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NUTRITIONAL PROPERTIES OF WHOLE SMALL GRAINS AND POTENTIAL BENEFITS FOR IMPROVING HUMAN HEALTH

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Abstract. *Small grains are an important raw material in the diet of humans and domestic animals, an important element of crop rotation and part of the agricultural strategy in many countries. Recently, there has been an increased interest in the potential health benefits of whole grains and their substances that can be provided to consumers. The aim of this review is to highlight the characteristics of whole small grains playing a significant role in improving human health. In order to collect the relevant facts, the authors consulted the leading databases (ScienceDirect, Scopus, Google Scholar, PubMed) and analysed the research works of numerous authors. Grain products are sources of folate, iron, thiamine, niacin and dietary fibre. Consumption of whole grain products provides a better quality diet, rich in proteins, lipids, vitamin B (including thiamine, niacin, riboflavin), vitamin E and minerals (calcium, magnesium, potassium, phosphorus, iron and sodium). A diet rich in dietary fibres originating from whole grains results in a reduction in the risk of mortality from all causes of cardiovascular disease, atherosclerotic cardiovascular disease, ischemic stroke, contributes to a reduction in cholesterol content, the occurrence of type 2 diabetes and a reduction in the number of obese people. Dietary fibre and resistant starch provide a substrate for colon microbial fermentation, which leads to the production of short-chain fatty acids, which are a direct source of energy for the colonic epithelium and affect the sensitivity of the liver to insulin. The paper describes in detail the impact of consumption of whole wheat, barley, oats, rye and spelt on human health.*

Key words: *Wheat, Barley, Oats, Rye, Alternative Grains, Bioactive Substances, Impact on Human Health*

Introduction

According to a recent estimate, about 800,000 plant species grow on Earth, of which only a hundred currently meet the majority of global food production. Moreover, fewer than 20 plant species satisfy approximately 90% of food needs [1]. However, it is estimated that 50,000 plants are edible and could be used significantly more in human nutrition. Some of them can be cultivated [2].

The term cereals originates from the Latin word "*cerealis*," which translates to "grain," and botanically represents the fruit known as a grain or caryopsis (Lat. *caryopsis*). Cereals are annual plants from the grass family (monocot family *Poaceae*, also known as *Gramineae*). The main cereals include soft hexaploid wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), and rye (*Secale cereale* L.).

Alternative cereals are those plant species and varieties that are cultivated on small areas or not at all, and which can represent a substitute or alternative to commercially grown species. These alternative plant species have a regional character. In other words, what is alternative in one region may not be alternative in another. Alternative cereals include einkorn wheat (*Triticum monococcum* L.), emmer wheat (*Triticum dicoccum* L.), spelt wheat (*Triticum spelta* L.), and club wheat (*Triticum aestivum* ssp. *compactum*). In a broader sense, the group of alternative cereals also includes durum wheat (*Triticum turgidum* ssp. *durum*), hulless oats (*Avena nuda*), hulless barley (*Hordeum vulgare* ssp. *nudum*), and triticale (X *Triticosecale* Wittmack).

The type of cereals predominantly produced in different parts of the world depends on various factors, with ecological, cultural, and economic ones being the most significant. Temperature and water availability are probably the most critical environmental factors determining the crops cultivated in a given region.

The beginning of cereal use in human diets marks an important step in human evolution. Most scientists believe that humans started cultivating cereals about 10,000 years ago, but recent discoveries show that this occurred much earlier. A collection of cereals found at an ancient site in Israel is estimated to be around 23,000 years old [3]. The earliest food preparation from cereals dates back even further. Evidence suggests that early *Homo sapiens* consumed starch-based snacks from cereals about 105,000 years ago [3]. Remnants of grass seeds, mainly sorghum, found on ancient African stone tools indicate early processing and cultivation of plants for food. Around 30,000 years ago, plant food processing, including flour production, was common practice across Europe [4]. Around 7,000 BCE, people in Greece cultivated wheat, barley, and oats [5]. It is known that the Carthaginian army of General Hannibal consumed porridge before and during their famous crossing of the Alps in 218 BCE.

Cereals and cereal products are staple foods in the diets of most people [6]. They are the most important source of energy in the diet of the majority of the world's population. In developing countries, 60% of energy intake directly comes from

cereals, and this figure is even higher in the poorest countries [6]. In contrast, in the developed world, cereals account for about 30% of dietary energy intake.

The grain of cereal consists of approximately 75% carbohydrates, mainly starch, and about 6-15% protein, which globally contributes more than 50% of the energy supply [7]. The significance of cereals and cereal products is underscored by the fact that global food security largely depends on cereal production, which amounts to around 2,600 million tons annually [8].

Recently, interest has increased in the potential health benefits that whole grains and their substances can provide to consumers. The aim of this review paper is to highlight the characteristics of whole cereals that give them a significant role in improving human health. For the purpose of gathering relevant facts, the authors reviewed leading databases (ScienceDirect, Scopus, Google Scholar, and PubMed) and analyzed research papers from numerous authors.

Morphological Features and Anatomical Structure of Cereal Grain

Cereal grain consists of three main parts: the bran, the germ, and the endosperm. The bran is the outer layer of the grain, enveloping it on the surface, and serves a protective role, safeguarding the germ and endosperm from adverse external influences. The germ (live cells) or embryo is the reproductive organ and contains all the future plant organs. The endosperm contains reserve nutrients used by the germ during germination and seedling growth. It consists of two parts: the outer aleurone layer and the inner layer that makes up the core of the endosperm.

Small grains in human diet

The significance of grains and grain products is often analysed in scientific and professional literature in relation to consumption levels and nutritional value [9]. Some grain products (bread, rolls and tortillas, pastries, and other flour-based products) are presented as sources of folate, iron, thiamine, niacin, dietary fibre, manganese, and zinc. The consumption of whole grain (synonymously referred to as integral) products provides a higher quality diet, rich in proteins, lipids, vitamin B (including thiamine, niacin, riboflavin), vitamin E, and minerals (calcium, magnesium, potassium, phosphorus, iron, and sodium). The bioavailability of manganese is particularly important due to its role in metabolic processes as well as the functioning of the nervous, immune, and reproductive systems [10, 11]. Many studies highlight the negative impact of phytates, substances found in grains and grain products, on the bioavailability of minerals and trace elements. To ensure high bioavailability and adequate mineral supply, the interaction between phytic acid and minerals must be considered.

Current research focuses on the significance of grains in the diet, especially whole grains, due to the presence of dietary fibres and bioactive compounds in grain kernels. Dietary fibres are unevenly distributed within the kernel, with the highest

concentration in the outer tissues [12]. Whole or coarsely milled grains contain more dietary fibres and phytochemicals with potential anti-inflammatory and antioxidant properties than refined grains [13]. Based on a series of systematic reviews and meta-analyses, there is significant epidemiological evidence that dietary fibres and whole grain foods are associated with a reduced risk of diet-related non-communicable diseases (DRNCD) [14, 15]. Diets high in dietary fibres and whole grains result in a reduced risk of mortality from all causes, cardiovascular diseases [16], atherosclerotic cardiovascular diseases, ischemic stroke, type 2 diabetes, certain types of cancer [17], and obesity [18]. Dietary fibres and resistant starch provide substrate for microbial fermentation in the colon, leading to the production of short-chain fatty acids, which are a direct energy source for the colonic epithelium and influence liver insulin sensitivity [12]. The importance of dietary fibres in colorectal cancer prevention remains controversial. However, studies conducted on large population samples have shown that high intake of dietary fibres, especially from grains and whole grains, is associated with a reduced risk of colorectal [19] and gastric cancer [17]. Many other studies confirm the protective role of dietary fibres in the prevention of colorectal cancer [20]. An inverse association has been observed between the consumption of whole grains and grain fibres and reduced overall mortality and mortality from specific causes.

The significance of grains, particularly whole grains, in the prevention of DRNCD is crucial in understanding the three periods of dietary transition related to changes in diet and lifestyle [21]. In the first period, present in both developed and developing countries, the diet was based on cheap and monotonous plant-based food – starch, low in fat, and high in dietary fibres [21]. This period is characterized by greater food availability and improved nutritional status of the population. In the second period, there was a shift in food consumption patterns from basic carbohydrate-rich foods to plant oils, animal products, and sugar, but generally, there was no significant change in overall energy supply. This means that in a period characterized by a sedentary lifestyle, energy-dense foods predominated, consisting of high fat, cholesterol, sugar, and other refined carbohydrates, with low polyunsaturated fatty acids and dietary fibres [21]. Rapid urbanization became the main driver of this qualitative dietary transition, accompanied by technological changes, a decrease in heavy labour, an increase in leisure time, the development of food processing, mass media development [21], food marketing, and trade liberalization policies. The prevalence of diet-related diseases, coupled with global population growth and ecosystem imbalance, has led to dietary transition and entry into the next period. The main challenge of the third period involves changing dietary patterns to make the diet more sustainable and simultaneously profitable for people and the planet. The multinational initiative launched to transform food systems – The EAT-Lancet Commission on Food, Planet, Health, describes a universal healthy reference diet based on sustainable consumption principles. This diet focuses on increasing the consumption of diverse foods such as vegetables, fruits, whole grains, legumes, and nuts, while reducing the intake of foods like red meat, sugar, and refined grains [22].

Whole grains include products from various grains (e.g., corn, barley, oats, rice, and wheat), while whole wheat products are derived solely from wheat. The term "whole" indicates that all three parts of the grain seed—the bran, germ, and endosperm—are intact and present in their native form and proportion, thus providing maximum nutritional and health benefits. Whole grains and whole grain products are an important part of a proper diet.

Wheat (*Triticum* spp.)

The high prevalence of wheat in cultivation and human and animal diets is due to its adaptability and high yield potential, as well as the presence of gluten protein fractions that provide viscoelastic properties, enabling the production of bread, pasta, noodles, and other food products. Wheat also contributes to human nutrition with essential amino acids, minerals, vitamins, beneficial phytochemicals, and dietary fibre components. However, wheat products are known to cause some adverse reactions in humans, including intolerance (especially celiac disease) and allergies (respiratory and food allergies) [23]. Current and future activities in wheat breeding and production include maintaining wheat production and quality with reduced agrochemical inputs and developing varieties with improved quality for specific end-uses, especially for biofuels and human nutrition [24].

Wheat Grain Composition and Technological Characteristics of Wheat Flour

Starch is the most abundant chemical compound and the most important reserve polysaccharide in wheat, found in the form of semicrystalline granules. **Lipids** in wheat grain are located in membranes, organelles, and spherosomes and have diverse chemical structures. **Dietary fibres** include arabinoxylans, β-glucan, cellulose, arabinogalactan-peptides, and polysaccharides that differ from amylose and amylopectin in either the chemical composition of their monomeric molecules or the nature of their linkage. **Wheat proteins** constitute 8–15% of the wheat grain. Proteins are one of the most important groups of compounds in wheat grain, and wheat is classified into quality classes based on their content. Albumins and globulins make up 10–15% of total wheat proteins, primarily located in the outer parts of the wheat grain. Most albumins and globulins are metabolic proteins—enzymes or structural proteins. Nutritionally, albumins and globulins have a very good amino acid balance; they have relatively high tryptophan and methionine content and contain about 50% of the total lysine found in the grain. **Gluten proteins** are storage proteins and make up 85% of the endosperm proteins of wheat grain. These complex compounds are mainly responsible for the viscoelastic properties of dough and the baking quality of wheat.

Gluten proteins consist of two distinct types of proteins: monomeric gliadins and polymeric glutenins. Gliadins constitute 20–40% of the total proteins in wheat flour. Based on biochemical and genetic characteristics and mobility at low pH values in

polyacrylamide gel electrophoresis, gliadins are classified into three groups: α/β-, γ-, and ω-gliadins. α/β-gliadins are more prevalent compared to γ-gliadins, with their content ranging from 47.57% to 59.12% in bread wheat flour. This group of gliadins has a significant impact on increasing bread volume. Wheat varieties with a high content of α/β-gliadins can be used as improvers. Glutenins are the largest polymers in nature. In wheat, there are two classes of glutenin subunits: high-molecular-weight glutenin subunits (HMW-GS) and low-molecular-weight glutenin subunits (LMW-GS) [25, 26, 27, 28].

The ratio and interaction of components that make up flour are essential for the baking quality of the flour [29]. The quality of flour, the rheological and functional characteristics of dough, and bakery products largely depend on wheat proteins. High-molecular-weight glutenins make the dough elastic and allow it to retain the gas bubbles created by yeast, enabling it to rise. This is important for the quality of the final product, as gas retention determines the loaf volume and pore structure of the resulting bread. It has also been found that the influence of the x-type HMW-GS on baking quality is significantly greater than that of the y-type HMW-GS.

Reaction to Gluten in Humans

Although gluten proteins have the greatest impact on dough quality and various product qualities, they can affect user health. The high proline content makes gluten resistant to gastrointestinal tract enzyme degradation, resulting in large immunogenic gluten peptides reaching the surface of the small intestine mucosa and causing inflammatory reactions [30]. Gluten can cause several different disorders: celiac disease, wheat allergy, and gluten sensitivity, each associated with different pathomechanisms. Wheat allergy belongs to the group of food allergies resulting from an improper immune response to a food antigen. Immunoglobulin E (IgE) antibodies play a key role in the pathogenesis of this disease. Wheat allergy can manifest with a wide range of symptoms, such as urticaria/angioedema, anaphylaxis, atopic dermatitis, respiratory symptoms, or digestive disorders [31].

Celiac disease, or gluten-sensitive enteropathy, is a chronic autoimmune disease characterized by lifelong gluten intolerance and cannot be cured by temporarily eliminating gluten from the diet. Ingestion of gluten-containing foods leads to damage to the small intestine mucosa, which loses its villous appearance and becomes flattened, while the number of tissue lymphocytes and epithelial cells increases. The thickened mucosa has reduced absorption capacity, causing poor absorption of nutrients, minerals, and vitamins.

Barley (*Hordeum vulgare*)

Barley has various uses: it serves as food for humans (as bread grain and in other processed forms), feed for domestic animals, and in the industry for producing malt, beer, and alcohol. Depending on its use, different varieties with specific traits are created—varieties for human and animal food and varieties for malt production.

Barley was likely cultivated before other grains and was a staple food in human diets long before the Common Era. However, even in ancient times, barley bread was considered heavy food for humans. With the development and improvement of agricultural production in Europe, especially during the 17th and 18th centuries, wheat bread significantly supplanted barley bread, and today barley is rarely used in human food, except for beer and whiskey. However, the use of barley in human diets has persisted in some parts of the world. In the northern polar regions and high-altitude areas, barley is the only bread grain. Barley flour, compared to flour from other grains, is between wheat and rye flour in composition and better than oat flour. However, barley bread is significantly inferior in quality to wheat bread. This is due to the proteins, which differ in barley grain from those in wheat grain. Barley bread is coarse, sweet-tasting, quickly hardens, is not porous, but dense, and therefore harder to digest. Additionally, prolonged use causes bloating. It is recommended to mix barley flour with wheat or rye flour in a ratio of 1:10 to 1:5 (adding 10 to 20 kg of barley flour to 100 kg of wheat or rye flour). This flour mixture is used to make bread in many countries; Switzerland, Greece, Germany, Russia, our country, and many other countries in Asia and Africa [32].

Given its broader adaptability compared to corn, barley is an important cultivated plant in drier and cooler regions where corn cultivation is limited. The limiting factor in barley production is soil pH, where barley has difficulty growing and developing in soils with a pH value lower than 5.5 [32, 33]. Considering the aforementioned and increasingly pronounced climate changes, the newer breeding model of fodder barley clearly directs the selection process solely towards increasing yield, but certainly includes a number of other important traits, especially quality [34].

Usage and Economic Importance of Barley

In human nutrition, barley is used in the form of hulled, whole, or coarsely ground grains [35, 36]. Hulled whole barley grains are called groats, while coarsely ground grains are called barley grits. Groats are also made from hull-less barley, which is rarely grown in Europe. Groats can be added to soups instead of pasta or rice or cooked with milk for a meal. Barley grits are used to make porridge. Barley grain also serves as a substitute for coffee. For this purpose, the grain is roasted and ground. Roasting gives barley a pleasant taste and aroma. For coffee, hull-less barley varieties are preferred, but if unavailable, hulled varieties can be used after de-hulling. Compared to real coffee, barley coffee is more nutritious and does not negatively affect health, as it does not contain alkaloids like caffeine and cafestol.

Several researchers emphasize that barley can be used in the form of pearls/grits/flakes in porridges and soups as a rice substitute, as flour to thicken certain food products, or as an addition to food products such as yogurt, beverages, soups, porridge, cookies, noodles, muffins, flour-based snacks, and extruded cereal products. However, barley flour, whether whole or mixed with wheat flour, produces bread of poor baking quality.

The use of barley for making alcoholic beverages has been known for a long time. Herodotus (400 BC) and Pliny (23 BC) recorded in their writings that in Egypt, a barley-based alcoholic drink was made, which, according to the Greek philosopher Diodorus, was not inferior in strength and taste to wine. The suitability of barley for beer production depends, among other things, on the protein content in the grain; good brewing barley should not contain more than 12% protein [32, 37].

Importance of Barley for Human Health

Barley has always had the status of a "health-beneficial plant" and has been included in numerous medicinal mixtures [35]. Hippocrates detailed the use of barley and believed that broths and decoctions made from barley were the best food ingredients in the treatment of acute diseases. Clinical studies on humans have shown a link between barley consumption and health benefits. Barley consumption has a positive impact on reducing the risk of chronic heart disease, lowering blood cholesterol levels, and improving insulin response. This way, incorporating barley into the diet reduces the risk of type 2 diabetes [38]. In men with moderate hypercholesterolemia, blood lipids significantly decreased with a diet containing barley. According to the Food and Drug Administration (FDA), a daily intake of 3 g of barley β-glucans through food is sufficient to achieve a reduction in total serum cholesterol and low-density lipoprotein (LDL) cholesterol [38]. These beneficial effects can be attributed to the presence of β-glucans, which increase the viscosity of intestinal contents. This leads to slower food absorption, influencing blood glucose level control and bile acid binding [38]. Barley's potential as a prebiotic is particularly significant, as β-glucans and resistant starch contribute to the growth of selective beneficial microorganisms in the intestines, leading to the production of short-chain fatty acids, particularly butyrate and propionate. These fatty acids in the colon contribute to a healthy colonic mucosa and provide an energy source for epithelial cells.

Rye (*Secale cereale* L.)

Rye is an annual, cross-pollinated grain with an effective gametophytic self-incompatibility system. It was first cultivated in the Caspian Sea region around 3000-4000 BCE. The Slavic peoples brought rye to Eastern Europe, and during their migration to the West around 500 BCE, they transmitted their knowledge of rye cultivation to Germanic, Celtic, and Finnish peoples [39]. Rye was cultivated in Europe a thousand years BCE when it was genetically close to wheat and barley (tribe *Triticeae*) [40]. However, it produced significantly denser bread compared to wheat bread. During the Middle Ages and the modern era, up to the 1960s, rye was the main grain in the vast area between Germany and eastern Siberia. Significant advancements in breeding self-pollinating grains—wheat and barley—led to reduced interest in rye in regions where tolerance to environmental stress (temperature, water) was not a crucial prerequisite for cultivation.

Composition of Rye Grain

Whole rye flour in dry matter contains 56-70% (w/w) starch, 8-13% protein, 2-3% lipids, 2% ash, and 15-21% total fibres. Rye grain has the highest fibre content among cereal grains [41]. Arabinoxylans are the most important and typical component of rye fibres. Other fibre components include cellulose, fructans, mixed-linkage β-glucans, and resistant starch.

Dietary fibres and rye proteins (especially albumins and globulins) are essential in human nutrition and are responsible for the beneficial health effects of rye bread with lower glycemic load. The health effects of rye fibres have been studied in relation to the behavior of its components in the human digestive tract [42]. Rye fructans and fructooligosaccharides act as prebiotics in the colon, where they are completely fermented into short-chain fatty acids [41]. However, insoluble arabinoxylans, cellulose, and lignin are resistant to microbial degradation in the intestines.

Rye flour contains 30% more iron, twice as much potassium, and three times more sodium than regular bread. Rye bread is among the most recommended foods for anemia. It is a treasure trove of vitamins, particularly those of the B group. The outer layer of the rye endosperm, like wheat, is rich in minerals and vitamins. Rye contains polyphenols with antioxidant activity [43].

Importance of Rye for Human Health

Consumption of whole grain products is associated with a reduced risk of developing many modern diseases and health disorders. Whole grain rye flour is richer in essential dietary fibres than whole grain wheat flour. Plant fibres stimulate bowel function and reduce the risk of constipation. They increase the viscosity of the food mass, thus slowing down the emptying of the stomach and small intestine. This increases the feeling of fullness, which can reduce food intake.

Increased viscosity of the food mass containing rye bread leads to delayed digestion of the starch in rye flour. Therefore, the rise in blood glucose after consuming rye flour is lower compared to wheat flour products [44]. The low glycemic index of rye bread contributes to stable blood glucose levels, making rye bread a suitable food for type 2 diabetics and reducing the risk of its development. β-glucans found in rye flour have been proven to lower elevated LDL levels in the blood. Rye contains less starch than wheat and more free sugars, dominated by fructooligosaccharides. Along with fibres, they have a stimulating effect on the intestinal flora, especially on bifidobacteria, thus exhibiting a prebiotic effect. Prebiotics positively affect intestinal balance and consequently improve digestive system function. Studies have shown that people who regularly consume rye bread have a 30% lower chance of developing heart and other cardiovascular diseases compared to white bread consumers. Rye flakes' fibres influence the conversion of cholesterol into bile acids in the liver, improve colon function, and reduce the concentration of certain biomarker molecules that increase the risk of colon cancer. Some mechanisms underlying the beneficial

effects of fibres, especially regarding phenolic compounds, consist of the sorption and reduction of toxic substances from the intestinal wall and their elimination through feces [42].

Oats (*Avena sativa* L.)

Oats originate from Europe, Asia, and Africa, but they were first cultivated in Europe, making them a European cereal. Oats are an ancient cultivated plant. The cultivation of oats for bread was long known among the Celts and Germans. Oats are the grain of the northernmost regions of Europe, such as Ireland, Scotland, and Norway, as well as the mountainous regions of Central Europe. Oats were cultivated in Europe 1500–1700 BC. That the Slavs also cultivated oats in their ancient homeland is evidenced by the unchanged name for this grain among all Slavic peoples. In the mountainous regions of northern and central Europe, they were cultivated by the Celts during the Bronze Age, where other species like spelt and barley did not thrive, and they used oats for bread and porridge. In ancient Greece, oats are first mentioned in the sixth century BC.

Oats are used in animal and human nutrition because their grains have high energy and nutritional value. The grain contains about 12% protein, about 40% starch, 1.5% water-soluble sugars, 6–7% oil (significantly more than other true cereals), 11% cellulose, 10% hemicellulose, 3.2% mineral substances, and about 14% water [33]. The amino acid composition is favorable concerning essential amino acids, making oats superior to many cultivated plants, such as corn. Oats thrive on poorer soils where other grains yield lower harvests, making them suitable as animal feed. Both the grain and green mass, which can be combined with legumes, are used for feeding livestock.

Composition of Oat Grains

Oats have a well-balanced nutritional composition; they are a good source of carbohydrates and quality proteins with a favorable amino acid ratio. They contain a high percentage of lipids, especially unsaturated fatty acids, minerals, vitamins, and phytochemicals.

The oat grain (seed) consists of the germ, endosperm, hull, and husk. The husks make up 20–30% of the total mass of the oat grain and more than 90% of dietary fibre. However, the husks are removed when oats are used in human nutrition. All fibres found in the husks are water-insoluble, while in the rest of the oat grain, half are soluble and half are insoluble. The most important soluble fibre in oat grain is β-glucan [45]. It is found in the cell walls of endosperm cells and in the bran.

The release of β-glucan from oats occurs mostly in the stomach. Due to low pH, β-glucans have low hydrodynamic value there and few aggregates. In the small intestine, β-glucans remain unchanged, as there are no hydrolytic enzymes to break them down. During passage through the small intestine, viscosity increases due to the

formation of aggregates. Depending on the amount of mucin, whose production is stimulated by some soluble and insoluble fibres, aggregates of different sizes form. Besides mucin, the increase in viscosity also depends on the pH in the small intestine. The fermentation of β-glucan by intestinal microflora in the colon produces short-chain fatty acids: acetic, propionic, and butyric acid [45]. Besides β-glucan, oat grain contains a smaller percentage of fructose and glucose (3–4%) and other soluble (soluble arabinoxylan, indigestible starch) and insoluble fibres (cellulose). Considering the phytochemical characterization of oat grains, phenols (phenolic acids, flavonoids, avenanthramides, lignin), saponins, phytic acid, vitamins, and minerals should also be mentioned [46]. Oat grain contains more zinc than any other medicinal plant, as well as a significant amount of phosphorus and iron, and smaller quantities of trace elements like iodine and boron. Oats also contain vitamins A, beta-carotene, B1, B6, and E.

Significance of Oats for Human Health

The beneficial effects of oats on health have been established, such as against gastrointestinal issues and with anticancer effects. The consumption of oats in human nutrition has increased due to the health benefits associated with dietary fibres such as β-glucan, functional proteins, lipid and starch components, and phytochemicals present in oat grain. Oats also contain a diverse range of phenolic compounds, including ester conjugates of glycerol, ester alkyl conjugates, ether and ester glycerides, anthranilic acids (AVAs). These compounds have high levels of antioxidant activity. These antioxidants are concentrated in the outer layer of the grain in the bran fraction. The nutritional advantages of oats have attracted the attention of researchers worldwide, leading to increased interest from the food industry in using oats as an ingredient in various food products, including baby food, bread, oat milk, beverages, breakfast cereals, and biscuits. Due to the prophylactic benefits they provide, whole grain cereals are increasingly consumed today [47].

Spelt (*Triticum aestivum* ssp. *spelta*)

Spelt, or dinkel wheat, is among the oldest true cereal species in the *Poaceae* family. It originated in the Near East over 8,000 years ago through the spontaneous hybridization of wild grass species.

Composition of Spelt Seeds

Based on its qualitative properties, which align with modern nutritional requirements and minor demands on growing conditions, spelt holds a significant place in organic farming systems [48]. The hard, leathery husks protect the grain from air pollution and pest attacks, which is highly advantageous for growing this species in organic agriculture [49, 50]. Spelt grain has higher nutritional value compared to common wheat, containing higher amounts of total proteins (17–21%), which are richer in essential amino acids compared to wheat proteins. Additionally, the grain

contains 70% carbohydrates, 5–7% cellulose, about 2% oil, and mineral salts of phosphorus, iron, calcium, selenium, magnesium, and others (around 2%). The exceptionally high nutritional value is further enhanced by the high content of B-complex vitamins, E, and K, as well as trace elements like selenium, zinc, iron, and manganese [50, 51]. Due to its properties, spelt is grown organically in most Western European countries and the USA [51]. In Germany, Belgium, Switzerland, France, and Spain, the area under spelt cultivation exceeds 100,000 hectares.

Significance of Spelt for Humaan Health

A daily diet that includes cereal products, especially from whole grain flour, has a positive impact on human health, such as reducing the risk of type 2 diabetes, reducing obesity, and thus indirectly lowering cardiovascular mortality rates, and reducing colon cancer [52]. Spelt consumption is recommended for patients with various health issues, such as neurodermatitis and other allergies, high blood cholesterol, rheumatoid arthritis, ulcerative colitis, cancer, and depression [53]. Spelt contains gluten in approximately the same amounts as wheat and can cause allergies and gluten enteropathy [54], so it is not recommended for people allergic to these macromolecules or for those suffering from celiac disease.

In spelt bread, the average content of reduced glutathione (GSH) was 7% higher and the content of oxidized glutathione (GSSG) was 28% higher compared to wheat bread. The protective role of GSH in the human body includes protection from oxidative destruction by free radicals, elimination of lipid peroxidation products, preservation of the thiol-disulfide status of proteins and their repair, and consumption of products rich in glutathione reduces the risk of mouth and throat cancer.

Conclusion

Grains of cereal crops have been used as human food for over ten thousand years. They remain the most important food source today. The chemical composition of the grain has a crucial impact on its quality. Cereals are the main source of carbohydrates in human nutrition, providing the primary energy source, and to some extent, meeting protein needs. They can be consumed as whole grains or in their refined form. Cereal grain is a source of numerous mineral compounds, especially zinc, highly available iron, copper, manganese, phosphorus, potassium, calcium, and magnesium. Therefore, consuming whole grain products is associated with better diet quality and nutrient-rich food, such as proteins, lipids, vitamins, and minerals. Bran and germ contain various nutrients, including vitamins, minerals, phytochemicals (mainly polyphenols often called antioxidants), and dietary fibres, making any food made from whole grain flour richer in these nutrients and phytochemicals compared to refined flour.

People who consume larger amounts of whole grains are more likely to achieve the recommended intake of micronutrients, especially dietary fibres, to improve overall

diet quality. Whole grain flour and foods made from whole grain flour are promoted as part of a healthy, sustainable dietary profile based on the need for higher intake of plant-based dietary fibres and reduced consumption of meat and animal products with higher fat content. This recommendation is based on studies showing that higher consumption of whole grain products is associated with lower incidence and mortality from cardiovascular diseases, type 2 diabetes, and some types of cancer. Some results and effects of whole grain flour on body weight and fat are questioned, although benefits are generally reported. It can be said that the share of whole grain product consumption may not fully explain the observed health improvements, as people who consume such products tend to generally lead healthier lifestyles, including less smoking, less alcohol consumption, and more physical activity.

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НУТРИТИВНЕ ОСОБИНЕ ЦЈЕЛОВИТИХ СТРНИХ ЖИТА И ПОТЕНЦИЈАЛНА КОРИСТ ЗА УНАПРЕЂЕЊЕ ЗДРАВЉА ЉУДИ

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Сажетак. *Стрна жита важна су сировина у исхрани људи и домаћих животиња, битан елеменат плодореда и дио пољопривредне стратегије многих земаља. У последње вријеме је порасло интересовање за потенцијалном здравственом користи које цјеловита жита и њихове супстанце могу обезбиједити особама које их конзумирају. Циљ овог прегледног рада је да се истакну особености цјеловитих стрних жита које им обезбјеђују значајну улогу у побољшању здравственог стања људи. У срху прикупљања релевантних чињеница, аутори су извршили увид у водеће базе (ScienceDirect, Scopus, Google Scolar, PubMed) и анализирали истраживачке радове бројних аутора. Производи од жита су извор фолата, гвожђа, тиамина, ниацина и дијететских влакана. Конзумација производа од цјеловитих жита обезбјеђују квалитетнију исхрану, у којој је храна богата протеинеима, липидима, витамином Б (укључујући тиамин, ниацин, рибофлавин), витамином Е и минералима (калцијум, магнезијум, калијум, фосфор, гвожђе и натријум). Исхрана богата дијететским влаканима која потичу из цјеловитих жита резултира смањењем ризика смртности од свих узрока кардиоваскуларних болести, атеросклеротичних кардиоваскуларних болести, исхемијског можданиог удара, доприноси снижењу садржаја холестерола, појаве дијабетеса типа 2 и смањењу броја гојазних особа. Дијететска влакна и резистентни скроб обезбјеђују супстрат за микробну ферментацију дебелог црijева, што доводи до производње кратколанчаних масних киселина, које су директан извор енергије за епител дебелог црijева и утичу на осјетљивост јетре на инсулин. У раду је детаљно приказан утицај конзумирања цјеловите пшенице, јечма, овса, ражи и спелте на људско здравље.*

Кључне ријечи: *Пшеница, јечам, овас, раж, алтернативна жита, биоактивне супстанце, утицај на здравље људи*