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Barley in Human Nutrition and Health

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Abstract. *Barley was one of the first and the earliest crops domesticated by humans, cultivated around 7,000 to 5,000 BC. Region of Fertile Crescent has been suggested as the location where barley was originally domesticated. During the sixth and fifth millennium BC, barley spread from its centre of diversity to eastern parts of the Mediterranean basin, highlands of Ethiopia and the Indian subcontinent, and the Caucasus and Trans Caucasus regions. Barley reached China during the second half of the second millennium BC, from where it spread further to the Korean peninsula and Japan. The six-rowed types of barley reached Central and Northern Europe during the fourth and third millenniums BC, while two-rowed ear types have been introduced with seeds brought along by the crusaders from the Near East only during the twelfth and thirteenth centuries. Barley is the fourth most important crop in the world after wheat, rice and maize today. Different morphological types of this crop are present today, such as two-rowed or six-rowed genotypes, hulled or hull-less, and genotypes of different colours (black, blue, purple or yellow). Barley is grown on about 50 million hectares in the world in recent years, and the total annual grain production in the world is more that 140 million tons. Regarding cereal crops grown in the EU, the most important overall is barley.*

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Barley grain has three major uses: livestock feed, raw material for alcohol and starch production, and food. It is still a major staple food in several regions of the world: in the highlands of Central Asia, Andean countries and Baltic States, some areas of North Africa and Near East, and the Horn of Africa.

China is the largest consumer of barley as food (4 million tonnes), followed by USA (2.9 million tonnes), Russia, Germany, Morocco, Ethiopia and Saudi Arabia (from 1 to 1.3 million tonnes). In China, most of the barley was consumed in Tibet (56% of the total food production), with approximately 2.1 million people consuming barley. Saudi Arabia and Morocco have the highest average consumption (more than 35 kg per person per year), followed by Germany, Ethiopia (around 14 kg per person per year), UK, USA, Russia (about 10 kg per person per year), Brazil, China (3 to 4 kg per person per year). India has the lowest average annual consumption (0.7 kg per person).

Due to its high nutritional and healthy value discovered over recent years, there has been a growing interest for use of barley as human food. The high content of soluble dietary fibres present in barley have boosted the status of barley as a food ingredient. 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 fibres. Soluble fibre forms, a gel like substance, delays the gastric emptying and retains water. Cellulose is beneficial for digestion efficiency, binding to other micronutrients, and toxins such as bile acids. Lignin contains many different chemicals, such as ferulic acid, coumaric acid, vanillic acid, vanillin, syringaldehyde and furfural. Hemicelluloses are important components of dietary fibres, which exhibit strong sorptive properties for heavy metals, increasing health-promoting value of food. β-glucan decreases cholesterol level, has potentially cancer-protecting properties and controls blood glucose level. Human consumption of whole grains (e.g. barley, oat, brown rice, buckwheat, bulgur, millet, maize) has significant role in controlling weight, prevention the risks of gastrointestinal disorders including cancer, vascular and coronary diseases, and type II diabetes.

Keywords: Barley (Hordeum vulgare L.), Origin, Use, Human Nutrition, Dietary Fibre, β-glucan

3.1. Introduction

Cereal grains (which include wheat, rice, barley, maize, rye, oats and triticale) are one of the oldest components of human diet. Cereals cover 40% of all arable land and provide more than 50% of the food energy and represent a source of

50% of the protein consumed on Earth (Laskowski et al. 2019). In developing countries, cereals are used as staple foods and are good source of macro- and micronutrients. The importance of crop production is related to growing areas, yields per hectare and quantities produced (Dencic et al., 2012). In second half of twentieth and beginning of twenty-first century, crop production has been driven mainly by a significant increase in yields per unit land area (Janjic and Przulj 2020).

Grain of these crops is a source of numerous mineral compounds, cumulatively designated as crude ash. Cereal grain contains numerous nutrients: proteins, carbohydrates and other (fat, phospholipids, vitamins, minerals). Carbohydrates, as the major components of cereals, account for over 70% of the dry weight. The total carbohydrates consist of sugars, starches and a major portion of materials classified as hemicellulose.

Barley (*Hordeum vulgare*) was one of the earliest crops to be domesticated and it has been under cultivation since the beginning of civilization (Rawat et al. 2013). Barley played an important role in ancient Greek and Roman cultures as a staple bread-making grain as well as an important food for athletes. Gladiators were known as *Hordearii*, meaning *eaters of barley*. The use of barley grains in social and religious ceremonies by Hindus, Greeks and Romans illustrates its antiquity.

The aim of this work is to highlight the importance of barley in human nutrition and influence on human health.

3.2. Origin, domestication and spread

The origin and domestication of cultivated barley have been widely discussed; however, the debate on this subject still remains. There is no consensus on the area in which domesticated barley was historically grown. Some archaeological and genetic evidence indicates barley is a mosaic crop, developed from several populations in at least five regions: Mesopotamia, the northern and southern Levant, the Syrian Desert, and 1,500–3,000 kilometres to the east and in the vast Tibetan Plateau.

The geographic range of *Hordeum spontaneum* was clearly defined, and the Fertile Crescent (Fig. 3.1) has been suggested as the only location where barley was domesticated by a large number of researchers (Harlan and Zohary 1966; Nevo et al. 1984, 1986; Pakniyat et al. 1997; Badr et al. 2000; Nevo 2006; Zohary et al. 2012). The Fertile Crescent, often referred to as the *cradle of*

civilization, refers to a semi-circular area of the eastern Mediterranean region, including the valleys of the Nile, Tigris and Euphrates rivers. The region includes parts of the modern countries of Israel, Lebanon, Jordan, Syria, northern Egypt and Iraq, and the Mediterranean Sea coast on the West. The southern part lays in the Arabian Desert, and its southeast part is the Persian Gulf. Geologically, this region corresponds with the intersection of the Iranian, African, and Arabian tectonic plates.

Barley was one of the first and earliest crops domesticated by humans. Carbonized grains discovered from archaeological excavations at various sites in the Near and Middle East prove that barley was cultivated around 7,000 to 5,000 BC (Harlan 1976), and that the crop was domesticated about 8,000 BC (Zohary and Hopf 2001; Pourkheirandish and Komatsuda 2007). Both hulled and naked seed forms are found in domesticated barley: during the Neolithic period, both forms were grown, but in the Near East, naked barley cultivation declined beginning in the Chalcolithic/Bronze Ages about 5,000 years ago. Naked barleys, while easier to harvest and process, are more susceptible to insect attack and parasitic disease. Hulled barleys have higher yields; so within the Near East, keeping the hull was a selected trait.

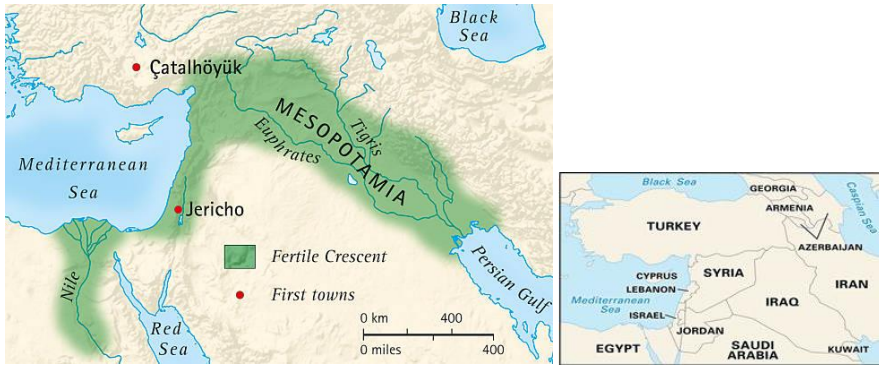

Fig. 3.1. The earliest cities for which evidence exists, appeared around the mouths of the Tigris and Euphrates rivers. Gradually civilization spread northward and around the Fertile Crescent. The map shows the countries that occupy this area today (Gill 2020)

During the sixth and fifth millennium BC, barley spread from its centre of origin in the near and Middle East to eastern parts of the Mediterranean basin, highlands of Ethiopia, the Indian subcontinent, and the Caucasus and Trans Caucasus regions. Barley reached China during the second half of the second millennium BC from where it spread further to the Korean peninsula and Japan. The six-rowed types of barley reached Central and Northern Europe during the

fourth and third millenniums BC, while two-rowed ear types are believed to have been introduced with seeds brought along by the crusaders from the Near East during the twelfth and thirteenth centuries. Barley was first introduced in North America probably by Columbus in 1492, and later by immigrants and settlers from Europe. Barley remained the main cereal food crop of northern Europe until the sixtieth century when it was gradually replaced, mainly due to culinary preference for wheat which showed better processing traits into numerous food products. The introduction of other cereals, rice and maize, beside wheat, in the human nutrition has led to a severe decrease of barley uses and cultivation (Haas et al. 2018).

Wild barley has several characteristics useful to a plant growing in wild, that aren't useful to humans (Dai and Zhang 2016). There is a brittle rachis (the part holding the seed to the plant) that breaks when the seeds are ripe, scattering them by wind; and the seeds are arranged on the spike in a sparsely seeded two rows. The wild barley always has a tough hull protecting its seed; the naked form (so called naked barley) is only found in domestic varieties. The domestic form has a non-brittle rachis and more seeds, arranged in a six-rowed spike.

3.3. Cultivation and economic importance

Barley is one of the most widely adapted crop in the world. Very few other crops show such wide altitudinal adaptation as barley does – from sea level to 4.500 m altitude (in both the Andes and the Himalayas). Moreover, barley is one of the most versatile cereals known to be well adapted to the different global climates through, due to its rich genetic diversity (Obsa et al. 2016; Jovović et al. 2020). It is adaptable to a range of climate conditions, greater than any other cereal, with varieties suited to temperate, subarctic, or subtropical areas. A moderately cool and dry climate is most suited for barley. Although barley is able to withstand heat in a dry climate or high humidity in a cool climate, it performs poorly in a hot and humid climate. Barley is regarded as a drought-tolerant crop which accounts for its popularity in areas receiving scarce rainfall. It is commonly grown in the semi-arid regions of North Africa, the near and Middle East, and South Asia, the Russian Federation, Eastern Asia, Europe, Australia and the Andean countries of South America. Spring barley is cultivated in larger areas than winter barley because its production is less risky. Winter barley is prone to damage from sharp winter conditions which affects the harvested yield. Furthermore, spring barley is preferred as a rotation crop with winter wheat as its short vegetation adapts in the crop rotation. Although it does best in vegetation seasons of at least 90 days, it is able to grow and mature in a shorter

time than any other cereal. Cultivation is possible even in very short seasons such as those of the Himalayan slopes, although the yield is lower.

Barley represent the fourth most important crop in the world after wheat, rice and maize. Different morphological types of this crop are distributed worldwide, including two and six-rowed, hulled or naked and genotypes of different colours (black, blue, purple or yellow). Harvested area is about 50 million hectares and the total annual grain production is more that 140 million tons in the world (Fig. ?.2).

Regarding cereal crops grown in the EU, the most important overall is barley. Almost 45% of worldwide barley grows on EU fields and in terms of global exports one fifth of this grain is from European economic area, in some years even a quarter. Less than 10% of globally traded barley is exported to Japan (especially brewing malt) and South American countries. Important competitors for the EU in this export market number are Russia, Ukraine and Australia. All of them export similar quantities to Europe, between 4 and 6 million tonnes, depending on production year. For instance, Canada, Argentina and Kazakhstan together have almost the same importance in the market of barley as just one of the big four. Interestingly, wherever barley is grown, the climate risks are very high, including also EU. Constant and stable yields in Germany are contrasted by extremely unstable yields in Spain. Very important competitor is maize, repeatedly replacing barley as feed ingredient.

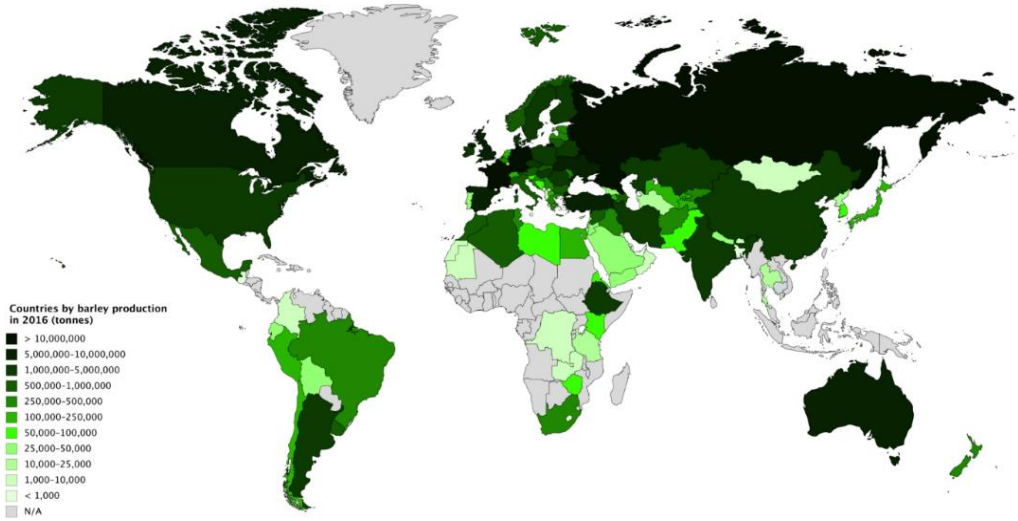

Fig. 3.2. A choropleth map showing countries by barley production in tonnes, based on 2016 data from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT 2016)

Majority of barley produced in Western Balkan countries is used as animal feed (Pržulj and Momčilović 2003). High β-glucan levels are a problem for brewing and low levels of β-glucan in malt are requested by the malting and brewing industries (Bamforth and Barclay 1993). Grain β-glucan is a problem in poultry diets because of *sticky droppings* phenomenon.

3.4. Barley for nutritional and health

Barley grain has three major uses: livestock feed, raw material for alcohol and starch production, and food (Pržulj et al. 1998; 2013). It is still a major staple food in several regions of the world: in the highlands of Central Asia, Andean countries and Baltic States, some areas of North Africa and Near East, and the Horn of Africa. In these regions live the poorest farmers in the world and they depend on low productive systems and living conditions. In developed countries very low quantities of barley are used as human food. Poor baking quality and taste restricted its use in human diet. However, in the last two decades dishes with barley were rediscovered of with a significant increase in the total amount of barley used for food (Pržulj et al. 2014).

China is the country with the largest consumption of barley in human diet accounting for 4 million tonnes, followed by USA (2.9 million tonnes), Russia, Germany, Morocco, Ethiopia and Saudi Arabia, ranging from 1 to 1.3 million tonnes). Barley is dominantly consumed in Tibet, accounting for 56% of the total food production, and 2.1 million people consuming barley. Saudi Arabia and Morocco have the highest average consumption (more than 35 kg per person per year), followed by Germany, Ethiopia (around 14 kg per person per year), UK, USA, Russia (about 10 kg per person per year), Brazil, China (3-4 kg per person per year). India has the lowest average annual consumption (0.7 kg per person) (Sakellariou and Mylona 2020).

3.4.1. Traditional uses of barley

Barley flour is receiving more importance over the last years due to its valuable bioactive compounds. Barley products are suitable for use in many dishes, including different types of bread, pasta, and for baby foods (Newman et al. 1998; Izydorczyk et al. 2005). Most of barley has used as pearled barley in soups and flakes in breakfast cereals.

Over the years, there has been accumulated local knowledge on preparation, health and nutritious attributes of barley as food. Barley cultivars used in human

diet have particular characteristics appreciated by consumers that cannot be replaced by barley varieties used for feed or malt. Local knowledge and the unique genetic material needs to be preserved for future generations. Barley products utilized for traditional preparations can be classified in: a) whole grain products; b) cracked grain products; c) raw-grain flour (fine and coarse) products; d) whole roasted grain products and e) roasted-grain flour (fine and coarse) products.

Morocco is the largest consumer of barley as food, where this crop played a significant role in food security throughout history. Since the beginning of the second millennium succeeding dynasties have relied on large barley grain storage facilities as bulwarks against hunger. About 20% of barley grain in Morocco is used as food, mainly in the mountainous and southern parts of the country. Consumption is higher in dry years. Barley grain is mainly used as food in the rural mountain and southern areas of Morocco with an average annual consumption of 54 kg per person, compared with 5.5 kg per person in the cities (Belhadafa et al. 1992). Barley is used as flour, as semolina, and as whole-dehulled grain (Amri et al. 2005). A large variety of dishes, including soups, bread, and couscous are made from barley. Preparations include both product from fully mature grains and grains harvested at physiological maturity (*Azenbou*). Azenbou, is one of the most interesting receipts of Chleuh's (Berber) tradition of countryside. Barley is collected while still green by hand, before the grain matures for the harvest. People of the countryside consider this sophisticated preparation as a delicious and almost ritual introduction to a prosperous period of the year. In past, azenbou was the practical solution providing food before the new harvest, after a harsh winter, or when food reserves were exhausted. Barley grain stored underground for over three years is called *Aballagh* and is used to produce both flour and semolina (coarse flour) (Amri et al. 2005).

Barley accounts for over 60% of the food of the people in the highlands of Ethiopia (Yirga et al. 1998); it is used in diverse recipes that have deep roots in culture and tradition. Some recipes, such as *Besso* (fine flour of well-roasted barley grain moistened with water, butter or oil), *Zurbegonie* (same type of flour used for besso dissolved in cold water with sugar) and *Chiko* (besso soaked with butter alone), which have long shelf life, can only be prepared from barley grain. Other recipes, such as *Genfo* (thick porridge), *Kolo* (dehulled and roasted barley grain served as snack), *and Kinche* (thick porridge) are most popular when made from barley grain, but can be prepared from other cereals as well (Fig. ?.3). Barley is the preferred grain, after tef, for making the traditional bread called *Injera*, which can be used either solely or in combination with tef flour or other cereal flours. Other recipes, such as *Dabbo* (bread), *Kitta* (thin, unleavened, dry bread) and *Atmit* (soup) can be prepared only with barley or blended with other

Fig. 3.3. Some recipes from barley grain in Morocco and Ethiopia (Mohammed et al. 2016)

cereal flours (Fig. 3). Among local beverages *Tella* and *Borde* are prominent, and best made from barley grain. Barley spikes both unripe at milk or dry stage and ripe and dry are also roasted over flame and the grain is eaten as snack called *Eshete* or *Wotelo* if the spikes are unripe or *Enkuto* if the roasted barley spikes are dry (Bekele et al. 2005). Barley is also traditionally used in the preparation of a gruel utilized as weaning food.

In Yemen, barley is grown at 1,800-3,000 meters above sea level, and the grain is used in various dishes and local drinks. *Maloog* and *Matany* are two types of bread made from a blend of barley flour and bread wheat flour the earlier, and barley flour and lentil flour the latter. *Nakia* is a local drink made from boiled barley grain (Lutf 2005).

In the Andes of Colombia, Ecuador, Peru and Bolivia, barley is the staple food of farmers at altitudes between 2,200 and 4,000 meters above sea level. It is the crop best adapted to high altitudes, drought, salinity, and aluminium toxicity. Early maturing and cold tolerance make it suitable to the short frost-free growing seasons in the high altitudes (Capettini 2005). In this area barley is roasted and finely ground into *Machica* or *Pito*; barley rice, coarsely cracked barley, is used for soups; and barley flakes, a relatively recent product, are eaten for breakfast.

Naked barley is preferred, and has a higher price than regular barley. For example, in Ecuador, variety Atahualpa, with its larger and lighter hull-free kernels, is payed 10% more than other varieties (Capettini 2005). Naked barley is the main staple food crop in Tibet (Tashi 2005). The main product of naked barley is the roasted barley flour known as *Tsangpa*; *Chang* brewed from naked barley is the most important alcoholic beverage. In addition barley is used for cakes, soups, porridge and snack foods. To prepare *Tsangpa* the grain is carefully cleaned, washed and roasted with fine sand. The sand is needed to distribute the heat evenly and prevents the barley kernels from burning. After roasting the sand is sieved off and the remaining roasted barley grain (called *Yue*) is grounded into Tsangpa using a water mill. Tsangpa can be eaten as such (mixed with sugar) or can be the basic ingredient for the preparation of soups, cakes, and beverages (Tashi 2005).

Barley is also used in many other countries in traditional dishes such as *Kasha* in Russia and Poland, *Miso* in Japan, and *Sattu* or *Popped* barley in India. After rice barley is the second most important food crop in Korea. In the West Asia-North Africa region, much of the barley is consumed as pearled grain in soups, ground grain in cooked porridge and flour in flat bread.

3.4.2. Food uses of barley in developed countries

In most developed countries the use of barley in human food is very limited, accounting for less than 5% of the total production (Jadhav et al. 1988; Berglund et al. 1994; Köten et al. 2013; Ge 2019). However in the past two decades there has been a renewed interest in food uses of barley, even in countries where barley never had a prominent position as a food crop. The whole grain can be processed to produce blocked, pot, and pearled barley, barley flakes, and flour (Newman 1985). Barley products are suitable for use in many food preparations, including different types of bread, pasta, rice extender, and for baby foods, although most of the use has been largely confined to pot or pearled barley in soups and flakes in breakfast cereals. Flour obtained from sprout grain retains 87% of the initial β-glucan content and higher levels of ascorbic acid, riboflavin, and phenolic compounds compared to non - sprouted grains (Friedt 2011; Lemmens et al. 2019). Roasted barley can be used as coffee-substitute; *Barley coffee* is very popular in Europe. In Italy, known as *Caffe d'orzo*, is commonly used as a breakfast drink for children, often mixed with milk.

3.4.3. Nutritional value of barley

Combined effects of cultivar-specific traits, weather conditions and agricultural practice determine quality and chemical composition of barley grain (Pržulj et al. 2010, 2014). The high content of soluble dietary fibre present in barley have boosted the status of barley as a food ingredient (Pržulj et al., 1997). Besides that, barley has some unique phytochemical properties, such as the presence of all eight tocol vitamins, 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 fibre (Berglund et al. 1992; Grando and Gormez Macpherson 2005).

Barley is a good source of dietary phenolic compounds, which can be found free as well as bounded to fibre. The flavanols, especially catechin, procyanidins and prodelphinidins, are the main compounds in the free phenolic fraction of barley grain. The storage barley grains proteins belong to two solubility classes – globulins and prolamins. Globulins cover 10–20% of the total protein content of barley grains (Lásztity 1995). Barley protein has moderate nutritional quality - rich in prolamin storage proteins (hordeins) and deficient in lysine. Higher protein content is in correlation with lower essential amino acids, mainly lysine (Shewry et al. 1982).

There is evidence that lately has increased and renewed interest in barley as healthy food in general and as a source of soluble fibre implicated in hypocholesterolemia and hypoglycaemia in non-insulin-dependent diabetes (Empilli et al. 2002). Due to its high nutritional value over recent years, there has been a growing interest for barley use as food in human diet (Sakellariou and Mylona 2020). Whole grain barley has high levels of dietary fibre (14.8 g/100 g) and sufficient levels of other bioactive compounds and minerals - calcium, iron and zinc (Irakli et al. 2020). Barley has a significantly higher protein content (10–20%) compared to corn (9.5%), but lower compared to wheat (14%) (Biel et al. 2020). Moreover, barley protein contains essential amino acids and is characterized by desirable functional properties (such as elasticity, water holding, and emulsifying capacity), which makes it an ideal component of food supplements (Wang et al. 2010; Gupta et al. 2011; Huang 2020).

Barley is an excellent source of dietary fibre, particularly β-glucan and antioxidant polyphenols (Biel et al. 2020; Huang 2020). Beta-glucan has important health benefits, such as the control of cholesterol and blood glucose levels (Hassan et al. 2012; Tong et al. 2015; Wang et al. 2017). It is an important dietary source of antioxidants, due to its vitamin E isomers (tocotrienols and tocopherols) content, which is higher, compared to other cereals (Wayns et al. 2007). Antioxidants, such as vitamin E, play a major protective role against free radicals and thus, are important elements in human nutrition. Vitamin E content and antioxidant capacity in barley are genotype-dependent, proposing breeding strategies for potential functional food applications (Martínez et al. 2018).

3.4.3.1. Dietary fibre

Cereals are excellent sources of dietary fibre (DF) and the quality of a cereal and cereal products depend on the content and composition of dietary fibre (Sudha et al., 2007). Crude fibre is a component of dietary fibre. DF contains many components with different physical and chemical properties which have a different influence on human organism (Cummings and Englyst 1991). DF is composed of carbohydrate polymers with ten or more monomeric units, which are not hydrolysed by the endogenous enzymes in the small intestine of humans (Codex Alimentarius 2008, 2009). The components of crude fibre are cellulose, lignin and partly hemicellulose. Although too high amounts of DF could decrease nutrients absorption, its content in food for human is essential as it stimulates intestinal peristalsis (Ötles and Cagindi 2006).

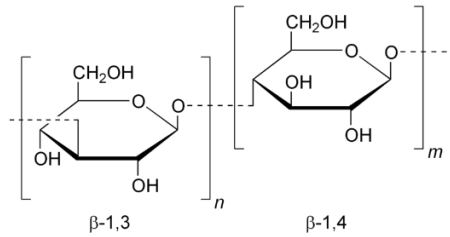

Fig. 3.4. Part of the 1–3, 1–4 β-D-glucan molecule (Channell et al. 2016)

Neutral detergent fibre (NDF) is the insoluble carbohydrate fraction – lignin, hemicellulose and cellulose, representing the most of the structural components in plant cells, but not pectin. The concentration of NDF in feeds is negatively correlated with energy concentration. The NDF content in small grain cereals varied from 40% DM in hulled oat to 11% DM in triticale (Biel et al. 2020). Hulled oat has the highest content of acid detergent fibre, hemicellulose and acid detergent lignin (Biel et al. 2020).

DF is categorized into soluble and insoluble fibre on the basis of their digestion by floral bacteria in intestine, dissolution capability in water, and other chemical properties such as water retention (Biel et al. 2020). Soluble cell wall polysaccharide (1→3), (1→4) – β-glucan (Fig. ?.4) is an important nutritional component due to its high viscosity in aqueous media. The soluble and insoluble components of DF behave differently, according to whether they are hydrated, swollen, or attacked by enzymes. In insoluble fibre, carbohydrate chain does not dissolve in water, fermentation is limited, and retain water. Soluble fibre forms a gel like substance delay the intestine emptying and also retains water. Although insoluble and soluble DF have different effects on intensities in human organism, both fractions have some components, such as uronic acids, that have the same action: the reduction of postprandial blood glucose level concentrations (Newman and Newman 2006). Wheat, triticale and barley fibre primarily consists of insoluble fibre, whereas hulled oats grain contain higher proportions of soluble fibre (Biel et al. 2020).

Similar to general characteristic of fibre cellulose is beneficial for digestion efficiency and it also binds to other micronutrients and toxins such as bile acids. Lignin contains many different types of chemicals, such as ferulic acid, coumaric acid, vanillic acid, vanillin, syringaldehyde and furfura (Dhingra et al. 2012). Lignin are placed in cell walls. Bile acid links to cellulose, where cellulose has a role of “catalyst”, stimulates “polyesterification” of bile acid and turns it to an “inactive form” reducing the faecal toxicity (Papandreou et al. 2015). Cellulose and lignin bind heavy metal, but not efficiently like hemicelluloses, and it also depends on the origin of the fraction. Hemicellulose is mixed polysaccharide and

prime compound of plant cell walls, accounting up to one-third of the total dry plant biomass (Schädel et al. 2010). Hemicellulose are important components of DF, which (apart from pectin) exhibit strong sorptive properties for heavy metals, increasing health-promoting value of food. High hemicelluloses concentration has a beneficial effect as they expand and absorb water in human intestines (Moure et al. 2006; Williams et al. 2019).

The genetic analysis of β-glucan was prerequisite for successful barley breeding for malt and low β-glucan content. Since barley grain germination is central process in malt producing these analyses involve both β-glucan synthesis and β-glucan degradation by β-glucanases (Han et al. 1995). Three β-glucanases genes are known, but these are not important for the breeding of barley varieties for human nutrition since barley products and β-glucan extraction is based on unmalted grain. Powell et al. (1985) reported that β-glucan content in barley grain is controlled by a simple additive genetic system.

Pleiotropic effects of the waxy-starch allele at the granule-bound starch synthase locus facilitated barley breeding for human consumption for high grain β-glucan content (Patron et al. 2002). Positive correlations between waxy starch and grain β-glucan was found and most barley varieties developed for human consumption are waxy (Fastnaught et al. 1996; Xue et al. 1997; Dodig et al. 2007). Also many of the waxy-starch varieties are naked. Naked varieties have increased β-glucan content due to elimination of the „diluting" effects of the hull (Xue et al. 1997). Naked varieties are more appealing for human food uses because dehulling/pearling is not required. However, due to lower yield potential and lower vigour of naked varieties there are restriction in their cultivation (Winkler et al. 2017). This means that naked barley has bad position at the market and that these varieties can only be sold for the same value as feed barley.

3.4.3.2. β-glucan content

A major cell wall carbohydrate of cereal grains, first of all oats and barley, is β-glucan (Delaney et al. 2003). It is polymer chain, polysaccharide, composed entirely of glucose units linked together. Higher grain β-glucan levels can be achieved in barley compared to oats (Aman and Graham 1987). β-glucan and arabinoxylan are the two major constituents of barley endosperm cell walls, and β-glucan levels are lower in the hull and outer layers of the grain (Henry 1987). β-glucan decreases cholesterol level, has potential cancer-protecting properties and controls blood glucose level (Silva et al. 2015). The highest β-glucan content (3.9–5.7%) was found in oat grains (Tab. ?.1) (Biel et al. 2020). Wheat grains, just

like triticale, contain β-glucan in much lower concentrations than barley, oat or rye grains (Tab. 3.1). The lowest amount of β-glucan is in rice (0.4–0.9% DM).

Tab. 3.1. β-glucan content (%) in cereal grains (Biel et al. 2020)

Item	Range
Barley	3.2–4.6
Oat	3.9–5.7
Rye	0.7–1.5
Triticale	0.5–1.0
Rice	0.4–0.9
Wheat	0.5–1.1

High β-glucan content in human food is generally desirable, whereas, a lower β-glucan content in animal feed, may be preferable. Human consumption of whole grains (e.g. barley, oat, brown rice, buckwheat, bulgur, millet, popcorn) has significant role in controlling weight (Pauline and Rimm, 2003; Arndt, 2006), prevention of risks of gastrointestinal disorders including cancer (Ranhotra et al., 1991), vascular and coronary diseases, and type II diabetes (Liu et al., 1999; Pins and Kaur, 2006). The United States Food and Drug Administration (1997) approved the heart-health benefit claim of some foods containing soluble fibre derived from oats. European Food Safety Authority (EFSA 2011) panel concluded that 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 risk reduction related with reduction in cholesterol levels (Biel et al. 2020). Due to the accepted health statements related to effects of β-glucan to 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 support the development of food products on the basis of oat and barley grain or flours as an ingredient (Ames et al. 2015; Biel et al. 2020).

3.5. Conclusion

In the human diet, cereals are the main source of carbohydrates, providing the major source of energy and to some extent of protein. As whole grain, they are also rich source of vitamins, minerals (zinc, iron, copper, manganese, phosphorus, potassium, calcium and magnesium) and fats. High dietary fibre and

whole grain foods in human diet reduce the risk of weight gain, type 2 diabetes, cardiovascular disease and obesity. Cereals are also significant source of β-glucan, which high content in human diet may be very desirable. Consumption of whole grain cereal products is associated with higher diet quality and nutrient-dense foods delivering protein, lipids, vitamins and minerals. The potential health benefits and nutritional value of barley and oats as well as their by-products need to be further studied and exploited in the production of novel functional foods. Due to that, breeding programs should focus on developing new cultivars of prominent nutritional value including high levels of β-glucan, vitamin E and antioxidants that are beneficial to human health, as well as on cultivars with improved sensory characteristics suited for different uses in food industry.

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Јечам у људској исхрани и здравље

Ново Пржуљ, Ана Велимировић, Милан Миросављевић, Драган Брењо, Војислав Тркуља, Предраг Илић, Зоран Јововић

Сажетак

Јечам се почео гајити око седам до пет хиљада година п.н.е. и представљао је један од првих и најранијих усјева које су људи доместификовали. Регион Плодног полумјесеца (Југозападна Азија) означен је као подручје гдје је јечам изворно доместификован. Током шестог и петог вијека п.н.е. јечам се из свог центра диверзитета проширио на источне дјелове медитеранског базена, висоравни Етиопије и Индијског потконтинента, те регије Кавказа и Транскавказја. У Кину је стигао у другој половини другог вијека п.н.е. одакле се проширио даље на Корејско полуострво и Јапан. Шестерореди типови јечма доспјели су у средњу и сјеверну Европу током четвртог и трећег вијека п.н.е., док су сјеме двореди типова донијели крсташи са Блиског истока тек током дванаестог и тринаестог вијека. Јечам је данас четврти најважнији усјев у свијету, након пшенице, пиринча и кукуруза. Данас су присутни различити морфолошки типови ове гајене биљке, као што су двореди и шестерореди генотипови, пљевичасти и голи, те генотипови различитих боја (црни, плави, љубичасти или жути). Јечам се посљедњих година у свијету гаји на око 50 милиона хектара, а укупна годишња производња износи више од 140 милиона тона. У ЕУ јечам је најзаступљеније жито у производњи. Зрно јечма има три главне намјене: сточна храна, сировина за производњу алкохола и скроба, те храна за људску употребу. Још увијек је главна прехрамбена намирница у неколико регија свијета-висоравни средње Азије, андске земље и балтичке државе, нека подручја Сјеверне Африке и Блиског истока, те Рог Африке. Кина је највећи потрошач јечма као хране (4 милиона тона), а слиједе САД (2,9 милиона тона), Русија, Њемачка, Мароко, Етиопија и Саудијска Арабија (од 1 до 1,3 милиона тона). У Кини се јечам највише употребљава на Тибету (56% укупне производње), а конзумира га око 2,1 милиона људи. Највећу просјечну потрошњу имају Саудијска Арабија и Мароко (више од 35 kg по особи годишње), затим Њемачка и Етиопија (око 14 kg по особи годишње), Велика Британија, САД, Русија (око 10 kg по особи годишње), Бразил, Кина (3 до 4 kg по особи годишње). Најмању просјечну годишњу потрошњу има Индија (0,7 kg по особи).

Због утврђене високе нутритивне и здравствене вриједности, посљедњих година расте интересовање за употребом јечма као хране. Висок садржај

растворљивих дијеталних влакана присутних у јечму повећава значај јечма као хране. Производи с новим функционалним и нутритивним особинама предуслов су већег коришћења овог жита као производа са високим удјелом дијеталних влакана. Форма растворљивих влакана - супстанце попут гела, одлаже пражњење желуца и задржава воду. Целулоза је корисна за ефикасност варења, везивање микронутријената и токсина. Лигнин садржи више различитих једињења, као што су ферулинска киселина, кумаринска киселина, ванилинска киселина, ванилин, сиринголдехид и фурфурал. Хемицелулоза је важна компонента дијеталних влакана, која показује јака сорпцијска својства за тешке метале, повећавајући вриједност хране у функцији побољшања здравља. Треба рећи да β-глукан смањује ниво холестерола и има својства потенцијалне заштите од карцинома те контролише ниво глукозе у крви. Конзумација цијелог зрна жита у људској исхрани (нпр. јечам, овас, смеђи пиринач, хељда, булгур, просо, кукуруз) има значајну улогу у контроли тјелесне тежине, превенцији ризика од гастро-интестиналних поремећаја укључујући карцином, васкуларне и коронарне болести и дијабетес типа 2.

Кључне ријечи: Јечам *(Hordeum vulgare L.),* поријекло, употреба, људска исхрана, прехрамбена влакна, β-глукан