by software Statgraphic Plus 7.0. Superscripts used in tables and figures mean statistically significant differences ($P<0.05$).

2. Results and discussion

2.1. Qualitative parameters of composite flours

Additions of Hylon® VII (HAS), Hi-maize™ 260 (RS_2), Novelose® 330 (RS_3), and Barliv™ barley betafiber (BG) changed the basic parameters of flours. The total ash content significantly decreased with the increased ratio of HAS and both RSs and increased with the increased ratio of BG in the flour reflecting content of incombustible compounds supplied by the additives. All agents significantly decreased wet gluten content as a consequence of the dilution of glutinous proteins, though not below 25 ml in case of either starchy agent. BG affected the wet gluten content more negatively and in flours with ≥15% of BG gluten was not possible to be determined. The gluten swelling significantly decreased at the addition of 20% of RS_3 and at all ratios of RS_2. Only ≥15% of HAS increased gluten swelling significantly. BG decreased gluten swelling and at ≥15% this parameter was not possible to be determined. The reason could be the change of the viscoelastic structure of gluten to a gel-like state due to the presence of β-glucan (Irakli et al., 2004). RS_3 significantly increased the sedimentation index. RS_2 significantly and HAS linearly decreased the sedimentation index, though neither decreased its value below 22 ml (minimal value required by norm STN, 2003). Low concentration (5%) of BG increased the sedimentation index, but higher (15–20%) concentration decreased its value below 22 ml. Composite flours with all added agents had significantly lower falling number then basic wheat flour. Addition of 20% RS_2 decreased falling number under the critical value (220 s, STN 46 1100-2., 2003). All ratios of BG affected the falling number very negatively (≥10% below 220 s).

2.2. Rheological parameters

Increased ratios of all additives increased water absorption related to the high water binding capacity of non-starch polysaccharides (Skendi et al., 2010), similarly to fibres due to the high number of hydroxyl-groups in their structure (Wang et al., 2002).

The dough development time and dough stability were reduced by all added starchy agents. The addition of 20% RS_2 and ≥15% HAS had the highest negative effect on dough stability as a consequence of the dilution effect of gluten-creating proteins and the weakening of gluten structure. On the contrary, addition of BG significantly increased dough development time and decreased dough stability in comparison to control. Skendi and co-workers (2010) published that addition of β-glucan to weak wheat flour increased development time and improved dough stability, but in strong flour both parameters were increased. Mohamed and co-workers (2005) mentioned that increasing of β-glucan content did not significantly reduce dough stability. The difference could be explained by different origin, molecular weight, solubility, and concentration of β-glucan, and also by the different origin (cultivar) and type of basic wheat flour. The dough softening parameters generally increased with the addition of HAS, RS, and BG. The higher was their amount the higher were the dough softening parameters. The effect of RS_2 was higher than that of RS_3. The farinograph quality numbers were lower at all ratios of added HAS and RS and also at ≥10% of BG than those of the control. Rheological evaluation confirmed the behaviour of non-interacting polysaccharides and the transition of dough properties from the desired viscoelastic to gel-like structure.

2.3. Bread quality parameters

The weight of loaves with added HAS, RS, and BG were statistically significantly higher than the control due to higher dough water absorption. The specific volumes of loaves in all samples were lower than in control, the lowest with the addition of HAS, the highest with the addition of ≥10% of RS_3. Loaf volume reduction was expected as amylolytic enzymes cannot digest RS to sugars available for fermentation and CO_2 production. Addition of BG had the strongest negative effect on weight and volume and loaves with ≥10% of BG were non-acceptable. Jacobs and co-workers (2008) reported that 1% of β-glucan in wheat flour reduced loaf volume by 15%. Each percentage of added BG in our study reduced loaf volume by ≈3.5%.

All breads containing HAS, RS, and BG had higher water content in crumb on the 1st and 2nd day after baking in comparison to control. Water loss from the 1st to 2nd d was 4.0% in the control bread, 1.0–2.6% in breads with HAS, 0.0–4.0% with RS_2, and 1.4–4.1% with RS_3. Lower water loss resulted in finer bread crust. Breads with HAS and low amounts of RS and BG maintained water better than control wheat bread and were fresh for a longer time.

The sensory evaluation revealed that additions of HAS and RS influenced crust and crumb colour. The higher the ratios of HAS or RS the brighter both crust and crumb were. At ≥15% of HAS or RS crumbs were less elastic, tougher, more sticky, the taste and aroma also changed. Significant differences were in the sensory evaluation of breads supplemented with ≥15% of RS_3, 20% of RS_2, and with all ratios of BG. All were less accepted by panellists, but they expressed that bread containing RS_3 up to 15% were very tasty. Addition of 5% of HAS decreased sensory parameters only slightly, higher ratios did not change sensory quality, nevertheless breads with ≥15% of HAS were less tasty. SANZ and co-workers (2009) performed similar experiment with RS_2 and RS_3 in muffins, where RS_3 had higher impact on the texture, and muffins were less accepted, but RS_2 supplementation did not cause significant differences in the acceptability of the muffins. ÖZTURK and co-workers (2009) tested the addition of three agents containing RS_3 and found that loaf volume was reduced less significantly by Novelose® 330, and the RS_3 agents had no negative influence on crumb colour and bread appearance.

None of the loaves with BG were accepted by panellists due to sticky crumb, taste, and appearance. Limited potential of β-glucan extract supplemented into wheat bread has been reported by HAGER and co-workers (2011). However, β-glucan added to composite flour in its natural form could have different effect than as extract or commercial agent. KNUCKLES and co-workers (1997) evaluated sensory characteristics of wheat pasta and bread supplemented with fractions of barley flour fortified with β-glucan in different ratios. The supplementation increased water absorption, dough development and blending time, however, breads with ≤20% of barley flour with β-glucan were acceptable for consuming.

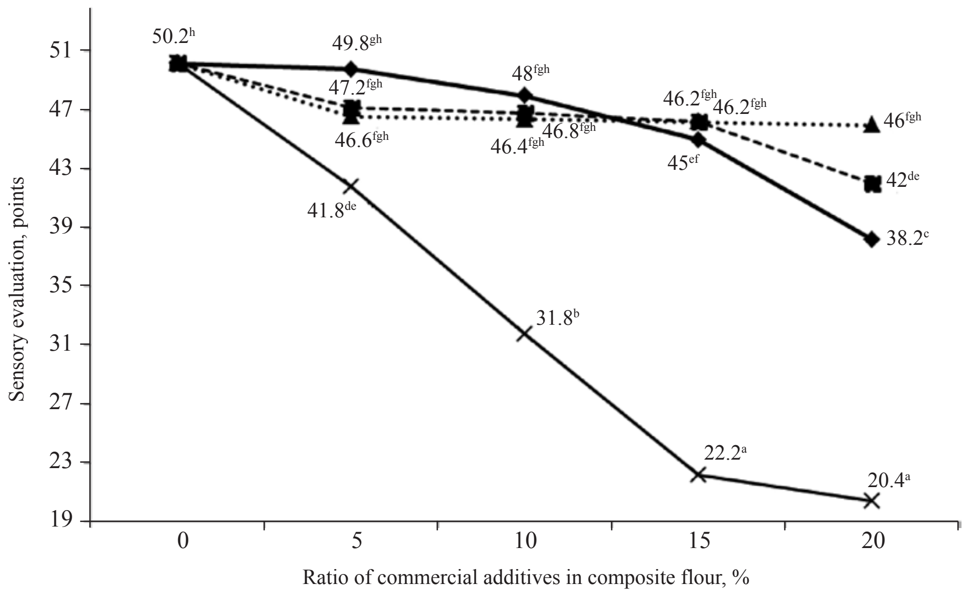

Fig. 1. Sensory parameters of breads baked from composite flours supplemented with agents containing HAS, RS, and BG. ▲: Hylon VII; ■: Hi-maize 260; ◆: Novelose 330; ×: Barliv barley betafiber

2.4. Total, soluble, and resistant starch and β-glucan content in breads

Contents of resistant, soluble, and total starch in flours and breads are shown in Tables 1 and 2. The RS content was significantly increased in flours and breads by the addition of starchy agents. The highest RS contents were in flours supplemented with HAS but the baking process reduced it in the breads. The addition of RS_2 and RS_3 increased the RS content in flour, which was enhanced by the baking process. The supplementation with RS_3 increased the content of RS in bread more than 5 times compared to flour. Similar trend was detected by Hung and co-workers (2005) at the addition of high amylose wheat flour. The content of RS in foods was generally in range 0–4%. Breads non-supplemented with RS contain 1–2.5% of RS (Tas & El, 2000) but daily intake of RS should be ≥17 g (Landon, 2007). This relates to 200 g of bread with added 15% of Novelose® 330 in our study.

Soluble starch content decreased with the addition of HAS, RS_2, and RS_3 in flours and more or less also in breads. The total starch content in flours and breads increased ambiguously with the supplementation.

The content of β-glucan in flours after addition of BG was in the range of 4.6–13.5% (Table 3) and in baked breads decreased only slightly due to hydrolysis or reduction of some dietary fibre by the high temperature during baking. Consumption of ß-glucan reducing total blood cholesterol should be ≥3 g daily (FDA, 1997). The β-glucan content in regular wheat bread is about 1.4% in dry bread weight or 0.63% in fresh bread (Hager et al., 2011). Approximately 100 g of bread made in our study with the addition of 5% of BG to basic wheat flour contains three grams of ß-glucan.

Table 1. Content of resistant, soluble, and total starch in flours

Flours	Resistant starch (%)		Soluble starch (%)		Total starch (%)	
	x	SD	x	SD	x	SD
Control wheat flour	0.39	± 0.00[a]	73.44	± 0.22[g]	73.83	± 0.22[ab]
5% Novelose® 330	2.66	± 0.01[b]	70.57	± 0.13[ef]	73.23	± 0.13[a]
10% Novelose® 330	4.84	± 0.04[d]	70.41	± 0.36[de]	75.25	± 0.34[bcd]
15% Novelose® 330	7.19	± 0.14[e]	68.06	± 0.25[b]	75.25	± 0.16[bcd]
20% Novelose® 330	9.06	± 0.12[f]	68.24	± 0.36[b]	77.30	± 0.44[f]
5% Hi-maize™ 260	2.68	± 0.09[b]	72.55	± 0.80[g]	75.23	± 0.87[bc]
10% Hi-maize™ 260	5.19	± 0.15[d]	71.50	± 0.65[f]	76.68	± 0.77[def]
15% Hi-maize™ 260	7.53	± 0.02[e]	69.45	± 0.04[cd]	76.97	± 0.06[ef]
20% Hi-maize™ 260	8.58	± 0.13[f]	67.80	± 0.75[b]	76.38	± 0.88[cdef]
5% Hylon® VII	3.67	± 0.14[c]	69.88	± 0.88[de]	73.55	± 0.82[a]
10% Hylon® VII	7.18	± 0.19[e]	68.44	± 0.22[bc]	75.62	± 0.38[cde]
15% Hylon® VII	11.05	± 0.09[g]	68.16	± 0.00[b]	79.21	± 0.09[g]
20% Hylon® VII	13.54	± 0.42[h]	62.54	± 0.80[a]	76.07	± 0.72[cdef]

Superscripts represent statistically significant differences at $P<0.05$.

3. Conclusions

Analysed qualitative parameters of flour, rheological parameters of dough, quality parameters of bread, contents of total, soluble, and resistant starch and β-glucan were influenced by the addition of commercial agents containing high amylose starch, resistant starches, and barley

Table 2. Content of resistant, soluble, and total starch in baked breads

Samples	Resistant starch (%)	Soluble starch (%)	Total starch (%)
	x SD	x SD	x SD
Control wheat flour	2.07 ± 0.03[a]	69.67 ± 0.19[i]	71.74 ± 0.17[bc]
5% Novelose® 330	4.53 ± 0.02[d]	67.09 ± 0.19[fg]	71.62 ± 0.17[b]
10% Novelose® 330	6.60 ± 0.07[g]	65.48 ± 0.25[c]	72.08 ± 0.28[bc]
15% Novelose® 330	8.75 ± 0.29[i]	66.36 ± 0.20[def]	75.11 ± 0.46[e]
20% Novelose® 330	10.81 ± 0.16[l]	61.75 ± 0.45[a]	72.56 ± 0.28[c]
5% Hi-maize™ 260	3.95 ± 0.03[c]	66.26 ± 0.09[cde]	70.21 ± 0.06[a]
10% Hi-maize™ 260	5.95 ± 0.04[f]	65.85 ± 0.42[cd]	71.80 ± 0.41[bc]
15% Hi-maize™ 260	8.00 ± 0.04[i]	68.01 ± 0.19[h]	76.01 ± 0.23[ef]
20% Hi-maize™ 260	9.53 ± 0.11[k]	64.01 ± 0.36[b]	73.53 ± 0.46[d]
5% Hylon® VII	3.58 ± 0.05[b]	67.04 ± 0.45[efg]	70.62 ± 0.50[a]
10% Hylon® VII	5.02 ± 0.05[e]	67.34 ± 0.42[gh]	72.37 ± 0.47[bc]
15% Hylon® VII	7.33 ± 0.08[h]	69.13 ± 0.16[i]	76.46 ± 0.14[f]
20% Hylon® VII	7.83 ± 0.02[i]	67.44 ± 0.82[gh]	75.27 ± 0.84[e]

Superscripts represent statistically significant differences at $P<0.05$

Table 3. Content of β-glucan in flours and baked breads

Samples	β-glucan in flours (%)	β-glucan in loaves (%)
	x SD	x SD
Control wheat flour	0.61 ± 0.02[a]	0.26 ± 0.03[a]
5% Barliv™ barley betafiber	4.60 ± 0.02[b]	3.99 ± 0.07[b]
10% Barliv™ barley betafiber	8.40 ± 0,04[c]	7.86 ± 0.35[c]
15% Barliv™ barley betafiber	11.26 ± 0.03[d]	10.20 ± 0.00[d]
20% Barliv™ barley betafiber	13.52 ± 0.04[e]	-

Superscripts represent statistically significant differences at $P<0.05$

β-glucan. Composite flours with added starchy agents up to 15% (w/w) satisfied the quality required for bakery utilization and were accepted by sensory evaluation. Higher ratios reduced gluten quality, sedimentation index, or falling number. Addition of barley β-glucan decreased all parameters even at a low ratio (5%). Higher ratio was not acceptable from technology or sensory points of view. All starchy and β-glucan agents increased water absorption of dough, reduced dough stability, consequently significantly increased weight and reduced volume of loaves, but water retention in bread crumb was higher. The highest content of RS in final bread was in loaves with added RS_3 (Novelose® 330). According to our study, the daily intake of RS could be provided by the consumption of 200 g of bread with

15% of Novelose® 330. Suggested daily intake of ß-glucan needed for serious clinical reduction of total blood cholesterol could be received by the consumption of 100 g of bread with 5% of Barliv™ barley betafiber, if the technological and sensory parameters are overlooked.

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