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Content of *B*–glucan in cereals grown by organic and conventional farming

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Abstract. In this paper, the results obtained from the investigations performed on determination of the content of soluble dietary fibre component *β*–glucan in different cereals grown by conventional and organic farming method are presented. Because dietary fibre and its components have great importance for human and animal nutrition as well as health benefits, it was a need to investigate the content of *β*–glucan from cereal domestic origin. Standardized enzymatic–gravimetric method–a mixed–linkage *β*–glucan assay Megazyme Kit (Megazyme, Ireland) was used for determination of *β*–glucan content in 27 different cereal samples: barley, oat, rye and wheat, grown at three locations during 2013. The mean values of *β*–glucan content in cereals conventionally grown ranged from 34.41 ± 1.47 g.kg^{-1} db with barley, through 23.5 ± 4.52 g.kg^{-1} db and 15.61 ± 0.36 g.kg^{-1} db with oat and rye, respectively to 5.60 ± 1.02 g.kg^{-1} db with wheat. The mean values of *β*–glucan content in analyzed cereals which were organically grown ranged from 33.28 ± 2.34 g.kg^{-1} db with barley, 21.3 ± 1.87 g.kg^{-1} db with oat, 15.81 ± 2.30 g.kg^{-1} db with rye and to 6.04 ± 0.58 g.kg^{-1} db with wheat. Compared to the other cereals investigated, barley grown by either conventional or organic farming method proved to have the highest content of *β*–glucan demonstrating its good perspective in cereal processing and technology, food market and human and animal nutrition. The positive/negative correlations allow indirect evaluation of cereals in breeding work aimed at creation of forms with increased/decreased content of *β*–glucans in grain.
***Keyword**:* barley, dietary fibre, farming type, oat, rye.

Introduction

Cereals are naturally rich in dietary fibre. Dietary fibre components, *β*–glucans by definition are chains of D–glucose polyglucides, linked by *β*–type glycosidic bonds.

These six–sided D–glucose rings can be connected to one another, on a variety of positions on the D–glucose ring structure. Either β(1,6) or β(1,4) side chains of varying distributions and lengths are linked to a backbone of β(1,3)–linked D–glucopyranosyl units [ABUAJAH *et al.*, 2013].

Cereal *β*–glucans are primarily linear with large regions of β(1,4) linkages separating shorter stretches of β(1,3) structures. The β(1→3)–D–glucans extracted from grains tend to be both soluble and insoluble.

The structural differences of β–glucans have impact on their functional and nutritional properties, plenty of health benefits including the control of blood cholesterol, low glycaemic response, prebiotic, and immunomodulatory effects.

Many diseases are currently believed to be associated with a lack of dietary fiber intake in food.

So, nutritional composition including β–glucan content of the whole grain flours of different cereals was analyzed in order to select the best variety for the development of fermented product and potentially probiotic lactic acid bacteria [DUCHONOVA *et al.*, 2013].

In the research of Noss and collab. was concluded that innate immunity reactions are not exclusively induced only by β–(1→3)–glucans, but also by β–(1→6) and β–(1→4)–structures [NOSS *et al.*, 2013, BUTNARIU, *et al.*, 2005, STEFAN, *et al.*, 2013, BARBAT, *et al.*, 2013].

There is evidence that the soluble dietary compound *β*–glucan has health claim permitted now in many countries, related to cereal–derived *β*–glucan that may significantly reduce the risk of diseases and strengthen the immune system. [VETVICKA *et al.*, 2007; EFSA Journal, 2009; European Commission Regulation, 2011].

It was reported that cereal products with beneficial influence on postprandial plasma glucose and insulin responses can be tailored by fermentation and enclosure of high–amylose and/or high–β–glucan barley and oat kernels [ALMINGER and EKLUND–JONSSON, 2008].

Additionally, *β*–glucan was reported that increase the body's defense against the harmful effects of stress and injury [CRAMER *et al.*, 2006].

Oat *β*–glucans can be highly concentrated in different types of oat brans. Eligible sources of soluble fiber providing *β*–glucan include: oat bran, rolled oats, whole oat flour, oatrim, whole grain barley and dry milled barley.

Because the oat kernel is non–digestible it must be used in milled form in order its nutritional benefits to be realized [TOSH *et al.*, 2010; DECKER *et al.*, 2014].

It was reported that oat β–glucan has cholesterol–lowering properties [OTHMAN *et al.*, 2011, WOLEVER *et al.*, 2011, WHITEHEAD *et al.*, 2014] and its intake is beneficial in the prevention, treatment and control of diabetes and cardiovascular diseases [DAOU and ZHANG, 2012].

Oat is a rich source of the water–soluble fibre (1→3)–(1→4)–*β*–D–glucan, and its effects on health have been extensively studied the last 30 years.

Oat *β*–glucans are the only dietary fiber currently recognized by the European Food Safety Authority (EFSA) to be able to reduce a disease risk [European Commission Regulation, 2011, BUTU, *et al.*, 2014a, STEFAN, *et al.*, 2013, BUTNARIU, 2012, PETRACHE, *et al.*, 2014].

β–glucans of barley are the cause of poor chick performance, most likely due to the increase in the viscosity of the intestinal contents.

The negative effects related to the use of barley in poultry diets was reviewed by Jacob and Pescatore [JACOB and PESCATORE, 2012].

Contrary to these findings, several scientific studies have shown that barley (1–3,1–4)–β–D–glucan reduces blood cholesterol levels [STEINER *et al.*, 2015].

Whole–grain barley pasta containing 3b% barley β–glucans appeared to be effective in modulating the composition and metabolic pathways of the intestinal microbiota, leading to an increased level of short–chain fatty acids in the healthy subjects samples [DE ANGELIS *et al.*, 2015].

Possible industrial applications and new technologies will define the future prospects of *β*–glucans in foods, medicines, cosmetics, and other products indicate that *β*–glucans will have an increasing role in current and future global food and medical sectors [INSTITUTE OF FOOD TECHNOLOGISTS, 2014, ZHU *et al.*, 2016].

Organic farming is a way of food producing that respects natural life cycles and operates in accordance with objectives and principles. As a part of an extensive supply chain, it also includes food processing, distribution and retailing.

Demand for production of the organic products in the European Union has increased and the EU has developed comprehensive rules on the organic production, processing, distribution, labelling and controls [COUNCIL REGULATION (EC), 2007, EUROPEAN PARLIAMENT LEGISLATIVE RESOLUTION, 2012].

The improving of the nutritional composition of cereals by organic production was reported in the study of 22 spring barley genotypes grown both organically and conventionally during two seasons [LEGZDINA *et al.*, 2014].

It was found that the organic farming increased the average content of the peptide lunasin by 47–92 %. Ten out of 22 barley genotypes produced

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significantly more lunasin under organic farming in both years.

Organic production and dietary fibre are increasingly attracting the attention of researchers taking into regard the fact that they have an important role for human and animal nutrition and their health.

The law for organic agricultural production, food products and food in Macedonia was introduced in 2009, and changes and supplements in 2011 [OFFICIAL GAZETTE 146, 2011, BUTU, *et al.,* 2014b, RODINO, *et al.,* 2014, IANCULOV, *et al.,* 2004].

The survey of quality properties of cereals grown in different regions in Macedonia through organic and conventional farming was made by Menkovska and collab. [MENKOVSKA *et al.,* 2014].

The investigation of the content of dietary fibre and its soluble and insoluble fractions (submitted for publication) was also conducted by the same authors [BUTNARIU, 2014, MIHALACHE, *et al.,* 2016, STOLERU, *et al.,* 2015, BUTNARIU, 2006].

The aim of this paper was to continue the research on dietry fibre and to determine the content of soluble dietary fibre component *β*–glucan in different cereals grown by conventional and organic farming in the country, as well as to find out the influence of the cereal kind and farming method on their values.

Material and methods

Sampling

27 cereal samples of wheat, barley, rye and oat were analysed for *β*–glucan content.

They were collected in 2013 from three locations in Macedonia: Veles, Stip–Ovce Pole, and Negotino and were produced by organic and conventional farming method.

Method for determination of β–glucan content

A mixed–linkage *β*–glucan assay kit (Megazyme, Ireland) based on the method published by McCleary and Codd [McCLEARY and CODD, 1991] was applied for determination content of cereal *β*–glucan.

The method has been accepted by the AOAC [Method 995.16, McCLEARY and CODD, 1991], AACC [METHOD 32–23.01, 2013] and ICC [STANDARD METHOD No.166, 1998].

The principle of the method in brief is that cereal samples (1 g in duplicate) were suspended and hydrated in sodium phosphate buffer pH 6.5 for hydrolysis with highly purified lichenase enzyme and filtered, then hydrolysis with *β*–D–glucosidase. ß–D–glucan is specifically hydrolyzed by lichenase to oligosaccharides, which are quantitatively cleaved to glucose by ß–glucosidase.

Glucose is measured using glucose oxidase–peroxides–buffer mixture.

Statistical Analysis

The results have been shown as a mean value ± standard deviation. The value of *β* content was calculated on dry weight basis.

Data were tested for significance using analysis of variance, the F–test using the software package Statgraph 3.0 [STATISTICAL GRAPHICS, Warrenton, Virginia, USA].

Results and discussion

The results of the determination of *β*–glucan content in different cereal samples are given in Figure 1.

The mean values of *β*–glucan content in cereals conventionally grown, ranged from 34.41 ± 1.47 $g.kg^{-1}$ db with barley, through 23.5 ± 4.52 $g.kg^{-1}$ db and 15.61 ± 0.36 $g.kg^{-1}$ db with oat and rye, respectively to 5.60 ± 1.02 $g.kg^{-1}$ db with wheat.

The mean values of *β*–glucan content in analyzed cereals which were organically grown ranged from 33.28 ± 2.34 $g.kg^{-1}$ db with barley, 21.3 ± 1.87 $g.kg^{-1}$ db with oat, 15.81 ± 2.30 $g.kg^{-1}$ db with rye and to 6.04 ± 0.58 $g.kg^{-1}$ db with wheat. Presented values are means ± sd; Data statistically insignificant ($p > 0.05$)

According to the determined content of *β*–glucan in different cereals grown by organic and conventional farming (Figure 1), barley has shown to be the richest cereal with this fiber component among the all cereals analyzed, while the wheat was the poorest one, both cereals grown by organic either by conventional farming.

Oat is the second cereal rich in *β*–glucan content after barley grown also by organic either by conventional farming type. In comparison with the farming type, organic farming has demonstrated higher values of β–glucan content in rye and wheat, while lower values in barley and oat.

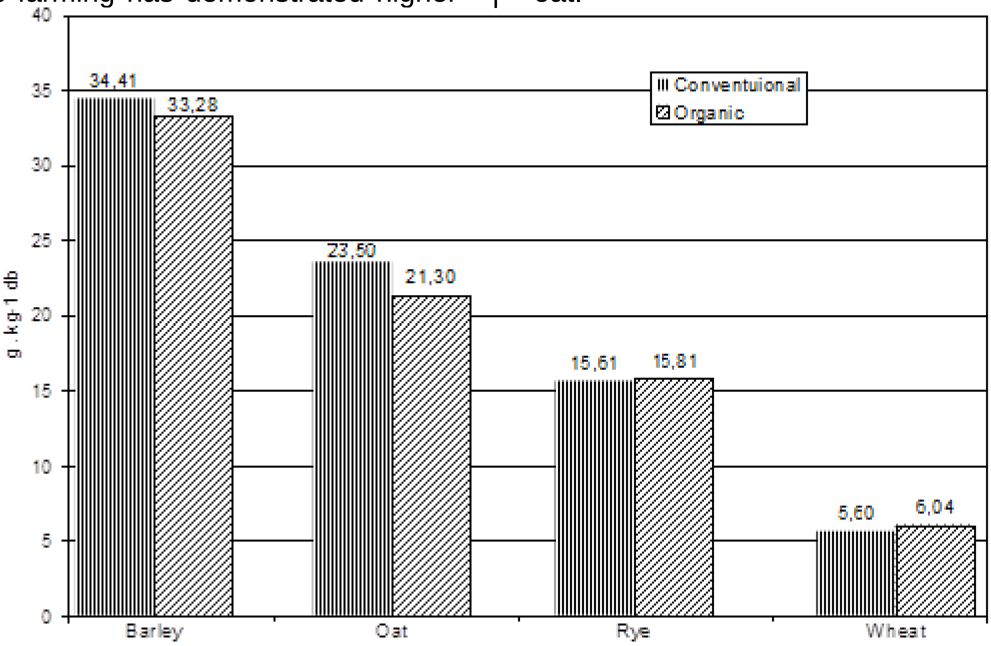

Figure 1. Content of β–glucan in different cereals grown by organic and conventional farming (g. kg^{-1} db)

The differences were insignificant. Higher values for β–glucan content was obtained in barley and oat grown by conventional method. The decreasing of β–glucan content in organic barley was lower (– 3.28 %) than that in organic oat (– 9.36 %). The increase in β–glucan content in organic wheat was higher than that found in organic rye (+ 1.28%) and (+ 7.86%) respectively (Table 1). The percentage of increasing/decreasing in β–glucan values according to the farming type can be seen in Table 1.

Table 1.

The increasing/decreasing ratio of cereal β–glucan content of different cereals in relation to farming type

Cereal	Relation	%
Barley	O/C	– 3.28
Oat	O/C	– 9.36
Rye	O/C	+ 1.28
Wheat	O/C	+ 7.86

C–Conventional; O–Organic

The values of β–glucan content determined in our analyses for oat samples were lower than those reported by Lee and collab. and Zute and collab. [LEE *et al.*, 2011, ZUTE *et al.*, 2015].

According to these authors the differences found in β–glucan content within the same oat genotype might be due to the environmental effects. Studies of Gazal and collab. pointed out the genotypic effects on β–glucan content of oat, demonstrating that it can be highly predictable [GAZAL *et al.*, 2014].

The β–glucan content in rye (Figure 1) was lower than that found in oat and barley, as was also reported by Demirbas through the study of cereal grains bread in Turkey [DEMIRBAS, 2005, BUTNARIU and CORADINI, 2012, DIMITRIU, *et al.*, 2016, BUTNARIU, *et al.*, 2012]. As for the β–glucan content determined by this

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researcher in barley grown organically and conventionally, it was positively correlated with the fat content (r = 1.00 and r = 0.57, respectively), and with ash content (r = 1.00 and r = 0.99 respectively), but it was negatively correlated with the protein content (r = –1.00 and r = –0.28, respectively).

There were negative correlations found in wheat conventionally grown between the *β*–glucan content and fat, as well as between the protein and ash content (r = – 1.00).

These correlations allow indirect evaluation of cereals in breeding work aimed at creation of varieties with increased/decreased content of *β*–glucans in grain.

The content of the *β*–glucan analyzed in our cereals was in the range of the findings of Havrlentova and collab. widely varying depending of the analytical method used (enzymatic–gravimetric or enzymatic method) [HAVRLENTOVA *et al.*, 2011, HAMBURDA, *et al.*, 2016, BUTNARIU and GIUCHICI, 2011, STOLERU, *et al.*, 2016].

Study of Shewry has also reported variation in the contents of *β*–glucan in wholemeal, flour and bran of wheat [SHEWRY, 2013].

This study in the frame of EU FP6 Healthgrain study conducted on 151 wheat lines representing a range of geographical origins has shown that the wholemeal flours from the same lines contained from 0.5 % to 0.95 % dry weight of *β*–glucan.

Different results for *β*–glucan in wholemeal flour (ranging from 2.0 % to 14.3 %) were obtained from the large-scale study reported by Pritchard and collab. on 338 hexaploid wheat lines from the Australian Winter Cereals Collection [PRITCHARD *et al.*, 2011, BUTU, *et al.*, 2015, CAUNII, *et al.*, 2015, BUTU, *et al.*, 2014c, BUTNARIU, *et al.*, 2015a].

The researches explained the widely variation of *β*–glucan content between genotypes of wheat and other cereals in whole grain, white flour and bran fractions as a result of the environment conditions, genetic differences, and to specific interactions between the genotype and environment.

In the experiments conducted on naked and husked oat cultivars genotype was found to have the largest effect on the grain composition and *β*–glucan contents.

The highest contents of b–glucan were found in the groats of husked cultivars by Redaelli and collab. [REDAELLI *et al.*, 2015].

The effect of applied nitrogen fertilizer rate and of growing season on *β*–glucan content in oat grains during a three–year growing period was also evaluated by Brunava and collab. [BRUNAVA *et al.*, 2015].

It was determined that the content of *β*–glucan in naked oat genotypes was significantly ($p < 0.05$) higher than in the husked genotypes.

The authors concluded that the effect of growing season on *β*–glucan content was significant ($p < 0.05$) for both (naked and husked) oat genotypes. *β*–glucan content of naked oat breeding lines was significantly ($p < 0.05$) higher in 2011 comparing with 2012 and 2013, due to differences in precipitation during the grain filling period.

Redaelli and collab. [REDAELLI *et al.*, 2015] reported that the *β*–glucan content in oat grains ranged from 17.3 to 57.0 $g \cdot kg^{-1}$ and Biel and collab. [BIEL *et al.*, 2014] found that there were significant differences between husked and naked oat genotypes in *β*–glucan content.

Studies of Biel and collab. have shown that naked oat genotypes have higher concentrations of *β*–glucans (from 39.2 to 48.9 $g \cdot kg^{-1}$) compared with those in husked the oats (from 27.5 to 34.7 $g \cdot kg^{-1}$) [BIEL *et al.*, 2014].

In the study of Brunava and collab. the *β*–glucan content ranged from 28.3 to 33.5 $g \cdot kg^{-1}$ for husked and from 32.0 to 47.4 $g \cdot kg^{-1}$ for naked oat genotypes, depending on growing season and nitrogen application rate [BRUNAVA et al., 2015].

Biel and collab. found that naked (44.2 $g \cdot kg^{-1}$) and dehulled (47.6 $g \cdot kg^{-1}$) oats contained significantly more *β*–glucan than husked oats (31.2 $g \cdot kg^{-1}$) [BIEL *et al.*, 2014, BUTNARIU, *et al.*, 2016, STOLERU, *et al.*, 2012, BUTNARIU, *et al.*, 2015b].

Our further investigations should be focused on examination of environmental effects on cereal *β*–glucan content, as well as of particular cereal genotype.

Conclusions

The following conclusions can be drawn:

- Barley grown by either conventional or by conversion farming method showed to have the highest value of *β*–glucan content when compared to the other cereals investigated.
- The results obtained in our investigation proved that after barley, oat could be also a significant source of *β*–glucan, while wheat could be an unsuitable one.
- Organic farming method has a good perspective in producing cereals with positive health benefits regarding fiber source, as well as food technology and healthy nutrition.
- The positive/negative correlations allow indirect evaluation of cereals in breeding work aimed at creation of varieties with increased/decreased content of *β*–glucans in cereal grain.

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