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Utilisation of triticale (X *Triticosecale* Wittmack) and residual oat flour in breadmaking

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Abstract: During the last few years, non-bread cereals, as a rich source of bioactive components, play an increasingly important role in the production of new healthier food. A large number of diet-related diseases in society requires developing and regular consumption of high-quality food. In this study, triticale flour was supplemented with residual oat flour (ROF), which is a by-product in the production of oat fibre concentrate, to obtain triticale-oat bread with improved chemical composition and quality. The flours obtained from 3 winter triticale cultivars were enriched with 10%, 15%, and 20% of ROF. An increasing level of ROF resulted in higher protein and lipids content and a two-fold increase in β-glucan content (from 0.3% for control breads to 0.6% for 20% ROF) what improved the quality of dietary fibre in breads (DF). The bread parameters, especially bread volume (BV), the shape of loaves, crust colour and crumb texture, decreased with the addition of ROF. The triticale-oat breads with the best quality were obtained from 10% addition of ROF. Results confirmed the possibility of utilisation triticale and ROF for the production of bread with a unique chemical composition constituting a simultaneously rich source of DF.

Keywords: bread; cereals; chemical composition; dietary fibre

In recent years, the number of civilisation diseases in the population has grown continuously, and most of them are diet-related (Kawakita et al. 2019). Therefore, the demand for natural foods, including bread products, with specific healthy properties continues to increase (Zhang et al. 2019). One way to increase the nutritional value in bread production is to use non--bread cereals with specific chemical composition. Oat, barley, and triticale are very often classified as raw material with functional properties. There is also a wide range of other raw plant materials and alternative grains, which are sources of specific ingredients and are used as additives during bread production. Consumers understand the role of health-promoting additives; therefore, the consumption of bread products enriched with bioactive components is still increasing (Brodowska et al. 2014; Gosine and McSweeney 2019).

Triticale is produced on a large scale in many countries all over the world and offers many agronomic advantages such as high yield potential, good grain quality, disease resistance, and environmental tolerance. Despite valuable grain composition but low breadmaking value, triticale is still considered to be non-bread cereal and simultaneously underestimated from the nutritional point of view. This cereal is a rich source of protein and bioactive components, and it is similar to wheat in dietary fibre (DF) content, but with different proportions of soluble and insoluble fractions. Its utilisation in bak-

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ing is, to a large extent, limited by the high α-amylase activity and weak rheological properties of dough (Fraś et al. 2016). However, recently many studies about the human utilisation of triticale have been conducted. Moreover, to improve the quality, prohealthy value and attractiveness of bread products, triticale flour is often enriched with different plants with bioactive properties like pumpkin, flax or sunflower seeds as well as nettle, artichoke, kale, broad beans, fenugreek seeds, buckwheat hulls, mulberry, and tea extracts (Kaszuba et al. 2017; Makowska et al. 2017).

Oat and its products are very often used to supplement wheat breads because of their unique chemical composition and functionality. Oat grain has the most favourable composition of all cereals. It contains large amounts of essential exogenous amino acids, lipids with beneficial proportions of saturated and unsaturated fatty acids, vitamins, phenolic and first and foremost DF with a high concentration of β-glucan (Sterna et al. 2016; Rauf et al. 2019). Oat flour is one of the most commonly used additives for improving the quality of wheat bread. The residual oat flour (ROF) described in the present study is a by-product in the production of high fibre oat concentrate, and it is a rich source of β-glucan. According to manufactures, both of these products, oat fibre and ROF, are produced from four oat cultivars, using only physical methods. The addition of ROF to bread makes it possible to utilise a by-product in a very simple way. The nutritional value of ROF is slightly lower in comparison to the oat flour available on the market, but on the other hand, its use as a by-product is much cheaper (Gołębiewska et al. 2018).

Considering the need to develop healthier foods and simultaneously utilise non-bread cereals and related products, the aim of this study was to optimise the level of ROF that should be added to obtain triticale bread of good bioactive value and acceptable technological quality.

MATERIAL AND METHODS

Raw material. Three Polish winter triticale cultivars supplied by Danko Plant Breeders Ltd., Co. and Plant Breeding Strzelce Ltd., Co. were grown in 2016 in 2 places (Choryń/Borowo) located in the same climatic area. The ROF was donated by Microstructure Ltd., Co. (Poland). The content of its chemical composition described previously by Gołębiewska et al. (2018) was as follows: protein 13.9%, ash 1.6%, lipids 7.4%, starch 63.8%, non-starch polysaccharides (NSP) 5.1%, insoluble fraction of NSP (I-NSP) 1.9%, soluble fractions of NSP (S-NSP) 3.2%, lignin 1.0%, DF 6.1%, β-glucan 2.3%.

Sample preparation. To produce flour, the triticale grain was conditioned to 14% moisture content and ground on the Brabender Quadrumat Senior Laboratory Mill (Germany). Triticale flour was supplemented with ROF to obtain 10%, 15%, and 20% concentrations of ROF, and 100% triticale bread was used as a control (CB). Breads were baked (laboratory oven; Labor-Mim, Poland) in duplicates using 100 g of flour with 1.5 g of salt and 3 g of yeast (ICC/131; 2005). The bread volume (BV) was measured using the 3D laser scanner Next Engine (Santa Monica, USA), and the shape of the loaves, crust colour and crumb texture were subjectively evaluated. All the breads were freeze-dried in the Alpha 1-4 LD plus Martin Christ lyophiliser (Osterore am Harz, Germany) and ground in the Perten Laboratory Mill 3100 with a sieve diameter of 0.5 mm (Hagersten, Sweden).

Analytical methods. Protein content was analysed using the Dumas method (AOAC 990.03, 1995) in the Rapid N Cube apparatus (Elementar, Germany). Total lipids and ash content were determined gravimetrically (AOAC 923.03, 1995). DF content was determined using the enzymatic-chemical method in accordance with AACC 32-25 (2003) procedures as the sum of NSP, lignin and associated polyphenols and resistant starch (RS). NSP content with its S-NSP and I-NSP fractions was determined using gas chromatography (GC) (Clarus 600 chromatograph; Perkin Elmer, USA), and lignins were determined gravimetrically. RS and β-glucan content were measured with standard procedures (AACC 32-40.01, AACC 32-23, 2003). The falling number (FN) of flour was determined using a FN 1800 Perten apparatus (Hagerstern, Sweden) (ICC/107/1; 2005). The water absorption (WA) of flour was determined in the Brabender farinograph (Duisburg, Germany) (ICC/115/1; 2005). All analyses were performed in duplicate, and the results reported on a dry weight basis (% of d.w.). The mean values were accepted if the difference between duplicates was below 10%.

Sensory analysis. The breads obtained from Preludio and Panteon cultivars with 10% of ROF were baked in the bakery. Both bread samples from the commercial baking were submitted to a panel of 14 tasters (6 men and 8 women), according to EN ISO 8586:2014 procedure, in order to evaluate the sensory attributes. The analysis was performed with a profile method on a ten-point scale. For comparison purposes, the common wheat-rye bread available in the market was used as the reference sample. The analysis included the evaluation of bread crust (smoothness, gloss, thick-

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ness, colour, even colour, crunchiness), bread crumb (flexibility, porosity, colour, even colour, bread and yeast aroma, moisture as well as bread, yeast, salty and sour taste) and bread slices (shape, appearance, crumb, and crust connection).

Statistical analysis. For statistical analysis, a one-way ANOVA and Tukey's contrast analyse were performed, and the significance level was set to $P < 0.01$ or $P < 0.05$. Statistical analyses were performed using Tibco Statistica software, version 13.3 (TIBCO, USA).

RESULTS AND DISCUSSION

Technological parameters. The addition of ROF significantly affected most of the technological parameters of triticale flour and the bread quality. After the addition of ROF to triticale flour, FN values increased significantly in comparison to CB, in the case of Fredro and Preludio cultivars, and ranged between 242 s to 309 s and 205 s to 255 s, respectively. For the Panteon cultivar, there were some irregular relationships between FN and individual ROF concentrations with obtained values between 214 s for 10% ROF and 249 s for 15% ROF (Table 1). These results might be related to the higher content of soluble fractions of DF in ROF and higher water retaining capacity in comparison to triticale flour and are in line with data presented by Fraś et al. (2016), who reported values in a range between 62 s and 231 s. The addition of ROF increased the farinograph WA, but not always significantly. The obtained values ranged between 50.9% for Preludio control flour and 67.8% for Panteon with 20% ROF. The highest average WA at a level of 67.6% was observed for breads from Panteon cultivars (Table 1). The observed values of WA are probably the result of small differences in DF content between the samples; however, these results are consistent with those of other authors. Majzoobi et al. (2015) presented WA values between 65.4% and 67.3%, after the addition of whole-grain oat flour, while Mariotti et al. (2006) obtained lower values between 55.3% for control flour and 59.3% for 40% oat flour.

Table 1. Mean values of FN, WA, and BV for analysed cultivars and different ROF concentrations

Cultivar	ROF	FN (s)	WA (%)	BV (cm^3)
Fredro	CB	242^{c}	60.4^{ab}	362^{a}
	10%	281^{b}	59.1^{b}	341^{ab}
	15%	301^{a}	59.8^{ab}	326^{b}
	20%	309^{a}	61.7^{a}	317^{b}
	F-statistic	64.69^{**}	3.22^{ns}	12.44^{**}
Panteon	CB	230^{b}	66.5^{a}	402^{a}
	10%	214^{c}	67.6^{a}	339^{b}
	15%	249^{a}	68.5^{a}	286^{c}
	20%	227^{bc}	67.8^{a}	309^{bc}
	F-statistic	13.79^{**}	1.44^{ns}	30.32^{**}
Preludio	CB	205^{c}	50.9^{b}	329^{a}
	10%	231^{b}	51.4^{ab}	339^{a}
	15%	249^{a}	52.6^{ab}	336^{a}
	20%	255^{a}	53.4^{a}	335^{a}
	F-statistic	46.71^{**}	4.56^{*}	0.43^{ns}

*, **Significant for $P = 0.05$ and $P = 0.01$, respectively; [ns]not significant; [a–c]homogenous group, data with different superscript letters within columns significantly differ ($P < 0.05$); FN – falling number; WA – water absorption; BV – bread volume; ROF – residual oat flour; CB – control bread

The supplementation of non-bread flour-like triticale with ROF that contains non-gluten forming proteins causes gluten dilution and consequently reduces its breadmaking properties and results in difficulties in dough handling, lower BV and reduced bread textural properties. The BV decreased in comparison to CB in the case of Fredro and Panteon cultivars, and the values changed from 362 cm^3 to 317 cm^3 and from 402 cm^3 to 309 cm^3, respectively. There were no significant differences in the case of breads obtained from the Preludio cultivar, and the average value was 335 cm^3. Aside from BV, some features such as the shape of loaves, crust colour or crumb texture were evaluated. Regardless of the triticale cultivar, the CB and breads with 10% ROF were evaluated as round-topped, with a normal, light brown crust and quite a smooth surface and elastic crumbs with regular porosity. After the addition of 15% or 20% of ROF, these parameters significantly decreased (Figure 1). The breads were medium round or flat-topped, with pale crust and a wrinkled top surface, and non-elastic and sticky crumb texture, especially in the case of 20% ROF. Moreover, there were some problems during bread making in the case of the highest ROF concentrations. Mechanical treatment was difficult, and the dough was consistently very sticky and malleable. Similar results were obtained by Peymanpour et al. (2012), who supplemented wheat bread with oat flour and observed decreased BV of 290 cm^3 for CB and 133 cm^3 with a 50% addition of oat flour, whereas Mariotti et al. (2006) observed higher results between 778 cm^3 and 422 cm^3, independently of the breadmaking method. The same author also reported poorer wheat bread parameters such as bread grain and

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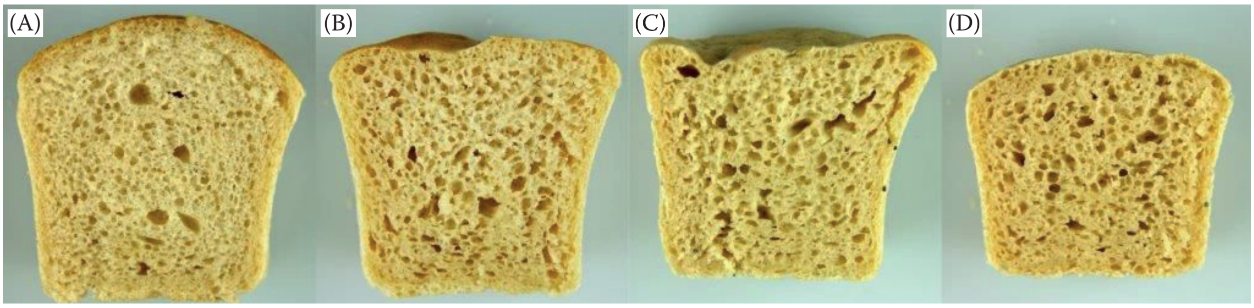

Figure 1. Inside view of breads made of Panteon cultivar: (A) CB, (B) 10% ROF, (C) 15% ROF, (D) 20% ROF

CB – control bread; ROF – residual oat flour

total cells with the addition of oat flour, and in the case of a 40% addition of oat flour, it was impossible to bake bread. Majzoobi et al. (2016) analysed the textural properties of bread with the addition of whole-grain oat flour (10–30%). With rising oat flour concentration, they observed increased bread hardness and chewiness and decreased cohesiveness and elasticity, while Londono et al. (2015) observed that β-glucan addition negatively impacted on elastic properties of wheat dough. Taking into account the decreasing technological parameters but a comparable bioactive value that accompanied ROF addition, the best bread quality was obtained for 10% ROF addition. This solution allows for optimal utilisation of ROF as a by-product while maintaining the good quality of bread.

Chemical composition. The supplementation of triticale with ROF caused a slight increase in the protein content of the breads, with values ranging between 9.0% for Preludio CB and 14.3% for Panteon with 15% ROF (Table 2). Breads obtained from the Panteon cultivar were simultaneously the highest source of protein, regardless of ROF concentration. The ash content was similar for all samples with an average value of 2.4%, whereas the lipids content increased significantly from 1.2% for Fredro CB to 2.6% for Preludio with 20% of ROF. Due to the innovative nature of the present study, there is no data in the literature about supplementation with triticale flour, and so far, research has been conducted mainly on wheat flour. Gambuś et al. (2011) obtained a similar increase in protein and lipid content after supplementation with 20% of wheat and rye flour with ROF. Also, El Shebini et al. (2014) analysed the protein and ash content in wheat-oat snacks containing the addition of 25% of oat flour and obtained values at a level of 15.1% and 2.1%, respectively. A twofold increase in lipid content after ROF supplementation resulted in triticale-oat breads with a significantly higher nutritional value in comparison to control samples, especially considering the valuable composition and properties of oat lipids.

ROF contains 6.1% of DF; thus, its addition to triticale flour meant that the content of DF in breads decreased or did not change as the ROF concentration increased. Nevertheless, the DF content (over 6 g 100 g^{-1}) allows us to include all the obtained breads among food products that are high in fibre, according to Regulation (EC) No. 1924/2006 of the European Parliament and of the Council on nutrition and health claims made on food. The highest sources of DF were triticale-oat breads obtained from the Panteon cultivar (8.6%) and the lowest from the Preludio cultivar (6.7%) (Table 2). The DF content in breads did not increase, but the content of its individual components changed significantly after the addition of ROF. Both cereals have different proportions of DF, and NSP constitutes over 73% of their individual components. The predominant part of NSP in triticale is I-NSP, in which arabinoxylans consists of over 80% (Fraś et al. 2016). In oat, the main part of NSP is S-NSP in which the main component is β-glucan. Therefore, after supplementation, the proportion of I-NSP and S-NSP have changed and the breads obtained have a unique combined composition of DF. The content of the I-NSP significantly decreased after the addition of ROF, and values ranged between 4.2–3.4%, 4.0–3.7%, and 3.3–3.0%, respectively for Fredro, Panteon, and Preludio cultivars. The S-NSP in triticale-oat breads slightly increased, and values ranged between 1.4–1.6%, 2.1–2.3%, and 2.1–2.4%, respectively for Preludio, Panteon, and Fredro cultivars. The β-glucan content significantly increased after the addition of ROF, and the obtained values ranged between 0.2% for Preludio CB and 0.6% for Panteon with 20% ROF (Table 2). The combination of two non--bread cereal products means that the new breads contain valuable NSP components, characteristic of each cereal and simultaneously have improved bioactive

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Table 2. Mean values of bread nutrient and bioactive components (% of d.w.) for analysed cultivars and ROF concentrations

Cultivar	ROF	Protein	Ash	Lipids	I-NSP	S-NSP	NSP	Lignin	RS	DF	β-glucan
Fredro	CB	10.4^{b}	2.4^{a}	1.2^{c}	4.2^{a}	2.3^{ab}	6.5^{a}	0.4^{a}	2.1^{a}	8.9^{a}	0.3^{b}
	10%	10.4^{b}	2.3^{a}	1.7^{b}	4.0^{ab}	2.1^{b}	6.1^{ab}	0.3^{a}	1.8^{b}	8.2^{b}	0.4^{ab}
	15%	11.0^{a}	2.4^{a}	1.9^{ab}	3.7^{bc}	2.2^{ab}	5.9^{b}	0.4^{a}	1.9^{b}	8.2^{b}	0.5^{a}
	20%	11.0^{a}	2.4^{a}	2.0^{a}	3.4^{c}	2.4^{a}	5.8^{b}	0.5^{a}	1.9^{b}	8.2^{b}	0.5^{a}
	F-statistic	6.60**	2.20^{ns}	38.06**	16.95**	4.83*	5.89*	1.73^{ns}	28.22**	5.96**	10.96**
Panteon	CB	13.9^{b}	2.4^{b}	1.4^{a}	4.0^{a}	2.2^{a}	6.2^{a}	0.4^{b}	2.1^{a}	8.6^{a}	0.3^{c}
	10%	13.9^{b}	2.4^{b}	1.7^{a}	3.9^{ab}	2.1^{a}	6.1^{a}	0.3^{b}	2.1^{a}	8.4^{a}	0.4^{b}
	15%	14.3^{a}	2.4^{a}	2.2^{b}	3.8^{ab}	2.2^{a}	5.9^{a}	0.6^{a}	2.1^{a}	8.7^{a}	0.6^{a}
	20%	14.0^{ab}	2.4^{a}	2.5^{b}	3.7^{b}	2.3^{a}	6.0^{a}	0.7^{a}	1.9^{a}	8.6^{a}	0.6^{a}
	F-statistic	7.20*	30.90**	25.83**	4.23*	1.96^{ns}	0.70^{ns}	19.92**	3.06^{ns}	0.51^{ns}	33.01**
Preludio	CB	9.0^{c}	2.4^{c}	1.4^{d}	3.3^{a}	1.4^{ab}	4.7^{a}	0.5^{b}	1.8^{a}	6.9^{a}	0.2^{c}
	10%	9.7^{b}	2.5^{b}	1.8^{c}	3.1^{ab}	1.4^{b}	4.4^{ab}	0.5^{b}	1.6^{b}	6.5^{b}	0.3^{b}
	15%	9.8^{b}	2.5^{a}	2.3^{b}	2.9^{b}	1.5^{ab}	4.3^{b}	0.7^{a}	1.6^{b}	6.6^{ab}	0.5^{a}
	20%	10.8^{a}	2.5^{a}	2.6^{a}	3.0^{b}	1.6^{a}	4.6^{ab}	0.6^{ab}	1.5^{b}	6.6^{ab}	0.5^{a}
	F-statistic	40.50**	53.40**	254.01**	9.12**	6.74**	6.13**	9.34**	16.23**	3.78*	34.08**

*, **Significant for $P = 0.05$ and $P = 0.01$, respectively; ^{ns}not significant; $^{a-c}$homogenous group, data with different superscript letters within columns significantly differ ($P < 0.05$); ROF – residual oat flour; NSP – non-starch polysaccharides; I-NSP – NSP with its insoluble fractions; S-NSP with its soluble fractions; RS – resistant starch; DF – dietary fibre; CB – control bread

value. Gambuś et al. (2011) obtained a similar and lower content of DF in wheat-oat and wheat-rye-oat breads with values at a level of 6.7% and 7.9%, respectively. The content of particular DF fractions of wheat-oat breads was similar to triticale-oat breads, with values at a level of 2.4% of S-NSP and 4.2% of I-NSP. Huttner et al. (2010) analysed the chemical composition of different types of oat flour and obtained values of β-glucan content higher than in the presented data, in a range between 3.8%–4.5%. Angioloni and Collar (2012) also analysed β-glucan content in bread supplemented with 60% of oat flour and obtained significant higher values at a level of 2.4%. With respect to the other DF components, there was a slight increase in lignin content after the addition of ROF with an average value of 0.5% and a slight decrease of RS with an average value of 1.9%.

Sensory quality. Triticale-oat bread is a new product not available on the market. Besides its unique chemical composition, it also has a specific taste. Therefore, a sensory analysis of breads obtained from Panteon and Preludio cultivars with 10% ROF was performed. In the case of crust smoothness, gloss, and thickness, both breads were evaluated as better in comparison to the CB, whereas the crust colour obtained from the Preludio cultivar was evaluated as worse because it was lighter. The evenness of colour in both analysed samples was better, but crust crunchiness was significantly lower than the reference bread (Figure 2A). The best crumb flexibility was evaluated for bread obtained from the Preludio cultivar, followed by the CB and Panteon. The crumb porosity in both breads was estimated lower, but crumb moisture, colour, and colour evenness was better than in the control. The intensity of bread and yeast aroma as well as the yeasty taste of the bread were more noticeable in the CB than in breads with ROF. The interpretation of these features is very subjective because lower values do not always mean lower quality. It depends on personal and, more generally, social preferences. The salty taste was more noticeable in both triticale-oat breads, while a sour taste was predominant in the CB (Figure 2B). With respect to bread slices, the best shape was evaluated for breads from the Preludio cultivar, while bread obtained from Panteon was negatively evaluated in comparison to the control. The appearance of ana-

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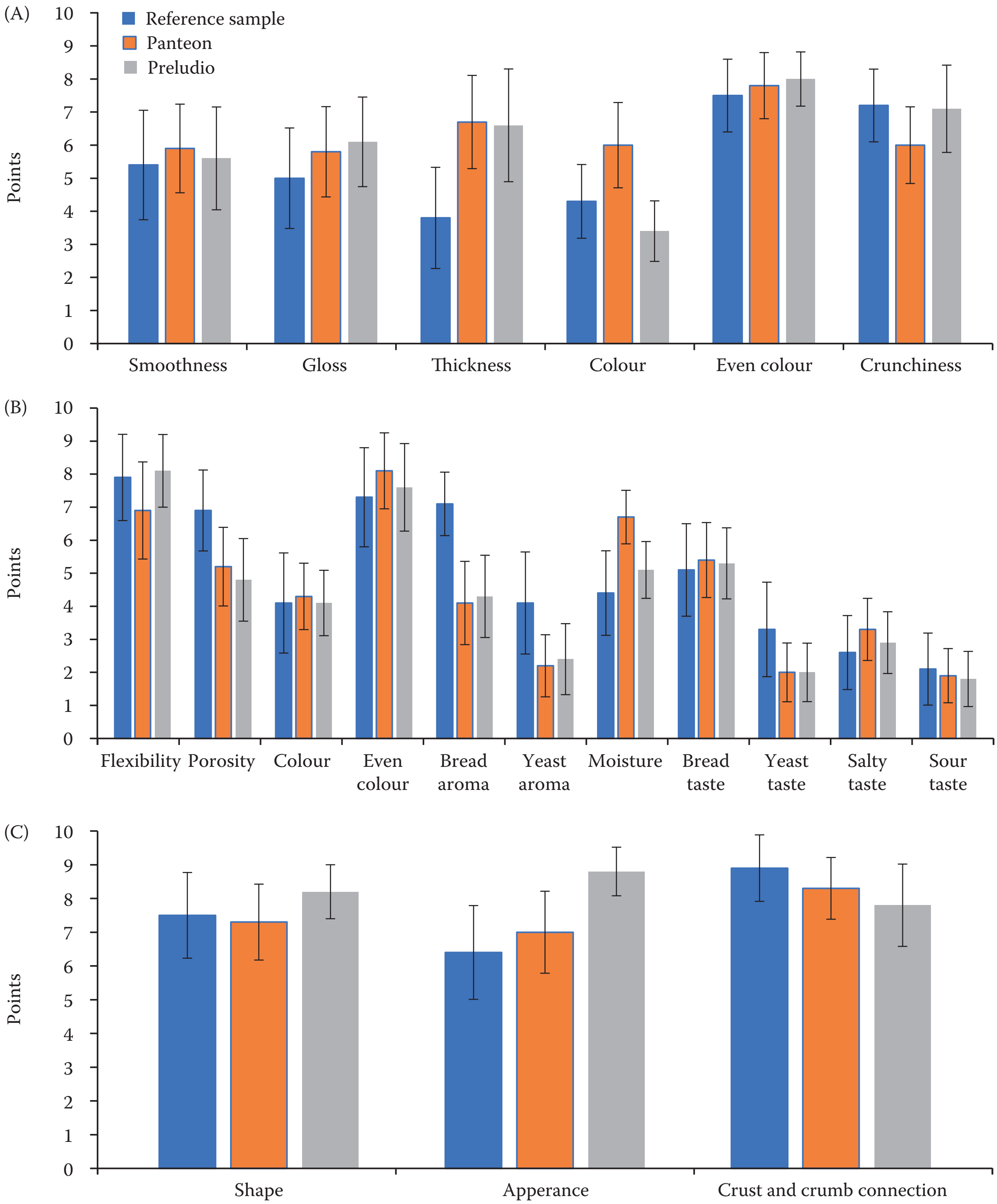

Figure 2. The results of sensory analysis for Panteon and Preludio cultivars with 10% of ROF (expected values and quartile ranges): (A) crust parameters, (B) crumb parameters, (C) slice parameters

ROF – residual oat flour

lysed slices was evaluated as better for triticale-oat breads compared to the control, while the crumb and crust connection was significantly better with respect to the reference bread (Figure 2C). For most of the assessed features, they were rated more advantageous in comparison to the CB that confirms the attractive-

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ness of new products for the consumer. Because triticale is rarely used in breadmaking, so there is little literature data on its sensory quality. However, many authors described the sensory properties of bread with the addition of oat flour. Majzoobi et al. (2016) did a sensory evaluation of wheat breads containing different levels of oat flour and showed that with increasing oat flour concentration parameters such as colour, texture, taste, and overall acceptability decreased. Similar results were obtained by Peymanpour et al. (2012), who analysed crust and crumb colour, texture, taste, and chewiness and observed the best results in sensory quality for 10% and 20% additions of oat flour.

CONCLUSION

Based on the presented results, the addition of a by-product in the form of ROF to triticale flour made it possible to obtain bread with good biological value. All breads had contained comparable content of nutrients, and the breads with ROF addition characterised by a significantly higher content of β-glucan in comparison to the CB. It indicates that this type of bread may be an alternative cereal product. Non-bread cereals offer many nutritional benefits not found in commonly used grains. Nowadays, food products not only satisfied hunger but also should prevent nutrition-related diseases. Most of them are considered to contain health benefits by consumers (Gosine and McSweeney 2019). The use of ROF is also economically important and is in line with current global trends. Waste materials are increasingly used in food processing, and therefore the utilisation of by-product is an interesting solution in bread production (Zdybel et al. 2018). The obtained results showed that there is a possibility to use by-product and non-bread cereal as potential raw materials for designing and creating novel food.

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