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Nutritional, Antioxidant and Sensory Characteristics of Bread Enriched with Wholemeal Flour from Slovakian Black Oat Varieties

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Abstract: This paper is a report on the nutritional composition (dry matter, total protein, fat, crude fibre, ash, β-glucan content, and selected mineral compounds), antioxidant (antioxidant activity with the DPPH method and total anthocyanin content), physical properties, and sensory profiles of prepared bread enriched with black oat flours (variety *Norik* and *Hucul*) in amounts of 3, 6, and 9%. In the enriched breads (especially with 9% addition), there was a significantly higher ($p < 0.05$) content of protein (~13.00%), fat (~1.35%), crude fibre (~0.55%), ash (~1.25%), and β-glucan (~0.17%) with comparison to the control bread (12.01%; 0.87%; 0.47%; 0.92%; 0.07%, respectively). Among mineral compounds, the amount of manganese (~73.00 mg/100 g), iron (~45.00 mg/100 g), and calcium (~40.00 mg/100 g) were the highest in enriched breads with 9% of oat flours. In the case of antioxidant potential and total anthocyanin content, the same tendency was observed, and the values obtained were the highest in the case of 9% addition, especially with the *Hucul* variety (1.98 mg TEAC/g; 21.01 µg/g). The sensory properties of the prepared enriched breads were overall evaluated as good with the best score in smell, taste, colour, and properties of bread crumb (soft and flexible) compared to the control sample. Consumption of enriched breads with black oat can also increase the assortment of bakery products in markets, which is now popular for consumers.

Keywords: bakery products; cereals; health benefits; mineral composition; anthocyanins

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1. Introduction

Bread is an essential food consumed globally and plays an important role in human nutrition [1]. The preparation of sourdough bread was already known to Egyptians in ancient times. The yeast in bread, pickled fruit, vegetables, beer, or ripening cheeses were some of the first processes associated with the use of microorganisms in the kitchen. Commercial use of yeast, or baker's yeast, only came with the advent of modern microbiology, and yeast in dried form has only been used since World War II. The ancient Egyptians discovered yeast by accident around 1200 BC. At that time, they baked unleavened bread from flour, water, and salt until they once left the dough in the sun, and it fermented because of bacteria and yeasts. Despite this, they tried to bake it and the result surprised them in the form of fluffy bread with a brown crust [2]. In recent years, it is very popular to consume sourdough bread, which can be related to the philosophy of the "return to traditional foods" lifestyle, whereas sourdough bread was prepared thousands of years ago as a daily product of our ancestors. Production of sourdough bread has been enormously successful in response to consumer demand for organic, tasty, and healthy foods. Fermentation technology has been shown to be perfect for upgrading the shelf life, texture, palatability, and nutritional values, especially of wheat and rye breads, and produce more aerated bread [3,4]. Yeast as an organic substance is activated during the mixing of flour with water, and this mixture is the basis of sourdough bread. It is created by a fermentation process in which flour and water interact actively. During this process in room temperature, enzymes begin to break down starch into simple carbohydrates, sucrose and maltose, which are necessary for bacteria and yeasts. Bacteria convert them into acids, lactic and acetic, which contribute to the typical bread smell and taste. Yeasts produce carbon dioxide, which creates a typical spongy structure in the dough [2]. The microorganisms can break down complex and more difficult-to-digest substances present in flour into simpler ones that our body can process and digest more easily. They reach our digestive system already partially digested by microorganisms in the sourdough and, therefore, are much easier for our body to digest, which is also the main positive of sourdough [5].

In recent years, many studies have been conducted to increase bread nutritional composition and explore the potential of adding flour and other ingredients rich in bioactive compounds to bread [6–8]. Oat (*Avena sativa* L.) is one of the most adventurous cereals in human diets and contains a variety of biological components—antioxidants, proteins, lipids, vitamins, mineral compounds, soluble fibre–β–D–glucan, and especially avenanthramides, a unique group of N-cinnamoylanthrannilic acid derivatives present in oats but not in other cereals [9–11]. A colour-coded diet, which is rich in natural dyes, is characterised by numerous health-promoting properties. Plant anthocyanins can act as antioxidants and help prevent civilisation diseases, inflammation, cancer, and aging. The colour in the cereal grains is localised in the bran layers. In many scientific publications, interesting genotypes of red, purple, blue, and amber grain seeds are reported. Based on the benefits of coloured cereals, functional foods are a potential to develop and use for health protection [12].

The aim of the present work is to determine the nutritional, antioxidant, physical, and sensory parameters of sourdough bread without and with the addition of 3%, 6%, and 9% flour from two Slovakian black oat varieties.

2. Materials and Methods

2.1. Materials

In this study, for the enrichment of sourdough bread, Slovakian black oat varieties *Norik* and *Hucul* were used, and both were purchased from the Research Institute of Plant Production (Piešťany, Slovakia). Before the bread procedure, the oat grains were milled to wholemeal flour using a laboratory mill, the Perten Mill 3100 (Springfield, Geneseo, IL, USA). Wheat flour T 650 and rye flour T 930 were obtained from the Kolárovo Mill a.s., Vitaflora (Kolárovo, Slovakia); salt was purchased from the local market.

2.2. Sourdough Making

The sourdough was developed using rye flour T 930 (100 g), which was mixed with water (90 mL) and spontaneously fermented at 25 °C for 7 days. Every day, the substrate was mixed with an alimentation of rye flour (20 g), and an adequate amount of water was added daily. After seven days of alimentation with rye flour, the sourdough was ready for using and stored at 5 °C.

2.3. Experimental Baking of Breads

The experimental baking was performed under laboratory conditions. Control bread was prepared using 100% wheat flour T 650, sourdough 4%, salt 1.8%, and water (by water absorption according to the farinograph results—water absorption 59.8%). The enriched bread was prepared the same way but with addition of 3, 6, and 9% of *Norik* wholemeal flour and with the addition of 3, 6, and 9% of *Hucul* wholemeal flour. All dough variants were mixed separately using a laboratory Diosna SP12 mixer (Osnabrück, Germany), using parameters described previously [13], placed in baking forms, and let to rise in an electronically controlled stage oven with a fermentation station (Miwe Condo, Arnstein, Germany) for 4 h at 30 °C. Then, each sample was baked by steaming for 10 min at an initial temperature of 240 °C, then for 25 min at a temperature of 220 °C.

2.4. Sample Preparation

For measurement of antioxidant activity and polyphenol contents, samples were extracted using 80% ethanol for 2 h (0.5 g of sample with 20 mL of ethanol solution), centrifuged at 4000× *g*, and decanted. In the case of the total anthocyanin content, 5 g of the sample was extracted with 10 mL of acidic ethanol (ethanol with 7% hydrochloric acid addition) until samples have been made completely colourless, and then they were filtered using a Whatman filter. All extractions were made in three independent repetitions.

2.5. Total Ash, Crude Protein Content, and Total Fat Determinations

The ash, dry matter, and crude protein content was determined following the AACC methods. Nitrogen content was measured by the semi-micro Kjeldahl method. Nitrogen was converted to protein using the conventional factor of 5.7.

The total fibre content was evaluated using an Ancom^{200} Fibre Analyzer (New York, NY, USA), strictly according to the producer's method.

The fat content was detected with the Ancom XT15 Fat Extractor (New York, NY, USA), according to the producer's instructions—the sample (1.5 g, $W1$) was weighted in a special filter bag (XT4, Ancom, New York, NY, USA) and dried for 3 h in an oven (WTB, Binder, Germany) at 105 °C to remove moisture prior to extraction. The samples were placed in a desiccant pouch for 15 min and after reweighted ($W2$) and extracted for 60 min at 90 °C with petroleum ether. After the process, the samples were removed and dried in an oven at 105 °C for 30 min, placed in a desiccant pouch, and reweighted ($W3$). The *Fat content* (%) was calculated using the following formula:

$$Fat\ content\ (\%) = \frac{W2 - W3}{W1} \times 100$$

2.6. Antioxidant Activity, Total Polyphenol, Anthocyanin and β-Glucan Contents

The free radical scavenging activity of the samples was measured using 2,2-difenyl-1-picrylhydrazyl (DPPH) according to the procedures described by Yen and Chen [14]. Results were expressed as mg Trolox equivalent antioxidant capacity per g of sample (mg TEAC/g).

The total polyphenol content was measured spectrophotometrically, using the modified Folin–Ciocalteu method described by Singleton et al. [15]. The total polyphenol content was expressed as mg gallic acid equivalent (GAE) per g of sample.

The anthocyanin content was measured according to the method of Fuleki and Francis [16] with modifications [17]. The concentration (mg/g) of total anthocyanins was calculated according to the following formula and expressed as the equivalent of cyanidin-3-glucoside (Cy-3-glc):

$$A\left(\frac{mg}{g}\right) = \frac{A \times M_w \times 1000}{\varepsilon \times L}$$

where A is the absorbance difference = $(A_{520} - A_{700})$pH 1.0 − $(A_{520} - A_{700})$pH 4.5; M_W is the molecular weight of Cy-3-glc = 449.2 g/mol; ε is the extinction coefficient of Cy-3-glc = 1700 cm/mol; L is the absorption; path length in cm = 1.

Total β-glucan content was evaluated using an enzymatic kit according to the manufacturer's instructions (Megazyme International Ireland Co., Ltd., Wicklow, Ireland). The absorbance was measured at 510 nm.

2.7. Mineral Compounds Composition

The number of mineral elements (Ca, Fe, K, Mg, P, Al, Cd, Cu, Cr, Mn, Mo, S. Se, Sr, Zn, and Pb) was analysed by the ICP-OES method (ICP-OES spectrophotometer, Thermo iCAP Dual 6500, Thermo Fisher Scientific, Waltham, MA, USA) described in detail previously [18].

2.8. Sensory Characteristics

The sensorial properties were tested by a panel of 30 trained panellists (in age 22 to 65; 15 women and 15 men). The breads were evaluated 12 h after baking. Panellists were asked to evaluate general appearance, surface, and properties of the bread crust, appearance of the crust, structure, and flexibility of breadcrumb, flavour, and taste. Ratings were made on a 5-point hedonic scale, where 5 means "I like very much" and 1 means "I dislike very much".

2.9. Statistical Analysis

The obtained results of the analyses (n = 3) were subjected to the analysis of variance (Duncan's test) at alpha = 0.05 using the SAS v9.2 software (SAS Institute Inc., Cary, NC, USA).

3. Results and Discussion

3.1. Total Ash, Crude Fibre and Protein, and Fat Content

The total content of ash in the prepared bread ranged from 0.92% to 1.27% (Table 1). The addition of black oat wholemeal flour caused the ash that had the highest values in the variant with 9% addition of both varieties. Oat grains contain a higher amount of phosphorus, iodine, selenium, iron, and magnesium compared to wheat and rye [19]. Black oat varieties compared to common yellow varieties contain a higher amount of ash content. These findings confirmed Gambuś et al. [20], who determined ash in yellow varieties in the amount of 3.35% and in black varieties of 3.66%. Our findings are comparable with the findings of Gambuś et al. [21]; these authors evaluated the ash content in bread prepared with 20% substitution of wheat flour with oat flour. The control sample had 0.87% ash, while bread with oat contained 1.62% of the total ash content. Similarly, in the study of El-Rashed et al. [22] on bread with 25% substitution of wheat flour with oat flour the amount of ash was higher (1.59%) compared to the control sample (0.78%). Chauhan et al. [23] confirmed that addition of oat flour to wheat bread can increase the ash content. In their study, the total content of ash ranged from 0.75% (control wheat bread) to 1.53% (bread with 25% oat flour).

Table 1. Nutritional parameters of the breads analysed.

Sample	Ash (%)	Crude Protein (%)	Crude Fibre (%)	Fat Content (%)
C	0.92 ± 0.02^{d}	12.01 ± 0.06^{d}	0.47 ± 0.03^{b}	0.87 ± 0.02^{f}
H3	0.97 ± 0.03^{d}	12.35 ± 0.01^{c}	0.54 ± 0.01^{a}	1.01 ± 0.01^{e}
H6	1.21 ± 0.06^{ab}	12.38 ± 0.04^{c}	0.55 ± 0.01^{a}	1.22 ± 0.02^{c}
H9	1.25 ± 0.01^{ab}	13.02 ± 0.99^{a}	0.56 ± 0.01^{a}	1.33 ± 0.05^{b}
N3	1.09 ± 0.01^{c}	12.41 ± 0.02^{c}	0.53 ± 0.01^{a}	1.12 ± 0.01^{d}
N6	1.18 ± 0.01^{bc}	12.67 ± 0.02^{b}	0.55 ± 0.01^{a}	1.29 ± 0.02^{b}
N9	1.27 ± 0.05^{a}	13.91 ± 0.12^{a}	0.56 ± 0.02^{a}	1.42 ± 0.01^{a}

The same letter in column means homogenous groups. C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

The total content of crude protein in the tested bread ranged from 12.01% to 13.91% (Table 1). The addition of wholemeal flour of black oat varieties positively influenced this parameter. Oat proteins have high nutritional value with good digestibility [24]. Oat proteins have a higher lysine amount and a lower glutelin and prolamin amount compared to other cereals, so oat proteins complement the human body's need for amino acids [25]. Ciesarová et al. [26] evaluated sourdough bread in which wheat flour was substituted with 30% of wholemeal flour from yellow oat. The crude protein content was in the amount of 13.3%. Gambuś et al. [20] determined (in bread enriched with 10% black oat) protein content at the level of 12.35%, which is comparable to our findings. However, the findings of El-Rashed et al. [22] showed that the content of crude proteins decreased slightly in bread enriched by oat (11.48) compared to the control sample (11.70%). The addition of 10% oat protein into wheat bread positively increases the amount of all essential amino acids with higher contents of leucine (0.96%) and tyrosine (0.43%) compared to the control sample (0.90% and 0.37%, respectively) [27].

The total fibre content in the bread tested ranged from 0.47–0.56% (Table 1). Crude fibre is the lignin and cellulose of the food. Crude fibre is important for the functions of the gut microbiota as an important moderator of positive effects: regulation of metabolic processes, appetite, and chronic inflammatory pathways [28]. Whole-grain oat flour also positively influenced this parameter, similarly to the ash and crude protein parameter. Gambuś et al. [20] confirmed that total fibre content in bread with 10% wholemeal oat flour is higher (5.95%) compared to the control sample (3.99%). Total dietary fibre in sourdough bread with 30% wholemeal flour from yellow oat was 10.15% in the study by Ciesarová et al. [26].

The fat content in the enriched breads was in the range of 0.87–1.42% (Table 1). Oat addition increases the content of fat, which is not surprising as oat is rich in fat compared to other cereals. The fat content in oat grain is two to three times higher than that of other cereals. In the world range of oats, the fat content varies between 3.1 and 11.6%. In oats, up to 80% of all fatty acids are unsaturated, making oats the most attractive cereal in terms of fat content and composition. Palmitic, oleic, and linoleic acids are the most abundant [29]. Linoleic acid can play a healthcare role in anti-inflammatory, anticancer, reduction in blood fat, and immunity enhancement, so the addition of oat to dairy products can be an effective tool for producing food with added health benefits [30]. The fat content was slightly higher in bread with the *Norik* variety. The increase in fat content in wheat bread with the addition of 10, 15, 20, and 25% oat flour confirmed Chauhan et al. [23]. The variant with 25% contained 5.85% fat.

3.2. Dry Matter Content and β-Glucan

The dry matter content in the prepared breads ranged from 90.15% to 90.66% (Table 2). Similar results were also determined in wheat bread with the addition of 5, 7, and 10% oat flour in the study by Gambuś et al. [20]. The addition of oat effectively increased the amount of β-glucan in the prepared bread. While the control bread contained 0.07%, in the variant with 9% of both black oat varieties, the content was 0.17% (Table 2). Oat fibre is a rich source of β-glucans (β-D-glucans), which have nutritional and palliative effects on the human body—hepatoprotective, immunostimulatory (activates macrophage immune cells), anti-inflammatory, antidiabetic, antimicrobial, and antifibrotic effects—and can also lower glucose and cholesterol levels. The molecular weight of the oat β-glucan is higher than that of barley. Its high viscosity, even at low concentrations (1%), is supposed to be able to delay gastric emptying and slow intestinal transit, and thus, delay sterols and glucose absorption, which may contribute to lower insulin levels and plasma glucose. Currently, its anticytotoxic, antitumour and antimutagenic effects have also been proven [31]. Temnikova [32] determined the content of β-glucan in wheat bread as a control sample and in bread with 3, 5, 7, 10, and 15% addition of oat flour. While in the control bread, the presence of β-glucan was not detected, the addition of oat effectively increased this parameter (0.3%, 0.5%, 0.6%, 0.9%, and 1.4% as the highest in the 15% addition). The same tendency was also detected in the study by Pastuszka et al. [27]—the amount of β-glucan increased with the addition of oat protein to wheat bread (control sample 0.20%, bread with 5% oat addition—0.31% and bread with 10% oat addition—0.41%). Astiz et al. [33] found that the addition of oat flour to wheat bread in amounts of 5, 10, 15, and 25% positively influenced not only nutritional parameters but also whether oat β-glucan had a positive technological effect on the rheological properties of the dough, as well as a positive effect on the properties of the bread crumb. These authors recommended application of 25% oat flour to wheat flour, and it would be a good option to make premixes to obtain breads of good technological and sensory quality and also prebiotic activity.

Table 2. Results of dry matter and β-glucan content of the breads analysed.

Sample	Dry Matter (%)	β-Glucan (%)
C	90.15 ± 0.12 ^{d}	0.07 ± 0.01 ^{c}
H3	90.62 ± 0.13 ^{a}	0.09 ± 0.02 ^{c}
H6	90.51 ± 0.16 ^{b}	0.16 ± 0.02 ^{a}
H9	90.44 ± 0.11 ^{b}	0.17 ± 0.01 ^{a}
N3	90.37 ± 0.11 ^{c}	0.14 ± 0.01 ^{b}
N6	90.49 ± 0.09 ^{b}	0.16 ± 0.01 ^{a}
N9	90.66 ± 0.15 ^{a}	0.17 ± 0.01 ^{a}

The same letter in column means homogenous groups. C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

3.3. Antioxidant Activity, Total Polyphenol and Anthocyanin Content

The antioxidant activity in the breads tested ranged from 1.73 to 1.98 mg TEAC/g (Table 3). The addition of black oat wholemeal flour to wheat bread increased antioxidant activity with higher values in the *Hucul* variety. Varga et al. [34] compared the content of total soluble antioxidants in the husks (where antioxidant substances are in the highest concentrations) of yellow, red, and black oat varieties. Generally, the black and red varieties, because of the higher content of bioactive compounds, had stronger antioxidant activity—they contained 57.6% more total soluble antioxidants than the yellow varieties and 61.9% more than red varieties. Oat grains are a source of several natural antioxidants such as tocopherols, alkylresorcinols, and phenolic acids and their derivatives and a unique source of avenanthramides (N-cinnamoylanthranilate alkaloids) and avenalumic acids (ethylenic homologues of cinnamic acids), which are not present in other cereal grains. In a study with healthy people, avenanthramides in combination with polyphenols in oats had a positive impact on serum superoxide dismutase (increase), reduced glutathione hormones by 8.4 and 17.9%, and reduced the content of potentially mutagenic malondialdehyde by 28.1% [35]. The positive influence of increasing antioxidant activity by oat addition also confirmed Saka et al. [36]. These authors used oat bran in amounts of 0, 5, 10, and 15% in bread, which caused enrichment of the breads with antioxidants. For the nutritional properties of bread, as well as antioxidant activity, bread technology is responsible. Fermentation during the preparing of bread dough can change the health-promoting properties of cereals but also improve the texture and taste of whole-grain products, increase or stabilise the content of various biologically active compounds, delay the bioavailability of starch (low glycemic index products), and improve the bioavailability of mineral compounds [37].

Table 3. Results of antioxidant activity, total polyphenol, and anthocyanin content.

Sample	DPPH (mg TEAC/g)	TPC (mg GAE/g)	TAC (µg/g)
C	1.73 ± 0.04 ^{e}	0.16 ± 0.01 ^{d}	n.d.
H3	1.86 ± 0.03 ^{c}	0.22 ± 0.01 ^{cd}	10.50 ± 0.71 ^{d}
H6	1.95 ± 0.02 ^{ab}	0.25 ± 0.02 ^{c}	14.50 ± 0.71 ^{bc}
H9	1.98 ± 0.03 ^{a}	0.29 ± 0.02 ^{bc}	21.01 ± 2.83 ^{a}
N3	1.79 ± 0.01 ^{de}	0.25 ± 0.01 ^{c}	12.52 ± 0.71 ^{cd}
N6	1.85 ± 0.02 ^{cd}	0.34 ± 0.02 ^{c}	15.50 ± 0.71 ^{bc}
N9	1.86 ± 0.01 ^{bc}	0.45 ± 0.08 ^{a}	18.01 ± 1.41 ^{ab}

The same letter in column means homogenous groups. DPPH—2,2-diphenyl-1-picrylhydrazyl; TEAC—Trolox equivalent; TPC—total polyphenol content; TAC—total anthocyanin content; GAE—gallic acid equivalent. C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

The total polyphenol content ranged from 0.16 to 0.45 mg GAE/g (Table 3). Similar to antioxidant activity, the addition of black oat wholemeal flour positively influenced the polyphenol content with the highest value in the addition of 9% by both varieties. Generally, higher polyphenols were detected in breads with the *Norik* addition. According to Kim et al. [38], oat grains contain polyphenols, including caffeic acids, coumaric acids, gallic acids, hydroxybenzoic acids, protocatechuic acids, syringic acids, and vanillic acids, as bioactive compounds. Kilci and Gocmen [39] tried to improve the traditional Turkish tarhana dish by adding oat flour. Their allowance of 10, 20, 30, or 40% (as a substitute for wheat flour in this dish) caused an increase in total polyphenols of 11.38, 11.58, 12.46, and 16.89%, respectively, compared to the control sample. Soaycan et al. [40] analysed 22 commercial oat products (oat bran, flaked oats, rolled oats, and oatcakes). They found that oat products can provide between 15.79 and 25.05 mg of total phenolic acids and between 1.1 and 2 mg of avenanthramides in a 40 g portion. From phenolic acids, ferulic was dominant in all products (58–78.1%). Their studies confirmed that commercial oat products can be a good source of phenolic acids and avenanthramides for consumers.

Total anthocyanins were detected only in bread with oats (Table 3). These compounds ranged from 10.50 to 21.01 µg/g. Generally, breads with variety *Norik* contained higher content. Anthocyanins are better extracted in an acidic environment, which is provided by lactic acid bacteria during the production of sourdough bread. We assumed that during the preparation of the dough, because of the acid pH, the anthocyanins were better extracted from the bran of the wholemeal flour to the dough. Anthocyanins attract a lot of attention because of their attractive nutritional profile: they are attributed with positive antioxidant, anticancer, and protective effects, with slowing ageing, and with having a positive effect on gut health. Coloured cereals are rich in these pigments, while they are concentrated mainly in the bran layers [41].

3.4. Mineral Compounds Composition

Bread with the addition of oat wholemeal four contained, compared to the control sample, higher contents of calcium, iron potassium, manganese, phosphorus, and sulphur (Table 4). Variety *Norik*, especially in a 9% addition, contained the highest mineral components. Mineral compounds with potential health risks responsible for contaminating food include mainly lead and cadmium. The lead content in the tested samples was in the amount of ~0.01 mg/100 g, which does not cause negative effects in the human body, according to the Slovak regulation from 19 December 2006 [42]. For consumers, there can be an attractive amount of manganese and calcium in enriched bread, whereas nowadays there is a lower amount of these compounds by diet, which can cause problems with the bones, teeth, and nervous systems. Temnikova et al. [32], also in bread enriched with oat, determined a higher amount of phosphorus, iron, calcium, and potassium compared to the control sample. Alemayehu et al. [43] determined in black oat the amounts of iron (3.00 mg/100 g), copper (0.2 mg/100 g), zinc (1.62 mg/100 g), potassium (250 mg/100 g), calcium (85.7 mg/100 g), and magnesium (80.2 mg/100 g). The black variety compared to yellow variety contained a generally higher amount of these compounds. Oat has very good nutritional properties, but in some countries, such as the Slovak Republic, it is still consumed in low amounts, while the most-consumed products are flakes. The results of this study show that oat flour, especially coloured varieties, can be an effective tool to produce new cereal foods with added values.

Table 4. Results of the mineral compounds profile of the prepared breads.

Mineral (mg/100 g)	C	H3	H6	H9	N3	N6	N9
Al	0.33 ± 0.14 ^{a}	0.21 ± 0.10 ^{ab}	0.33 ± 0.07 ^{a}	0.37 ± 0.13 ^{a}	0.24 ± 0.07 ^{ab}	0.22 ± 0.06 ^{ab}	0.21 ± 0.04 ^{ab}
Ca	35.83 ± 1.40 ^{d}	41.53 ± 0.59 ^{ab}	39.39 ± 1.09 ^{bc}	40.55 ± 0.47 ^{ab}	41.25 ± 0.59 ^{ab}	37.68 ± 2.37 ^{cd}	42.10 ± 0.61 ^{a}
Cd	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}	0.01 ± 0.00 ^{a}
Cr	0.08 ± 0.06 ^{ab}	n.d.	0.04 ± 0.06 ^{b}	0.02 ± 0.01 ^{b}	0.14 ± 0.01 ^{a}	0.01 ± 0.00 ^{b}	0.08 ± 0.01 ^{ab}
Cu	0.24 ± 0.03 ^{a}	0.24 ± 0.03 ^{a}	0.26 ± 0.03 ^{a}	0.23 ± 0.01 ^{a}	0.24 ± 0.01 ^{a}	0.22 ± 0.01 ^{a}	0.21 ± 0.04 ^{a}
Fe	2.39 ± 1.43 ^{d}	2.88 ± 0.96 ^{d}	3.57 ± 0.81 ^{c}	2.43 ± 0.03 ^{d}	2.65 ± 0.88 ^{d}	4.15 ± 0.03 ^{a}	5.35 ± 0.74 ^{a}

Table 4. *Cont.*

Mineral (mg/100 g)	C	H3	H6	H9	N3	N6	N9
K	198.5 ± 0.45 e	207.3 ± 2.64 cd	209.1 ± 2.88 bc	211.1 ± 0.98 b	205.2 ± 1.89 d	211.6 ± 1.19 b	220.1 ± 0.44 a
Mg	69.24 ± 0.33 d	73.66 ± 0.31 bc	74.03 ± 0.59 b	75.58 ± 1.01 bc	72.66 ± 0.52 c	72.69 ± 0.53 ab	75.14 ± 0.57 a
Mn	1.31 ± 0.08 b	1.32 ± 0.01 b	1.44 ± 0.01 a	1.46 ± 0.03 a	1.38 ± 0.03 ab	1.38 ± 0.04 ab	1.38 ± 0.03 a
Mo	0.05 ± 0.01 a	0.03 ± 0.00 c	0.04 ± 0.01 abc	0.03 ± 0.00 c	0.04 ± 0.01 ab	0.03 ± 0.01 bc	0.03 ± 0.00 c
P	189.1 ± 0.80 e	191.2 ± 0.44 d	192.5 ± 0.24 c	194.3 ± 00.38 b	190.9 ± 0.91 d	191.9 ± 0.64 cd	195.4 ± 0.29 a
Pb	0.01 ± 0.00 a	0.01 ± 0.00 a	n.d.	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a
S	147.7 ± 0.34 d	143.9 ± 0.35 e	178.9 ± 0.53 b	183.8 ± 0.29 a	144.1 ± 0.25 e	146.9 ± 0.32 e	150.9 ± 0.25 c
Se	0.03 ± 0.00 a	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sr	0.26 ± 0.01 c	0.25 ± 0.01 c	0.31 ± 0.01 a	0.26 ± 0.01 c	0.24 ± 0.01 d	0.28 ± 0.01 b	0.31 ± 0.01 a
Zn	1.26 ± 0.01 c	1.20 ± 0.01 d	1.20 ± 0.01 d	1.20 ± 0.01 d	1.16 ± 0.01 e	1.34 ± 0.01 b	1.37 ± 0.01 a

The same letter in column means homogenous groups. C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

3.5. Sensory Evaluation

The results of the sensory evaluation are presented in Figures 1 and 2. All parameters evaluated were better with the enriched samples compared to the control sample (Figures 3 and 4). The bread with a 3% *Hucul* addition was evaluated as the best sample. The surface and properties of the crust were evaluated as the most balanced of all indicators. The enriched breads had better porosity and properties of the bread crumb compared to the control sample. It probably was caused by the presence of non-starch polysaccharides, which generally improve the structure of bread crumb compared to wheat, which is poor for these kind of compounds. The biggest differences were in the smell and taste, in the sense that the control was significantly behind compared to bread with any addition of oat flour. Breads with oats had fuller, more pronounced taste and smell. The control received only 3 points, while the best-rated bread was the *Hucul* 3% with 5 points. Gambuś et al. [20] investigated the properties of wheat breads with the addition of whole-grain oat flour from the yellow and black varieties in amounts of 5, 7, and 10% (compared to a 100% wheat flour control). In the sensory analysis performed, the evaluators gave all samples the highest or almost the highest total number of points. In general, the best results, even better than the control for some traits, were detected with 5% addition of black oat flour. They then evaluated these breads after 1, 2, and 3 days for properties such as crumb moisture, hardness, cohesion, chewiness, and elasticity. Based on the results, it can be concluded that the best result was again the addition of 5% black oat flour, and in general, in the observed results, black oats turned out better than yellow oats. Zaki et al. [44] also confirmed that oat flour can improve not only the nutritional but also the sensory characteristics of cereal products. These authors evaluated cakes and biscuits with the addition of oat flour in amounts of 25, 50, 75, and 100%. In sensory evaluation, especially cakes and biscuits with 50 and 75% were evaluated as the best in aroma, taste, and structure. Oats are undervalued and their use in the daily diet is currently largely limited to oatmeal or porridge. Processing oat to develop useful and tasty food products would be a possible solution for its advance, commercialisation, and improved consumption, thereby increasing viability and improving the living conditions of the population [23].

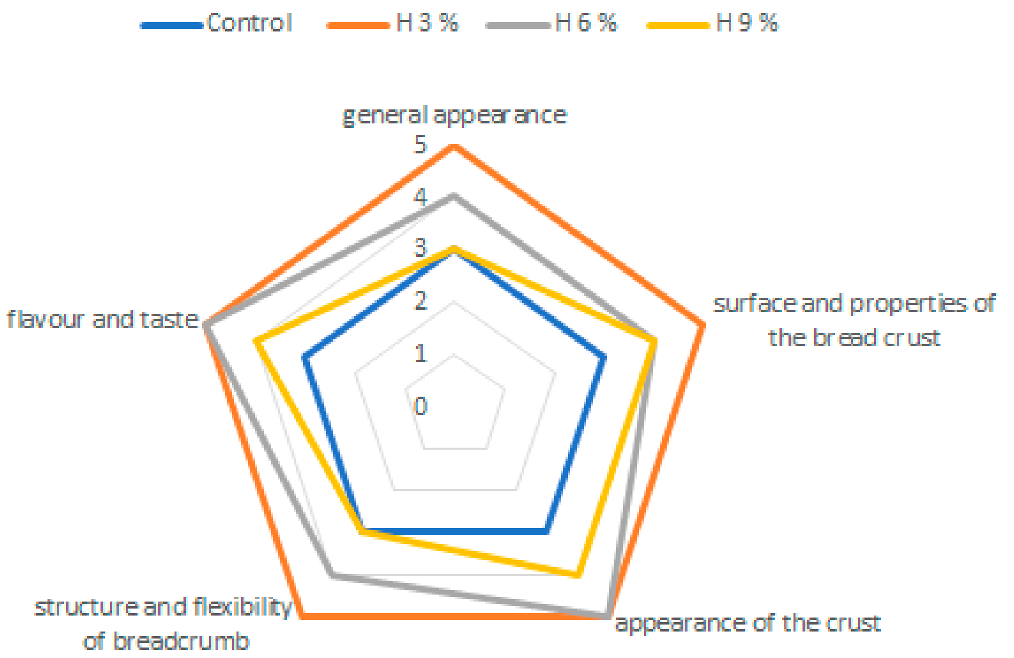

Figure 1. Results of sensory evaluation of breads with addition of *Hucul* black oat wholemeal flour (sum of all panellists). C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

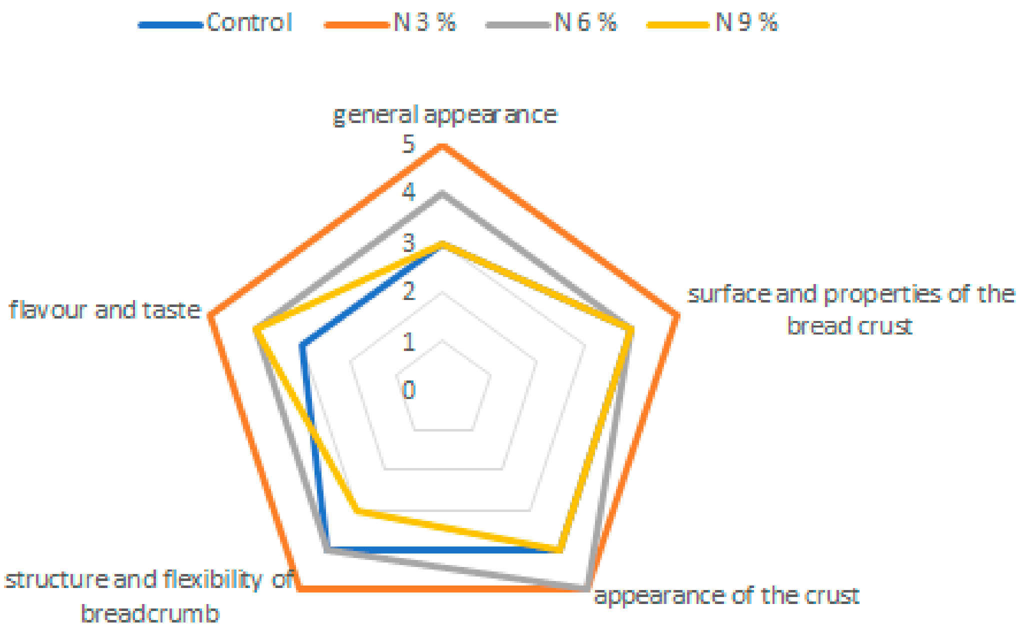

Figure 2. Results of sensory evaluation of breads with addition of *Norik* black oat wholemeal flour (sum of all panellists). C—control bread; H3—bread with 3% *Hucul* addition; H6—bread with 6% *Hucul* addition; H9—bread with 9% *Hucul* addition; N3—bread with 3% *Norik* addition; N6—bread with 6% *Norik* addition; n.d.—not detected; N9—bread with 9% *Norik* addition.

Figure 3. Bread with *Hucul* wholemeal flour addition (from left side: control sample, sample with 3% addition, sample with 6% addition, and sample with 9% addition).

Figure 4. Bread with the addition of *Norik* wholemeal flour (from left side: control sample, sample with 3% addition, sample with 6% addition, and sample with 9% addition).

4. Conclusions

In the experimental breads, the advantages of black oat wholemeal flour were most evident because even in relatively low concentrations they were able to influence the nutritional composition, while this was more evident with a 9% addition. Oat flour also improved the content of biologically active substances compared to the control. Based on sensory evaluation, we can say that compared to the 100% wheat flour, all the others turned out better or even significantly better, especially in smell and taste, which is an important fact for the possible inclusion of such breads in production. It can also be said that products with a higher addition of oat flour, especially the *Hucul* variety, turned out better, which is a positive fact in the context of the amount of antioxidant substances, since with a higher addition of this flour, their amount also increases. Enriched products are currently widely praised for their health benefits. When comparing the results, we can see that enriching already interesting breads was more than a good idea. Oats, which are sensorially significant in themselves, improved the taste and aroma perception of the evaluated products and positively highlighted them at colour, even in low concentrations. Generally, we can recommend the use of the black oat variety for bread production, especially for small bakeries, which are specialised for sourdough breads. Breads with black oat can be attractive to the consumer, especially those who are familiar with healthy lifestyles.

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