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Barley: A Cereal with Potential for Development of Functional Fermented Foods

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Abstract

Cereals like barley are now increasingly being explored for their application as ingredients for improving the functional properties in diverse foods. Cereal-based /cereal containing probiotic functional foods are becoming increasingly popular owing to their potential health benefits. Barley is considered as a rich source of dietary fiber, phytochemicals, vitamins and minerals. The presence of β-glucan in whole grain barley has been largely credited for its health benefits. The phytochemicals in barley exhibit strong antioxidant, antiproliferative, and cholesterol lowering abilities, which are potentially useful in lowering the risk of certain diseases. Barley, due to its nutritional contents are considered good substrate for the growth of lactic acid bacteria (LAB) /probiotic bacteria. Several studies have demonstrated the fermentation of barley by LAB. Hence barley can be a good substrate to produce functional fermented foods using lactic acid bacteria. The content of dietary fibre in barley can serve as prebiotics for the probiotic bacteria and thus can add to the functional value of fermented foods. In addition to this barley proteins are said to be good candidates for value-added application as food supplements owing to their functional properties.

Keywords: Barley, β-glucan, Phytochemicals, Probiotics, Functional, Fermented food

Barley, considered as the most ancient and diverse food crop was primarily used for the animal feed. The cereal is considered as a rich source of dietary fiber, niacin, magnesium, copper and iron. The presence of barley fiber, especially β-glucan in whole grain barley, has been largely credited for the health benefits (Makeri *et al.* 2013). Additionally, it also contains phytochemicals including phenolic acids, flavonoids, lignans, tocols, phytosterols, and folate. These phytochemicals exhibit strong antioxidant, antiproliferative, and cholesterol lowering abilities, which are potentially useful in lowering the risk of certain diseases (Idehen *et al.* 2017; Zhu, 2017). In addition to this barley proteins owing to their functional properties such as emulsifying capacity and stability, foaming, elasticity, cohesiveness, and water holding capacity can enhance rheological attributes of food products. Due to its nutritional aspects, barley can be a very good substrate for the growth of fastidious Lactic acid bacteria. Several studies have demonstrated the fermentation of cereal substrates by LAB. Fermentation of whole-grain barley flour, barley and barley malt media with different species of *lactobacilli* was reported by a number of researchers (Hole *et al*. 2012; Salari *et al.* 2014; Pallin *et al.* 2016; Liptakova *et al*. 2017). The effects of food matrices containing barley β-glucans on probiotic features of the *Lactobacillus* strains were reported in a study by Arena *et al.* (2014). Rat studies have shown that administration of barley ß-glucans promoted the growth of colonic *Lactobacillus* and *Bifidobacterium* (Shen *et al*. 2012). The nutritional and functional aspects of barley as well as its suitability as a substrate to support the growth of lactic acid bacteria provides an impetus to explore barley as a functional ingredient for development of functional fermented foods. This write up provides a brief overview on barley, its nutritional and functional aspects as well as its suitability as a substrate for growth of LAB/ probiotic bacteria.

History

Barley (*Hordeum vulgare L.*) belongs to the family *Poaceae* (the grasses). It is considered as the most ancient crop and the world's first domesticated crop. Archaeologists revealed that barley was first domesticated in the Fertile Crescent of the Middle East at least 10,000 years ago. Barley has been cultivated for centuries due to its versatility, ability to adapt to unfavourable climate and soil conditions. It is one of the most widely adapted crops in the world and is grown further toward the poles, into deserts, and at higher elevations than any other crop. It is relatively cold-tolerant and is considered the most tolerant to drought, alkali, and salt among small-grain cereal species (Stanca *et al*. 2016; Zhu, 2017). It performs best under well- drained fertile loam soils with moderate precipitation (400–800 mm) and temperatures (15–30°C). Throughout its history, it has remained a major food source for some cultures principally in Asia and northern Africa (Newman and Newman, 2006). Modest quantities of non-alcoholic drinks based on barley and malt are consumed in various parts of the world (Ullrich, 2011). Barley was recognised early on as a hearty tasting, high-energy food. The Roman gladiators were known as ''hordearii''or ''barley men'' for eating barley to give them strength and stamina (Shewry and Ullrich, 2014). Barley is primarily used for feed and thus commands a lower price than other cereals, legumes, and oilseeds. Barley, ranks fourth among cereals with respect to worldwide production (Zhu, 2017). Europe is the largest producer of barley, followed by North America, Asia, Oceania and Africa. Only 2% of the world barley supply is used directly for human consumption, 65% utilized for animal feed and as raw material to produce malt (33%) for the brewing industry and thus considered as multipurpose cereal (Sullivan *et al*. 2013). As far as India is concerned, barley is a relatively small winter crop cultivated in northwest India and its production has been growing steadily on demand from the malting and brewing industry and the current production of barley is about 1.95 MMT (GAIN, 2019). Barley (*Yava* in Sanskrit) has been mentioned in *Veda* and *Purana*. It is considered as the most ancient cereal in *Atharva Veda.* It is kept under *shukadhanya varga* in *Charak Samhita*, *Sushruta Samhita* and *Astanga Hridaya* (Kumari Rajesh *et al*, 2016)

Varieties

Barley is classified as spring or winter types, two-row or six-row, hulled or hulless by presence or absence of hull tightly adhering to the grain. Based on grain composition, barley is further classified as normal, waxy or high amylose starch types, high lysine, high β-glucan, and proantho-cyanidin-free. Hull-less barley have better nutritional value than hulled barley, as it contain more proteins, lipids and soluble dietary fibres. Barley of different classes have different physical and compositional characteristics and accordingly have different processing properties and end-use quality. It depends on the processer that for what purpose they want to use it (Shewry and Ullrich, 2014). Traditionally, India produced six-row varieties of barley, which are mostly for food and feed use and unsuitable for malting. Recently, a few high quality, malting grade barley varieties have been developed through public-private breeding programs, and these varieties are steadily replacing older varieties. Trade sources report that some malting and brewing companies are promoting the cultivation of malting-grade barley varieties under contract farming (buy-back arrangement) in the traditional growing areas of Rajasthan, Punjab, and Haryana (GAIN, 2019).

Food Products

Barley products have traditionally been consumed in countries and regions of world where challenging

Table 1: Classes of processed barley for food applications

Processed Barley	Description
Hulled Barley	It is the whole grain form of barley with only the outermost hull removed. This variety of barley is very nutritious, high in fiber and protein.
Hulless Barley	This type of barley has an outer hull which is loosely attached to the kernel.
Barley Grits	This form of barley consists of kernels that are toasted and then cracked into small pieces.
Barley Flakes	This type of barley is similar in appearance to rolled oats. The barley kernels have been sliced, steamed, rolled to become flakes, and then dried.
Barley Flour	Dehulled or hulled and pearled barley grain further ground to flour using pin or hammer mills to produce whole and pearled barley flours respectively or roller milled to produce white barley flour and fiber- rich fractions.
Pearl Barley	Dehulled or hull-less barley grains are further abraded to remove rough, fibrous bran layers and germ and to obtain smooth, white grain (endosperm), called pearled grain.

Source: Shewry and Ullrich (2014).

conditions existed for other crop production. For consumption as food, the barley grains were pearled, roasted, rolled, flaked or ground to grits and flour and incorporated into a variety of foods. The processed varieties of barley are shown in Table 1.

Barley and its ingredients have been traditionally used for preparation of a number of food products (Table 2). Still, unlike other cereal foods, barley foods have not received much attention in the world food scenario. There are many reasons for the unpopularity of barley foods. Foods made using barley are lacking in good sensory attributes and therefore many efforts are done to improve the sensory properties of traditional and existing barley foods such as breads, noodles, tortillas, pasta and flatbreads. Barley food gives a dark crumb colour and unfamiliar flavour which worsen with increasing proportions of added barley flour and affect the sensory attributes of the product. Barley is lacking in gluten which is essential for producing many leavening food products. It gives weaken dough strength and reduced loaf volume thus it is a major challenge for in the preparation of barley food. In addition to this due to high in β-glucan content, is the another hurdle in utilizing the barley flour for the production of soft baked product with low moisture content such as cookies and crakers. In spite of this, β-glucan helps in improving the dough property (Baik, 2016). Izydorczyk *et al*. (2001) observed a significant increase in peak dough resistance, mixing stability and work input with the addition of β-glucan.

Number of research attempts have been made to utilise barley for preparation of various foods such as roller-milled and sieved barley flour fraction containing 42% total dietary fibre and 19% β-glucan (Knuckles *et al*., 1997). Barley flakes were added to bread dough at 15% and produced a bread with lower loaf volume but the product possessed desirable texture and flavour qualities (Kawka *et al*. 1999). Bread dough containing 20% rolled-milled barley flour, 15% wet glucan and 20ppm ascorbic acid produced a bread similar to that of 100% wheat flour bread (Gujral *et al*. 2003). Addition of 60% wheat flour and 40% hull-less barley flour improved the loaf volume of baked bread (Trough *et al*. 2004). In an attempt, *Balady* bread was prepared by incorporating barley flour from 0-100% and it was observed that *balady* bread showed an acceptable sensory attributes with 15-30% barley flour incorporation and any further increase in barley flour incorporation resulted in harder, darker and nonuniformly shaped *balady* bread (Ereifej *et al*. 2006).

In Indian subcontinent, barley (popularly called *jau*) flour alone or blended with wheat flour is used to prepare *chapatti*. It was observed that *chapatti* prepared with wheat-barley flour blend showed increased extensibility with 20% barley flour incorporation

Table 2: Selected traditional barley foods prepared from various types of processed barley grain ingredients around the world

Processed Barley Grain Ingredient	Food Product	Country/Region
Flour	Pinni	India
	Barley bread	Middle East, Egypt
	Injera (pancake like product)	Ethiopia
	Kitta (unleavened, thin, dehydrated bread)	Ethiopia
	Shorba (soup)	Ethiopia
	Tihilo (Flour dough balls)	Eritrea
Roasted hulled grain	*Boricha and mugicha* (Barley tea)	Korea, Japan
Whole grain	Jhang Chang	India
	Nakia (Beverage)	Yemen
	Sanchak tukba (Porridge)	Tibet
Malt	*Borde, bequre* (unfermented or slightly fermented beverage)	Ethiopia
Roasted grain	*Kolo* (grain mixed with roasted legumes and oil seeds)	Ethiopia and Eritrea
	Tijmirout, yue (Popcorn like products)	Morocco and Tibet
Roasted grain flour	*Tsangpa-ba* (Dough balls with butter and tea)	Tibet and Nepal
	Chiko, besso (Dough balls with water, butter or oil)	Ethiopia

Source: Thakur and Bhalla (2004); Baik (2016).

(Gujral and Pathak, 2002). Barley grains were also used for preparation of barley water (*jau nu pani*) and the barley water is consumed by those suffering from kidney stones and urinary tract infections. It is believed that barley water helps in maintaining the pH balance in our body by making it alkaline. It eventually restricts the production of kidney stones.

It is also said that drinking barley water helps in cleansing the kidneys by flushing all sorts of toxic materials out of the body through urine. Regular intake of barley water create required bladder pressure and make the kidney stone elimination process easier. It provides enough vitamin B6 to our body, which is reported to play a crucial role in break down of the calcium oxalate masses formed inside kidneys. The magnesium content in barley is said to speeds up the dissolution of calcium oxalate crystals (Curhan *et al.* 1999; Minal *et al.* 2017).

Nutritional aspects

Whole barley grain consists of about 65–68% starch (Griffey *et al*. 2010; Zhu, 2017). Barley starch, its composition, structure, properties and various modifications of barley starch tried have been effectively reviewed by Zhu (2017). Total fiber in barley ranges from 11–34%, of which 3–20% is soluble dietary fiber mostly in the form of β-glucan (Jalili *et al*. 2000; Andersson *et al.* 2004; Makeri *et al.* 2013). The β-glucan content of barley can range from approximately 2-11%, which is generally higher than oats (2.2–7.8) and wheat (0.4-1.4%). Protein 10–20% and other constituents include 2–3% free lipids and 1.5–2.5% minerals. Barley also contains a myriad of other components including a number of antioxidants and phenolic compounds (Borneo and Leon, 2012).

Barley as a substrate for LAB /Probiotics

LAB are usually nutritionally fastidious organisms requiring fermentable carbohydrates, amino acids, B-vitamins, nucleic acids and minerals to grow. A number of LAB species have been shown to grow well in different kinds of cereals, indicating that cereals are a good source of the nutrients which the LAB require. Decrease in starch content during fermentation of barley with *lactobacilli* has been reported (Liptakov *et al*. 2017). *L. reuteri* has been reported to grow well in different kinds of cereals (Pallin *et al*. 2016). Fermentation of whole-grain barley flour with different species of *lactobacilli*, including *L. reuteri*, has been shown to increase the content of free phenolic acids six-fold (Hole *et al*. 2012). Difference in acid buffering capacity have been shown to exist in different cereals such as wheat, barley, maize, oat and sorghum (Giger-Reverdin *et al*. 2002) and such differences possibly exist between the barley varieties also. Pallin *et al.* (2016) in their study used *L. reuteri* strains in fermentations of six varieties of barley comprising of both untreated and heat-treated (with inactivated indigenous enzymes) flour. The performance of *L. reuteri* strains were compared with two probiotic strains of human origin (DSM 17938 and ATCC PTA 6475), one previously isolated sourdough strain (LTH 5531) and one strain of *Lactobacillus plantarum* (36E). Analyses of growth (CFU) and metabolism (1H-NMR) revealed differences at species level, with *L. plantarum* showing a higher capacity to assimilate nutrients without help of the cereal enzymes. Similarities were observed between *L. reuteri* strains isolated from sourdough, while the greatest differences between *L. reuteri* strains were observed between strains 6475 and 17938. It has also been showed that the production of metabolites was significantly different between *L. reuteri* and *L. plantarum* in barley flour.

Feng *et al.* (2005) investigated the growth abilities of *L. plantarum, L. fermentum, L. reuteri* and *L. lactis* during barley tempeh fermentation. *L. plantarum* multiplied from 4.8 to 7.4 log cfu/g dry tempeh and *L. fermentum* increased from 4.4 to 6.8 log cfu/g during 24 h incubation at 35ºC. *L. reuteri* and *L. lactis* had significantly slower growth, with increases from 4.8 to 5.6 log cfu/g and 5.0 to 5.4 log cfu/g, respectively.

β-glucans from barley and oats administered to rats have been shown to promote the growth of colonic *Lactobacillus* and *Bifidobacterium* (Shen *et al*. 2012). In order to identify the prebiotic potential of barley β-glucans, the effects of two different β-glucans-enriched matrices were investigated on probiotic strains *Lactobacillus acidophilus* LA5, *Lactobacillus plantarum* WCFS1, *Lactobacillus plantarum* CETC 8328 and *Lactobacillus fermentum* CECT 8448 by Arena *et al*. (2014). Their results showed that food matrices containing β-glucans (β-glucans enriched pasta and barley flour) stimulated the growth of the bacterial strains analysed to a greater extent than traditional pasta and MRS alone. Also the ability of β-glucans to influence the growth of microorganisms was strain-selective, as a significantly higher stimulation was observed for *L. plantarum* WCFS1 and *L. plantarum* CETC 8328 than *L. acidophilus* LA5 and *L. fermentum* CECT 8448. Furthermore, differences in growth were observed on the different β-glucan enriched matrices. The growth of *L. fermentum* CECT 8448 was only affected by barley flour rather than by β-glucans enriched pasta, while the growth of *L. plantarum* WCFS1, *L. plantarum* CETC 8328 and *L. acidophilus* LA5, was positively influenced by both barley flour and β-glucans enriched pasta. They also studied the effects of food matrices containing barley β-glucans on probiotic features of the *Lactobacillus* strains and reported that such matrices were able to improve the growth rate of the *Lactobacillus* strains both in unstressed conditions and after exposure to *in vitro* simulation of the digestive tract. Further in their study, they checked the effect of β-glucans-containing food on bacterial adhesion to enterocyte-like cells and observed a positive influence on probiotic-enterocyte interaction.

Charalampopoulos *et al*. (2002) investigated the overall growth kinetics of the potentially probiotic *L. fermentum*, *L. reuteri, L. acidophilus* and *L. plantarum* strains in malt, barley and wheat media. They reported that the malt medium supported the growth of all strains more than barley and wheat media due to its chemical composition. Novik *et al.* (2007) studied the use of the protein and polysaccharide fractions

Table 3: Phytochemicals present in barley and its proposed health benefits

Phytochemicals	Health benefits
Phenolic acid	Antioxidant, antiradical and antiproliferative potential.
Flavonoids	Provides protection against UV radiation in response to excess light stress, Prevents cancer and coronary heart disease.
Lignans	Antioxidant, antitumor, antibacterial, insecticidal, fungistatic, estrogenic and antiestrogenic activity, Protect against coronary heart disease.
Tocols (tocotrienols, tocopherols)	Antioxidant activity and inhibits the lipid peroxidation in biological membrane, Clear the atherosclerotic blockages in carotid artery and reduces the risk of stroke, Protect against cardiovascular disease, Promote apoptosis induction.
Phytosterols	Decreases serum cholesterol levels, protect against coronary heart disease and prevent colon cancer.
Folates	It is involved in many metabolic pathways and have the same biological activity as folic acid (Vitamin B_9).

Source: Idehen et al. (2017); Zhu (2017).

of barley spent grain as a basis of growth media for probiotic bacteria. High values of biomass yield, cell viability, and organic acid production were observed in the variants of media containing the barley spent grain supplemented with lactose, ascorbic acid, yeast extract, and mineral salts. Salari *et al*. (2014) in their investigation on physicochemical characteristics of fermented cereal-based beverages made by 48 h fermentation of malt, barley and barley-malt media by two potentially probiotic strains of *Lactobacillus paracasei* and *Lactobacillus delbrueckii* revealed that the selected probiotics grew well on single and mixed substrates without any supplementation. The highest microbial growth (9.7 log cfu/ml) was found in malt medium after 15 h fermentation. A significant decrease in pH value to 4.25 and a considerable increase in total titratable acidity level to 2.96 g/100 g lactic acid were obtained by initial 6-h fermentation of *L. paracasei* on malt medium. Gum extracted from barley has been tried as encapsulation material for probiotic yeasts to enhance their stability (Ragavan and Das, 2018).

Functional aspects

Barley is gaining its popularity because of its association with β-glucan fiber and phytochemical compounds which are associated with various health benefits (Idehen *et al.* 2017; Zhu, 2017). A number of epidemiological studies have shown that regular consumption of whole grain barley can reduce the risk of developing chronic diseases (Dongowski *et al*. 2002; Sullivan *et al*. 2013). The presence of barley fiber, especially β-glucan in whole grain barley, has been largely credited for these health benefits. Additionally, it also contains phytochemicals including phenolic acids, flavonoids, lignans, tocols, phytosterols, and folate. These phytochemicals possess strong antioxidant, antiproliferative, and cholesterol lowering abilities, which are potentially useful in lowering the risk of certain diseases (Idehen *et al.* 2017; Zhu, 2017). The phytochemicals present in barley and their proposed health benefits are shown in Table 3. It was approved by the US Food and Drug Administration that there is a relationship between β-glucan soluble fiber and reduction in the risk of coronary heart diseases and it was an additional incentive that stimulated research interest on barley as a source for bioactive components. Other bioactive barley components include minerals, vitamins, and various phytochemical molecules, which are also associated with certain health benefits (Idehen *et al.* 2017). Barley is also an important source of protein, insoluble fibre, vitamins and minerals. Due to the phytochemicals barley exhibit high antioxidant activity and that makes the barley as a useful natural means for the prevention of diabetes and obesity development and progression (Zielinski and Kozlowska, 2000). Selenium and vitamin E in barley provides beneficial antioxidant effects. It is having good diuretic activity and is useful in urinary tract infections. Flavonoids in barley are reported to have antioxidant, anticancer, anti-allergic, anti-inflammatory, anticarcinogenic and gastroprotective properties. Barley contains gluten, contraindicated in celiac disease. Its availability and ease of handling leads it to be increasingly incorporated into foods with the purpose of increasing daily fiber consumption.

Lowers the Blood Cholesterol level

The FDA concluded that daily consumption of 3 g of soluble β-glucan from whole-grain barley or certain dry milled barley products would produce the same cholesterol-lowering effect as oat products (lowering plasma total cholesterol by 5–8%). Shen *et al.* (2016) reported that polyphenols from black highland barley is found to have strong superoxide radical, hydroxyl radical, 2,2-diphenyl-1-picrylhydrazyl radical-scavenging activity, and antioxidant ability. They revealed that mice which were administered 600 μg black highland polyphenol extract per gram body weight showed significant reduction in total cholesterol (23.33%), LDL cholesterol (26.29%), and atherosclerosis index (38.70%), in addition to increasing high density lipoprotein cholesterol (HDL, 17.80%).

Behall *et al*. (2004) reported that the total cholesterol was significantly lower when the diet contained 3 or 6 g β-glucan/d from barley than when it contained no β-glucan and the greatest change was observed in the men and postmenopausal women and it was revealed that it was the effectiveness of barley β-glucans in barley food products which lowered the blood cholesterol. β-glucan binds to bile acids in the intestines and thereby decreases plasma cholesterol levels. Absorbed soluble fiber decreases cholesterol synthesis by liver and cleansed the blood vessels. The β-glucan in barley can lowers the total cholesterol, LDL-cholesterol and triglycerides while not significantly affecting HDL-cholesterol reported by Talati *et al.* (2009). Barley is a rich source of tocols, including tocopherols and tocotrienols, which are known to reduce serum LDL cholesterol through their antioxidant action (Qureshi *et al*. 1986, 1991; Fardet, 2010; Belobrajdic and Bird, 2013). Being a good source of niacin also helps in reducing LDL levels and increasing HDL levels.

Reducing Cardiovascular Risk

High blood cholesterol level is a significant risk factor in the occurrence of CVDs. Polyphenols play a major role in moderating CVDs because of their antiradical scavenging potential. Barley possesses the antioxidant activity due to the presence of tocotrienols and tocopherols which are the strong antioxidant and thought to be important for cardiovascular health. Among the most economically important cereals (wheat, barley, rice, rye, and oat), barley has been reported to have the highest amounts of tocols and phytosterols (Belobrajdic and Bird, 2013). Behall *et al.* (2004) reported that on increasing the soluble fiber through the consumption of barley in a healthy diet can reduce cardiovascular risk factors. The approval, by the US Food and Drug Administration, of the claim that had established a relationship between β-glucan soluble fiber from barley and reduction in the risk of coronary heart disease. Folate has been associated with cardiovascular health and it was revealed that its suboptimal presence in humans has been associated with the increased risk of cardiovascular ailment (Santilli *et al*. 2016). Consumption of natural antioxidants, such as polyphenols, in daily diets can, thereby improves the cardiovascular health. Behall *et al.* (2006) reported that when participants used barley to deliver 20% of their energy intake for five weeks their blood pressure was reduced and it was revealed that fiber content of barley was responsible for this effect.

Type II Diabetes and Glycemic Control

Barley and barley food products have been shown to produce favourable effects on glycemia. Regular consumption of barley in diet is reported to help in fight against diabetes (Sullivan *et al.* 2013). The mechanism responsible for these effects are due to the ability of barley β-glucan which possess a very high molecular weight that exhibits high viscosity at a low concentration and consuming the β-glucan rich barley can increase the viscosity of the meal bolus in the stomach reducing the mixing of food with digestive enzymes and delaying gastric emptying. Increasing the viscosity has also been shown to retard the absorption of glucose and slow the rate of starch digestion in *in vitro* digestion model studies (Regand *et al*. 2011).

Tosh (2013) conducted a comprehensive review of human studies investigating the role of barley and oat food products in lowering post-prandial blood glucose. Urooj *et al.* (1998) reported that the insulin requirement was reduced for some type 2 diabetic subjects when barley was consumed. Tappy *et al.* (1996) reported a linear inverse relation between the β-glucan content and the glucose plasma peak. In addition to that barley phytochemical compounds have potent anti-inflammatory actions and could thereby moderate diabetes and obesity risk (Hanhineva *et al.*, 2010; Salas-Salvad *et al.* 2011). Minaiyan *et al.* (2014) investigated the effect of hydroalcoholic extract of barley seeds and a protein enriched fraction on blood glucose of normal and streptozotocin (STZ)-induced diabetic rats. Their findings suggested that barley seeds hydroalcoholic extract has a role in diabetic control in long term consumption, and this effect might be at least due to its high fiber content.

Acts as Prebiotics

Barley contains β-glucan levels in the range of 3–8 g per 100 g of dry weight. β-glucans have been shown to be highly fermentable by the intestinal microbiota of caecum and colon, and could enhance the growth rate and the lactic acid production of microbes isolated from human intestine. Arena *et al*. (2014) investigated the effects of food matrices containing barley β-glucans *viz*., β-glucans enriched pasta and barley flour on growth and probiotic features of four *Lactobacillus* strains. Their study results showed that β-glucans from barley were able to improve the growth rate of the tested probiotic bacteria both in unstressed conditions and after exposure to *in vitro* digestive tract simulation, with a selective influence on *L. plantarum* species.

Reducing Colon Cancer Risk

Research report says that diet/lifestyle is responsible for approximately 20-80% human cancer mortality. Food / food ingredients, especially those that can tackle the impact of reactive oxygen species, can protect against DNA damage and stimulate the immune system, thus lowering cancer risks. Barley and its products have bioactive compounds with antioxidative and immunomodulatory activities that are associated with cancer moderation (Idehen *et al*. 2017). Most studies regarding the chemoprevention of carcinogenesis by barley have mainly involved the effect of barley fiber, especially β-glucan. Besides its high level of β-glucan soluble fibre, barley is an excellent source of insoluble fibre important in maintaining digestive health and protecting against colon cancer reported by Aune *et al*. (2011). Dongowski *et al*. (2002) reported that regular barley consumption can prevent colonic cancer. The anti-carcinogenic benefits of germinated barley foodstuff (GBF) was reported by Kanauchi *et al*. (2008).

Antimicrobial activity

Pallin (2015) studied the fermentation of barley flour with *Lactobacillus reuteri* and observed a potentially bioactive compound in fermented barley i.e., reuterin. In all barley varieties, fermentation by *Lactobacillus reuteri* and *Lactobacillus plantarum* produced 1,3-propanediol. *L. reuteri* are able to produce the antimicrobial substance reuterin by fermentation of glycerol. Further he evaluated a synbiotic formulations of barley and *L. reuteri* using an intestinal epithelial cell model (IPEC-J2) and revealed that untreated barley flour increased the permeability of the cell layer, while heat-treated flour did not. Barley β-glucans can selectively support the growth of *Lactobacilli* and *Bifidobacteria*, both of them being antagonists to pathogenic bacteria in the digestive system reported by Zekovic *et al.* (2005).

Acts as Antianxiety and anticonvulsive

Gamma-aminobutyric acid (GABA) is an inhibitory neurotransmitter that reduces neural excitability in the mammalian central nervous system with three subclasses of receptors, namely, relaxing, antianxiety, and anticonvulsive. It alleviates pain, regulates sleep and increases cognitive and reproductive effects (Manayi *et al.* 2016). Barley bran is reported to be more efficient than wheat bran in the GABA production (Jin *et al.* 2013). Barley grass contains 20 amino acids associated with energy production, cell building, and regeneration (Lahouar *et al.* 2015; Jiazhen *et al.* 2016; Zeng *et al.* 2018). Pallin (2015) studied the fermentation of barley flour with *Lactobacillus reuteri* and observed a potentially bioactive compound in fermented barley i.e., GABA, which was found in all samples (untreated, heat-treated and unfermented), suggesting that it was present in the flour from the start.

Management of kidney stone

Chakradhar (2012) reported that, an alkali preparation of barley given in *Paneeyakshara* form helped in the disintegration and expulsion of kidney stones and it produced total relief in sign and symptoms of renal calculi. Al-Razzuqi and Al-Ebady (2011) studied on the role of barley in the improvement of nephrocalcinosis in experimental rabbit model and their results showed a significant reduction in blood urea nitrogen and serum Na+ levels with insignificant change in serum creatinine and K+ in comparison with the control group. It revealed a significant reduction in calcium deposition from renal parenchyma after 10 days of treatment, with improvement in nephrocalcinosis severity indicating that barley has a significant diuretic and attenuating effect in reducing calcium deposits in renal tissues, with a significant effect on lowering oxalic acid toxicity through its diuretic action.

Reducing Inflammatory Bowel Disease (IBD) Risk

Germinated barley foodstuff (GBF) is a source of fiber and glutamine-rich protein. GBF is a prebiotic product that increases butyrate production by intestinal bacteria. These compounds may affect the repair and restoration of function of colonocytes. Bamba *et al*. (2002) studied the effect of administration of 20-30 g of GBF to patients with mild or moderate Ulcerative colitis exacerbation. After four weeks of therapy, the patients demonstrated clinical and endoscopic improvements, indicating that GBF may play an important role in IBD therapy. Patients receiving prebiotic supplementation demonstrated an improvement of clinical status as well as prolonged remission.

Provide Satiety and Weight Loss

Insoluble fiber provides bulkiness in the intestine, thereby it gives satiety which further decreases the appetite. Barley has been suggested as satiety inducing food due to its low GI values and high viscous fibre content (Aldughpassi, 2013). Schroeder *et al.* (2009) reported that whole grain with high-fiber barley foods significantly decreased the hunger whereas whole wheat and refined rice foods was unable to do the same, indicating that barley grain can help in reducing the weight by providing satiety. Barley may also be able to whittle down the tummy fat. Shimizu *et al.* (2008) in their study on men with high cholesterol found that when the subjects partly replaced rice with pearl barley for 12 weeks their abdominal fat, body mass index and waist circumference were significantly reduced. The high β-glucan content is considered to be responsible for this beneficial effect. The study also found that consuming pearl barley resulted in lower levels of total and low-density lipoprotein cholesterol.

Skin Booster

Barley contains important nutrients that can feed skin. It is a great source of protein and has vitamin B as well as minerals like iron and zinc. It also contains selenium which can protect against damage from the harmful rays of the sun and help to preserve the elasticity of skin. One study has found that a fermented barley and soybean product improved skin hydration and had a moisturizing effect (Lee *et al.* 2015).

Other benefits of Barley

Barley is intensively used as a raw material in the starch industry generating large quantities of protein as a by-product that can be valorized in the food industry. Barley proteins are good candidates for value-added application as food supplements owing to their functional properties, including emulsifying capacity and stability, foaming, elasticity, cohesiveness, and water holding capacity that enhance rheological food properties (Wang *et al*. 2010). Despite the limited nutritive value of barley proteins in the human diet due to their low digestibility, they constitute a good source for essential amino acids, such as threonine, valine, lysine, phenylalanine, and arginine (Sullivan *et al*. 2013). The low digestibility may, in fact, be a desirable attribute as it ensures a controlled release of bioactive compounds and exerts a protective effects on the gastrointestinal tract. Hence, barley proteins have a potential for application in food development with a competitive advantage compared to whey and soya proteins.

CONCLUSION

Barley is still an underutilized cereal for food production. It possess a plethora of health benefits owing mainly to its β-glucan content and polyphenols. The health benefits of barley are being increasingly studied and documented. Fermentation of barley by lactic acid bacteria has been reported in a number of studies. Fermented barley represent a largely unexplored source of new nutrients and biotherapeutics and the biotransformation of barley compounds by lactic acid bacteria has the potential to generate a highly diverse set of metabolites. Hence barley can be one of the most suitable cereal for functional fermented food development. Further, the technological as well as sensory aspects of processed barley should be taken into account to improve its use as a functional ingredient or food.

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