AUCTORES
Globalize your Research

Journal of Nutrition and Food Processing

Gashaw Abebaw*

Open Access

Review Article

Review on Structure, Functional and Nutritional Composition of Barley (Hordeum vulgare)

Gashaw Abebaw

Department of Food Process Engineering, College of Engineering and Technology, Wolkite University, Wolkite, Ethiopia

Corresponding Author: Gashaw Abebaw, Department of Food Process Engineering, College of Engineering and Technology, Wolkite University, Wolkite, Ethiopia.

Received date: March 22, 2021; **Accepted date:** March 29, 2021; **Published date:** April 05, 2021

Citation: Gashaw Abebaw (2021) Review on Structure, Functional and Nutritional Composition of Barley (Hordeum vulgare). J. Nutrition and Food Processing, 4(2); DOI:10.31579/2637-8914/046

Abstract

Barley is a resilient plant, tolerant of a range of conditions, which may have been cultivated since 15 000 BC (Fast & Caldwell, 2000). Cultivated barley, *Hordeum vulgare*, is mainly grown for animal feed, especially for pigs, for malting and brewing in the manufacture of beer, and distilling in whisky manufacture. A small amount of barley is used for food. Barley is one of the leading grain crops produced in the world with growing worldwide recognized as a source of food and many valuable nutritional components that enrich the human diet. Barley grain is used primarily for malting and livestock feeding, and the straw is also an important feedstuff when more desirable forages are not available

Keywords: grain; functional; composition; barley; animal feed; beer; nutritional components

Introduction

Barley is a resilient plant, tolerant of a range of conditions, which may have been cultivated since 15 000 BC [1]. Cultivated barley, *Hordeum vulgare*, is mainly grown for animal feed, especially for pigs, for malting and brewing in the manufacture of beer, and distilling in whisky manufacture. A small amount of barley is used for food. Pearled barley is eaten in soups and stews in the UK and the Far and Middle East; barley is also used in bread (as flour) and ground as porridge in some countries [2]. The barley head or spike is made up of spikelets, which are attached to the rachis in an alternating pattern. The outer layers of the barley kernel consist of a husk, completely covering the grain; the pericarp (to which the husk is tightly joined in most species); the testa or seed coat, and the aleurone. Barley (*Hordeum vulgare*) is a very important grain in the world today and it ranks the fourth in both quantities produced and in area of cultivation of cereal crops in the world. The annual world harvest of barley in the late century was approximately 140 million tonnes from about 55 million hectares. It is very versatile in every way and has been well adapted through its evolution. It is the most adaptable of the cereals. Much of the world's barley is produced outside of the regions where cereals such as maize and rice can grow well. It extends into the arctic or subarctic. Some species approach the subtropical Zone. Hordeum species are found in most areas with a Mediterranean climate. The genus is also represented in zones with an oceanic as well as a continental climate [3]. Barley also has a very good resistance to dry heat compared to other small grains. This feature allows it to grow near-desert areas such as North Africa. Barley is a cereal that belongs to the grass family Poaceae. There are three types of barley:

i) *Hordeum vulgare*: a six-rowed type of barley that has a spike notched on opposite sides with three spikelets on each notch. At each notch there is a flower or floret that later develops into a kernel;

ii) *Hordeum distichum*: a two-rowed type of barley that has central florets producing kernels and it has lateral florets that are sterile; and

iii) *Hordeum irregular*: the least cultivated, with fertile central florets and varying proportions of fertile and sterile lateral florets [4]

Barley (Hordeum vulgare) is one of the cereals which tolerate rather well abiotic stress conditions. Growers driven by the market demands tend to cultivate wheat even in areas that are more suited for the barley; such areas can, however, easily be brought again under barley. Although the area under barley and wheat can be interchanged, on an overall basis, the area under barley cultivation is governed by a wide range of other factors like demand from consumers or market price. Barley was the staple food of people in many countries for ages, but it drew away from favor due to changes in food preferences. Barley is now again returning to favor as it is considered the best food for health by nutritionists [5].

1. Distribution And Production Of Barley

1.1 Production of Barley

Barley is one of the leading grain crops produced in the world with growing worldwide recognized as a source of food and many valuable nutritional components that enrich the human diet. Barley grain is used primarily for malting and livestock feeding, and the straw is also an important feedstuff when more desirable forages are not available. Most barley is grown for malt due to the price premium [6]. Barley (*Hordeum*

vulgare L.) is grown as a commercial crop in some one hundred countries worldwide and is one of the most important cereal crops in the world. Barley assumes the fourth position in total cereal production in the world after wheat, rice, and maize, each of which covers nearly 30% of the world's total cereal production [7]. The Russian Federation, Canada, Germany, Ukraine, and France are the major barley producers accounting for nearly half of the total world production.

Country/ Region	Area harvested (million ha)	Grain yield (tonnes/ha)	Total production (million tonnes)
Australia	3.4	1.9	7.5
Canada	4.4	2.6	11.4
France	1.7	5.7	9.8
Germany	2.1	6.4	13.6
Russian Federation	7.7	2.5	19.5
Spain	3.0	2.1	6.2
Turkey	3.6	1.9	6.6
Ukraine	3.9	2.6	10.2
United Kingdom	1.2	5.4	6.7
United States	1.7	3.1	5.4
World Total	**54.3**	**2.6**	**141.2**

Source: FAOSTAT data, 2004

Table. 1: *Barley production*

The annual production reached over 144 million tons in 2014, and the top producers in terms of production quantity are Russia, France, Germany, Australia, and Ukraine [7]. Barley has great adaptability to harsh environmental conditions and can thrive on marginal lands. It is cultivated across a wide range of production areas in the world such as at the high altitudes of the Himalayas and near the Arctic Circle [8]. Barley is one of the commonly grown food security crops in high altitude areas of CASCAPE intervention areas. The total number of households cultivating barley in the Amhara Region was estimated to be 1,391,000, while the total number of households cultivating barley at the national level was estimated to be 4,148,00 [9]. Similarly, the total number of households cultivating barley in South Gonder (in which Dera District is found) was estimated to be 182,750, while the total number of households cultivating barley in West Gojjam (in which Burie and Jabitehenan are found) was estimated to be 103,450 [10]. Its grain is used for the preparation of different foodstuffs, such as Injera, Kolo, and local alcoholic drinks, such as Tela. The straw is used as animal feed, especially during the dry season. The national area coverage of barley was estimated to be 1,047,000 ha with a productivity of 1.63 tons ha-1 while the regional area coverage and average productivity were estimated to be 328,000 ha and 1.3 tons ha-1, respectively [11]. Similarly, the total area coverage for South Gonder was estimated to be 35,861 ha with a productivity of 1.3 tons ha-1, while for West Gojjam 24,649 ha with a productivity of 1.1 tons ha-1. Among other factors contributing to the low productivity of the crop, the low yielding ability of farmers' cultivars and soil acidity problems are the major bottlenecks.

Barley is regarded as a drought-tolerant crop which accounts for its popularity in areas receiving scanty rainfall. It is commonly grown in the semi-arid regions of North Africa, the Near- and Middle-East, 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 it is less risky. Winter barley is prone to damage from winter kill which affects the harvested yield. Furthermore, spring barley is preferred as a rotation crop with winter wheat as its short duration helps in fitting in the crop rotation very well. The production of barley between the decades 1970 to 2000 then fluctuated around 150 million tons with a little increase during the 1980s. Production has further decreased to around 140 million tons during 2000- 2007. European countries produce the bulk of barley. The USSR, now the Russian Federation, has produced the highest quantity of barley among all nations over the last fifty years

1.2 Classification of Barley

Barley is one of the most ancient crops cultivated already some 10 000 years ago. Barley cultivated for food and feed belongs to the species *Hordeum vulgare L.* [12]. Although the barley crop is distributed throughout the world, its supposed progenitor, Hordeum vulgare L. ssp. spontaneous C. Koch occurred in a more restricted area, namely the Middle East and adjacent regions of North Africa [13]. After domestication, unrecorded migration and trade would have rapidly distributed the barley crop outside the region of its origin. The result is the development of landraces adapted to northern and western European environments and later to North American, Australian, and Southern African environments [14]. Barley is well adapted to a wide range of environments. It is grown in different latitudes from the equator up to the 65th latitude in the north and the 50th latitude in the south as well as from sea level up to mountain slopes. Consequently, the list of agronomic criteria used in breeding consists of at least increased and stable yield, early flowering, and harvest, winter hardiness, resistance to extremes of temperature, edaphic factors and water stress, resistance to drought and soil acidity, salt tolerance, resistance to diseases and insect pests, and lodging. Quality criteria for breeding are determined according to the respective uses (processing characteristics and nutritional value) of barley. Extensive cultivation, intensive breeding, and selection have resulted in thousands of commercial varieties of barley. For commercial purposes, barley varieties are classified into broad classes that are used as a basis for world trade. The major factors used to distinguish barley varieties are feed or malting barley, winter or spring growth habit, 6-, 4- or 2-row varieties, covered or naked/hulled barley, and starch amylose/amylopectin ratio.

1.3 Common Usage and Nutritional Composition

1.3.1 Healthy Benefit of barley

Barley is a major cereal grain, commonly found in bread, beverages, and various cuisines of every culture. Whole grains are important sources of dietary fiber, vitamins, and minerals that are not found in refined or "enriched" grains. Refining grains removes the bran, germ, and most of their fiber and nutrients [15]. Barley has many economic uses today. Barley is produced primarily as animal feed. For example, over half of the barley grown in the United States is used for livestock feed. Barley as feed

has the same nutritive value as corn. Barley is high in carbohydrates, with moderate amounts of protein, calcium, and phosphorus. It also has small amounts of B vitamins. The entire barley kernel is used as feed after it has been steamrolled or gone through a grinding process. By-products from the brewing process and malt sprouts are also used in livestock feed. It is found that two-rowed barley is most often used for animal feed because it produces higher weight and superior kernel production. Barley is also used in the production of beer and some wines. About 25% of the cultivated barley in the United States is used for malting, with about 80% being used in beer production, 14% used in distilled alcohol production, and 6% used for malt syrup, malted milk, and breakfast foods. A small amount of the produced barley is used for human food in the form of pearl barley or the form of flour for porridge. Sometimes barley is grown as a hay crop in some areas. Only the smooth varieties or awnless varieties are used in hay production. Winter barley also can be used for hay if pasteurized before the stems start to elongate. The amount of barley used for ethanol has been increased significantly in the last decade, especially in some EU countries [16].

Barley has been used to formulate various "healthy" food products such as pasta and bread [17]. The major component of barley kernel is starch that may amount to over 70% of the dry weight [18]. Therefore, it may be expected that the quality of barley-based food/feed products can be much affected by the starch properties. Starch is also a byproduct of the barley fractionation process for β-glucan production [18. Understanding the starch properties provide a basis for value-added processed products containing barley. Recently produced novel starches from genetic mutants such as the "amylose-only" genotype provide various possible applications for the food and other industries [19]. A systematic review of various aspects of the starch is needed to support the current exploitation of barley as a sustainable crop. Pearling reduces the contents of insoluble fiber, protein, ash, and free lipids, but increases the contents of starch and β-Glucan by the removal of outer layers, including the hull (palea and lemma), bran (pericarp, testa), and germ (embryo), which are richer in insoluble fiber, protein, ash, and lipids and poorer in starch and β -Glucan can than the endosperm (27, 28). Generally, hulled barley is preferred to hulless barley for malting and brewing because of the contribution of the hull to beer flavor and as a filtering aid during brewing. In addition to its robust flavor, barley's claim to nutritional fame is based on its being a very good source of dietary fiber and a good nutritional source of Iron, Calcium, Magnesium, Selenium, Copper, Boron, Zinc, Molybdenum, and a better source of Protein, Carbohydrates, and Lipids [20]. Barley is a good source of both soluble and insoluble dietary fibers and in particular, the beta-glucan. The beta-glucan content of cereals ranges from 1% in wheat grains, 3-7% in oats, and 5-11% in barley. Beta-glucan is principally found in the aleurone layer and endosperm in barley. Compared to insoluble fiber such as cellulose, beta-glucan is more flexible, soluble, and viscous. It confers many health benefits including reducing the risk of heart disease, lowering blood cholesterol levels, increasing insulin response in diabetics, and preventing obesity and cancer. There is an increasing interest in using beta-glucan from barley as a functional food ingredient. Barley's fiber can prevent several different conditions. For example, when barley's fiber binds to and removes cholesterol-containing bile, this can be very beneficial for people struggling with heart disease since it forces the body to make more bile by breaking down cholesterol, thus lowering cholesterol levels. According to the Archives of Internal Medicine confirms that eating high fiber foods, such as barley, helps prevent heart disease. People eating the dietary fiber, 21 grams per day, had 12% less coronary heart disease (CHD) and 11% less cardiovascular disease (CVD) compared to those eating the least, 5 grams daily. Those eating the most water-soluble dietary fiber fared even better with a 15% reduction in risk of CHD and a 10% risk reduction in CVD. The fiber in barley also helps to prevent blood sugar levels from rising too high in people with diabetes [21].

There is growing interest in using barley for food production due to its various health effects, such as lowering blood cholesterol, regulating glycemic index, and antioxidant activity (Baik and Ullrich 2008). Functional components of barley responsible for these health benefits include β-glucans, tools (such as tocotrienols and tocopherols), polyphenols (such as phenolic acids, proanthocyanidins, and catechins), and others [22]. Whole barley grain is mostly used for feeding animals. For food purposes, barley is mainly used as a de-hulled grain or high fiber content product. Food produced from barley is a good source for many nutrients such as protein, fiber, minerals, and B-vitamins. The fiber content of barley is high and rich in β-glucan that is mainly soluble. Fiber-rich cereals such as barley are beneficial for balancing the human diet in a manner that is of no relevance for animals. Low-digestible carbohydrates, especially β-glucan and resistant starch have a positive impact on lowering post-prandial blood glucose levels. Further, β-glucan has been reported to reduce blood cholesterol levels. Barley products are thought to be good for diabetics, obese and overweight people, and for those who have a high blood cholesterol level [23]. The β-glucan from barley is also known to stabilize digestion processes in young farm animals, especially in piglets [24]. However, due to its viscosity-enhancing property, β-glucan causes undesirable effects in the digestive tract especially of young avians. But with the increasing age of the birds the ant nutritive effect decreases [25]. The β-glucan levels are shown in Table 6. Although barley has a relatively high protein content, it does not have the same baking characteristics as wheat gluten. Therefore, typical barley bread has low bread volumes. Barley flour is primarily used in combination with other flours to make multigrain bread. The production of barley is presented in Table 1, the proximate composition in Table 2, and the chemical composition in Table 3. The starchy endosperm consists of food reserves in the form of highly digestible carbohydrates (mainly starch), whereas the bran contains high levels of fiber and comparatively more minerals and fat than the endosperm.

Chemical Composition of Barley Grain

The barley grain consists of (19, 31) - Starch - 65-68% Protein - 10-13.6% β -Glucan - 4-9% Lipids - 2-3% Minerals - 1.5-2.5% Total dietary fiber - 11-34% Soluble dietary fiber - 3-20% (Nutrition Data 2009) .

Component	% of dry matter
Carbohydrates	78 – 83
Starch	63 – 65
Sucrose	1 – 2
Other sugars	1
Water-soluble polysaccharides	1 - 1.5
Alkali-soluble polysaccharides	8 – 10
Cellulose	4 – 5
β-glucan	1 – 4
Lipids	2 – 3
Protein	10 – 12
Albumins and globulins	3.5
Prolamins (hordeins)	3 – 4
Glutelins (hordenins)	3 – 4
Nucleic acids	0.2 – 0.3
Minerals	2
Other	5 – 6

Source: MacGregor and Fincher, 1993; Lyons, 1978 (β-glucan); Marins de Sa and Palme, 2001(β-glucan)

Table. 2: *Chemical composition of barley grain*

Fraction	% Kernel (by weight)	Key nutrients
Hulls (husks)	9 – 14	Cellulose, lignin, silica, pentosan, phenolic compounds
Seed coat	5.5 – 6.5	Cellulose, lipid
Aleurone layer	11 – 13	Lipid, protein, β-glucan, arabinoxylan, minerals, vitamins
Embryo	2.5 – 4.0	Lipid, storage protein, cellulose, sugars, minerals, vitamins
Endosperm	65 – 68	Starch, protein, β-glucan, arabinoxylan

Source: compiled from Briggs, 1978; Palmer, 1989

Table. 3: *Composition of barley grain*

Structural properties of barley grain

Barley cell walls encapsulate starch granules embedded in a protein matrix. With thin cell walls and loose packing of endosperm, the large mealy grains allow a rapid water up-take and uniform distribution of water and enzymes synthesized during germination. On the contrary, due to thick cell walls and tightly packed endosperms, small steely grains retard mass transfer in the endosperm. Large, plump kernels are desired for malting. The fraction above the 2.5 mm sieve is normally used for malting and the rest is included in the feed fraction. A larger uniform grain size is desired because it enables homogenous water up-take and modification. For feed use, barley grain is considered to have a poorer nutritive value than wheat or maize because of its higher fiber and consequently lower starch content. The barley hull has approximately 13% fiber, and dehulling is not practical for feed uses because the hull is fused to the seed by a cementing substance produced by the caryopsis Figure (1).

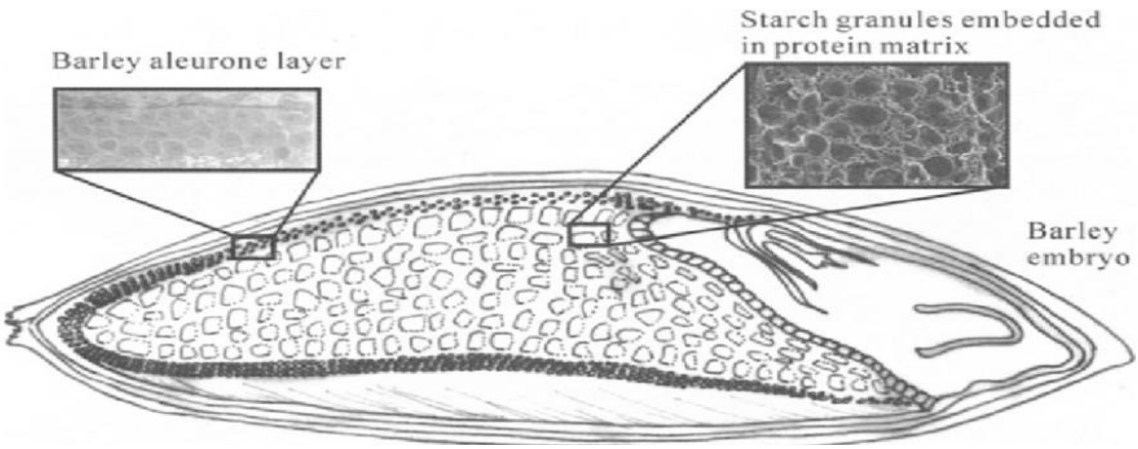

Figure 1: *Structural barley grain*

Embryo

A covering that botanists called the integument covers the female ovule in a barley plant. When an egg cell from a barley ovule unites with a sperm cell, it forms a zygote, containing genes from both parent plants. The zygotes grow into a seed embryo. The integument covering the ovule becomes the covering of the barley seed. Many seeds remain dormant or have other conditions, under which the seeds germinate, the process by which a plant emerges from an embryo. Barley seeds do not have a special period of dormancy. When they have water and warm temperature, they germinate.

Endosperm

The protective layer of endosperm tissue surrounds the embryo, which rests in a special sac. The endosperm collects fats, protein, and starch for the growing embryo.

Gibberellic Acid

The seed absorbs water through a process called imbibitions. The water moves a hormone called Gibberellic acid to the aleurone cells, which are proteins in the endosperm. The Gibberellic hormone activates the DNA coding for amylase, an enzyme that turns the starch in the endosperm into maltose, a sugar that the embryo needs for nutrition. This is the malt sugar that is the necessary ingredient for making beer, giving it its distinctive flavor. The protein-rich aleurone layer of the endosperm is what makes barley, brown rice, and other grains "chewy."

Seed Growth

The amylase is shipped into the embryo by the endoplasmic reticulum, usually abbreviated ER. The amylase goes to the Golgi, a sac-like, flattened, layered organ near the nucleus of the barley seed embryo. The Golgi load proteins and carbohydrates into vesicles or bubbles bound by membranes for transport to the growing plant cells.

The Radicle

The radicle is the first part of the barley plant to emerge from the seed. Fueled by sugar carried by the vesicles, the new plant grows larger.

1.3.2 Detailed nutritional composition

Moisture content

The moisture content is considered one of the most important quality criteria of malting barley. Wet barley respires more rapidly than dry barley, which may lead to a rise in temperature. High temperature and humidity may then activate the growth of bacteria and fungi, and lead to germination losses and production of mycotoxins. Safe storage conditions are a moisture level of 10-12% and a temperature of 15 ^{o}C (Briggs, 2001). To avoid spoilage, immediate drying of barley after harvesting is needed.

Carbohydrates

Carbohydrates constitute the bulk of the total dry matter of the barley grain. Most of the carbohydrate in barley is starch which serves as an energy source during germination. Over 96% of the total grain cellulose is present in the hulls (husks) [26]. Mono- and di-saccharides (sucrose, glucose, fructose, and maltose) are present in lesser amounts, but their concentration is twice as high as in other cereals. Of the non-starch polysaccharide fraction the content of arabinoxylan (total 6.7% of which 0.4% is water-soluble; [27] and β-glucan (4.6% is of relevance when barley is fed to young monogastric, due to the negative effects on digestion. It is noteworthy that contrary to this, the low-digestible carbohydrates especially β-glucan and resistant starch have a positive impact on human health due to their role in lowering post-prandial blood glucose levels and in reducing the blood cholesterol level [28].

Proteins

The proteins of barley can be divided into four solubility groups: albumins (water-soluble); globulins (soluble in dilute saline); prolamins (soluble in alcohol/water mixtures); and glutelins (soluble only in dilute acid or alkali). Prolamins, called hordeins in barley, are the major storage proteins and account for 35 to 50% of the total nitrogen in the grain. The albumins, globulins, glutelins consist predominantly of structural and metabolic proteins [29]. The protein content of barley grains varies considerably. The precise composition depends on the growth conditions and the rate and timing of nitrogen fertilization [30]. For this reason, an appropriate comparator must be used for the comparative analysis. In general, the protein content and protein quality of barley grain are not sufficient for high-performing monogastric farm animals. Consequently, their diets have to be supplemented with other protein sources. The low content of the consequence of the high content of hordeins is relatively low in these amino acids. The amino acid composition of crude protein in barley grain fractions [31]. Hordeins have been reported to interfere with the brewing process; the amount of extract that ultimately can be derived from the malt is inversely related to the protein (hordein) content of the original grain.

Vitamins

The vitamin content of barley grains varies widely. Un-germinated barley does not contain vitamins A, C, and D, although the carotenoids and sterols that are present may act as precursors for vitamins A and D, respectively [32]. Vitamin E, a mixture of tocopherols, occurs in barley oil. Barley is unique among cereals in having all eight naturally occurring

tocopherols. The tocopherols are found exclusively in germ tissue (embryo, scutellum) and tocotrienols in the starchy endosperm and aleurone [33]. Barley also contains B vitamins. These vitamins are mainly present in the embryo and the aleurone layer [34]. Typical ranges of B vitamin and folate concentrations in barley.

Minerals

The major constituents of the mineral fraction of barley are magnesium, phosphorus, potassium, calcium, and sodium. The average mineral content varies significantly, and this appears to be due to several factors, including the variety in question, the growing and soil conditions, and fertilizer application. Major constituents based on a compilation of worldwide. A high portion of phosphorus in barley grain is bound to the phytate complex (51-66%) making much of the phosphorous unavailable to monogastric animals. Yet barley contains MOR [35] phosphorous than common cereal grains and the phosphorous bioavailability of barley is higher than that in other grains [36]. The amounts of copper, iron, manganese, and zinc present in barley grain may vary to a large extent due to growing conditions and this has to be taken into account when diets for farm animals are formulated [37]. As with vitamins, these minerals are mainly concentrated in the embryo and the aleurone layer (Duffus and Cochrane.

Lipids

In the mature barley grain, the lipid content is approximately 3%. Lipids constitute only a small part of the dry matter in most barley tissues yet they comprise significant reserves in the embryo and the aleurone layer of the grain. They are essential for the functional integrity of the cells. The composition and distribution of lipids in the different parts of barley grain are presented.

Amino acid

The amino acid composition of barley protein is quite similar to the other cereal grains. High glutamic acid and proline contents and relatively low amounts of basic amino acids characterize the barley grain. The average amino acid composition of typical hulled and hull-less barley. As with most nutrients in barley, other than fiber, removal of the hull has the effect of increasing the protein and amino acid levels in the remainder of the kernel. In particular, hulled barley protein is slightly higher in lysine than that of hull-less barley. Table (4,5,6)

Amino acid	Barley	Bran	Flour
Alanine	4.4 - 4.6	4.1 - 5.0	3.9 - 4.4
Arginine	4.2 – 6.2	4.6 - 5.7	4.6 - 5.5
Aspartic acid	6.8 - 7.4	6.4 - 8.6	5.7 - 7.1
Cystine	1.0 - 1.79	0.3 - 2.3	1.4 - 2.1
Glutamic acid	21.9 - 26.1	20.6 - 26.6	23.3 – 28.5
Glycine	4.2 – 5.1	3.9 - 5.0	3.4 - 4.3
Histidine	1.9 – 3.3	1.4 - 2.2	2.2 - 2.4
Isoleucine	3.1 - 3.9	3.4 - 3.7	3.5 - 3.7
Leucine	5.4 - 7.1	6.6 - 7.5	6.6 - 7.0
Lysine	3.1 - 4.2	3.3 - 5.0	3.4 - 4.1
Methionine	1.4 – 3.2	1.7 - 2.3	1.6 - 2.7
Phenylalanine	4.2 - 5.4	5.1 - 5.4	5.0 - 5.5
Proline	11.4 – 12.4	9.9 – 11.9	10.1 – 12.8
Serine	3.7 – 5.4	4.4 - 4.7	4.0 - 4.4
Threonine	3.0 - 3.7	3.2 - 3.8	3.0 - 3.6
Tyrosine	1.9 - 2.8	2.5 - 3.3	2.9 - 3.2
Valine	3.9 - 5.3	4.7 - 6.1	5.2 - 5.4

Source: compiled from Bhatty, 1993; Briggs, 1978; Harrold, R. L., 1999; Bull and Bradshaw, 1995; NRC, 1998; Ensminger et al., 1990 (values taken from the last four references were calculated from dry matter basis to % of protein, based on reported protein levels)

Table.4: *Amino acid composition of barley and its fractions (g amino acid/100 g crude protein)*

Compartment	Lipid class (wt %)		
	Nonpolar lipid (NL)	Glycolipids (GL)	Phospholipids (PL)
Whole grain	65 - 75	6 – 26	9 – 20
Embryo	76 - 90	6	18
Bran-endosperm	64 - 68	13	23
Aleurone	82	-	-
Coleorhiza	74	4	22
Coleoptile	67	6	27
Scutellum	88	3	8
Hull	76	18	6

Source: adapted from Morrison, 1993

Table.5: *Composition of lipids in the principal parts of barley grain*

Tissue	Tissue in grain (wt%)	Lipid in tissue (wt%)	Lipid as fraction of total lipid (%)
Whole grain	100	2-4.2	100
Embryo	3-6	19.6-24.0	17.9-37
Endosperm	88-97	1-3	63-72
Hull	6.8	2.4	5.0

Source: adapted from Morrison, 1993

Table.6: *Distribution of lipids in the principal parts of barley grain*

Antioxidants

Barley contains a group of natural antioxidants called flavonoids. In general, cereals have only a small amount of flavonoids, except the barley grains contain measurable amounts of catechin (the same antioxidants found in green tea). Flavonoids as powerful antioxidants have anti-cancer, anti-allergic, anti-inflammatory, anti-carcinogenic, and gastroprotective properties. Besides flavonoids, barley also contains another group of antioxidants called Tools (vitamin E, the same antioxidants found in carrots). The main source of tools in our diet are vegetable oils, but a substantial amount of them are also present in barley. Toxicol content of barley confers many health benefits such as modulating degenerative diseases, cardiovascular diseases, and lowering blood cholesterols. The most active form of tool is alpha-tocopherols which show the ability to decrease lipid oxidation, platelet aggregation, and inflammation.

Reference

1. Fast & Caldwell, (2000). Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, Geneva, Switzerland.
2. Klopfenstein, C.F. (2000). "Nutritional quality of cereal-based foods", in K. Kulp and J.G. Ponte, Jr. (eds.), *Handbook of cereal science and technology, Second edition*, Marcel Dekker, Inc., New York, USA, pp. 705 – 723.
3. Robinson L, Juttner J, Milligan A, Lahnstein J, Eglinton J K, Evans D E (2007) the Identification of a Barley Haze Active Protein that Influences Beer Haze Stability: Cloning and Characterisation of the Barley SE Protein as a Barley Trypsin Inhibitor of the Chloroform/methanol Type. J Cereal Sci, 45: 348
4. Bekele, B., Makkouk, K.M., Yusuf, A., Alemayu, F.,Lencho, A. (2001). Occurrence and distribution of barley yellow dwarf virus (BYDV) isolates in central Ethiopia. Inter. J. Pest. Mande.t, 47. pp 115-119.
5. Sardana V, Zhang G P .(2005). Genotypic Variation in Some Quality Traits of Malt Barley (*Hordeum Vulgare* L.) Caused By Time of Nitrogen Application and Kernel Position Within the Spike. Cereal Res Commun, 33: 817–823
6. FAOSTAT data. (2004).
7. Fassler C, Arrigoni E, Venema K, Hafner V, Brouns F, Amado R (2006). Eur. J. Nutr. 45:445–453
8. Fineli. (2001). National Public Health Institute, Nutrition Unit. Helsinki, FinlandUmeta M, West CE and H Fufa. Content of zinc, iron, calcium and their absorption inhibitors in foods commonly consumed in Ethiopia. J. Food Compos. Analysis.18: 803-817
9. Bultosa G (2007). Physicochemical Characteristics of Grain and Flour in 13 Tef. J. Appl. Sci. Res. 3(12): 2042- 2051
10. National Association Commodity Marketing Authorities(2001). National Barley Standards
11. Ahmed Z, Tetlow IJ, Falk DE, Liu Q, Emes MJ. (2016). Resistant starch content is related to granule size in barley. Cereal Chem 93:618–630.
12. Howard TP, Fahy B, Leigh F, Howell P, Powell W, Greenland A, Trafford,Smith AM. (2014). Use of advanced recombinant lines to study the impact and potential of mutations affecting starch synthesis in barley. J Cereal Sci 59: 196–202.
13. Ellis, R.P. (2002). "Wild barley as a source of genes for crop improvement", in G.A. Slafer, J.L. Molina-Cano, R. Savin, J.L. Araus, and I. Romagosa (eds), *Barley Science, Recent advances from molecular biology to agronomy of yield and quality*, Food Products Press, Binghampton, USA, pp 65-83.
14. Asare EK, Jaiswal S, Maley J, B°aga M, Sammynaiken R, Rossnagel BG, Chibbar RN. (2011). Barley grain constituents, starch composition, and structure affect starch *in vitro* enzymatic hydrolysis. J Agric Food Chem 59:4743–4754.
15. Gao J, Vasanthan T, Hoover R. (2009). Isolation and characterization of high-purity starch isolate from regular, waxy, and high-amylose hulless barley grains. Cereal Chem 86:157–163
16. Sagnelli D, Hebelstrup KH, Leroy E, Rolland-Sabat´e A, Guilois S, Kirkensgaard JJK, Mortensen K, Lourdin D, Blennow A. (2016). Plant-crafted starches for bioplastics production. Carbohydr Polym 152:398–408.
17. Edeogu, F. C. Ezeonu, A. N. C. Okaka, C. E. Ekuma, and S. O. Elom, (2007). Proximate composition of staple food crops in Ebonyi State (South Eastern Nigeria), *International Journal of Biotechnology and Biochemistry*
18. FAOSTAT. (2017). (Statistics Division of Food and Agriculture Organization of the United Nations).
19. Goldstein A, Annor G, Putaux JL, Hebelstrup KH, Blennow A, Bertoft E.(2016). Impact of the full range of amylose contents on the architecture of starchgranules. Int J Biol Macromol 89:305–318.
20. Gujral HS, Sharma P, Kaur H, Singh J. (2013). Physicochemical, pasting, and thermal properties of starch isolated from different barley cultivars. Intl J Food Prop 16:1494–1506.
21. Gupta M, Bawa AS, Semwal AD. (2009). Morphological, thermal, pasting and rheological properties of barley starch and their blends. Int J Food Prop 12:587–604.
22. Stölken, B., Schumann, W., Bolduan, G. Hackl, W. (1996). Beta Glucane und Pentosane in Getreidesortimenten aus Mecklenburg-Vorpommern. Kongressband 1996, VDLUFA – Darmstadt, Schriftenreihe 44, pp. 241-244.
23. Maley J, Asare EK, B°aga M, Rossnagel BG, Chibbar RN, Sammynaiken R. (2010). Application of aerosol-spray deposition for determination of the fine structure of barley starch using atomic force microscopy. Starch 62:676–685.
24. Sharma P, Tejinder S. (2014). Extraction of starch from hulled and hull-less barley with papain and aqueous sodium hydroxide. J Food Sci Technol 51:3870–3877.

25. Kim BS, Kim HS, Hong JS, Huber KC, Shim JH, Yoo SH. (2013). Effects of amylosucrase treatment on molecular structure and digestion resistance of pre-gelatinized rice and barley starches. Food Chem 138:966–975.
26. Piironen, V., Lindsay, D.G., Miettinen, T.A., Toivo, J., Lampi, A.M. (2000). Plant sterols: biosynthesis, biological function and their importance to human nutrition. J Sci Food Agric 80, pp. 939 - 966.
27. Marins de Sa, and Palmer, G. H. (2001). The relationship between single grain analyses and malt modification.
28. Harrold R.L. (1999). Feeding barley to swine. EB-73, North Dakota St. U. Extension Service, Fargo, ND, U.S.A.
29. Lyddon C (2007) Europe races to produce more 'green' fuel. World grain, 25(1), 28-32
30. Mazanec K, Dycka F, Bobalova J. (2011). Monitoring of barley starch amylolysis by gravitational field flow fractionation and MALDI-TOF MS. J Sci Food Agric 91:2756–61.
31. Central Statistics Authority (CSA), (2012).Agricultural sample survey 2011/2012 Vol. I. report on area and production for major crops (private peasant holdings, *meher* season). Statistical Bulletin, AddisAbaba, Ethiopia.
32. Briggs, D.E. (1978). Barley, Chapman & Hall, London, UK, 612 p.
33. Nakamura Y. (2015). Biosynthesis of reserve starch. In: Nakamura Y, editor. Starch metabolism and structure. Tokyo: Springer. p 161–209.
34. Newman, C.W. and Newman, R.K. (2011). "Nutritional aspects of barley seed structure and composition", in Shewry, P.R. (ed.), *Barley: Genetics, biochemistry, molecular biology and biotechnology*, C.A.B International, Wallingford, UK, pp. 351 - 368.