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Mini Review

Nutritional and functional perspectives of barley β-glucan

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Abstract

Barley *(Hordeum vulgare)*, one of the important cereals in world after wheat, rice and maize. β-Glucan, a polysaccharide and soluble dietary fiber, has great potential as a nutraceutical ingredient. Its potential is not utterly utilized in food industry and used as fodder in developing countries with limited human consumption mainly due to lack of awareness. Consumers should prefer the foods rich in functional ingredients owing to their consciousness about health with good nutrition. β-glucan play a pivotal role as nutraceutical food in preventing cardiovascular diseases, controlling diabetes mellitus, regulating cholesterol level in body. New and novel research domains like molecular weight of β-glucan in relation to industrial important aspects will broaden the scope for utilization in different food systems. Research and studies related to different extraction methodologies and techniques for β-glucan, its functional properties and potential use in beverage manufacturing will enhance the health beneficial verdicts. Food industry can exploit β-glucan as for its functional properties i.e. thickening, stabilizing, emulsifying and gelling to maintain the stability of ingredients especially in beverage production. By manipulating the extracted β-glucan and protein contents from barley, numerous types of malt (beer) and different beverages can be prepared to satisfy different quality parameters of consumers. The physicochemical, nutritional, functional attributes, yield and purity of the β-glucan depends substantially to extraction procedures from the raw material ultimately exhibiting health benefits, which are associated with lowering of blood glucose level and CVDs boosting immune system for better gut health.

Introduction

In today's live style, human health has received an unprecedented important status due to interest in nutrition and balance diet. The foods which provide additional health benefits by promoting and combating chronic diseases beyond meeting basic nutrients are known as functional foods (Nicoli *et al.*, 1999). The functional foods are not intended only to satisfy hunger, but also provide necessary nutrients to human for the prevention of nutrition- related diseases (Menrad, 2000). Functional foods including functional beverages are important for the promotion of health and diseases prevention. The functional foods in last two decades have given approach for the development of new functional beverages. The global market of functional foods has been estimated to be at least 33 billion US$ (Hilliam, 2000). They provide to get prevention from illness and also minimized the additional burden to maintain the health care system (Shahidi, 1998; Menrad, 2000).

The barley (*Hordeum vulgare* L.) accounts for 12% of the world's total cereal production and occupies fourth position with respect to grain production after wheat, rice and corn (Jadhav *et al.*, 1998). The barley grain was produced 137.47 million metric tones in the world during the crop year 2006-2007 (FAS, 2008). The leading barley producing countries around the world are EU countries (51.65 million tones) followed by the Russian Federation (25.01 million tones) and Canada (13.17 million tones) (Charles and Cleary, 2005). Over the globe approximately, 81% of annual barley production is used for feed, 9% for seed, 8% for malt and alcohol production and only 2% is used for human consumption (AERI, 1986). Thousands of years ago, it has been found that barley crop was grown and cultivated along the Nile River during the historic time of Egyptian (Wendorf *et al*., 1979). The barley crop is generally found in two forms one is hulled and other is hull-less. Barley strains which are hull-less

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are rich in starch, protein and β–glucan as compared to other strains. This valuable crop contained dietary fiber and is famous for due to the occurrence of β–glucan that is soluble in nature (Bhatty, 1999). The naked grain of barley is found to be suitable for food processing industry because of the presence of all nutrients which retained during processing while grain with hull is utilized for brewing. The presence of bioactive ingredients in barley grain made it favorable to use in human diet (Bhatty, 1996).

Barley is getting renewed interest as an ingredient in the production of functional foods due to its higher content of bioactive compounds. Barley possesses high amount of dietary fiber (DF) with high proportion of soluble viscous components, offering more suitability among cereal grains in the human diet (Bjorck *et al.,* 1990). The β-glucan fiber is unique and is present as soluble and insoluble forms. The barley cultivars of high-amylose and waxy hulless have more amount of β-glucan up to 7-8% whereas the other regular hulls barley contained less than 4.6% (Tiwari and Cummins, 2008; Gao *et al*., 2009).

The extracted β-glucan is soluble to about 54% inside water and is known as soluble dietary fiber (Anker-Nilssen *et al*., 2008). The possible mechanism for the reduction in cholesterol and decline in lipid levels with the consumption of dietary fiber is due to gel formation inside human body however there is no clear consensus among the scientists (AbuMweis *et al*., 2010). The barley and oat crops are well known for β–glucan that contains linear chain glucose molecules, which are partially soluble polysaccharides and β–glucan concentration significantly effected by environmental conditions (Aastrup, 1979; Aman *et al*., 1989). Zhang *et al.* (2002) adopted an enzymatic procedure to measure the amount of extracted β–glucan from barley and collected samples from China, Australia and Canada. It has been estimated by Ragaee *et al.* (2001) that barley, oat, rye and wheat grains are rich sources of available β–glucan for utilization in human diet. The different amount of β-glucan has been estimated in different cereal crops and founded nearly to be 3% to 7% in dehulled barley and about 2% to 0.5% in rye and wheat respectively (Beresford and Stone, 1983; Lee *et al*., 1997). Normally the samples contained plant cell wall structure are purify and is extracted with the application of chemical agents and the characterization techniques includes nuclear magnetic resonance (NMR), Fourier-transform infrared (FT-IR) for the estimation of plant cell wall based polysaccharides having cereal β-glucan and to determine the ratio between the β-(1→3) to β-(1→4) by using liquid state 1H NMR (Petersen *et al*., 2000; Johansson *et al*., 2004; Lazaridou *et al*., 2004; Seefeldt *et al*., 2008; Seefeldt *et al*., 2009).

The current review on β-glucan has been done in order to give the overview of potent health benefits of Barley. To make masses aware about the suitability and functionality of this cereal. People are not using barley as staple food and missing the chance to avail its nutraceutical as well as functional attributes. Therefore, this review will help common people as well as researchers to focus on the usage of Barley as source of β-glucan for functional, nutraceutical and health verdicts.

Different extraction methodologies and techniques

The cereals containing β-glucan is present in walls of the endospermic region of cells with lipid and protein matrix, so the extraction process is not simple. When extracted β-glucan analyzed for different quality attributes needs optimum conditions and purity of β-glucan. Different methods and techniques have been developed for purification and isolation and to get potential bioactive compound (β-glucan) various critical points should be considered. It has been found that the molecular weight of the isolated β-glucan is directly proportional to the methodology applied for extraction (Tosh *et al*., 2003; Du *et al*., 2014). The extraction techniques from cereals comprises of three basic steps i.e to inactivate endogenous enzyme, isolation of β-glucan and finally to precipitate the extracted β-glucan. The enzyme inactivation includes refluxing above 60^{o}C with aqueous ethanol (Charles and Cleary, 2005)

Various isolation and extraction procedures for β-glucan include dry milling and solvent extraction from oat and barley (Dawkins and Nnanna, 1993; Saulnier *et al*., 1994; Wu and Stringfellow, 1994; Ahmad, 2009). These methods including for β–glucan isolation was found to recover it about 89% and 31% by solvent extraction, by milling and air classification respectively and 41% to 81%. B-glucan extracted in a neutral and alkaline medium and through hot water about 90% β-glucan extracted (Wu and String-Fellow, 1994; Burkus and Temelli, 1998; Morgan and Offman *et al*., 1998; Ahmad, 2009). A research conducted by Rimsten et al. (2003) in which the findings revealed that 84% and 72% of β-glucan extraction achieved through NaOH and Na_2CO_3 from the sample of hulled barley bran and small quantity may also be lost during isolation process. Scientists have reported that the viscosities of solutions prepared with different concentrations of β-glucan in food application depends upon the conditions like pH and temperature maintained during extraction process and in a product formulation if there is higher amount of β-glucan is required then low viscous forming extracts can also be used (Burkus, 1996; Burkus and Temelli, 1998). An advanced methods devised by Carr *et al*. (1990) to measure the β-glucan and contents of extracted β-glucan. The scientific literature showed that the recovery of β-glucan depends upon the conditions of extraction media which comprises of pH, temperature and ionic strength. During extraction of β-glucan, the solvents like distilled water with 4% NaOH could also be used and the viscoelastic properties of β-glucan found to be effected by the extraction media and low viscosity is observed if extensive boiling time is maintained and good quality gum with high viscosity is achieved by a appropriate combination at high pH (Johansson *et al.,* 2000). Izydorczyk *et al.* (1998a, 1998b) reported the similar findings in the previous decade, including NaOH, water and $Ba(OH)_2$, $Ba(OH)_2$/ H_2O having sequential techniques of β-glucan extraction and this method consists of repeated extraction from every barley samples and collected/ isolated material and then combined in the end. A water extraction method that showed increased amount of about 90% β-glucan could be isolated at 45, 60 and 95°C. Similarly, another procedure elaborated by Morgan and Ofman (1998) that 89-94% extraction of β-glucan achieved through hot water including freezing and thawing of the samples and this finally extracted β-glucan namely "Glucagel™" and is available in the market for food application. The yield and purity of β-glucan during extraction process depends upon the conditions maintained i.e pH and temperature. It is also concluded that the most pure fraction of β-glucan is collected by treating the samples with thermostable alpha- amylase (Symons and Brennan, 2004).

The method followed by Bhatty (1995) for the extraction of β-glucan in which he added NaOH in barley flour at room temperature and centrifugation is carried out at 6000×g for 15 minutes and this process is repeated for residue recovery. The impurities discarded and clear supernatant collected and pH adjusted to 6.5 with the addition of HCl and after that inside it calcium chloride and enzyme termamyl put in with concentrations 70 mg/100ml and 0.1 ml/100ml respectively. This content is incubated for 1 hr at 96°C with continuous shaking then the contents are cooled to 25°C and HCl put in to set the pH at 4.5. The centrifugation is applied to the collected supernatant at 6000×g for 15 minutes and the impurities are removed after centrifugation. Inside suspension 50% equal in volume ethanol is incorporated and placed it at 4°C for overnight and the process of centrifugation is again applied at 6000×g for about 15 minutes. The so extracted crude β-glucan gum again resuspended in H_2O and the residue of impurities cleaned twice with the addition of 50% ethanol. Finally, the centrifugation applied and the crude β-glucan gum pellets completely homogenized in water and freeze dried the contents to recover the β-glucan gum. In the same way to extract more pure β-glucan Westerlund *et al.* (1993) developed a method that included heat treatment and solvent extraction. The method comprising enzymatic extraction techniques for β-glucan has been found to be excellent as compared to the acid and alkaline methods. The yield and purity of the extracted β-glucan depends upon the extraction technique and by adopting the enzymatic methods because more impurities are removed (Ahmad *et al*., 2010). The most recent studies by Sharma *et al.* (2010) showed that the roasting, which is a type of heat treatment has no bad effect on the extractability of β-glucan but the ratio between soluble to insoluble β-glucan fiber is changed due to decrease in soluble form of β-glucan. There are many methods and procedures that are reported and available in literature, the scientists Vasanthan and Temelli (2008) has grouped these techniques into two categories i.e dry and wet conditions. The wet conditions adopted for the isolation of β-glucan are found to be more complicated and involved two to three separate stages (Brennan *et al.*, 2002). Similarly, scientists optimized the conditions for β-glucan extraction from different barley sources. The optimum temperature value was 55°C for β-glucan solubilization and this solubility stops with an increase in temperature above 55°C and slight increase in β-glucan extraction was observed at pH 8 with the other optimal conditions obtained after signal to noise ratio were: rate of stirring, 1000 rpm; size of particle, 100 µm; time for extraction, 3 hours and solvent flour ratio was equal to 5 (Benito-Roman *et al*., 2011). The ultrafiltration process is used to separate the macro food molecules from the smaller food molecules and Patsioura *et al*. (2011) applied this process to get optimum yield from the oat mill waste with high molecular weight β-glucan and including three different membranes and transmenbrane pressures.

Functional attributes of β-glucan

The functional properties need comprehensive knowledge about the β-glucan structure and its composition, to get beneficial effects for human health and in the different food systems (Satrapai and Suphantharika, 2007; Mikkelsen *et al*., 2010). Generally, cereals are good source of β-glucan and among cereals richest sources are barley and oat containing 4-7%. Advancement in extraction techniques make it possible to isolate even more than 90% pure β-glucan, so it is very important to understand its functional properties before incorporation into value added food products (Meena *et al*., 2013). Paquin (2008) described, that the reduction in viscosity of the prepared fruit based juices, having β-glucan which could be maintained with the addition of other polysaccharides like xanthan gum to regulate the blood glucose. Most recently, similar types of studies revealed that care should be taken when β-glucan used in products preparation because different degradation reaction carried out in the presence of ascorbic acid and ferrous iron. To stabilize the β-glucan formulation it was concluded that xanthan gum restrict reduction in viscosity but this method is not effective in complete protection of β-glucan during storage (Paquet *et al*., 2010). The most prevalent effect of high temperature is to enhance the dissolution of β-glucan into soluble form and maximizes its physiological properties (Jaskari *et al*., 1995; Singhania *et al*., 2013).

The functional claims associated with barley β-glucan with respect to polyphenol and antioxidant properties might be depends upon the isolation method and its level of purity. Similar studies conducted by Thondre *et al.* (2010) to estimate the free radical scavenging and reducing capacities in which they used different solvents such as 70% ethanol, 70% acetone, 70% methanol and acidified methanol for β-glucan rich barley extracts. The scientists elaborated that with the incorporation of barley β-glucan, the properties of food system changes including viscosity and high quality emulsion and foam forming characteristics. It was also demonstrated that mechanical agitation in the form of homogenization results in loss of shear thinning behavior / flow in different solutions containing β-glucan. The samples prepared with the application of high pressure homogenization process both the viscosity and molar mass minimizes (Kivela *et al*., 2010). Similar observations were conducted by Morgan and Ofman (1998) that when barley β-glucan used more than 0.5% it forms soft gels and its stability and viscosity is directly related to time temperature combination and pH of the food system when used as a gelling agent (Burkus and Temelli, 1999). Molecular weight as a function of viscosity has been mentioned by many scientists. Properties of β–glucan can be evaluated by carefully measuring molecular weight for its practical application in the food chain. Barley and oat excelled in terms of β–glucan from other cereals (Burkus, 1996). The β-glucan extracted from barley imparts unique mouth feel and increased amount of dietary fiber and hence give thickening properties to the beverages. Gums from β–glucan showed similar thickening properties as in case of pectin, alginates, xanthan and carboxymethylcellulose (Giese, 1992).

The properties of β–glucan make it suitable for the preparations of different foods include sauces, soups and different beverages. The β–glucan is found to offer functional properties beyond nutritional benefits which imparts viscous, emulsifying, thickening, stabilizing and gelling effects (Dawkins and Nnanna, 1993; Burkus and Temelli, 1999; Ahmad *et al,* 2009). Kivela *et al*. (2009) studied the effect of different levels of organic acids in prepared beverages from oat based β-glucan. It has been concluded that molecular weight and viscosity is influenced greatly with the addition of ascorbic acid but the other two acids i.e citric acid and malic acid causes least reduction in viscosity. Lam and Cheung (2013) explained that a continuous three dimensional structure of long chain polymers in which cross linked is involved in gelation process and this structure is responsible for thickening properties of liquid. Buliga *et al.* (1986) concluded that glucose units join together to form long chain of β–glucan which is 3-7% of total grain weight that gives it to viscous properties. It is observed that linear fraction of amylase thicken while β–glucan gels the structure through cross linkages. These linkages give viscosity due to branches at (1→3) (1→4) linkages which are highly soluble fraction of barley and provide thickening, emulsifying and gelation for different foods e.g. soups, sauces and ice creams etc. (Wood, 1986).

Potential use of β-glucan in beverages preparations

Beverages are considered to be an excellent medium for the supplementation of nutraceutical components for enrichment (Kuhn, 1998) such as soluble fiber or herbal extract (Swientek, 1998). The food and beverages sector is found to be suitable media for formulating new recipes to explore health benefits with the utilization of functional and bioactive ingredients present in barley crops. The present food and beverages industry aimed to increase such types of foods which directly improving consumer's health or providing physiological effects and fulfill the nutritional needs to the body (Ahmad *et al.*, 2012). There is a wide range of nutritious product that could be made for humans however, its dough rheological characteristics related to taste, appearance and baking attributes have made its limited utilization. Polysaccharides are abundantly incorporated into food systems to get thickening and stabilization properties and consumers preferred food without or least levels of preservatives and for this purpose barley β-(1→3)-D-glucan is famous to made low caloric food recipes (Bhatty, 1999). It has been observed that functional beverages have made its large market share and industry analyst is predicting continual growth in this sector (Potter, 2001; Sloan, 2002).

Barley β-glucan is exploited for the production of low fat products and also use in dairy products (Kontogiorgos, 2004; Zhu *et al.,* 2015). The demand for value added beverages serving as nutraceutical ingredients is increasing and a lot of new formulations are changing rapidly (Giese, 1992). Market and consumer acceptance is expanding for different functional drinks like soda pop, juices and dairy beverages. Numerous food items are consumed as beverages such as iced teas and coffees, sports and energy drinks, herbal teas, frozen carbonated beverages, mint blends, vegetable juices and smoothies. Traditional soft drinks have handsome share in local market but during recent years, local and exotic soft drinks such as the teas, iced coffees, isotonic or sports drinks, non-carbonated beverages and ready to serve medicinal teas made from herbs drinks are becoming popular to customers while demand for traditional drinks decreases. Drinks provide proteins, vitamins, minerals and dietary fiber in addition to taste and aesthetic satisfaction to the consumers. Development of a nutraceutical beverage containing essential ingredients is challenge faced by beverage industry (Swientek, 1998).

Beverages are not only consumed for satisfaction and good taste but also serve as a rich source of different kinds of vitamins, proteins and inorganic compounds like minerals and fiber. The big hurdle in beverage industry is to develop nutraceutical beverage containing essential nutrients. The beverages with best quality attributes are prepared during processing and storage includes some extra technological knowhow and commonly barley is incorporated in cereal based products. To get the maximum benefits with the utilization of β-glucan is recommended by FDA, which is 3 g of β-glucan/day and this is the amount to be incorporated in to new product development. Among the new types of products the beverages with β-glucan proved to be suitable and good decision for their incorporation hence the FDA later on amended their health claims with the intake of oat and barley β-glucan up to 10% in human diets (FDA, 2004).

The acceptance of the functional beverage in market is increasing and the consumer ready to pay even high prices to get the health benefits of such types of products and it is also came to know that the nutraceutical efficacy of the product mainly depends upon the extraction procedures which alters the molecular weight, solubility characteristics and physiological parameters of the barley β–glucan (Jonas and Beckmann, 1998; Regand *et al*., 2011). During processing, it was found that freezing conditions does not alter the molecular weight characteristics of β–glucan but only minimizes the gelling properties because β–glucan found to be sensitive (Beer *et al.*, 1997; Suortti *et al*., 2000; Kerckhoffs *et al*., 2003). The beverages formulated with the application of heat have shown sedimentation problem however the higher viscosity developed as compared to the pulse electric field (PEF) treated beverage showed less microbial stability, for a period less than a year, at low temperature in comparison to products prepared with trial at high temperature. Barley β-glucan beverage was formulated by incorporation of orange flavor at different levels. Comparison and analysis of the prepared drink for different organoleptic attributes with same pectin dose showed peel and fruity orange aroma, sweetness was same for all treatments while sourness level was found to be different (Temelli *et al.,* 2004).

Beverages prepared with 0.5-0.7% β-glucan was more viscous with same dosage of pectin than beverage with 0.3% thickener. These beverages showed same acceptance to customer panel. Declining trend was observed in colorimetric values of beverages during storage (first week) and then stabilized. Beverages prepared with increasing concentration of β-glucan showed lighter color and cloudiness however pectin does not affect these parameters. Cloud loss was observed in β-glucan based drink during first three weeks under storage conditions. The β-glucan extracted from barley has potential to provide health, nutritional and functional benefits in the prepared beverage that is necessary for beverage development (Temelli *et al.*, 2004). Functional beverage can be developed from β-glucan in combination with whey protein isolate showed excellent values for quality and overall acceptance and was acceptable for a period of 18 week while values for quality attributes like sweetness, sourness and flavor intensity, were found to be non-significant. The key role of β-glucan breakdown in beverages system is OH- radial stimulated the oxidative cleavage. To get the maximum potential with the utilization of β–glucan into food application for the development of new products it is important to know the thermodynamics characteristics with remaining ingredients used together (Burkus, 1996).

Similar studies conducted by Temelli *et al.* (2004) elaborated that the drinks made with the combination of β–glucan and whey protein isolates when consumed, prevented the body from different diseases. Another studies performed by the scientists Kulkarni *et al*. (2008) who developed a drink similar to tea like extract from barley. This type of drink is famous in Japan and they revealed that the temperatures range from 150°C to 280°C effects when barley is sub critically extracted. The extracted samples at 205°C were subjected to different physicochemical tests including amount of residual matter, anti oxidant activity and different sensory attributes and the most important antioxidant founded was 5-Hydroxymethyl-2-furaldehyde at these conditions.

In a pilot plant production very simple method is adopted to develop a beverage having barley or pectin. The water is taken in a steam jacket kettle then added β–glucan or pectin and left for boiling up to one minute. This blend is cool kept for cooling near to 70°C. The sucrose is taken and premix in small quantity of water then added with high fructose corn syrup (HFCS) and flavor. This prepared mixture is homogenized at 2000 psi and again transferred to steam kettle jacket. At the end citric acid, ascorbic acid and β–glucan incorporated to the prepared blend. Pasteurization is carried out at 90°C for half minute and finally sterilized bottles were hot filled and stored at refrigeration conditions (Temelli *et al.*, 2004). Two different soups were prepared with the addition of β-glucan from two sources one from barley and the other from oat. It was estimated that β-glucan source has significant effect on quality attributes and this was due to freezing on the molecular weight and other sensory parameters of the soups made with the addition of β-glucan (Lyly *et al.*, 2004).

Health benedictions of β-glucan

As dietitians and health experts give considerable importance to the fiber in diet due to its health claims, so the barley can be used as a good source of soluble and insoluble fiber (Oscarsson *et al*., 1996). This soluble dietary fiber which is commonly known as β-glucan and comprises of a mixed linkage i.e (1→3) (1→4)-β-D-glucan from oat and barley and these cereal crops significantly reduces the blood cholesterol and regulated the postprandial glucose responses (Ripsin *et al.*, 1992; Tappy *et al*., 1996; Drzikova, 2005; Ahmad and Anjum, 2010). The barley, β-glucans were investigated into human subjects for its physiological effects and it was demonstrated that the diets with rich in soluble fiber from β-glucan with different molecular weights has a reasonable effects on cardiovascular diseases and significantly reduces the body weight (Kristen *et al*., 2008).

Last decade research revealed that foods containing minimum glycemic-index (GI) have positive effect in insulin-resistance syndrome. Glucose and lipid metabolism and fibrinolytic activity have been increased evidently and have positive effects on diabetes and heart diseases, (Jenkins *et al*., 1987; Jarvi *et al*., 1999; Cloetens *et al*., 2012). The reduction in GI upto 3.85 units can be achieved by utilizing 50 g of food having one gram of β-glucan. The viscosity develop from fiber (β-glucan) has beneficial effect for the reduction in glycemic index (Jenkins *et al.*, 1978; Wood *et al*., 1994). The suggested mechanism to maintain the level of blood glucose and insulin is that after consumption of β-glucan, it slows down the absorption process in small intestine due to the development of increased viscosity (Wursch and Pi-Sunyer, 1997; Wood *et al*., 2000). Furthermore, some researchers (Gallaher and Hassel, 1995; Jalili *et al.*, 2000) have also described a mechanism that the cholesterol quantity inside body is maintained and its absorption or re-absorption is hindered due to the increase in β-glucan viscosity in small intestine.

Research studies indicated that β-glucan regulates glucose level in the blood by decreasing the absorption of glucose in the intestinal tract (Wood *et al*., 1990; Wood *et al.*, 1994). The effect of dietary fiber can be evaluated with different aspects (Stone and Clark, 1992). Diabetes can be treated with products having β-glucan in their formulation because it can reduce blood glucose level by decreasing the rate of absorbance of glucose in the blood. Viscosity of β-glucan and its bile salt scavenging properties may be the reason of lowering blood glucose and cholesterol levels (Marlett *et al.,* 1994; Davidson and McDonald, 1998). Its incorporation in functional food not only reduces blood glucose level but also increase palatability (Jenkins *et al*., 2002; Ahmad, 2009). The oat based β-glucan hydrolysates were developed and it was found that in vitro studies the β-glucan with molecular weight of 730,000g/mol showed maximum binding of bile acid. The biological experimental trials on rats showed maximum reduction in cardiovascular diseases and to maintain the lipids level and improving the bile acid excretion with the addition of extracted β-glucan from oat source in diets (Bae *et al.*, 2010). The pasta products are famous in various parts of Asia. The new type of functional product developed and substituting the wheat flour with oat based extracted β-glucan and banana flour for noodles preparation. The prepared noodles were evaluated for sensory and glycaemic indices. Comparable results were obtained with high levels of macro minerals and minimum glycaemic index with the incorporation level of 30% banana flour and oat based extracted β-glucan (Choo and

Aziz, 2010)

For the development of new products from barley having low glycemic index, purified β-glucan incorporation is needed with maximum hypocholesterolemic effect and food items including β-glucan bars with glycemic index of 78 (McIntosh *et al*., 1991; Foster-Powell and Miller, 1994; Tappy *et al*., 1996). It was reported that the diets containing soluble dietary fiber rich in β-glucan from cereal sources with high molecular activity causes the excretion of bile acids and principally the neutral sterol and the fermentation process of the β-glucan and resistant starch also affected the steroids in feces. It is also estimated that with the utilization of β-glucan, it increases the viscosity in the small intestine and this high viscous gum type solutions results for the reduction of bile acid and triglyceride absorption so consequently decreases plasma cholesterol level and also changes digestive enzyme activity (Dongowski *et al*., 2002). More findings were compiled about the physiological properties of β-glucan inside human body by many scientists including Casterline *et al.* (1997) and Wood and Beer (1998) showed that there are two mechanisms by which cholesterol is maintained. One mechanism showed that high viscous nature of β-glucan, restrict the absorption of cholesterol and lipid constituents and the second mechanism is to entrapment of bile acids inside gut during digestion. The compound in binding form or unabsorbed form is then excreted out from the body and the remaining β-glucan in side the colon are undergo to fermentation by colonic microorganisms (Bell *et al.*, 1999). When fermentation is carried out in large intestine such compounds are formed that has short chain fatty acids. The capacity of barley β-glucan to lower the blood cholesterol levels and glycemic responses in both animals and humans are well established and during the 2005, food and drug administration (FDA) demonstrated a health claimed for the consumption of barley as a source of functional food. To evaluate the health claims of barley β-glucan researchers made semolina spaghetti samples with the addition of different levels of β-glucan from barley and it was concluded from the trial that the sample from barley balance (BB) containing a dose of 10% has a significant effect in the reduction of incremental areas under the curve (IAUC) and glycemic index (GI) (Chillo *et al*., 2011).

The cereal crops containing polysaccharides showing wide range of functional properties including a substantial level of phenolic compounds. Thondre *et al.*, 2011 isolated three barley β-glucan extracts by using four different solvents. They calculated that the barley fiber rich fraction (BFRF) has highest level of polyphenols with maximum antioxidant activities than barley balance (BB) and glucagel. The latest trend towards food research are emphasizing prebiotics concept, which explains increasing the number of beneficial microflora and stimulating their activity in colon host bacteria (Gibson and Roberfroid, 1995). The barley β-glucan in vitro trials both for humans and animals elaborated to enhanced the growth of beneficial microflora of bifidobacteria and lactobacilli (Kontula *et al.*, 1998; Drzikova *et al.*, 2005). Evdokia *et al.* (2010) demonstrated that the diet prepared with the addition of barley β-glucan according to the recommended daily intake resulted significant increase in bifidogenic properties and there is no adverse effect calculated in older group of volunteers. Jones *et al*. (2000) and Plat and Mensick (2001) demonstrated that β-glucan involved to minimizes the cholesterol by inhibiting the mechanism of absorption and also retard the biosynthesis of cholesterol production inside human body. It is also elaborated that a minute quantity of β-glucan that is absorbed from the small intestine and finally reaches into blood stream and it is concluded that phytosterol solubility and its maximum absorption to intestinal micelles is a good characteristic to suppress the phytosterol cholesterol. Barley and oats are found to have potential for the reduction of bad cholesterol (LDL) which is its unique aspect of β-glucan (Joseph *et al*., 2007).

Conclusion

It is concluded that β-glucan from barley enhance the nutritional profile of food and quality attributes as well, So distinctive research is mandatory to estimate the different processing parameters for β–glucan which affect its rheological as well as molecular weight properties and search out the processing techniques to improve the incorporation of β–glucan in variety of foods stuffs

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