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Influence of technological parameters on chemical composition of triticale flakes

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Abstract. Triticale is hybrid crop developed by crossing wheat (*Triticum*) and rye (*Secale*) and in last years it become more popular for food applications, including flake production. Different approaches are developed to improve flakes technology by applying different cooking, rolling, toasting parameters resulting in high quality products. All these technologies influence also nutrition quality of product due to the different stability of these compounds during mechanical and thermal treatment. The aim of current experiment was to investigate the influence of technological parameters on chemical composition of triticale flakes. In current experiment triticale grains and triticale flakes obtained by different technologies was tested. For evaluation of the influence of technological parameters, different flaking and rolling parameters were tested. For all samples were determined composition of basic nutrients (fats, proteins, fibres, sugars, ash), minerals (Ca, Mg, K, Zn, P), vitamins, total phenolics and antioxidant activity. Triticale has high nutritional quality, containing significant amounts of protein, fibres, vitamins and minerals. Technological processes significantly influence cereals composition, but it depends on parameters tested. Control sample showed lower results and hierarchical cluster analyses showed that samples 1/3/1, 2/1/2/1, 2/1/3/1, 2/1/4/1 are similar in composition of bioactive compounds. Results showed that for selection of the best method for flaking physical and/or sensory properties should be taken in account.

Key words: triticale, flakes, technology, chemical composition.

INTRODUCTION

The health benefits of cereal products and consumer's acceptance should be prioritised (Fardet, 2014). Cereal consumption is significant factor influencing healthful lifestyle that helps to maintain healthful body mass index (Barton et al., 2005). Different trends become popular in last years to improve the nutrient composition of cereals, often in response to public health concerns and consumer demands, for example decrease of sugar and sodium, increase level of fiber level, use of whole grain, fruit powders (Oliveira et al., 2018), legumes etc. (Thomas et al., 2013). Part of consumers prefer use of traditional flakes for not only making of porridge but also consuming with milk or yogurt. Cereal flakes traditionaly are produced by steaming to certain moisture content followed by flaking, but for consumption without hot water treatment harder structure remains. Different approaches is developed to improve flakes production technology by using reduced or high pressure treatment, selected rolling and toasting parameters resulting in high quality products. One of the property that could be influenced by these techniques is bulk density and improved sensory properties of products. Volume of flakes is very important because consumer researchs shows influence of volume to selection of portion size and results about breakfast cereals showed that by reducing flake size, panelists took smaller volume of sample, but still they took more energy value (Rolls et al., 2014). Technology used in current experiemnts could increase bulk density and could result in lower consumption of food.

Triticale is hybrid crop developed by crossing wheat (Triticum) and rye (Secale cereale) and in last years it become more popular for food applications, including muesli production (Senhofa et al., 2015). Comparing to wheat triticale has similar content of protein, with a slightly higher amount of lysine (0.33–0.71%) (Fraś et al., 2016) and also similar content of fibre, but with a higher amount of soluble fraction, especially water-extractable arabinoxylans (Rakha et al., 2011). Technologies applied influence also nutrition quality of product due to the different stability of these compounds during mechanical and thermal treatment (Fraś et al., 2016).

The aim of current experiment was to investigate the influence of technological parameters on chemical composition of triticale flakes.

MATERIALS AND METHODS

Triticale flakes samples preparation

In the present experiment three different technologies for flakes production were used: traditionally commercially processed flakes (control sample) – purchased ready-made triticale whole grain flakes from JSC Dobeles dzirnavnieks (Latvia). Processing technology includes purified triticale grains steaming, rolling and drying.

Samples numbered with first code 1 (cooking method 1)– cooked triticale flakes obtained by 1 min steaming and 0.5 ± 0.1 bar pressure 10 min and different flaking rolls gap settings (respectively, sample 1/3/1 – 0.06 ± 0.01 mm and sample 1/4/1 – 0.04 ± 0.01 mm). Processed triticale flakes were transferred for drying in the Mitchell Bach Dryer (GmbH Baker Perkins, UK) for 35 ± 5 min at 80 ± 1 °C. Samples numbered with first code 2 (cooking method 2) – triticale grains were transferred in the Rotary Cereal Cooker (GmbH Baker Perkins, UK) with adding of extra water 20 ± 3% from grains total amount, after that samples were 5 min steamed and cooked 30 ± 5 min at 1.2 bar pressure. Samples 2/1/2/1, 2/1/3/1, 2/1/4/1 differing by flaking rolls gap settings, respectively, 0.10 ± 0.01, 0.06 ± 0.01 and 0.04 ± 0.01 mm gap. Processed triticale flakes were transferred for drying in the Mitchell Bach Dryer (GmbH Baker Perkins, UK) at 80 ± 1 °C for 30 ± 5 min.

Toasting procedure was performed in falling temperatures under 200 ± 10 °C for less than one minute in the toaster New Thermoglide Toaster Rig (GmbH Baker Perkins, UK).

Methods

Basic nutrients were determined by following methods: fat – § 64 LFGB L 20.01/02-5, fatty acids – § 64 LFGB L 13.00-26/-27/20, carbohydrates (calculated by difference), sugars (fructose, glucose, sucrose, maltose, lactose) – § 64 LFGB L 00.00-

143, salt (from sodium) – calculated, fibres – § 64 LFGB L 00.00-18, protein – § 64 LFGB L 17.00-15, energy value – calculated in kcal and kJ.

Vitamins were determined by following methods: vitamin B1 (thiamine) – § 64 LFGB L 00.00-83, vitamin B2 (riboflavin) – § 64 LFGB L 00.00-84, vitamin B6 – § 64 LFGB L 00.00-97, niacin – SLMB 62/12.2.1.

Mineral substances were determined by following methods: calcium, iron, potassium, magnesium, phosphorus – DIN EN ISO 11885, ICP-OES, zinc – DIN EN 15763, sodium – DIN EN ISO 11885, ICP-OES.

Extraction process and determination of total phenolic compounds, $DPPH^{\cdot}$ radical scavenging activity and $ABTS^{\cdot+}$ radical scavenging activity was determined according methodology used for grains (Kruma et al., 2016).

Data Treatment

Experimental results presented are means of three parallel measurements and were analysed by Microsoft Excel 2013, XLSTAT 2018 and SPSS 23. Analysis of variance (ANOVA) and Tukey test was used to determine differences among samples. Hierarchical cluster analysis was used to identify relatively homogeneous groups of cases based on tested parameters, using an algorithm that starts with each case (or variable) in a separate cluster and combines clusters until only one is left. Standardizing transformations were performed and agglomeration schedule, cluster membership for a range of solutions were tested for selection of best solution.

RESULTS AND DISCUSSION

Carbohydrates are the major nutrients in triticale grain and flakes (Table 1) and no significant differences ($p > 0.05$) in content of carbohydrates were observed in flakes produced by different technological parameters. Starch content was the lowest in control flakes, but also no significant influence of technological parameters was observed. The lowest content of fibres were in control sample, and only in sample 2/1/2/1 it remained in the same level as in triticale grains.

Table 1. Content of carbohydrtaes, starch, sugars, fibers in triticale grains and flakes

Samples	Carbohydrates, g 100 g^{-1}	Starch, g 100 g^{-1}	Sugars, g 100 g^{-1}	Fibres, g 100 g^{-1}	Protein, g 100 g^{-1}
Triticale grains	68.49 ± 1.78a*	48.12±1.05a	1.07 ± 1.11c	15.64 ± 0.7c	11.79 ± 0.14a
Control Flakes	69.41 ± 2.72a	50.4 ± 2.05a	1.06 ± 0.05c	12.79 ± 0.18a	13.13 ± 0.58b
1/3/1	70.56 ± 3.04a	52.65±2.00ab	0.58 ± 0.01a	14.41 ± 0.62b	11.27 ± 0.44a
1/4/1	71.46 ± 1.12a	54.73±1.75b	0.59 ± 0.02a	14.06 ± 0.23b	10.86 ± 0.45a
2/1/2/1	69.28 ± 1.27a	51.02±1.35a	0.72 ± 0.01b	15.36 ± 0.39c	11.49 ± 0.26a
2/1/3/1	69.78 ± 2.06a	52.41±1.42ab	0.70 ± 0.03b	14.95 ± 0.16b	11.35 ± 0.29a
2/1/4/1	70.48 ± 1.17a	51.46±1.22a	0.68 ± 0.01b	14.6 ± 0.66b	11.22 ± 0.50a

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

Protein content of triticale grains was 11.79 g 100 g^{-1} and it was similar comparing to data found in different triticale varieties grown in Poland ranging from 11.8 until

15.2. g 100 g^{-1} (Fraś et al., 2016). Proteins in triticale flakes ranged between 10.86 to 13.13 mg 100 g^{-1}. In control sample content of proteins was higher comparing to grains, but in flakes made by Cooking method 1 and Cooking method 2 no significant differences were obtained. Cereals are not rich in fats and analysed triticale grains contained only 2.1 g 100 g^{-1} (Table 2) mainly consisting of polyunsaturated acids (61%). Comparing flakes, the highest content of fats and its fractions were observed in control sample followed by sample 2/1/2/1 treated in increased pressure and cooked for 35 minutes. Cereal consumption was related to increased intake of fiber and decreased intake of fat and cholesterol and predictive of lower body mass index (Barton et al., 2005).

Table 2. Content of fats in triticale grains and flakes

Samples	Fat, g 100 g^{-1}	Fatty acid, saturated, g 100 g^{-1}	Fatty acid, monounsaturated, g 100 g^{-1}	Fatty acid, polyunsaturated, g 100 g^{-1}
Triticale grains	2.1 ± 0.06c*	0.47 ± 0.02b	0.35 ± 0.01a	1.28 ± 0.05b
Control Flakes	3.11 ± 0.1d	0.56 ± 0.02c	0.67 ± 0.02b	1.89 ± 0.02c
1/3/1	1.88 ± 0.04a	0.42 ± 0.02b	0.31 ± 0.01a	1.15 ± 0.02a
1/4/1	1.76 ± 0.04a	0.31 ± 0.01a	0.31 ± 0.02a	1.14 ± 0.03a
2/1/2/1	2.04 ± 0.07bc	0.43 ± 0.01b	0.32 ± 0.01a	1.29 ± 0.03b
2/1/3/1	1.91 ± 0.09b	0.42 ± 0.02b	0.32 ± 0.01a	1.17 ± 0.01a
2/1/4/1	1.9 ± 0.07b	0.32 ± 0.01 a	0.32 ± 0.01a	1.16 ± 0.04a

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

Cereal consumption was related to increased intake of calcium, iron, folic acid, vitamin C, and zinc (Barton et al., 2005). Grain products are source of B group vitamins. Triticale grains contained 0.350 mg 100g^{-1} vitamin B1, and during processing it decreased significantly, showing the lowest results in control flake sample (0.073 mg 100 g^{-1}) and the highest in sample 1/3/1 treated at lower pressure (cooking method 2) (0.167 mg 100 g^{-1}) (Table 3). Content of thiamine in triticale was reported 0.378 mg 100 g^{-1} (Zhu, 2018). Sumczynski et al (2018) reported thiamine content in wheat flakes ranging from 0.15–1.05 mg 100 g^{-1} and it is mainly higher comparing to results of current study. Content of B2 vitamin decreased during thermal tretment, except sample 2/1/2/1 (no significant differences comparing to triticale grains). The lowest level in control flakes were observed. Content of B2 vitamin in wheat flakes were in similar range 0.032–0. 350 mg 100 g^{-1} (Sumczynski et al.,2018). In tested triticale grains content of vitamin B6 was 0.257 mg 100 g^{-1} , whereas in experiments reported in literature twice higher content was detected – 0.403 mg 100 g (Zhu, 2018). Vitamin B6 level the lowest was in control sample and for all samples made with cooking method 2 content was the highest. Niacin was only one vitamin from tested that increased during thermal treatment up to two times. Similar results were obtained for the bread and in this case nicotinic acid and nicotinamide increased during toasting steps (Nurit et al., 2016).

Table 3. Content of vitamins in triticale grains and flakes

Samples	Vitamin B1, mg 100 g^{-1}	Vitamin B2, mg 100 g^{-1}	Vitamin B6, mg 100 g^{-1}	Niacin, mg 100 g^{-1}
Triticale grains	0.350 ± 0.011f*	0.096 ± 0.003c	0.257 ± 0.004d	0.548 ± 0.019a
Control flakes	0.073 ± 0.001a	0.040 ± 0.002a	0.110 ± 0.005a	0.667 ± 0.027b
1/3/1	0.167 ± 0.008e	0.085 ± 0.002b	0.219 ± 0.008b	0.877 ± 0.026c
1/4/1	0.134 ± 0.004d	0.082 ± 0.001b	0.217 ± 0.007b	0.869 ± 0.011c
2/1/2/1	0.107 ± 0.004c	0.093 ± 0.003c	0.236 ± 0.010c	1.182 ± 0.040d
2/1/3/1	0.098 ± 0.005c	0.085 ± 0.001b	0.223 ± 0.009bc	1.273 ± 0.019d
2/1/4/1	0.087 ± 0.001b	0.088 ± 0.002bc	0.222 ± 0.008bc	1.270 ± 0.051d

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

Content of total phenolic compounds in triticale grain was 34.22 mg 100 g^{-1} (Table 4) and comparing to literature it is similar – 295.02 µg g^{-1} (29.5 mg 100 g^{-1}) range (Irakli et al., 2012). In samples made by cooking method 2 and also 1/3/1/ significant TPC increase were determined. DPPH antioxidant activity in flakes was significantly higher compared to grains, and similar trend for ABTS antioxidant activity was observed. Exception was sample 2/1/4/1 were significant lower activity was observed. For both antioxidant assays higher results for Cooking method 2 was observed. Processing of sorghum with dry heat did not affect the total phenolic compounds and antioxidant activity, whereas the wet heat decreased total phenolic compounds and antioxidant activity (Cardoso et al., 2014). In our experiment wet treatment was used but decrease of antioxidant activity for two samples was not observed (1/4/1 and 2/1/3/1).

Table 4. Content of total phenolics and antioxidant activity of triticale grain and flakes

Samples	TPC, mg 100 g^{-1}	DPPH, mM TE 100g^{-1}	ABTS, mM TE 100g^{-1}
Triticale grains	34.22 ± 0.97c*	1.15 ± 0.44a	7.05 ± 0.22b
Control Flakes	26.96 ± 1.36a	1.79 ± 0.22b	8.45 ± 0.29c
1/3/1	36.15 ± 1.42c	2.31 ± 0.03c	6.97 ± 0.21b
1/4/1	29.8 ± 0.86b	2.35 ± 0.05c	9.21 ± 0.33d
2/1/2/1	38.15 ± 0.59d	2.83 ± 0.02d	10.11 ± 0.27e
2/1/3/1	42.89 ± 0.47e	2.78 ± 0.04d	12.35 ± 0.11f
2/1/4/1	42.74 ± 1.35e	2.86 ± 0.08d	6.3 ± 0.26a

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

For antioxidant activity even increase was observed and mainly it could be explained by transformation of some bound antioxidants to free form with higher activity. Oat-based breakfast cereals, irrespective of brand, variety or cost, are a significant source of polyphenols and antioxidant compounds (Ryan et al., 2011) and use of triticle could also be perspective source of phenolics.

The main mineral substances were determined in triticale grain and flakes. The highest content of zinc, phosphorus, magnesium and potasiums were in triticale grains, whereas iron was in higher concentration in flakes made by cooking method 1 and cooking method 2 (Table 5 and 6). It is possible to conclude that tendencies of changes of mineral substances differ and mainly flakes production resulted in decrease in mineral content. In quinoa's 100% of phosphorus remained for steamed preparation. In steamed buckwheat retention of minerals ranged from 87% for zinc to 98% to calcium and 100% for iron (Mota et al., 2016).

Calcium was the only one mineral in the highest concentration in control sample, but other substances as Fe, K, Mg and P were in lowest concentration in control flakes.

Table 5. Content of calcium, iron, potassium and magnesium in triticale grains and flakes

Samples	Calcium, mg 100 g^{-1}	Iron, mg 100 g^{-1}	Potassium, mg 100 g^{-1}	Magnesium, mg 100 g^{-1}
Triticale grains	45.04 ± 1.96d*	3.77 ± 0.16a	582.61 ± 6.71c	161.03 ± 3.52d
Control flakes	55.06 ± 2.7e	3.49 ± 0.08a	486.1 ± 12.99a	127.03 ± 2.52a
1/3/1	34.76 ± 1.33 a	4.31 ± 0.22b	501.88 ± 18.71a	137.89 ± 5.63b
1/4/1	40.85 ± 1.13bc	4.50 ± 0.20b	552.22 ± 13.58b	149.33 ± 7.30c
2/1/2/1	38.45 ± 1.35 b	4.19 ± 0.18b	510.53 ± 10.04a	143.72 ± 7.16c
2/1/3/1	40.93 ± 0.62bc	4.31 ± 0.17b	516.65 ± 11.9a	150.69 ± 6.34c
2/1/4/1	42.01 ± 1.68c	4.28 ± 0.18b	518.94 ± 16.77a	151.64 ± 6.86c

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

No significant differences in the content of minerals between cooking methods was observed, because loses of minerals were mainly influenced by rolling thickness. The major losses occur probably due to the solubilisation of minerals by water during the steaming process, with the exception of manganese, iron and calcium (Mota et al., 2016). Comparing to literature (Zhu, 2018) content of mineral substances in tested triticale grains were higher, except phosphorus level was lower.

Table 6. Content of phosphorus, zinc and total ash in triticale grains and flakes

Samples	Phosphorus, total, mg 100 g^{-1}	Zinc, mg 100 g^{-1}	Ash, g 100 g^{-1}
Triticale grains	436.64 ± 9.08d*	3.12 ± 0.07c	1.98 ± 0.05b
Control flakes	346.61 ± 5.93a	2.84 ± 0.06b	1.56 ± 0.07a
1/3/1	368.37 ± 5.01b	2.49 ± 0.07a	1.88 ± 0.07b
1/4/1	408.69 ± 6.39c	2.65 ± 0.04a	1.86 ± 0.03b
2/1/2/1	382.49 ± 13.25b	2.63 ± 0.13a	1.93 ± 0.05b
2/1/3/1	402.55 ± 15.96c	2.68 ± 0.13a	1.91 ± 0.02b
2/1/4/1	394.29 ± 17.44bc	2.57 ± 0.35a	1.90 ± 0.06b

* Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

In current research triticale grains and flakes were classified based on the vitamin, mineral, total phenol content and antioxidant properties, using the hierarchical cluster analysis (Fig. 1).

According to agglomeration schedule coefficients samples can be divided in four clusters and three of them contains only one sample:

A – triticale grains; C – 1/4/1/;
B – control flakes; D – 1/3/1, 2/1/2/1, 2/1/3/1, 2/1/4/1.

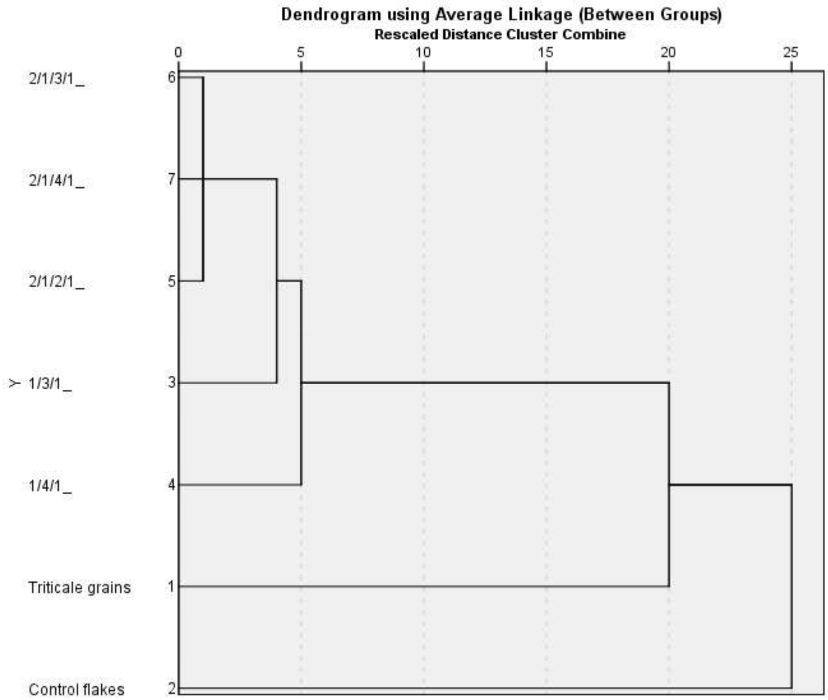

Figure 1. Dendrogram obtained by hierarchical cluster analysis using means of vitamins, minerals, total phenolics and antioxidant activity.

Triticale grains, control flakes and sample 1/3/1 did not show similarities with other samples, whereas the fourth cluster classify together samples prepared by cooking method 2 and also 1/3/1, showing similarities of these samples.

CONCLUSIONS

Triticale has high nutritional quality, containing significant amounts of protein and fibres, vitamins and minerals. Technological processes significantly influence cereals composition, but it depends on parameters tested. Control sample showed lower results and hierarchical cluster analyses showed that samples 1/3/1, 2/1/2/1, 2/1/3/1, 2/1/4/1 are similar in composition of bioactive compounds. Generally better results showed samples prepared by cooking method 2 with adding of extra water and after that samples were steamed and cooked 30 ±5 min at 1.2 bar pressure. Results showed that for selection of the best method for flaking physical and/or sensory properties should be taken in account.

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