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NUTRITIONAL QUALITY OF TRITICALE (×*TRITICOSECALE* WITTM.) GROWN UNDER DIFFERENT CROPPING SYSTEMS

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Triticale (× Triticosecale *Wittm.) is mainly used for animal feed, but recent studies have shown its possible beneficial effect for human health. The objective of this study was to investigate the nutritional quality of triticale grown under different cropping systems in Latvia. Two winter triticale varieties, 'Inarta' and 'Ruja', were cultivated in 2014 and 2015 under conventional and organic cropping systems. Protein, starch, and total dietary fibre were determined using standard methods. Ultrasound assisted extraction was used for isolation of phenolic compounds. Total phenol content (TPC) and radical scavenging activity in extracts were determined spectrophotometrically. Overall, the highest content of protein, TPC and ABTS cation scavenging activity occurred in triticale harvested in 2014, due to favourable weather conditions (warm weather and more precipitation in June–July) for accumulation of these compounds during grain filling. Higher starch content in all studied samples harvested in 2015, as compared to 2014, was explained by higher precipitation in July 2015. The type of cropping system had no significant effect ($p > 0.05$) on protein and starch content, while TPC, DPPH, and $ABTS^{\cdot +}$ scavenging activity was influenced by cropping system, depending on variety.*

Key words: *triticale, variety, organic, conventional cropping system, grain quality.*

INTRODUCTION

Organic cropping systems that aim at minimising the negative impact on soil, water, and air quality (Autret *et al.*, 2016) are gaining attention as alternatives to conventional cropping systems. They allow to achieve greater sustainability of agro-ecosystems, reducing external inputs (i.e. fertilisers and pesticides) and/or tillage, while increasing crop diversity and intensity (Benaragama, 2016). The core of sustainable organic production is systemic prevention of weeds, pests, and diseases, combined with nutrient self-sufficiency (Lammerts van Bueren *et al.*, 2002).

Growing of wheat in organic cropping systems is limited by disease due to solid smut (*Tilletia caries*). Triticale is resistant to this disease, and therefore can be used for production of new niche products from organic grains (Kronberga *et al.*, 2013). Generally, triticale combines traits of the rye genome, such as resistance to rust disease and environmental tolerance (including soil conditions, winter hardiness), with traits of wheat, such as high yield potential with good grain quality (Griffith and Lang, 2004; Rakha *et al.*, 2011). Therefore, it has the potential as an alternative crop for various end-uses in a wide range of environments; breeding programmes worldwide are aimed at improving abiotic stress resistance in marginal lands (acid, alkaline, sandy, element deficient or toxic soils), biotic resistance, food and feed quality, and to develop new triticale varieties for specific end-uses (Cantale *et al.*, 2016).

Triticale is traditionally used as a component of animal feed, but also on a smaller scale as a renewable crop for more sustainable energy production (Cantale *et al.*, 2016; Fraś *et al.*, 2016). Considering its valuable grain composition, it can also be used as a food ingredient, for example, in bread or as a replacement for soft wheat in biscuits, cakes, and cookies (Rakha *et al.*, 2011). Fraś *et al.* (2016) showed that triticale grain is comparable to wheat as a protein source (11.4–14.0%), with a slightly higher amount of lysine (0.33–0.71%). Its dietary fibre content is similar to wheat, but with a higher amount in the soluble fraction, especially water-extractable arabinoxylans, which display viscous properties in an aqueous solution (Rakha *et al.*, 2011). Triticale contains also many phenolics with antioxidant activity, alkylresorcinols, phytoestrogens, vitamins, and microelements (Jonnala *et al.*, 2010). Triticale varieties showed high and significant variability in the content of chemical components (Fraś *et al.*, 2016). Grain chemical composition is typically affected by environmental conditions, such as temperature during the grain filling period (Häne *et al.*, 2013) and water stress during grain development, both of which may affect the nutritional qualities in triticale end-uses (He *et al.*, 2012).

The aim of this study was to determine the nutritional quality of triticale grown under different cropping systems in Latvia.

MATERIALS AND METHODS

Two Latvian winter triticale (× *Triticosecale* Wittm.) varieties ('Inarta' and 'Ruja') were grown under conventional and organic cropping systems. Field trials were established in experimental fields of the Institute of Agricultural Resources and Economics (57°18'57"N, 25°20'19"E, 123 m altitude) in 2013/2014 and 2014/2015. The trial field was certified for organic cropping.

Sowing took place on 19 September 2013 and on 21 September 2014. A randomised plot design was used in the experiment. The triticale varieties were sown in four replicates. Experimental plot size was 12 m^2. The sowing rate was 400 seeds per m^2 in the conventional field and 450 seeds per m^2 in the organic field. Application of fertilisers and chemical pesticides on the conventional field was according to agronomical practice in Latvia.

Physical and chemical analysis. Moisture content was determined according to ISO 712:2010 A in triplicate (mean values are reported), at 130 ± 5 °C for 60 min.

Falling number (FN) was determined according to ISO 3093:2009 method using a Perten FN 1900 analyser (Perten, Sweden). Averages of two replications are reported.

Protein content was determined as the total nitrogen content by the Kjeldahl method in duplicate (mean values are reported). The content of protein was calculated using nitrogen conversion coefficient 6.25 (ISO 5983-1:2005).

Starch content was determined using standard procedure on a previously calibrated Infratec™ 1241 Grain Analyser Model 1241 (Foss, Sweden).

Total dietary fibre content was determined according to the standard method AOAC No 985.29 in triplicate (mean values are reported) using a Fibertec E System (Foss, Sweden).

Total phenol content. For sample extraction 20 mL of solvent (acetone : ethanol : water, 7 : 7 : 6) was used. Samples were extracted in a ultrasonic bath YJ 5120-1 (Oubo Dental, USA) at room temperature for 10 min, followed by centrifugation in a centrifuge CM-6MT (Elmi Ltd., Latvia) at 3500 rpm for 5 min. Clear supernatant was transferred to a 50 mL graduated flask. Solids were re-extracted following the same procedure. Supernatant was combined with the previous one and filled with solvent up to the mark. Total phenol content was determined according to the Folin–Ciocalteu spectrophotometric method (Singleton *et al.*, 1999): 2.5 mL Folin–Ciocalteu reagent (diluted 10 times with water) was added to 0.5 mL extract and, after 5 min, 2 mL sodium carbonate water solution (Na_2CO_3) (75 g·L^{-1}) was added. Then the sample was mixed. The control sample contained all the reaction reagents except the extract. After 30 min of incubation at room temperature, the absorbance was measured at 765 nm using a Jenway 6300 spectrophotometer. Total phenol content was expressed as gallic acid equivalents (GAE) per 100 g sample dry weight (DW).

$DPPH^{\cdot}$ radical scavenging activity of the grain extracts was measured as scavenging activity of the stable 2,2-diphenyl-1-picrylhydraziyl ($DPPH^{\cdot}$) radical, as described by Yu *et al.* (2003). The antioxidant reaction was initiated by transferring 0.5 mL plant extract into a sample cavity containing 3.5 mL freshly prepared $DPPH^{\cdot}$ methanol solution (0.004 g $DPPH^{\cdot}$ to 100 mL methanol). After 30 min of incubation in the dark at room temperature, the absorbance was measured at 517 nm. The radical scavenging capacity was expressed as mg of Trolox equivalents (TE) 100 g^{-1} DW of the samples.

$ABTS^{\cdot+}$radical scavenging activity of extract was measured by $ABTS^{\cdot+}$radical cation assay (Re *et al.*, 1999). Phosphate buffered saline (PBS) was obtained by dissolving 8.18 g sodium chloride (NaCl), 0.27 g potassium dihydrogen phosphate (KH_2PO_4), 1.42 g sodium phosphate dibasic (Na_2HPO_4), and 0.15 g potassium chloride (KCl) in 1 L of ultra-pure water. A stock solution of ABTS (2 mM) was prepared in 50 mL PBS. If the pH was lower than 7.4, it was adjusted with sodium hydroxide (NaOH). Ultra-pure water was used to prepare 70 mM potassium persulfate ($K_2S_2O_8$). $ABTS^{\cdot+}$radical cation was produced by reacting 50 mL $ABTS^{\cdot+}$ stock solution with 0.2 mL of $K_2S_2O_8$ solution and allowing the mixture to stand in the dark at room temperature for 15–16 h before use. The radical was stable in this form for more than two days when stored in the dark at room temperature. For the assessment of extracts, the $ABTS^{\cdot+}$ solution was diluted with PBS to obtain an absorbance of 0.800 ± 0.030 at 734 nm. Five mL of $ABTS^{\cdot+}$ solution were mixed with 0.05 mL extract. The absorbance was read at ambient temperature after 10 min. PBS solution was used as a blank sample. The radical scavenging capacity was expressed as mg of Trolox equivalents (TE) 100 g^{-1} DW of the samples.

Statistical analysis. The results (mean, standard deviation, *p* value) were processed by mathematical and statistical methods. Data were subjected to one-way and two-way analysis of variance (ANOVA) by Microsoft Office Excel 2007, significance was defined at $p < 0.05$.

RESULTS

For both winter triticale varieties a significantly higher yield (Table 1) was obtained in the conventional field ($p < 0.05$). The yield of winter triticale variety ‘Ruja’ was higher than the yield of ‘Inarta’ under both growing conditions in both years. The results of the grain quality parameter falling number are presented in Figure 1.

The chemical composition of winter triticale depending on growing conditions is presented in Tables 2 and 3. Higher starch content and lower protein content was observed in all triticale samples harvested in 2015 compared to those harvested in 2014.

Total phenol content (TPC) in triticale in 2014 was significantly ($p < 0.05$) higher than in 2015 (Fig. 2). In 2014, grain grown under the conventional system had significantly higher ($p < 0.05$) TPC that grain grown under the organic system. However, in 2015, TPC was similar in triticale from both cropping systems.

$ABTS^{\cdot+}$ radical scavenging activity (Fig. 3) was significantly ($p < 0.05$) higher in 2014 and it strongly correlated with TPC (Fig. 4).

All samples grown under the organic cropping system had significantly higher DPPH radical scavenging activity (Fig. 5) than in the conventional system.

Table 1

YIELD OF WINTER TRITICALE IN 2014 AND 2015, t ha^{-1}

Growing conditions	Year	Variety	
		‘Inarta’	‘Ruja’
Conventional	2014	3.63	5.16
	2015	4.48	5.44
Organic	2014	3.17	3.81
	2015	2.22	2.32

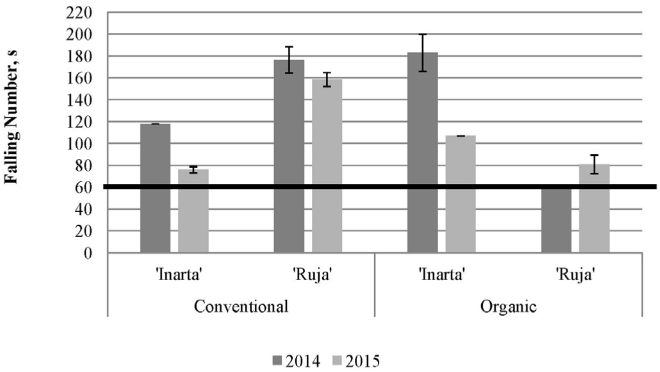

Fig. 1. Falling number of triticale varieties depending on growing conditions. The line shows the minimum requirement for FN value — 60 seconds.

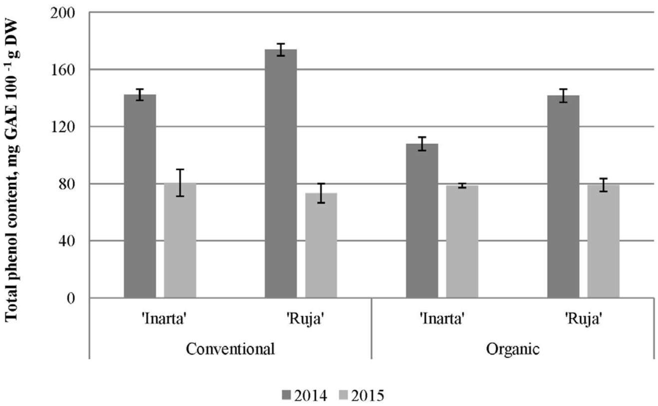

Fig. 2. Total phenol content in triticale varieties depending on growing conditions.

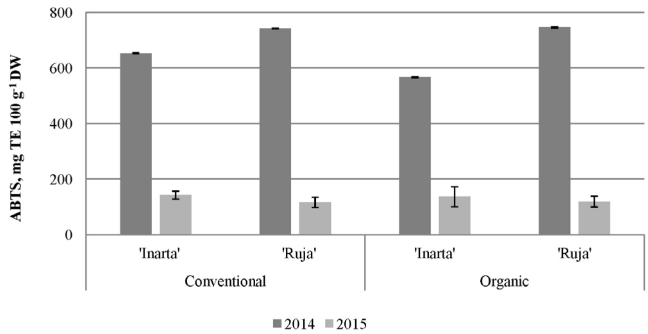

Fig. 3. $ABTS^{\cdot+}$ radical scavenging activity of triticale extracts depending on growing conditions.

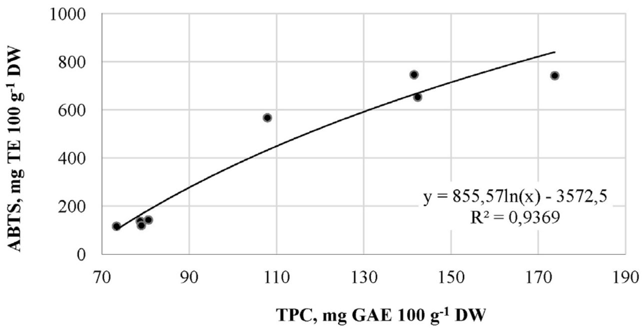

Fig. 4. Relationship between total phenolic content and $ABTS^{\cdot+}$ scavenging activity.

Table 2

CHEMICAL COMPOSITION OF THE TRITICALE VARIETY ‘INARTA’, g·100 g^{-1}

Parameter	Conventional		Organic	
	2014	2015	2014	2015
Moisture	9.19 ± 0.01	12.44 ± 0.10	8.94 ± 0.02	11.82 ± 0.05
Proteins	11.39 ± 0.01	8.31 ± 0.02	11.93 ± 0.09	7.27 ± 0.02
Starch	64.50 ± 0.30	70.20 ± 0.20	65.50 ± 0.20	70.60 ±0.30
Total fibre	17.19 ± 0.49	15.90 ± 0.18	15.32 ± 0.10	15.56 ± 0.12

Table 3

CHEMICAL COMPOSITION OF THE TRITICALE VARIETY ‘RUJA’, g·100 g^{-1}

Parameter	Conventional		Organic	
	2014	2015	2014	2015
Moisture	9.29 ± 0.01	12.08 ± 0.47	9.18 ± 0.02	11.97 ± 0.67
Proteins	9.70 ± 0.49	8.28 ± 0.17	11.14 ± 0.03	9.10 ± 0.31
Starch	64.20 ± 0.40	69.30 ± 0.30	63.20 ± 0.20	68.30 ± 0.40
Total fibre	17.23 ± 0.44	16.62 ± 0.25	16.72 ± 0.11	19.18 ± 0.37

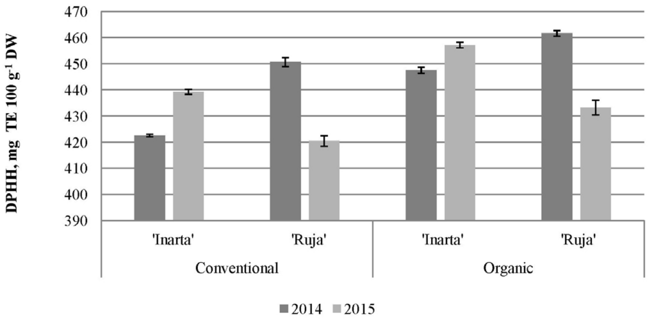

Fig. 5. DPPH radical scavenging activity of triticale extracts depending on growing conditions.

DISCUSSION

Weather conditions in 2014 and 2015 were significantly different in the triticale post-anthesis stage (June–July), when development of grain and its quality traits occurs. June 2014 was cool and had high precipitation, while July was warmer and with less precipitation, the larger part falling in one day — 1 July 2014. June in 2015 was slightly warmer than in 2014, and it was very dry with only 48.5% of the average long-term monthly precipitation. July 2015 also was warm, but precipitation was close to the long-term average.

The grain baking properties indicator FN was significantly higher in 2014 in the variety 'Inarta', which may be due to the lower precipitations in July just before harvest (Table 4), compared to that in 2015. Grain grown in the organic field had higher FN, thus being more suitable for bread making. The variety 'Ruja' did not show the same trend, as FN did not differ much depending on weather conditions and, in contrast to variety 'Inarta', grain from the conventional field had higher FN.

Protein content varied from 7.27 ± 0.02 g 100 g^{-1} ('Inarta', organic, 2015) to 11.93 ± 0.09 g 100 g^{-1} ('Inarta', organic, 2014). No significant effect of cropping system on protein content was found ($p > 0.05$). Triticale harvested in 2014 had significantly higher protein content ($p < 0.05$), irrespective of growing system or variety. This can be explained by the favourable weather conditions (warmer weather and more precipitation) for nitrogen accumulation in grain in June–July 2014 (see Table 4). Similar protein content in triticale varieties has been previously reported:

Table 4

WEATHER IN JUNE–JULY DURING TRITICALE POST-ANTHESIS STAGE

Year		GDD_5 *	Precipitation, mm
2014	June	259.7	108.3
	July	451.4	76.5
	Total (June–July)	**711.0**	**184.8**
2015	June	273.4	39.4
	July	344.2	91.5
	Total (June–July)	**617.6**	**130.9**

* Growing degree days above a base of 5 °C

Tohver *et al.* (2005) reported 9.7–14.5 g·100 g^{-1} depending on genotype grown in Northern conditions, Rakha *et al.* (2011) observed 11.7–15.7 g·100 g^{-1} depending on cultivar and growing site; and Fraś *et al.* (2016) reported 11.8–15.2% depending on cultivar (Fraś *et al.*, 2016). The observed inverse relationship between grain yield and protein content in our study was previously reported by several researchers (Martre *et al.*, 2003; Barraclough *et al.*, 2014).

The highest starch content among studied varieties was observed in the variety 'Inarta' in the organic field in 2015, and the lowest in the variety 'Ruja' in the organic field in 2014. Higher starch content in all studied samples in 2015 compared to 2014 was associated with higher precipitation in July 2015. This is consistent with the results of He *et al.* (2012) who found that water stress leads to a significant decline of ADP-glucose pyrophosphorylase expression in the mid grain filling stage of triticale, causing a decrease in total starch content. No significant difference in starch content was observed between conventional and organic cropping systems ($p > 0.05$), which indicates importance of genotype. Generally, the variety 'Inarta' had higher starch content irrespective of weather and growing conditions. This is in agreement with the results of Fraś *et al.* (2016) who reported that the content of starch differed significantly between triticale varieties, ranging from 60.8 g·100 g^{-1} to 67.6 g·100 g^{-1}. Rakha *et al.* (2011) indicated the average starch content differed in triticale cultivars grown in different locations: 63.5–70.4 g ·100 g^{-1} in one location and 59.2–66.4 g·100 g^{-1} in the other, which was explained by unfavourable weather conditions in the second location. A negative correlation ($r = -0.87$) was observed between protein and starch content, which is in agreement with previous findings of Rakha *et al.* (2011).

Fibre content in triticale was between 15.32 ± 0.10 g·100 g^{-1} ('Inarta', organic field, 2014) and 19.18 ± 0.37 g·100 g^{-1} ('Ruja', organic field, 2015). The observed differences in the organic cropping system may be due to weather conditions. Similar total dietary fibre content (13–16 g·100 g^{-1}) depending on growing location and cultivar was reported by Rakha *et al.* (2011).

Total phenol content ranged from 73.35 ± 6.74 mg GAE 100 g^{-1} ('Ruja', conventional, 2015) to 173.79 ± 4.14 mg GAE 100 g^{-1} ('Ruja', conventional, 2015). Our results showed that TPC in triticale in 2014 was 1.4–2.4 times higher than that in 2015, which was explained by differences in weather conditions. Hura *et al.* (2016) found differences in the quantitative and qualitative composition of individual carbohydrates and phenolic compounds, depending on the developmental stage and water availability. In July 2014, less precipitation might have caused higher TPC content in grain. Other researchers reported similar total polyphenol content, ranging between 1.3 mg GAE g^{-1} and 1.6 mg GAE g^{-1} (Fraś *et al.*, 2016), whereas the content 2.0 mg GAE g^{-1} obtained by Jonnala *et al.* (2010) was higher in comparison to the present study.

$ABTS^{\cdot+}$ radical scavenging activity was from 116 ± 18 mg TE 100 g^{-1} DW ('Ruja', conventional field, 2015) to 746 ± 2 mg TE 100 g^{-1} DW ('Ruja', organic field, 2014). Antiradical activity (ABTS) of triticale in 2014 was 4.1–6.4 times higher than in 2015, and was correlated with the TPC. DPPH radical scavenging activity did not show clear relationship with TPC, growing system or weather conditions.

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TRITIKĀLES (×*TRITICOSECALE* WITTM.) GRAUDU UZTURVĒRTĪBA DAŽĀDĀS AUDZĒŠANAS SISTĒMĀS

Tritikāli (× *Triticosecale* Wittm.) galvenokārt izmanto lopbarībai, bet pētījumu rezultāti liecina, ka to būtu lietderīgi izmantot arī pārtikā. Šī pētījuma mērķis bija izpētīt dažādās audzēšanas sistēmās Latvijā ražotas tritikāles uzturvērtību. Pētījuma objekts ir divas ziemas tritikāles šķirnes 'Inarta' un 'Ruja', kas audzētas 2014. un 2015. gadā konvencionālajā un bioloģiskajā audzēšanas sistēmā. Olbaltumvielu, cietes un kopējo šķiedrvielu saturs noteikts ar standartmetodēm. Fenolu savienojumu ekstrakcijai izmantota ultraskaņa. Augstākais olbaltumvielu saturs, kopējo fenolu saturs un $ABTS^{\cdot+}$ antiradikālā aktivitāte konstatēta 2014. gada ražā, pateicoties bioloģiski aktīvo savienojumu akumulēšanai labvēlīgiem meteoroloģiskajiem apstākļiem — augstāka temperatūra un mazāks nokrišņu daudzums jūnijā un jūlijā. Augstāks cietes saturs noteikts 2015. gada ražas paraugos, un tas pozitīvi korelē ar lielāku nokrišņu daudzumu 2015. gada jūlijā. Audzēšanas sistēmai nebija būtiskas ietekmes ($p > 0.05$) uz olbaltumvielu un cietes saturu, turpretī kopējo fenolu saturu un DPPH un $ABTS^{\cdot+}$ radikāļu saistīšanas aktivitāti ietekmēja gan audzēšanas sistēma, gan šķirne.