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ESTIMATION OF THE SELECTED WINTER WHEAT (*TRITICUM AESTIVUM* L.) VARIETIES CULTIVATED IN ORGANIC AND CONVENTIONAL CROP PRODUCTION SYSTEMS

PORÓWNANIE SKŁADU CHEMICZNEGO ZIARNA WYBRANYCH ODMIAN PSZENICY OZIMEJ (*TRITICUM AESTIVUM* L.) W EKOLOGICZNYM I KONWENCJONALNYM SYSTEMIE PRODUKCJI

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Streszczenie. Materiał badawczy stanowiło ziarno pszenicy ozimej (*Triticum aestivum* L.) pochodzące z doświadczenia przeprowadzonego w Gülzow (Niemcy) w latach 2010–2011. Celem badań było porównanie wybranych cech jakościowych czterech niemieckich odmian pszenicy ozimej (Akteur, Adler, Discus, JB Asano) uprawianych w ekologicznym i konwencjonalnym systemie produkcji. Oceną objęto zawartość: suchej masy, białka, tłuszczu, włókna surowego, węglowodanów ogółem, frakcji włókna (NDF, ADF, ADL, HCEL, CEL). W systemie ekologicznym w przypadku czterech odmian średnio z dwóch lat uzyskano o 27% mniej białka niż w ziarnie z uprawy konwencjonalnej ($p < 0{,}05$). Stwierdzono, że ziarno pszenicy ozimej z uprawy ekologicznej zawierało więcej węglowodanów ogółem ($p < 0{,}01$) i włókna surowego ($p < 0{,}05$) niż z uprawy konwencjonalnej. Poszczególne odmiany cechowały się istotnie zróżnicowaną zawartością włókna surowego, a także frakcji włókna. Na podstawie przeprowadzonych badań nie można jednoznacznie stwierdzić, który system uprawy pszenicy ozimej ma korzystniejszy wpływ na jej wartości odżywczą i pokarmową.

Key words: chemical components, cultivars, fibre fractions, organic and conventional crop production systems, winter wheat.
Słowa kluczowe: ekologiczny i konwencjonalny system produkcji, odmiany, pszenica ozima, skład chemiczny.

INTRODUCTION

Recently, an increase in the interest in organic farming has been observed. In such kind of cultivation system use of synthetic herbicides and pesticides is forbidden and mineral fertilisers have to be replaced by organic ones. This means that disease-resistant varieties selection and the plants protection are both of a crucial importance. The protection against diseases, pests and weeds has to be mechanical and only with use of agronomic methods. like application of appropriate succession and neighbourhood of plants, and excluding conventional means of plant protection (Żelezik 2009). Food produced in organic farming has

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higher nutritious and pro-health qualities than food produced conventionally. It is a resultant of several factors, including a cultivation method, a variety, maturity level and weather conditions during the vegetation period (Caris-Veyrat et al. 2004). The market offers increasingly high number of various organic products as the demand for such products increases. After UE had offered grants for organic production a lot of farms in Poland began organic production (Borówczak et al. 2007). However, it should be emphasised that the grain produced in the organic system contains less protein that conventionally produced cereal (Mazurkiewicz 2005; Kuś et al. 2010).

Wheat, mainly common wheat (*Triticum aestivum* ssp. *vulgare*), is the basic cereal cultivated in Polish conditions. In Poland wheat is cultivated on over 2.3 mln ha, of which 85.4% takes the winter wheat and 14.6% – the spring wheat (GUS 2015). The main objective of modern wheat cultivation is to obtain high yield varieties, which exhibit high baking qualities, have high nutrition quality and high disease resistance. Exceptional baking qualities as well as valuable chemical content make wheat a basic bread cereal in many countries. including Poland. The content and composition of dietary fibre are factors determining the quality of a cereal and cereal products. Many studies showed that because of its properties. fibre is important in prophylaxis and treatment of such diseases as diabetes, obesity, CHD, heart diseases as well as colon and large intestine cancers (Wang et al. 2002; Ferguson and Harris 2003). Animals are fed with wheat grain coming from overproduction in flour and bakery markets, with less robust grain or fodder varieties' grain. Despite containing less protein, wheat grain is very important as its source in animals' and humans' diets, especially in less developed countries, where bread and pasta are main dietary ingredients (Shewry 2009; Biel and Maciorowski 2012). Therefore, one of the main aspirations of cereal cultivation is to obtain varieties with higher protein content. This is difficult to achieve because of a negative correlation with grain yield. The protein content in grain is not an exclusively varietal characteristic as it also depends on weather and soil conditions. fertilization and chemical protection. A comparison of grains obtained from the organic crop production system and the conventional system is very difficult due to a need to analyse numerous variable parameters (Wiśniowska-Kielan and Klima 2006).

The aim of the presented research was to compare chemical composition of grain coming from the organic and the conventional crop production systems.

MATERIAL AND METHODS

The research was conducted in the years 2010–2011 in National Research Institute for Fishery in Gülzow (Germany). where organic and conventional production systems were compared at the same lacation. In 2010 in the conventional system there was chemical fertilization (nitrogen: 210 kg N · ha^{-1}), where in 2011 was 220 kg N · ha^{-1}. In both years full chemical plant protection (including herbicides, spraying against diseases and pests) were used, but in the organic system there was no mineral fertilization applied and a fore-crop of clover and a mixture of grasses were used as the source of nitrogen, without application of growth regulators or plant protection agents, including fungicides. In 2011 in the conventional system there was a winter barley as a fore-crop, while in 2010 there were grasses in the field. In the organic system in both years, a fore-crop were the same: clovers mixed with grasses. In both years the sowing dates were similar (23–24.09). Chemical content analysis were conducted on four varieties of winter wheat (the E elite class – Akteur and Adler and the A quality class: Discus and JB Asano). The varieties were chosen for the study according to several criteria: good disease resistance and length of blades (dwarf).

Chemical analyses were carried out on grain ground in a 1095 (Foss Tecator) laboratory grinder. Basic chemical composition was determined using standard methods according to AOAC (2006). In order to determine the dry mass, the samples were dried in an oven at 105°C until a constant mass was obtained. Fat as ether extract was determined using diethyl ether according to the Soxhlet method and crude ash was determined by burning in a muffle furnace at 580ºC for 8 h. Crude protein (N × 6.25) was determined according to the Kjeldahl method using a Büchi Scrubber B414 mineralisation kit and a Büchi 324 (Switzerland) distillation kit. Crude fibre (CF) was assessed according to the Hennenberg-Stohmann gravimetric method. The content of total carbohydrates was calculated according to the equation: total carbohydrates = 100 – (percentage content of protein in dry mass + fat content + crude fibre content + ash content).

The detergent fibre fractions: neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) were determined according to the method by Van Soest et al. (1991) using an 220 Fiber Analizer (Ankom Technology Co., Fairport, NY). The NDF fraction was determined with sodium lauryl sulphate (SLS), the ADF fraction with cetyl-trimethyl-ammonium bromide (CTAB), the ADL fraction with breakdown of the obtained ADF in 72% sulphuric acid. Hemicellulose content was calculated as a difference between NDF and ADF and cellulose – as a difference between ADF and ADL.

All of the analyses were carried out twice. The results are presented with standard deviation in g per kg d. m. The data was analysed using the complete randomised variance method. The analysis factors included the varieties and the years of the study. Due to the fact that only laboratory analyses repetitions were available, the sum of the error and the interaction of year × variety were used to test the significance of the main effects. The means were compared according to the Duncan's procedure at $\alpha = 0.05$ and $\alpha = 0.01$.

RESULTS AND DISCUSSION

The response of the examined wheat varieties was similar in different years of the study. For this reason the results were interpreted as means of the years 2010 and 2011 without presenting the interaction of the studied factors.

Protein is one of the most important nutrients. Its content is a basic criterion in assessment of baking quality of wheat. The protein content in grain is a hereditary feature highly influenced by habitat and agronomic factors (Podolska 2008). The levels of crude protein in wheat grain derived from the organic and the conventional crop production systems was different (Table 1). In case of the organic system the highest protein content was observed in Adler variety (126 g · kg^{-1} d. m.), whilst the lowest content was observed in JB Asano variety (106 g · kg^{-1} d. m.). In the conventional system the highest protein content was observed in Akteur (167 g · kg^{-1} d. m.) and Adler varieties (163 g · kg^{-1} d. m.) The lowest protein content was recorded in JB Asano (163 g · kg^{-1} d. m.).

Table 1. Chemical composition [g · kg^{-1} d. m.] of winter wheat grain in organic (O) and conventional (C) cultivation system
Tabela 1. Podstawowe składniki pokarmowe [g · kg^{-1} s. m.] w ziarnie pszenicy ozimej w systemach ekologicznym (E) i konwencjonalnym (K)

Item Wyszczególnienie	Dry matter Sucha masa [g · kg^{-1}]		Crude protein Białko surowe (N × 6.25)		Crude fat Tłuszcz surowy		Crude ash Popiół surowy		Crude fibre Włókno surowe		Total carbohydrates Węglowodany ogółem	
	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)
Akteur	897±8.3[a]	895±6.0	116±13.2	167±11.4	20±3.7	17±1.1	19±3.6	17±2.2	21±2.6	19±3.3	823±20.5	778±17.7
Adler	896±6.8	897±5.5	126±18.3	163±8.5	19±2.5	20±1.9	19±3.6	17±2.2	23±3.5	20±3.6	811±27.9	777±15.9
Discus	891±6.2	897±5.4	113±15.7	153±8. 9	20±0.8	18±0.5	19±2. 4	17±1.0	20±3.6	17±2.6	826±22.5	793±5.7
JB Asano	916±32.7	896±3.6	106±7.5	148±10.0	15±0.9	16±1.4	17±3.2	17±2.3	19±1.9	18±2.7	840±13.3	799±6.5
Mean value in organic cultivation system Średnia z prób w uprawie ekologicznej	900.4±18.5		115.7±14.9		19.1±2.9		19.1±1.8		21.3±3.0		852.3±22.1	
Mean value in organic cultivation system Średnia z prób w uprawie konwencjonalnej	896.9±4.8		158.3±11.8		18.00±1.8		17.6±1.8		18.9±2.9		787.1±14.9	

[a] Mean value ± standard deviation – Wartości średnie ± odchylenie standarowe.

The results were higher than the values presented by Oleksy et al. (2008) or Kraska and Pałys (2009), who reported the protein content at the level of only 110 g · kg^{-1} d. m. The authors studied winter wheat varieties cultivated in monocultures with various herbicide doses application. The differences between the authors confirm the fact that protein content in winter wheat grain is highly influenced by factors like cultivar, weather and soil conditions or applied fertilisers.

Fat is a component with higher influence on Gross Energy of wheat grain than protein, total carbohydrates or fibre. The highest fat content in the organic system was observed in Akteur and Discus cultivars and in the conventional system – in Adler cv. (all had ca. 20 g · kg^{-1} d. m. of fat, Table 1). Lasek et al. (2011) recorded almost 30% lower fat content in five spring wheat cultivars (Vinjett, Napola, Bryza, Zebra, Torka) and one winter wheat cv. (Muza), whilst Pieczyńska et al. (2012) found 40% lower fat content in winter wheat (Kobiera and Bogatka). Charalampopoulos et al. (2002) as well as Augustyn and Barteczko (2009) reported that the fat content in wheat grain ranges from 10.6 to 25.8 g · kg^{-1} d. m. regardless from the cultivation system. The most important environmental factor is air temperature during the cereal growth as it greatly influences the synthesis of lipid compounds in grain (Schipper et al. 1991).

Cereal grain is a source of numerous mineral compounds, determined cumulatively as crude ash. The mineral compounds are important for nutritional and technological reasons. The results of the present study confirmed the results of Wiśniowska-Kielan and Klima (2000). Kowieska et al. (2010) and Rachoń et al. (2012). The content of ash in the examined wheat varieties were similar regardless of the production system and reached 19 g · kg^{-1} d. m. in the ecological system and 18 g · kg^{-1} d. m. in the conventional system.

Crude fibre is a component of dietary fibre. In the literature there are several definitions of both dietary fibre and crude fibre. Dietary fibre contains many structures which differ in their physical and chemical properties as well as their influence on human organism (Cummings et al. 2004). The components of crude fibre are cellulose, lignin and partly hemicellulose. Appropriate fibre content in human food is essential as it stimulates alimentary canal peristalsis, but too high amounts could decrease nutrients absorption (Ötles and Cagindi 2006). Crude ash content in grain of wheat from the organic production system was significantly higher ($p < 0.05$) than in case of the conventional system (21.34 and 18.93 g · kg^{-1} d. m., respectively) – Table 1. Higher ash content was reported by Lasek et al. (2011), who recorded 27.20 · kg^{-1} of ash in Muza cultivar.

The content and composition of dietary fibre are factors determining the quality of a cereal and cereal products. Table 2 presents the content of particular detergent fibre fractions in grain of the studied wheat cultivars. The properties of fibre are mainly influenced by their origin and proportions of particular fractions (Nawirska-Olszańska et al. 2010). The highest content of NDF fraction was recorded in Adler cultivar in both organic and conventional production systems (155 and 133 g · kg^{-1} d. m., respectively). Its lowest content was recorded in JB Asano variety (128 i 125 g · kg^{-1} d. m., respectively). The research by Kowieska et al. (2010) the level of NDF fraction was variable and slightly lower (from 98 to 123 g · kg^{-1} d. m.). The differenced were caused by differential weather conditions. According to Jankowska (2003) herbicides have a significant influence on NDF fraction content.

Table 2. Fibre fraction [g · kg^{-1} d. m.] of winter wheat grain in organic (O) and conventional (C) cultivation system
Tabela 2. Frakcje włókna surowego [g · kg^{-1} s. m.] w ziarnie pszenicy ozimej w systemach ekologicznym (E) i konwencjonalnym (K)

Item Wyszczególnienie	NDF		ADF		ADL		HCEL		CEL	
	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)	O (E)	C (K)
Akteur	146±17.3[a]	131±14.3	32±4.3	30±3.0	7.9±1.1	7.0±1.5	115±11.1	101±12.1	23±3.2	22±1.6
Adler	155±14.2	133±12.9	32±3.7	31±3.5	7.6±0.7	6.6±0.4	123±10.6	102±9.8	24±3.5	23±3.2
Discus	144±20.2	126±11.9	29±5.5	27±2.5	7.9±0.8	6.9±0.8	115±15.1	99±10.0	21±4.7	19±1.9
JB Asano	128±8.0	125±14.5	31±2.9	30±2.5	7.8±0.2	7.0±0.3	97±7.9	94±12.1	23±2.9	22±2.4
Mean value in organic cultivation system Średnia z prób w uprawie ekologicznej	143.7±17.1		31.3±3.9		8.3±0.7		112.9±14.3		23.00±3.5	
Mean value in organic cultivation system Średnia z prób w uprawie konwencjonalnej	129.4±12.5		29.8±3.0		7.7±0.8		99.5±10.3		22.1±2.6	

[a] Mean value ± standard deviation – Wartości średnie ± odchylenie standarowe.

The research indicated that NDF content in animal feed (meadow hay) was influenced by ratio of applied nitrogen fertilisers to Starane 250 EC herbicide. The present research did not find significant differences between the production systems in terms of ADF fraction and its mean content in all of the samples from the organic system reached 31 g · kg^{-1} d. m. The quality of fibre if greatly determined by lignin content. The content of ADL fraction was significantly higher in grain from the organic system ($p < 0.05$, Table 3). Similarly, the content of cellulose and hemicelluloses was higher in grain from the organic system. The literature lacks information regarding dietary fibre determination in grain depending on crop production system.

Table 3. Traits comparisons of tested cultivation systems (Duncan test)
Tabela 3. Porównanie cech w ocenianych systemach uprawy (test Duncana)

Trait Cecha	Significance Istotność organic vs. conventional crop production systems system uprawy ekologiczny vs. konwencjonalny
Dry matter Sucha masa	NS[a]
Crude protein Białko surowe (N × 6.25)	*
Crude fat Tłuszcz surowy	NS
Crude fibre Włókno surowe	*
Crude ash Popiół surowy	NS
Total carbohydrates Węglowodany ogółem	**
NDF Neutral detergent fibre	*
ADF Acid detergent fibre	NS
ADL Acid detergent lignin	*
Cellulose Celuloza	NS
Hemicellulose Hemiceluloza	**

[a] NS – not significant difference – różnica nieistotna – $p > 0.05$, * – $p < 0.05$, ** – $p < 0.01$.

CONCLUSIONS

1. The chemical content of grain varied in terms of the most important nutrients (crude protein. crude fibre and particular crude fibre fractions) depending on the crop production system.
2. Wheat grain from the organic system contained on average 30% less crude fibre than in case of the conventional system.
3. The nutritious value is also determined by the content of crude fibre, which was significantly higher in the varieties in the organic production system (on average by 12%).

4. The contents of neutral detergent fibre, lignin and hemicelluloses in the varieties in the conventional crop production system were significantly lower than in case of the organic system.

The conducted research did not allow an unequivocal determination of the crop production system that would have more beneficial influence on nutritious value of winter wheat grain. Such determination would require further chemical analyses as well as technological and storage usefulness research.

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Abstract. Four winter wheat (*Triticum aestivum* L.) cultivars (Akteur, Adler, Discus, JB Asano) derived from organic and conventional production systems carried out in 2010–2011 at Gülzow (Germany) were evaluated. The wheat samples were analysed for content of dry mass, protein, fat, crude fibre, total carbohydrates and fibre fractions (NDF, ADF, ADL, HCEL, CEL). Grain originated from organic system had on average the crude protein 27% lower than that from conventional one ($p < 0.05$). It was found, that the winter wheat grain from organic system contained the higher level of total carbohydrates ($p < 0.01$) and crude fibre than that from conventional one ($p < 0.05$). The examined cultivars also significantly differed in the content of

crude fiber and dietary fiber fractions. The conducted research did not allow an unequivocal determination of the crop production system that would have more beneficial influence on nutritious value of winter wheat grain.