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Properties of Cereal β-D-Glucan Hydrocolloids and their Effect on Bread and Ketchup Parameters

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Microbiological and sensory evaluations of bread and ketchup supplemented with β-D-glucan hydrogels isolated from wheat, oat, barley, and rye were carried out. Adding hydrocolloids did not affect sensory parameters of bread negatively; moreover rye and oat β-D-glucans improved the total tastiness of bread. Water activity values in fortified breads showed β-D-glucans, except isolated from oat, as elements moderately increasing this parameter and subsequently increasing also bread freshness during the storage. All β-D-glucans resulted in softening the acidic taste of ketchup and did not negatively influence the total tastiness. Quality of fortified fresh tomato ketchups and stored for 180 days, were also not negatively influenced by the addition of hydrocolloids. Therefore, cereal hydrocolloids could be very perspective in the further exploitation in preparing new health-beneficial foods.

INTRODUCTION

Consumers are increasingly interested in buying products considered as healthier. Preferred and popular are foods with higher concentrations of complex saccharides and fibre [AACC, 2001]. Cereal β-D-glucans with glucose units linked by both β-(1→3) and β-(1→4)-linkages are known as valuable substances with functional and nutritive properties and due to their physical and physiological properties, they are of commercial importance [reviewed by Vasanthan & Temelli, 2008; Havrlentová *et al*., 2011]. Endosperm cell walls and sub-aleurone layers of cereals grains, especially those of barley and oat are good natural sources of β-D-glucans [Havrlentová & Kraic, 2006].

The effects of β-D-glucans on humans are varied. They are potent inducers of humoral and cell-mediated immunity [Estrada *et al*., 1997], important agents affecting some blood biochemical parameters, particularly decreasing total and LDL-cholesterol [Kerckhoffs *et al*., 2003; Cui & Wang, 2009], reducing the risk of cardiovascular diseases [Liu *et al*., 2002], and modulating glycaemic control [Nazare *et al*., 2009]. β-D-glucan is also a dietary constituent with well-documented effects on increasing satiety, thus helping to provide a feeling of fullness that may play a role in the control of energy balance [Howarth *et al*., 2001; Burton-Freeman, 2000; Khoury *et al*., 2012]. On the other hand, in a work by Vitaglione *et al*. [2010], eating midmorning barley β-D-glucan-enriched snacks did not modify food intake in the short term. Furthermore, β-D-glucans have antibacterial activity [Yun *et al*., 2003] and functions improving probiotic viability in yogurts [Vasiljevic *et al*., 2007]. This polysaccharide is also described as an agent to prevent colonic diseases, ulcerative colitis, and colon cancer [Nilsson *et al*., 2008].

Biological effects as well as physical and chemical properties of β-D-glucans, especially the solubility and ability to bind to cell receptors [Johansson *et al*., 2004; Tiwari & Cummins, 2009], depend on chemical conformation of the polysaccharide. Viscosity, one of the most important properties of the fibre [Mälkki, 2004], is influenced by solubility and molecular weight [AACC, 2001; Wood, 2004; Khoury *et al*., 2012]. The water-solubility depends particularly on the structure associated with the origin of the β-D-glucans. It decreases in main cereals in the order: oats > barley > wheat [Gajdošová *et al*., 2007].

Cereal grains as available sources of β-D-glucans are suitable for food supplementation and functional food development [Inglett *et al*., 2005; Ehrenbergerová *et al*., 2008]. β-D-glucans, especially in hydrocolloid form [Lazaridou *et al*., 2004; Lee *et al*., 2009], improve rheological properties of dough [Butt *et al*., 2008]. Their addition to food increases sensory as well as nutritional value, improves quality and stability during storage [Lyly *et al*., 2004; Skendi *et al*., 2010]. β-D-glucans have been tested as a thickening agent to modify

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texture and appearance in sauces, salad dressings, cakes, and ice creams [Soukoulis *et al*., 2009; Kalinga & Mishra, 2009; Lee *et al*., 2009] in development of low calorific foods [Inglett, 1990; Khoury *et al*., 2012]. They are used as an agent influencing nutritional quality of beverages, soups, oat flakes, oat milk, puddings, yoghurts, and biscuits [Lyly *et al*., 2003, 2004; Gormley & Morrissey, 1993; Hozová *et al*., 2004; Sudha *et al*., 2007; Müller *et al*., 1995; Kovacs, 1989].

The aim of this study was to evaluate i) microbiological parameters of the β-D-glucan hydrocolloids isolated from oats, barley, wheat, and rye, and to estimate ii) qualitative and sensory characteristics of bread and ketchup fortified with β-D-glucan hydrocolloids.

MATERIAL AND METHODS

Materials

The β-D-glucan hydrocolloids were isolated from oat (cultivar Kanton), barley (cultivar Oriflame), wheat (cultivar Yavaros-Tall), and rye (cultivar Daňkovské Nové). Mature seeds were obtained from the Gene Bank of the Slovak Republic of the Plant Production Research Centre Piešťany, Slovak Republic. Hydrocolloids were prepared according to the patent No 276 192 of Kuniak *et al*. [1992]. Concentrations of β-D-glucans in extracts were up to 2%. Hydrocolloids were double sterilized at 100°C and stored in the dark at 8±2°C.

Methods

Total number of microorganisms in functional foods as well as β-D-glucan hydrocolloids performed before bread and ketchup fortification was determined by plate counting method on glucose-yeast agar [STN ISO 4833], coliform bacteria on VRBL agar [STN ISO 4832], and yeasts and moulds on chloramphenicol glucose yeast agar [STN ISO 7954]. All agar types used were manufactured by Imuna Pharm JSC (Šarišské Michaľany, Slovakia).

Wheat breads were prepared from white bread wheat flour, salt, yeast, and water. Experimental breads without (control sample) and with β-D-glucans were prepared according to recipe (Table 1) using the mixing device Diosna SP12 (Germany) and the oven Miwe Signo (Germany). The 2% β-D-glucan hydrocolloids were added to the dough before mixing in a concentration of 50 mL per 1 kg of flour.

Ketchup was made from tomato purée, glucose syrup, vinegar, salt, aroma, starch, thickening agent, and water according to recipe (Table 2) by Kolagrex Int. Ltd., Kolárovo, Slovakia. Ketchup was prepared from tomato purée aseptically bottled in 200 kg batches, using stainless steel tanks for the processing. β-D-glucans fortification was carried out directly during the production process, in hot ketchup right up to packaging and bottling. The amount of β-D-glucan hydrocolloids (3 mL per 300 g of the food product) was calculated according to a recommended daily intake of β-D-glucans. Samples without the hydrocolloids addition were marked as a control.

The recommended daily intake of β-D-glucans in food products to fulfil health beneficial effects is stated in the range of 1.1-7.6 g and with a mean intake period of 5.5 weeks to decrease total blood cholesterol level and to reduce the risk of coronary heart disease [EFSA, 2010]. In bakery products with ≥3g/100g of β-D-glucans of oat grain fibre, the polysaccharide can stabilise sugar metabolism [EFSA, 2011]. In our research, the amount of β-D-glucans from cereal sources higher than 3 g/100 g was considered in breads and by assuming

TABLE 1. Formula for preparation of breads supplemented with insoluble β-D-glucans isolated from wheat, rye, barley, and oats.

Raw materials for 1 kg of dough			Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Wheat flour (g)			1 000	1 000	1 000	1 000	1 000
Salt (g)			16	16	16	16	16
Fresh active yeast (g)			20	20	20	20	20
Instant dried yeast (g)			30	30	30	30	30
Water (g)			550	550	550	550	550
β-D-glucan hydrocolloids (ml)			50	50	50	50	-
Conditions of preparation dough	Time to mastication (min)	slowly	6	6	6	6	6
		quickly	2	2	2	2	2
	Dough temperature (°C)		31.2	31.5	31.0	31.2	31.2
	Time to proofing dough (min)		50	50	52	50	50
Conditions of baking	Time of baking (min)		35	35	35	35	35
	Temperature (°C)	own	200	200	200	200	200
		bread	250	250	250	250	250
	Weight (g)	raw piece	600	600	600	600	600
		finished product	520	520	520	520	520

No. 1: wheat bread + wheat β-D-glucan hydrocolloid, No. 2: wheat bread + rye β-D-glucan hydrocolloid, No. 3: wheat bread + barley β-D-glucan hydrocolloid, No. 4: wheat bread + oats β-D-glucan hydrocolloid, No. 5: wheat bread (control sample). Concentration of β-D-glucans in breads balanced up to 100 mL.

TABLE 2. Formula for preparation tomato ketchup supplemented with insoluble β-D-glucans isolated from wheat, rye, barley, and oats.

Used raw material			Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Tomato purée 36-38 °Rf (%)			19	19	19	19	19
Glucosic syrup (%)			19.5	19.5	19.5	19.5	19.5
Vinegar (18%) (%)			1.4	1.4	1.4	1.4	1.4
Salt (%)			2	2	2	2	2
Aroma (%)			0.15	0.15	0.15	0.15	0.15
Starch (%)			2.5	2.5	2.5	2.5	2.5
Thickening (%)			0.03	0.03	0.03	0.03	0.03
Water (%)			55.4	55.4	55.4	55.4	55.4
β-D-glucan hydrocolloids (mL)			3	3	3	3	-
Condition to tanking	Temperature (°C)	Bottle	90	90	90	90	90
		ketchup	92	92	92	92	92
	pH		3.8 – 4.2	3.8 – 4.2	3.8 – 4.2	3.8 – 4.2	3.8 – 4.2

No. 1: ketchup + wheat β-D-glucan hydrocolloids, No. 2: ketchup + rye β-D-glucan hydrocolloids, No. 3: ketchup + barley β-D-glucan hydrocolloids, No. 4: ketchup + oats β-D-glucan hydrocolloids, No. 5: ketchup (control sample). Concentration of β-D-glucan in extracts balanced up to 6 mL.

a minimum of two pieces of bread (approximately 150 g) consumed by a person per day, the recommended daily intake is ingested.

The sensory evaluations of final wheat breads and tomato ketchups were accomplished by a five (Table 3) and four point (Table 4) hedonic scale, respectively, and for both food products were validated. Evaluations were generated by a panel of ten certified referees; young women in the age of 24-30 years of normal weight and with a university education. Sensory evaluations were carried out in a way that the highest grade in the evaluation corresponded with the fulfilment of all demands for organoleptic properties and the lowest grade (null) corresponded with major qualitative deficiencies. The total tastiness (%) of bread and ketchup, respectively, were evaluated graphically by means of a 100 mm unstructured line segment where average values of all analysed parameters for

TABLE 3. Scale of the sensory scoring evaluation of bread with β-glucans.

Parameter	Score scale	Score description	Parameter	Score scale	Score description
Form of product	4	good domed	Colour of crumb	4	typical
	3	moderately domed		3	soft tone
	2	soft domed		2	darker tone
	1	irregular		1	darkness
	0	spread, cracks		0	dark
Colour of crust	4	typical	Pliancy of crumb	4	very good, soft
	3	darker / lighter		3	soft
	2	dark / light		2	sufficient
	1	very dark / very light		1	low
	0	scorched		0	crumbly
Thickness / firmness of crust	4	semi-coarse / semi-hard board	Taste of crust / crumb	4	very tastefulness
	3	coarse / hard		3	less distinct
	2	thin / soft		2	un-savorous
	1	very thin / very soft		1	acid
	0	inconvenient		0	foreign
Aroma of crust / crumb	4	savorous, typical	Firmness of crumb	4	very soft
	3	less distinct		3	softer
	2	few distinct		2	medium hard
	1	unsavorous		1	harder
	0	foreign		0	hard
Porosity of crumb	4	uniform, fine walls, medium pores	Tackiness of crumb (to palate during long mastication)	4	very few adhesive, easy separate
	3	less uniform, soft walls, medium pores		3	few adhesive, separate
	2	non-uniform, ruder walls, small void		2	medium adhesive
	1	crumbly, dense pores		1	adhesive
	0	Smear, divided of crumbs		0	unacceptable
Total tastiness unacceptable very tasty, excellent			Total tastiness unacceptable very tasty, excellent		

TABLE 4. Scale of the sensory scoring evaluation of tomato ketchup with β-glucans.

Parameter	Score scale	Score description
Appearance and colour	3 2 1 0	typical, red brown-red brown foreign, undesirable
Aroma	3 2 1 0	savorous, typical in tomatoes less distinct unsavorous foreign, atypical
Consistence	3 2 1 0	semi-rigid, without particulate rigid without particulate semi-rigid, with particulate rigid with particulate
Taste	3 2 1 0	distinct, typical in tomatoes less distinct with cereal's starch odour dull with cereal's starch odour foreign, undesirable
Total tastiness unacceptable very tasty, excellent		

each sample were calculated to percentages; these values were marked on the line segment [Ingr *et al*., 2001]. Tests were carried out in a specialized laboratory at a temperature of 24°C.

Water activity (a_w) was measured in the bread crust 4 h after bread baking using AW Sprint TH500 (Pedak, Neythuysen, Netherlands) at laboratory temperature (24°C) in a dust free environment and determined by water adsorptive properties. The measurement was based on the balance of a_w of the sample and relative air humidity above the defined solutions over 24 h [Valík *et al*., 1990].

Statistical rheological parameters and sensory examinations were carried out using the SPSS for Windows (Release 11.5.1.) program. Sensory data were calculated using logarithmic transformation and were processed by using multifactorial (two- and three-way) analysis of variance.

RESULTS AND DISCUSSION

Bread

Organoleptic properties of fortified fresh breads were evaluated in the study (Table 5). Cereal β-D-glucans are useful substances in functional food preparation, especially in bakery, because of their excellent rheological properties [Butt *et al*., 2008]. Statistically significant differences in sensory evaluations were not confirmed between fortified breads and the wheat control (Table 6). Three parameters (form of product, colour of crust, and colour of crumb) had the same score ($p=1.000$) in all analysed types of bread. Differences ($p<0.069$) were observed in the aroma of crust. Control bread and bread fortified with barley β-D-glucans showed the best results (3.80) compared to other types of breads where scores for this parameter were lower (3.20 for wheat and oats β-D-glucans and 3.00 for rye). Only one statistically significant difference ($p<0.049$) was observed in firmness of crust. In comparison with other samples (the parameter was equal, 4.00), lower firmness of crust (3.60) was observed in sample No. 1 containing wheat β-D-glucans.

Substantial differences, not statistically significant, were recorded not only in aroma, particularly in the crust aroma, but also in aroma of bread crumb which evaluators considered to be less expressed in samples with the application of wheat, rye, and oat β-D-glucan hydrocolloids. Porosity of crumb was lower in all analysed bread samples fortified with cereal β-D-glucan hydrocolloids. Differences were also observed in the taste of bread crust. Firmness value in control samples was 3.80 with lower values (3.60) being recorded in those fortified with wheat, rye, and oat β-D-glucan hydrocolloids. On the other hand, a higher score for bread crust taste

TABLE 5. Sensory evaluation of breads supplemented with β-D-glucan hydrocolloids ($\bar{x}$, n=10).

Sensory parameter	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Form of product	4.00±0.00	4.00±0.00	4.00±0.00	4.00±0.00	4.00±0.00
Colour of crust	3.80±0.57	3.80±0.57	3.80±0.57	3.80±0.57	3.80±0.57
Thickness of crust	4.00±0.00	4.00±0.00	3.80±0.57	3.80±0.57	3.80±0.57
Firmness of crust	3.60±1.19	4.00±0.00	4.00±0.00	4.00±0.00	4.00±0.00
Aroma of crust	3.20±1.07	3.00±1.40	3.80±0.57	3.20±1.31	3.80±0.57
Aroma of crumb	3.60±1.47	3.60±1.47	4.00±0.00	3.80±0.57	4.00±0.00
Porosity of crumb	3.40±1.62	3.40±1.62	3.40±1.62	3.40±1.62	3.60±1.47
Colour of crumb	3.80±0.57	3.80±0.57	3.80±0.57	3.80±0.57	3.80±0.57
Pliancy of crumb	4.00±0.00	3.60±1.47	4.00±0.00	3.80±0.57	4.00±0.00
Taste of crust	3.60±1.47	3.60±1.47	4.00±0.00	3.60±1.47	3.80±0.57
Taste of crumb	3.80±0.57	3.40±1.62	3.60±1.47	3.60±1.47	4.00±0.00
Firmness of crumb	3.80±0.57	3.80±0.57	3.60±1.47	3.80±0.57	3.60±1.47
Tackiness of crumb (to palate during long mastication)	3.40±1.62	3.60±1.47	3.60±1.13	3.20±1.31	3.40±1.14

No. 1: wheat bread + wheat β-D-glucan hydrocolloids, No. 2: wheat bread + rye β-D-glucan hydrocolloids, No. 3: wheat bread + barley β-D-glucan hydrocolloids, No. 4: wheat bread + oats β-D-glucan hydrocolloids, No. 5: wheat bread (control sample). Concentration of β-D-glucans in breads balanced up to 100 mg.

TABLE 6. *P-Values* from analysis of variance for sensory evaluations of bread fortified with β-D-glucan hydrocolloids from different cereal sources.

Trait	*P-Value*
Form of product	1.000
Colour of crust	1.000
Thickness of crust	0.083
Firmness of crust	0.049
Aroma of crust	0.069
Aroma of crumb	0.277
Porosity of crumb	0.989
Colour of crumb	1.000
Pliancy of crumb	0.252
Taste of crust	0.322
Taste of crumb	0.469
Firmness of crumb	0.506
Tackiness of crumb	0.985

(4.00) was seen in the barley samples. In the taste of crumb, all samples with cereal β-D-glucans were worse compared to the control. Alternatively, in breads enriched with wheat, rye, and oat β-D-glucans, a higher level of firmness of crumb was shown in comparison with the control bread. Generally, it can be concluded that the lowest total tastiness was observed in bread with added wheat β-D-glucan (81.2%) compared to the control (90%) (Figure 1). On the other hand, the highest values in total tastiness were recorded in bread containing rye and oat β-D-glucans (95.2 and 91.4%, respectively).

Oat is a good source of β-D-glucan [Havrlentová & Kraic, 2006] with oat β-D-glucan usually exhibiting higher viscosity due to longer molecular chains [Beer *et al*., 1997; Gajdošová *et al*., 2007]. It is well documented in the literature that it is therefore more frequently used in the food industry [Lazaridou *et al*., 2004; Dongowski *et al*., 2005; Havrlentová *et al*., 2011]. In our study by preparation of bread enriched with cereal β-D-glucan, oat β-D-glucan was also deemed a good additive component with good sensory results. Hydrocolloids [Lazaridou *et al*., 2004; Lee *et al*., 2009] at a concentration

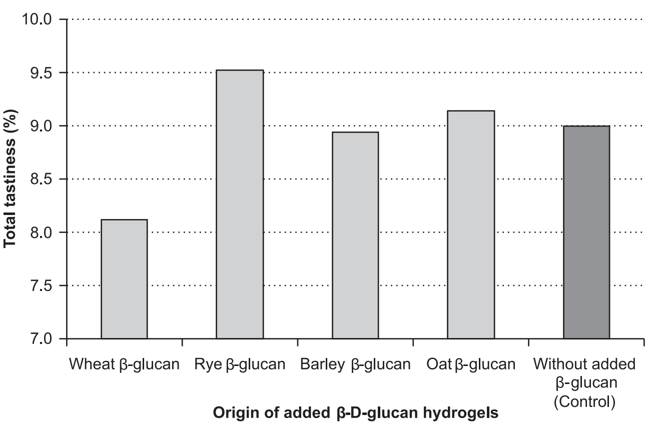

FIGURE 1. Total tastiness of wheat breads supplemented with β-D-glucan hydrocolloids extracted from different cereals.

of 2% were successfully used in our study and similar results were also reported by other authors [Lyly *et al*., 2004; Dongowski *et al*., 2005].

The other aim of this study was to analyse influence of different β-D-glucans on water activity (a_w) in breads. Water activity (a_w) values (n=3, a=0.05) were as follows: 0.917±0.003 (sample No. 1), 0.975±0.004 (No. 2), 0.967±0.003 (No. 3), 0.965±0.003 (No. 4), and 0.963±0.002 (No. 5). These values show that the addition of oat hydrocolloids moderately decreased the value of a_w by 0.046 whereas the remaining hydrocolloids increased a_w by 0.002-0.012 compared to the control. Molecular weight of cereal β-D-glucans influences the water activity in functional foods supplemented with this polysaccharide [Dongowski *et al*., 2005, Vasanthan & Temelli, 2008, Havrlentová *et al*., 2011]. This was well documented in the work of Skendi *et al*. [2010] where two different molecular weight barley β-glucan isolates were added to bread and water activity and other rheological properties of dough and bread characteristics were examined. Barley β-D-glucans addition affected flour, dough, and bread parameters [Skendi *et al*., 2010], which was also documented in our study by using different types of β-D-glucan hydrocolloids for the preparation of functional breads.

Ketchup

Microbiological analyses of the total number of coliform bacteria, yeasts, and moulds in β-D-glucan hydrocolloids confirmed the absence of microorganisms (<1 CFU/mL) and proved the microbiological safety of all the hydrocolloids used. The microbiological testing of tomato ketchup with added hydrocolloids after 180 days of storage at laboratory temperature (20 ± 2°C) confirmed that microorganisms were not present in any of the analysed samples and the addition of β-D-glucan hydrocolloids did not influence the microbiological sterility; neither immediately after producing nor after storage.

Organoleptic properties of β-D-glucan-enriched fresh and 180-days shelf-stored ketchups were determined. Results related to ketchup samples evaluated in two dates separately, on the day of production and 180 days after showed that the addition of β-D-glucans compared to control sample decreased the typical ketchup aroma and taste (Table 7). This phenomenon occurred in all used types of β-D-glucans in both monitored times. The addition of β-D-glucans did not affect the total tastiness of the ketchup significantly. However aroma of ketchup was significantly influenced by the addition of oat β-D-glucans, date of evaluation, and their interaction (Table 8).

Besides the microbiological purity of cereal β-D-glucans, good sensory characteristics in fortified bread and ketchup, softer ketchup texture, and pliant and tastier bread were revealed especially for β-D-glucans isolated from oat seeds. Analysing total tastiness in bread, it can be stated that this parameter increased in the order: wheat hydrocolloids < barley < control < oat < rye (Figure 1). In total tastiness of ketchup, the order was as follows: barley < wheat < rye < oat < control immediately after producing the fortified ketchup or rye < barley < wheat < oat < control after 180 days of storage, (Figure 2 and 3). In detail, in aroma of ketchup, the addition

TABLE 7. Sensory evaluation of tomato ketchup supplemented with β-D-glucan hydrocolloids immediately after producing and after 180 days storage ($\bar{x}$, n=10).

Sensory parameter	1st day					180th day				
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Appearance and colour	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
Aroma	2.00±1.79	2.67±0.99	2.67±0.99	2.83±0.53	3.00±0.00	2.80±0.45	2.80±0.45	2.80±0.45	2.80±0.45	3.00±0.00
Consistence	3.00±0.00	2.83±0.53	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
Taste	2.50±1.14	2.67±0.99	2.83±0.53	2.67±0.99	3.00±0.00	2.80±0.45	2.60±0.55	2.60±0.55	2.80±0.45	3.00±0.00

No. 1: ketchup + wheat β-D-glucan hydrocolloids, No. 2: ketchup + rye β-D-glucan hydrocolloids, No. 3: ketchup + barley β-D-glucan hydrocolloids, No. 4: ketchup + oats β-D-glucan hydrocolloids, No. 5: ketchup (control sample). Concentration of β-D-glucan in 300 g of tomato ketchup balanced up to 6 mL.

TABLE 8. MS values from analysis of variance for sensory parameters of ketchup fortified with β-D-glucan hydrocolloids from different cereal sources evaluated in two dates, right after producing (1st date) and after 180 days of storage (2nd date).

Source of variability	df	Aroma	Consistence	Taste
Date of evaluation (B)	1	0.378+	0.007	0.030
Ketchup (A)	4	0.314++	0.007	0.106
Evaluator (C)	9	0.068	0.003	0.063
A×B	4	0.238++	0.007	0.072
A×C	9	0.153+	0.003	0.102
B×C	36	0.051	0.002	0.060
Residual	36	0.056	0.003	0.057
Total	99			

+ $P < 0.05$, ++ $P < 0.01$

of oat β-D-glucan hydrocolloids immediately after production showed 2.83 points compared to 2.00-2.67 points in other used cereal hydrocolloids (Table 7). As well as taste, oat β-D-glucan hydrocolloids proved better results after 180 days storage compared to other added hydrocolloids (2.80 points compared to 2.60). Oat β-D-glucan can be identified in our study as the best positively influencing bread and ketchup sensory properties.

Through its structure and physical properties, oat β-D--glucan is often used in the food industry [Havrlentová *et al*., 2011; Gajdošová *et al*., 2007]. Oat gum (with β-D-glucan content of 65%, w/w) showed great potential as a gel-forming, thickening, and stabilizing agent [Ramos-Chavira *et al*., 2009]. Stabilizing ability was detected also in our study, where water activity was seen at approximately 0.917, *i.e.* less than in the control (0.963). In the literature, the presence of oat β-D-glucan concentrates resulted in low water activity and high stability in cereal bars [Gutkoski *et al*., 2007] and increased shelf-life with increased levels of β-D--glucans from barley and oat in cakes [Kalinga & Mishra, 2009] was observed.

The complex rheological behaviour of β-D-glucan concentrates isolated from cereals depends on the origin, technological pre-treatments, and concentration [Dongowski *et al*., 2005] and influences the effects in intestinal tract. The importance of food processing can alter postprandial glycaemic control. Good physicochemical properties (viscosity, optimum molecular weight) and concentration of β-D-glucan hydrocolloids remain in porridge or granola with added cereal β-D-glucans, whereas depolymerization in bread and pasta reduces β-D-glucan bioactivity [Regand *et al*., 2009].

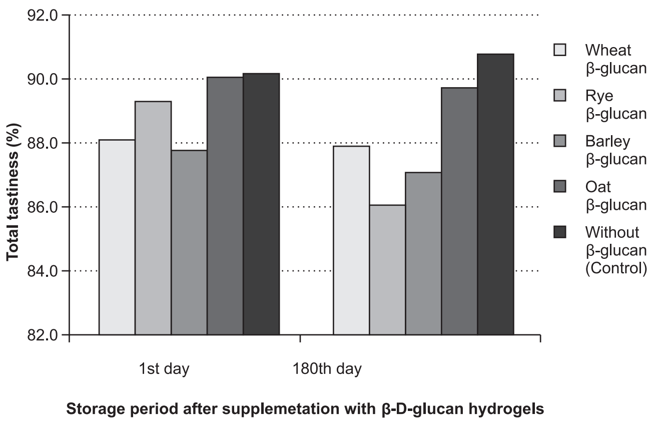

FIGURE 2. Total tastiness of ketchups supplemented with β-D-glucans extracted from different cereals added immediately after producing and after shelf-storage.

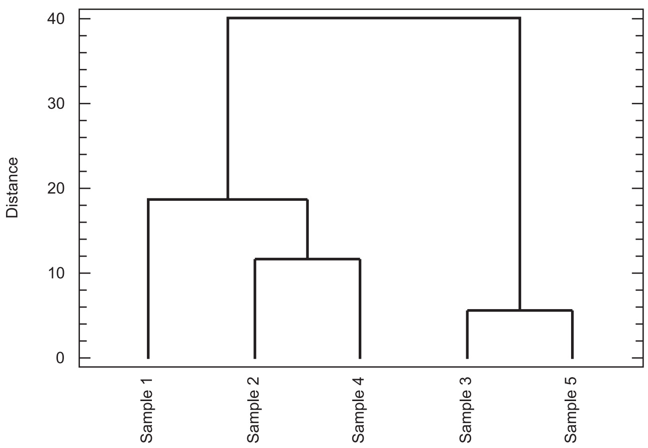

FIGURE 3. Statistical evaluation of similarities between groups of cereal-β-D-glucan-enriched foods (sample 1-4) and control (sample 5).

CONCLUSIONS

Our experiments revealed that there were no problems in microbiological parameters of isolated cereal β-D-glucan hydrocolloids. Addition of β-D-glucans especially originating from oat positively influenced sensory parameters of the bread crust and also contributed to softening of the acidic taste of ketchup. Fortification of bread and ketchup with β-D--glucan hydrocolloids can improve sensory parameters of both tested foods; consumption of these ingredients could supply compounds known as agents to prevent some of modern diseases associated with non-optimal nutritional status. Cereal β-D-glucan hydrocolloids could be exploited for a generation of new innovative products.

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