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REVIEW ARTICLE

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NUTRITIONAL VALUE OF WHEAT, TRITICALE, BARLEY AND OAT GRAINS

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ABSTRACT

Cereals are the main source of carbohydrates in the human diet, providing the major source of energy and contributing significantly to protein intake. Cereals make up the bigger part of crop production. The chemical composition of cereals depends on agrotechnical factors that affect the quality of grain. Naked oat has the highest protein content. The analysis of crude fat in the grain revealed that the highest values were identified for naked oat and the lowest – in the triticale. The study showed the differences in the profile of amino acids of grain of wheat, triticale, barley and oats. The content and composition of dietary fiber are factors determining the quality of cereal and cereal products. The content of different fiber fractions is also varying in each other cereals. Cereal grain is a source of numerous mineral compounds. Consumption of whole grain cereal products is associated with higher diet quality and nutrient-dense foods.

Key words: cereals, proximate composition, dietary fiber fractions, amino acids, β-glucan

INTRODUCTION

Cereal grain is one of the oldest components of human diet. The importance of crop production is related to harvested areas, returns per hectare (yields) and quantities produced. For the past five decades, growth in crop production has been driven mainly by a significant increase in yields per unit of land, together with crop intensification. Cereals, which include wheat, rice, barley, maize, rye, oats and triticale, make up the bigger part of crop production. They continue to be the most important food source for human consumption. Cereal grains cover 40% of all arable land and constitute more than 50% of the food energy and 50% of the protein consumed on Earth. World production of wheat, barley, oats and triticale are equal to about 713, 144.7, 23.8 and 14.6 million tons, respectively [Daryanto et al. 2016]. This output is either directly channeled to the food industry or used as animal feed. Cereal grain contains numerous nutrients: proteins, carbohydrates and other e.g. fat, phospholipids, vitamins, minerals and other nutrients. All cereals are considered as a good source of energy. Cereal grains help to reduce the risk of certain types of cancer and coronary heart disease [Song et al. 2018]. The aim of this study was to evaluate the nutritional value of wheat, triticale, barley and oat grains and their role in human nutrition.

ROLES OF WHEAT, TRITICALE, BARLEY AND OAT GRAINS IN HUMAN NUTRITION AND HEALTH

Wheat (*Triticum*) is one of the oldest cereals cultivated by man. The wheat genus includes many species, three of which – common (*Triticum aestivum* L.), durum (*Triticum durum* Desf.) and spelta (*Triticum spelta* L.) are spread worldwide. The common wheat (*Triticum aestivum* L.) is the most common species on a global scale and is the second most widely grown crop in the world. The main objective of modern wheat, mainly common wheat (*Triticum aestivum* ssp. *vulgare*) cultivation is to

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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. The studies demonstrated significant differences in the chemical composition of wheat grains caused by various weather conditions and agronomic treatments [Khan and Zeb 2007]. 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]. Wheat grain consumption accounts for 19% of the calories in the global human diet. Wheat is used globally for the production of bread, pasta and other bakery products. 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. Interestingly enough, some research indicates that the selection for high wheat yields is accompanied by the increase of photosynthetic productivity through the unintentional improvement of leaf anatomical and biochemical traits including tolerance to non-optimal temperature conditions [Brestic et al. 2018]. As for the protein content in grain is not an exclusively varietal characteristic as it also depends on weather and soil conditions, fertilization and chemical protection.

Triticale may play a role in the rising healthy food market and in the formulation of new cereal products. Triticale (X *Triticosecale* Wittmack) is a hybrid of A and B genomes of wheat (*Triticum turgidum* L., *Triticum aestivum* L.) and the R genome of rye (*Secale cereale* L.) designed to combine the high yield potential and good grain quality of wheat (versatile food applications) with the disease resistance and environmental tolerance of rye (tolerance to harsh growing conditions). The chemical composition of triticale appears to be more similar to wheat than rye. Compared with wheat, triticale has slightly higher levels of most of the nutritious compounds. One of the outstanding features of triticale has been traditionally its protein content. The protein content in triticale is influenced, among others, by fertilization [Stankowski et al. 2017]. Early triticale cultivars had poor feeding characteristics relative to wheat. Maurice et al. [1989] explained that genetic improvements to triticale have increased grain plumpness and lowered the protein content. Gatel et al. [1985] reported that with an equal crude protein content, triticale is richer in lysine than wheat grain, comparable to wheat in threonine and sulfur amino acid contents but slightly poorer in tryptophan than wheat. Triticale contained more lysine, arginine, aspartic acid, and alanine than wheat [Salmon 1984]. In particular, triticale's higher lysine content, better protein digestibility and better mineral balance make it suitable especially as a replacement for (or supplement to) other cereal grains in human food and animal feed. For human consumption triticale products such as whole berry, flakes and flour are available commercially, however usually only in specialty health food outlets. The majority of the triticale produced around the world is used for animal feed. Triticale has higher protein content than wheat, together with a more favorable amino acid balance, factors which are advantageous for the swine and poultry industries. It is also used as ruminant forage or feed (in the form of silage or hay). The main non-starch polysaccharide (NSP) constituent in the endosperm cell walls of triticale is pentosans with some β-glucan, such as in wheat and rye. Triticale has limited utilization, primarily as an animal feed (poultry, pigs, ruminants), but it can also be used in baking by supplementing with wheat due to its low gluten content [McGoverin et al. 2011]. Triticale grain has a starch content similar to that of wheat and higher than that of rye (61, 60 and 54%DM, respectively) [USDA 2018]. The composition of starch influences the digestibility and breadmaking quality. From a nutritional point of view, triticale grain is high in essential amino acids, which makes it more nutritionally valuable than wheat, even if its baking performance is inferior.

Barley (*Hordeum vulgare* L.) is among the most ancient cereal crops grown in the world today. Barley is evolutionarily closely related to two other small-grain cereal species, wheat and rye. Barley grain is widespread in human nutrition (flakes, groats, raw material for malt production) and in animal feeds. Currently there are various morphological variants of barley, such as two-row or six-row and different colors (black, blue, purple or yellow). Barley varieties can also be distinguished by being hulled or hull-less genotypes. The chemical composition and quality of barley grain change under the combined effects of cultivar-specific traits, weather conditions and agricultural practice. Tobiasz-Salach et al. [2018] have showed that the size of grain yield and yield elements of spring barley depended on the selected cultivar and foliar nutrition applied. The high content of soluble dietary fiber present in barley have boosted the status of barley as a food ingredient. Studies have associated the regular consumption of barley with its potential to reduce the risk of certain diseases, such as chronic heart disease, colon cancer, high blood pressure and gallstones [Idehen et al. 2017]. These therapeutic potentials are attributed to the presence of the bioactive components of vitamins, minerals, fiber, and other phytochemicals. In addition, barley has some unique phytochemical properties, such as the presence of all eight tocol vitamers, which are usually not complete in some cereal [Idehen et al. 2017]. Products with new functional and nutritional properties are a precondition for a higher acceptance of barley, for instance as products with a high content of dietary fiber (Table 1) [Biel et al. 2009, Woźniak et al. 2014, Biel et al. 2016, Alijošius 2014]. Due to its high viscosity in aqueous media, the soluble cell wall polysaccharide (1→3),(1→4)--β-glucan is an important nutritional component. Studies are currently available on the phytochemical composition of the standard and high β-glucan genotypes of barley. Barley is a good source of dietary phenolic compounds, which can be found free as well as bound to fiber. The flavanols, especially catechin, procyanidins and prodelphinidins, are the main compounds in the free phenolic fraction of barley grain. The storage proteins in barley grains belong to two solubility classes, namely globulins (a fraction soluble in dilute salt solutions) and prolamins (a fraction soluble in aqueous alcohols). Barley protein is rich in prolamin storage proteins (hordeins) and has moderate nutritional quality, being particularly deficient in lysine. The increase of protein content is accompanied by decreases in essential amino acids, mainly lysine [Jacyno 1989]. Shewry [2007] suggested that nutritional quality of the grain decreases with increasing grain protein contents as an increasing proportion of the nitrogen is incorporated into prolamin storage proteins. Valaja et al. [1997] showed that nitrogen fertilizer supply increased the crude protein content and digestible crude protein content in barley grain and lowered the lysine content in the protein. The reduced amount of lysine in protein is so slight that the total content of lysine in grain increases due to higher protein content [Thomke 1976]. Globulins cover 10–20% of the total protein content of barley grains [Lásztity 1995].

Oat grains (*Avena sativa* L.) have multifunctional uses including as human food, animal feed, health care. The cultivation area of oats in the world is remarkably smaller than other cereals crops such as maize, wheat, rye or barley [Daryanto et al. 2016]. This is probably due to the less yield performance of oats compared to other cereals [Brand et al. 2003]. Oats tolerate wet weather and acidic soils far better than other cereals, are resistant to diseases and require less agro-chemical and fertiliser input [Givens et al. 2004]. As a consequence, their production costs may be similar to wheat or barley. Oat grain is characterized by a good taste, dietetic properties and an activity stimulating metabolic changes in the body [Huttner et al. 2010]. All this makes its nutritive value high for both people and animals. Oat (*Avena sativa* L.) is considered distinct among cereals being a rich source of proteins (globulins), phenolic compounds (mostly avenanthramides) and dietary fiber in particular β-glucan and several vitamins and mineral components [Chaturvedi et al. 2011, Gujral et al. 2011, Ahmad et al. 2014]. Oats are receiving increased scientific and public interest and is becoming more popular as a raw material in food industry, because of known health benefits. Oats has attracted serious attention because of its prolamin composition and amino acid sequence. Therefore, it is of particular interest to use oat flour in gluten-free food product development for celiac patients. Although oats are included in the list of gluten-free ingredients specified in European regulations, their safety when consumed by celiac patients remains debatable. Some studies claim that pure oats are safe for most celiac people, and contamination with other cereal sources is the main problem facing people with this disease. However, it is necessary to consider that oats include many varieties, containing various amino acid sequences and showing different immunoreactivities associated with toxic prolamins [Comino et al. 2015]. The relevant gluten protein fractions for people with celiac disease include prolamins and glutenins but the alcohol-soluble fractions (prolamins) of wheat (gliadins), rye (secalins), and barley (hordeins) are considered to be of most concern to celiac individual. Oats also contain a prolamin fraction (avenin, which is similar to gliadins, secalins, and hordeins). However, oat avenins are structurally different from the triticale prolamin fractions and represent only 10–15% of total oat protein as opposed to the prolamin content of the triticale subgroup (wheat, rye, and barley) which can be as high as 30–50% [Butt et al. 2008]. Morphologically, oat can be classified as husked and naked. Due to the lack of glumes, the grain of naked oats differs significantly from that of husked grain oats in respect of its chemical composition and nutritive value. Naked oat grains has a higher energy value, contains more protein and lipids and less fiber compared to conventional oat (Table 1). As an alternative to naked oat, hulls can be separated from groats by dehulling grain prior to feeding to animals.

CHEMICAL COMPOSITION OF CEREALS

The chemical composition of cereals has essential influence on its quality and flour and various cereal products derived therefrom. The chemical composition of wheat, triticale, barley and oats (husked and naked) are presented in Table 1. Wheat grain has a higher protein content than other major cereals, such as barley (*Hordeum vulgare*), husked oat (*Avena sativa* L.), triticale. Only naked oat (*Avena nuda* L. em. Mansf.) has a highest protein content, although at a similar level as wheat (144 and 143 g per kg DM, respectively). Depending upon the wheat variety and climatic conditions during the growing season, the protein content of wheat may be higher than those of most other cereal grains. The protein contents of triticale ranged from 7.5 to 15.2% [Dennett et al. 2013, Manley et al. 2013], which appeared to be similar to that of wheat. Triticale is a better source of lysine content than wheat (Table 2) [Biel et al. 2009, Biel et al. 2016], which is the limiting amino acid in cereals. The analysis of crude fat in the grain revealed that the highest values were identified for naked oat (the mean 8.4% DM) and the lowest – in the triticale (the mean 1.2% DM). Most oat fatty acids are unsaturated. Fatty acids dominating in the lipid composition of naked oat grain include palmitic (15–18%), oleic

(34–37%), and linoleic (36–39%) acids [Krasilnikov et al. 2018]. According to the content of oleic and linoleic acid and their ratio (1 : 1), lipids of naked oat belong to the oleic-linoleic group of vegetable oils.

Carbohydrates, as the major components of cereals, account for over 70% of the dry weight. The total carbohydrates (TC) consist of sugars, starches and a major portion of materials classified as hemicellulose. The mean TC concentration ranged from 68% DM for husked oat to 87% DM for triticale grain (Table 1).

In general, cereals are excellent sources of dietary fiber (DF). The content and composition of dietary fiber are factors determining the quality of a cereal and cereal products. Crude fiber is a component of dietary fiber. In the literature there are several definitions of both dietary fiber and crude fiber. Dietary fiber contains many structures, which differ in their physical and chemical properties as well as their influence on human organism [Cummings and Englyst 1991]. Over the years, the definition of dietary fiber has been subject to much discussion. Although several definitions have been proposed over the past 40 years, the Codex Alimentarius Commission established a definition only in 2008, defining dietary fiber as follows: *Dietary fiber is composed of carbohydrate polymers with ten or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans* [Codex Alimentarius 2008, Codex Alimentarius 2009]. The components of crude fiber are cellulose, lignin and partly hemicellulose. Appropriate fiber content in human food is essential as it stimulates alimentary canal peristalsis, but too high amounts could decrease nutrients absorption [Ötles and Cagindi 2006]. High dietary fiber and whole grain foods reduce the risk of weight gain, and consequently reduce population burden diseases such as type 2 diabetes, cardiovascular disease, obesity and some cancers [Koh-Banerjee et al. 2004, Du et al. 2010, McKeown et al. 2010, Mann et al. 2015]. Most cross-sectional studies focus on the relationship between whole grain intake and anthropometric measures rather than all grains. The studies show that the inherent high-fiber content of whole grains may assist with weight loss through satiety and the reduction in postprandial glucose. The grain derived fiber, rather than fruit or vegetable fiber, is protective against weight gain [Liese et al. 2003].

The study showed the differences in the profile of amino acids of grain of wheat, triticale, barley and oats (Table 2). Cereal grains are mainly a source of carbohydrates in the human diet, but also provide significant amounts of protein. Out of 20 amino acids, a human being or an animal can synthesize only nine of them (nonessential amino acids). The remaining amino acids (essential amino acids) should be provided by their food. Cysteine and tyrosine are also regarded as semi-essential amino acids, as they can be synthesized exclusively with methionine and phenylalanine, respectively. Oats, like other cereals, are low in lysine but they are a perfect source of sulphur amino acids (husked oat – 4.08 and naked oat – 3.66 g/16 gN).

MINERAL COMPOSITION OF CEREALS

In developing countries, cereals are used as staple foods and are good source of macro- and micronutrients. Mineral compounds are a group of elements necessary in human nutrition. The human organism is incapable of producing them, hence they must be supplied in appropriate amounts with food. Cereal grain is a source of numerous mineral compounds, determined cumulatively as crude ash. The mineral compounds are important for nutritional and technological reasons. As shown in Table 1, the highest concentration of crude ash was in the barley grain (2.6% DM) and the lowest in triticale grain (1.3% DM). The content of ash in wheat grain is affected more by the weather during its maturation than by its genotype [Morris et al. 2009]. Cereals are also excellent sources of zinc, highly available iron, copper, manganese, molybdenum and boron and provide significant amounts of phosphorus, potassium, calcium and magnesium (Table 3) [Zhang et al. 2010, Biel et al. 2011]. The naked oat grain has the lowest concentration of K. The husked oat grain has the highest Ca content and the wheat grain has the lowest Ca content. Barley has the highest Mg content. The triticale grain has the lowest Mg content. Naked oat has the highest P content and the wheat has the lowest P content. Metals in adequate concentration are essential for healthy functions of body and also for proper growth and development of plants, but at higher concentrations are likely to act as toxins [Nkansah and Amoako 2010, Hina et al. 2012]. Metals like iron, zinc, copper, cobalt and manganese are essential metals since they play an important role in biological systems, while lead, cadmium are non-essential metals which can be toxic even in trace amounts [Soylak et al. 2004]. Approximately 1.5 billion people worldwide are facing iron (Fe) and zinc (Zn) deficiency in their diets [Assunção et al. 2003, Palmgren et al. 2008]. Fe is found in foods in two forms; heme and non heme iron. The heme iron is more bioavailable than the non heme [Van Moorsell 1997]. Cereals are good sources of Fe (Table 3). Body's mechanism maintains the Fe balance through stores, reutilizes and regulates in the body. Iron plays an important part in the production of hemoglobin and red blood cells. Insufficient amounts of iron lead to anemia [Sarpong 2014]. Zinc (Zn) affects the immune system, wound healing, the senses of taste and smell. Zn seems to support normal growth and development in pregnancy, childhood, and adolescence [Fraga 2005]. Copper (Cu) deficiency in humans is rare, but when it occurs it leads to normocytic, hypochromic anemia, leucopenia and neuropenia, and inclusive os-

Table 1. Chemical composition (g/kg DM) of wheat, triticale, barley and oats grains [Biel et al. 2009, Woźniak et al. 2014, Biel et al. 2016, Alijošius 2016]

Tabela 1. Skład chemiczny (g/kg SM) ziaren pszenicy, pszenżyta, jęczmienia i owsa [Biel i in. 2009, Woźniak i in. 2014, Biel i in. 2016, Alijošius 2016]

Item – Wyszczególnienie	Protein, N × 6.25 Białko, N × 6.25	Crude ash Popiół surowy	Crude fiber Włókno surowe	Crude fat Tłuszcz surowy	Total carbohydrates (TC) Węglowodany ogółem
Wheat – Pszenica	143	17	18	16	806
Triticale – Pszenżyto	95	13	10	12	870
Barley – Jęczmień	120	26	50	28	776
Husked oat – Owies oplewiony	115	23	136	48	678
Naked oat – Owies nagi	144	20	32	84	720

Table 2. Amino acids composition (g/16 g N) of wheat, triticale, barley and oats grain protein [Biel et al. 2009, Biel et al. 2016]

Tabela 2. Skład aminokwasowy (g/16 g N) białka ziarna pszenicy, pszenżyta, jęczmienia i owsa [Biel i in. 2009, Biel i in. 2016]

Item – Wyszczególnienie	Wheat – Pszenica	Triticale – Pszenżyto	Barley – Jęczmień	Husked oat – Owies oplewiony	Naked oat – Owies nagi
Lys	1.89	2.56	3.59	2.73	2.76
Met+Cys	2.77	3.43	3.11	4.08	3.66
Met	1.29	1.55	1.63	1.34	1.26
Cys	1.48	1.88	1.48	2.74	2.40
Thr	2.25	2.99	3.10	2.46	2.59
Ile	2.39	3.51	3.10	2.32	2.49
Trp	1.02	0.90	1.23	1.15	1.18
Val	3.30	4.71	4.45	3.20	3.31
Leu	5.82	6.35	6.31	5.26	5.25
His	1.90	1.99	2.11	1.74	1.76
Phe+Tyr	5.77	7.43	7.45	5.88	5.92
Phe	3.68	4.44	4.97	3.62	3.57
Tyr	2.09	2.99	2.48	2.26	2.35
Arg	4.19	5.41	4.41	5.79	5.32
Asp	4.67	6.27	5.93	7.37	7.02
Ser	3.61	3.88	4.23	3.86	3.38
Glu	33.12	29.42	24.83	19.12	18.24
Pro	7.29	8.59	9.26	4.54	4.01
Gly	3.36	3.91	3.99	3.81	3.93
Ala	2.58	3.85	3.82	3.51	3.72
Sum EAA – Suma EAA	27.11	33.87	34.5	28.82	28.92
Sum AA – Suma AA	85.93	68.76	90.90	76.88	75.4

teoporosis in children. Excessive dietary Zn can cause Cu deficiency. Chronic Cu toxicity is rare in humans, and mostly associated with liver damage [Kanumakala et al. 2002, Fraga 2005]. According to Zabłocka-Słowińska and Grajeta [2012] the knowledge about manganese (Mn) role in preventing certain diseases is still insufficient and therefore little is known about Mn influence on a human organism.

Table 3. The mineral composition (in kg DM) of wheat, triticale, barley and oats grain [Zhang et al. 2010, Biel et al. 2011]

Tabela 3. Skład mineralny (w kg SM) ziarna pszenicy, pszenżyta, jęczmienia i owsa [Zhang i in. 2010, Biel i in. 2011]

Elements – Pierwiastek	Wheat – Pszenica	Triticale – Pszenżyto	Barley – Jęczmień	Husked oat – Owies oplewiony	Naked oat – Owies nagi
Macroelements, g – Makroelementy, g					
Potassium – Potas K	4.14	4.70	4.4	3.67	2.41
Phosphorus – Fosfor P	3.44	3.85	3.6	3.60	4.59
Sodium – Sód Na	0.17	0.17	0.10	0.17	0.16
Calcium – Wapń Ca	0.37	0.4	0.4	1.31	1.07
Magnesium – Magnez Mg	1.51	1.1	1.8	1.39	1.18
Microelements, mg – Mikroelementy, mg					
Zinc – Cynk Zn	32	25	23	21	28
Iron – Żelazo Fe	39	37	76	41	35
Copper – Miedź Cu	7.4	3.4	3.3	4.0	4.3
Manganese – Mangan Mn	48.8	26	22	39	43

COMPONENTS OF DIETARY FIBER

The content of different fiber fractions is presented in Table 4 [Biel et al. 2011, Sykut-Domańska et al. 2013, Alijošius et al. 2016]. Dietary fiber is categorized into soluble and insoluble fiber, on the basis of their dissolution capability in water, ease of digestion by floral bacteria in intestine and other chemical properties such as water retention. In insoluble fiber, carbohydrate chain does not dissolve in water, fermentation is limited, they retain water. Soluble fiber forms a gel like substance delaying the gastric emptying and also retains water. The soluble and insoluble components of DF behave differently, according to whether they are hydrated, swollen, or attacked by enzymes, such behavior being reflected in their structure and physical characteristics. Although insoluble and soluble dietary fiber have different effects and intensities of effect on the human organism. This statement may not be completely true in global terms, since both fractions have some components, such as uronic acids, that have the same action: the reduction of postprandial blood glucose level concentrations [Wood et al. 1990]. The functional properties of DF from different sources should be studied in order to obtain from the individual characteristics of each one a more global and accurate vision of their behavior in the human organism. Oats grain (largely husked) contain higher proportions of soluble fiber, whereas wheat, triticale and barley fiber primarily consists of insoluble fiber (Table 4).

Neutral Detergent Fiber (NDF) is the most common measure of fiber used for animal feed analysis. NDF measures most of the structural components in plant cells (i.e. lignin, hemicellulose and cellulose), but not pectin. Further analysis can be done to the sample to determine individual components such as ADF analysis. Nutritional requirement tables for ruminants report limits for NDF intake. The level of NDF in the animal ration influences the animal's intake of dry matter and the time of rumination. The concentration of NDF in feeds is negatively correlated with energy concentration. The NDF content in grain varied between the different cereal (Table 4). Among the studied grain husked oat had the highest content of NDF (40% DM) and the lowest NDF level was found in triticale grain (11% DM). Husked oat grain had the highest mean contents of ADF and HCEL. Cellulose is an insoluble fiber, beneficial for it aids the intestines to perform digestion efficiently. Similar to general characteristic of fiber, cellulose also bind to other micronutrients, and toxins such as, bile acids. Lignin, another form of insoluble fiber, contains many different chemical species, including ferulic acid, coumaric acid, vanillic acid, vanillin, syringaldehyde and furfura. Lignins are deposited in cell walls after a cell has completed the growth phase, i.e. after full development of polysaccharide wall scaffolding. Considering content of these components allows estimation of the development level of plant material. The results of study showed highest concentrations of CEL and ADL in the grain of husked oat than other cereals. Bile acids association with cancer has been proven, due to its damaging impact on DNA. Now studies also suggest bile acids link with cellulose, where cellulose in a role of "catalyst", stimulates "polyesterification" of bile acid and turns it to an "inactive form" reducing the fecal toxicity [Papandreou et al. 2015]. Cellulose and lignin are also important in heavy metal binding, but not as much as in case of hemicelluloses, and it depends on

a fraction's origin. Major compounds of cell walls of every plant tissue are hemicelluloses, which are mixed

Table 4. Components (g in kg DM) of dietary fiber of wheat, triticale, barley and oats grain [Biel et al. 2011, Sykut-Domańska et al. 2013, Alijošius et al. 2016]

Tabela 4. Składniki (g w kg SM) włókna pokarmowego ziarna pszenicy, pszenżyta, jęczmienia i owsa [Biel i in. 2011, Sykut-Domańska i in. 2013, Alijošius i in. 2016]

Item – Wyszczególnienie	NDF	ADF	ADL	CEL	HCEL	TDF	IDF	SDF
Wheat – Pszenica	126	35	11	24	91	148	121	27
Triticale – Pszenżyto	114	27	9	18	88	146	120	26
Barley – Jęczmień	253	105	25	80	148	265	191	74
Husked oat – Owies oplewiony	402	183	23	159	220	191	68	123
Naked oat – Owies nagi	169	45	4	41	123	–	–	–

NDF – neutral detergent fiber; ADF – acid detergent fiber; ADL – acid detergent lignin; HCEL – hemicellulose; CEL – cellulose; IDF – insoluble dietary fiber; SDF – soluble dietary fiber; TDF – total dietary fiber.

polysaccharides and account for up to one-third of the total dry plant biomass. Hemicelluloses (HCEL) are important components of dietary fiber, which (apart from pectins) exhibit strong sorptive properties for heavy metals, therefore they increase health-promoting value of food. High hemicelluloses concentration has a beneficial effect as they expand and absorb water in human alimentary canal [Moure et al. 2006].

β-GLUCAN CONTENT

β-glucan is a major cell wall carbohydrate which is isolated from cereal grains, notably oats and barley. It is a polysaccharide composed entirely of glucose units linked together to form a long polymer chain. In addition to their cholesterol-lowering and potential cancer-protecting properties, β-glucans may be useful in controlling blood glucose levels [Silva et al. 2015]. As can be seen from Table 5 [Demibras 2005, Rakha et al. 2012], oat grains have the highest β-glucan content. The form of (1→3)-β-D (30%) and (1→4)-β-D (70%) mixed linkage glucan is found in oats [Papageorgiou et al. 2005]. The oat grain ranges from 3.9% to 5.7% β-glucan content. Wheat grains also contain β-glucan but in lower concentrations than barley, oat or rye grains and ranges from 0.5% to 1.1% β-glucan content, just like triticale (Table 5). The smallest amount of β-glucan is in rice (only from 0.4% to 0.9%). In human food, a high content of β-glucan may be desirable whereas, in animal feed, a lower β-glucan content may be preferable. In 1997 the United States Food and Drug Administration (FDA) approved the heart-health benefit claim shown on the label of many foods containing soluble fiber derived from oats. Moreover, in 2010, a European Food Safety Authority (EFSA) panel concluded that current scientific evidence supports the following two-part statement: "Oat β-glucan has been shown to lower/reduce blood cholesterol. Blood cholesterol lowering may reduce the risk of coronary heart disease". The intake of β-glucan is beneficial in lowering coronary heart disease risk. Incorporation of β-glucan in the diet (3 g β-glucan per day) supports cardiovascular heart disease (CVHD) risk reduction related with reduction in cholesterol levels. Due to the approved health claim related to β-glucan and normal blood LDL-cholesterol together with the presence of a wide range of tocols and phenolic compounds linked to health benefits, it is of interest to encourage the development of food products using oat and barley grain or flours as an ingredient [Ahmad et al. 2012, Ames et al. 2015].

Table 5. β-glucan content (%) in cereal grains [Demibras 2005, Rakha et al. 2012]

Tabela 5. Zawartość β-glukanu (%) w ziarnie zbóż [Demibras 2005, Rakha i in. 2012]

Item – Wyszczególnienie	Range – Zakres
Barley – Jęczmień	3.2–4.6
Oat – Owies	3.9–5.7
Rye – Żyto	0.7–1.5
Triticale – Pszenżyto	0.5–1.0
Rice – Ryż	0.4–0.9
Wheat – Pszenica	0.5–1.1

CONCLUSIONS

Cereals grains have nourished humanity since their domestication thousands of years ago and they continue to be the most important food source for human consumption. Cereals are the main source of carbohydrates in the human diet, providing the major source of energy and also contribute to some extent to protein intake. The essential influence on cereal grains quality has their chemical composition. As whole grain they are rich source of vitamins, minerals, carbohydrates, fats, and protein. Also, such cereal grains are chosen for consumption and they have high fiber content which is an important nutrient that helps to prevent weight gain and heart disease. Cereals differ from each other in protein (incl. amino acid), fiber, fat and carbohydrates content. The best source of protein is wheat and naked oat. Naked oat also has the highest fat content. The highest fiber content is in husked oat. The content of different fiber fractions is also varying in each other cereals. It is important, that high dietary fiber and whole grain foods in human diet reduce the risk of weight gain, and consequently reduce population burden diseases such as type 2 diabetes, cardiovascular disease and obesity, but too high amounts could decrease nutrients absorption. Cereals are also the most popular source of β-glucan, which high content in human diet may be desirable whereas. Cereal grain is as well a source of numerous mineral compounds, in particular zinc, highly available iron, copper, manganese, phosphorus, potassium, calcium and magnesium. Cereals and cereal products are important sources of energy and nutrients in the average human diet. Therefore, consumption of whole grain cereal products is associated with higher diet quality and nutrient-dense foods delivering protein, lipids, vitamins and minerals.

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WARTOŚĆ ODŻYWCZA ZIARNA PSZENICY, PSZENŻYTA, JĘCZMIENIA I OWSA

STRESZCZENIE

Zboża są głównym źródłem węglowodanów w diecie człowieka, zapewniając podaż energii i znacząco przyczyniając się do spożycia białka. Zboża stanowią większą część produkcji roślinnej. Jakość ziaren zbóż zależy od składu chemicznego. Nagi owies ma najwyższą zawartość białka. Analiza tłuszczu surowego w ziarnie wykazała, że najwyższe wartości stwierdzono w owsie nagim, a najniższe – dla pszenżyta. Wyniki badań przedstawione w literaturze wykazały różnice w profilu aminokwasów ziarna pszenicy, pszenżyta, jęczmienia i owsa. Zawartość i skład błonnika pokarmowego są czynnikami decydującymi o jakości zbóż i produktów zbożowych. Zawartość różnych frakcji włókna pokarmowego jest zmienna w poszczególnych gatunkach zbóż. Ziarno zbóż jest źródłem wielu związków mineralnych. Spożywanie pełnoziarnistych produktów zbożowych wiąże się z korzyściami zdrowotnymi oraz z wysokiej jakości dietą o dużej zawartości składników odżywczych.

Słowa kluczowe: zboża, skład chemiczny, frakcje włókna pokarmowego, aminokwasy, β-glukan

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