

## Scope of food barley research and development in India

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### Abstract

Since last two decades there are several reports on health benefiting properties of barley especially because of higher grain beta-glucan content as compared to other cereals. Regular consumption of barley can help in reducing the risk of cardiovascular diseases besides providing several other health benefits. Since most of the Indian population consumes cereals as their staple diet, there seems to be a potential for increased consumption of barley in the form of multigrain product/s to make the diet more healthy. In opinion article the potential uses of barley in Indian context has been discussed in brief.

**Keywords:** Barley, beta-glucan, health benefits, amylose, antioxidants

## 1. Introduction

Barley (*Hordeum vulgare* L.) is one of the first domesticated cereals of the world and in India it is considered as a sacred grain from ancient times. In the ancient literature and believes, barley has been considered as a health benefiting cereal (Malcolmson 2014) and still in several parts of the country barley based *sattu* is prepared and considered to have cooling effect on the body. However, the area and production of barley has gone down drastically from mid-sixties to early nineties mainly because of introduction of dwarf wheat varieties, assured irrigation and changes in food habits of the people. The area got stabilized since last two decades mainly because of increasing consumption of barley by barley malt industry. But now a new ray of hope is emerging with the identification of health beneficial properties of barley and barley is reviving again in the food segment (Keogh *et al* 2003, Klopfenstein 1988, Li *et al* 2003, Mertinez *et al* 1992, Malcolmson 2014). In this article present status of barley research and future prospects in India with respect to barley as food have been briefly compiled.

Barley and Oats are two cereals which have higher content of soluble fibres called beta-glucans as compared to other cereal grains (Shah *et al* 2017 and references therein). The beta glucans have been clinically proven

to lower the blood cholesterol and glucose levels. It has been shown that consumption of barley and oats lead to better colon health. The consumption of oats has increased phenomenally in last few years in the breakfast cereals and is expected to grow at a CAGR of 21% from 2015 to 2021 (<https://www.linkedin.com/pulse/oats-highest-growing-category-indian-breakfast-cereal-anita-patil>; accessed on 09.10.2018). According to Nielsen India report oats have a 26 per cent share in the Rs 720-crore breakfast cereal market (<https://www.foodnavigator-asia.com/Article/2018/05/14/Nestle-India-competes-for-bigger-slice-of-breakfast-market-share-with-new-cereal-launches>; accessed on 09.10.2018). As per the information accessed on 09.10.2018 (<https://www.prnewswire.com/news-releases/india-breakfast-cereal-market-outlook-2022-kelloggs-india-bagrrys-marico-and-pepsico-are-the-leading-players-300503259.html>) the Indian breakfast cereal market is growing with more than 17% CAGR since last five years. As per this report two kinds of breakfast cereals are available in the market, first category is hot cereals and ready-to-eat (RTE) cereals which include products like oats, oat bran, wheat bran and porridge while the second category encompasses ready-to-eat (RTE) cold cereals like cornflakes, wheat

flakes, muesli, etc. As per this accessed information Indian consumers prefer hot breakfasts and therefore this segment may have more potential from market perspective. Oat grains/products are generally imported, as grain Oats have limited area in India. However barley is the indigenous grain and thrives well in the adverse growing conditions. It has comparable health benefitting properties too. Hence, it is point to ponder why barley based products have not made that impact as Oats could do? The possible reasons and actions could be following:

i) There is little or lesser development of palatable barley based products for Indian market. As per a report (<https://www.businesstoday.in/lifestyle/health/oats-gain-popularity-at-indian-breakfast-tables/story/206925.html>; accessed on 09.10.2018), "Taste is clearly a window of opportunity for marketers to introduce new recipes, interesting mixes and different flavours. Given the inherent health benefits of oats, tastier options will surely be a winning mix," it says. Therefore development of barley based products which suits the taste and food habits of Indian consumers is the foremost priority area. The Indian food manufacturers must focus on development of barley based products like multigrain *atta* for chapatti, biscuit, bread, flakes, daliya, noodles, *sattu* etc. All these products need to be standardized and flavoured to make them palatable. *Sattu* can be a ready to serve flavoured drink.

ii) Consequent upon the availability of barley based products, there will be an urgent need for aggressive awareness campaign through media regarding health benefits of barley. In the present scenario of increasing urbanization and sedentary lifestyles, barley based products can be a boon by providing health benefits on regular consumption of products.

iii) There is an immediate need for the development of high yielding, biotic & abiotic stress tolerant hulless food barley varieties. Hulled barley poses problem in processing as removal of hull leads to extra expenditure and some of the nutrients lying in upper layer(s) get depleted.

iv) Policy makers may also consider increasing the support price of barley as it will encourage the resource poor farmers to grow barley as *Rabi* crop and increasing production of food barley will lead to availability of health food alternates to the population in general.

## 2. Some of the physical and biochemical constituents important for food barley

There is renewed interest in the barley grain since last few years due to its health benefits and it is expected that

in coming years the consumption of food barley may increase (Baik and Ullrich, 2008). For food barley there could be certain physical and quality aspects which may be incorporated to increase its health benefits. A brief account of these traits is being presented in following section.

**2.1 Hull content:** The food barley should preferably be hulless as mentioned above. The presence of hull may lead to lower recovery of end product, loss of nutrients upon dehulling or pearling and palatability issues. However the products where very high fibres may be required like multigrain chapattis and manufacturers add extra source of fibre like *Psyllium* husk, hulled barley may be used. Though there is need to standardize the grinding in such a manner that the final product i.e. *atta* or flour remain palatable. Again the industry may specify the hull percentage, in most of the Indian varieties the approximate range is 10-12 %.

One of the problem with hulless barley is comparatively lesser yield as compared to hulled ones. One of the factors could be loss of 10-12 % as husk, but similar is the situation in wheat. Barabaschi *et al* (2012) have stated that the reason for the difference in yield between hulled and hulless is not clearly understood. They have studied the effect of the *nud* gene on yield and stated that *nud* genes affect the hull content and did not find any pleiotropic effect on other traits.. They suggested that together with the finding of a QTL contributed by the hulless barley parent, there is great scope for improving the yields of hulless barley. Thomason *et al* (2009) reported that seeding rate also affects the hulless barley yields. Thus breeding, molecular biology and agronomic interventions taken together can help improve the yields of hulless barley yields. Further incorporation of disease resistance for rusts, blight, smuts *etc* may be an additional trait besides the quality requirements. The quality traits have been discussed in following sections.

**2.2 Beta-glucan content:** Barley and oats are two cereals blessed by nature to have a special polysaccharide, mixed linkage beta glucan (1 → 3, 1 → 4)-β-D-glucans) which have been reported to have several health benefitting properties (Ames *et al*, 2015 and references there in). Beta glucan in major component of endosperm cell walls and on an average contribute 70-75 % to cell wall composition. Beta glucans have been shown to reduce LDL cholesterol and triglycerides while not affecting the HDL cholesterol (Behall *et al*, 2004; ). Shimizu *et al* 2008, have shown that consumption of pearl barley with a high beta-glucan content reduces not only low density cholesterol but also visceral fat area. Barley has a lower glycemic index as compared to cereals like rice (Yamanaka-Okumura

*et al* 2009). Incorporation of barley beta glucans have been shown to lower the glycemic index of chapattis (Thondre and Henry, 2009). The glycemic index (GI) values of chapattis with 4 and 8 g beta-glucan per serving were 43% to 47% lower respectively as compared with chapattis without beta-glucan. Several studies have shown that consumption of barley controls the blood sugar level and one of the contributor to this attribute is beta glucan (Priebe *et al* 2010). In one another study it has been shown that consumption of barley beta glucans leads to better insulin response (Kim *et al* 2009). In a study on oat and barley based meals reduced glycemic value, however barley given better results possibly because of higher soluble fibre content (Behall *et al* 2004).

The work done at ICAR-IIWBR has identified several genotypes with higher grain beta glucan content (Kumar *et al.*, 2015). Some of these have been listed below (Table 1)

**Table 1.** Some of the high grain beta-glucan lines.

Genotype	Beta glucan (% dwb)	Grain type
BCU 554	7.1	Hulled
DWR 30	6.9	Hulled
DWRUB 75	6.6	Hulled
20 <sup>th</sup> IBON 3	6.2	Hulled
BHS 352	6.5	Hulless
HBL 276	6	Hulless
Dolma	5.5	Hulless

These lines can serve as source of high grain beta glucan trait in hulless barley and already attempts are underway in this regard. The objective of these attempts is to develop high grain beta glucan hulless varieties with higher yields and disease resistance for plains of India.

**2.3 Amylose content:** As discussed above it has been shown that barley has lower glycemic index. Barley has relatively lower glycemic index as compared to several other cereals. As per <https://www.health.harvard.edu/diseases-and-conditions/glycemic-index-and-glycemic-load-for-100-foods> (accessed on 12.10.2018) the glycemic index of barley is 28, Chapati (roti) has 54-62, whole wheat bread is 74, brown rice is 68, rolled oats 55 and cornflakes of 81. Thus barley can be a perfect blend to lower the glycemic index of multigrain foods. Though beta glucans and insoluble fibres are the major contributor to lower glycemic index, amylose content also adds to lower the glycemic index. The amylose content of barley range from a 24 % in normal barley to an exceptionally high-45 % as in glacier barley (Merritt 1967). The amylose molecule provides a high fiber source with a low glycemic index. More the amylose present, lower the glycemic index would be.

Diabetes patients may benefit from a diet high in amylose because of the slower insulin response, which prevents quick spikes in glucose levels. Therefore hulless varieties with higher amylose content need to be bred.

**2.4 Protein:** Cereals though are low in lysine content but serve as a good source of protein in Indian diet, since cereals are the major constituents of staple diet. The barley to be used for food purpose either raw, roasted or malted should have desirably higher protein content. However, there is an inverse correlation between starch content and protein content. Since starch is the major constituent of barley grain, grains with lower starch content are normally shrivelled and thus result in lower product recovery. At ICAR-IIWBR the work carried out during last few years has identified few genotypes with relatively higher grain protein and higher bold grain percentage. These are BK 1127 (registered with NBPGR, New Delhi) and BCU 2241.

**Table 2.** Mean performance of genotype BK 1127 with higher protein content \*

Genotype	1000 grain wt (g)	Protein (% dwb)	Bold grain (>2.5mm) (%)	Thin grain (<2.2 mm)(%)
BK 1127	59.8	14.4	86.9	1.3
DWR 28(C)	50.8	12.8	91.1	2
DWRUB52(C)	46.3	10.2	85.6	3.1
DWRB 92(C)	50.2	13.5	84.5	5.3
BH 902(C)**	42.1	11.1	85.6	5.3

\*Source: AICW&BIP – Barley Network (2013-14) \*\*Six rowed barley

**2.5 Arabinoxylans:** Arabinoxylans consist of a linear chain backbone of  $\beta$ -D-xylopyranosyl residues linked through (1  $\rightarrow$  4) glycosidic linkages (Izydorczyk and Dexter 2008). The barley arabinoxylans content is affected by genetic and environmental factors (Izydorczyk and Dexter 2008 and references therein). The content of arabinoxylans in barley is comparable to wheat (5.8), lower than in rye (7.6–12%), but higher than in oats (2.7–3.5%), sorghum (1.8%) or rice (2.6%) (Izydorczyk and Biliaderis, 1995). Fleury *et al* (1997) reported that the amount of arabinoxylans in hulless barley is lower than the hulled barley and has been linked to absence of hull in naked barleys. Six-rowed barley cultivars generally contain slightly higher levels of arabinoxylans than two-rowed cultivars (Fleury *et al* 1997). Recently, arabinoxylans have attracted a great deal of attention because of its biological activities such as immunomodulatory potential (Fadela *et al* 2018). Information on arabinoxylans content in hulless barley could not be traced and hence there is need of basic studies on this aspect and as a quality component in development of improved hulless barley genotypes.

**2.6 Essential Mineral:** It has been estimated that around 792.5 million people across the world are malnourished, out of which 780 million people live in developing countries (McGuire 2015). To make food barley a healthy combination of nutrients, content and bioavailability of essential mineral Zn, Fe and Se needs to be increased. Biofortified crops generated through different means are need of the hour (Garg *et al.* 2018). Attempts have been made to increase the Se content in barley through agronomic interventions (Rodrigo *et al.*, 2013). At ICAR-Indian Institute of Wheat & Barley Research, a hullless genotype DWRB 191 for high grain zinc content and DWRB 192, a hullless genotype with higher iron content has been developed (Anonymous 2018).

### 2.7 Barley phytochemicals and antioxidant activity

Besides providing basic nutrition, barley is also a store house of a number of phytochemicals. These substances have a number of biological functions and therefore called the bioactive compounds. Important groups of phytochemicals with great beneficial nutritional and health effects are phenolics, carotenoids, vitamin E compounds, lignans and  $\beta$ -glucan. The bioactive phytochemicals in barley have been recently reviewed by Idehen *et al.* (2017). Phenolics are the predominant compounds in cereals like barley which contribute to the antioxidant potential. Barley grain phenolics are composed of phenolic acids, flavonoids, tannins and proanthocyanidins and are concentrated in the hull, testa and aleurone. Barley can serve as an excellent dietary source of antioxidants with antiradical and antiproliferative potentials for disease prevention and health promotion (Madhujith and Shahidi, 2007). Epidemiological studies have shown that regular consumption of whole grains and wholegrain products is associated with reduced risks of various types of chronic diseases such as cardiovascular diseases (CVD), type 2 diabetes and some cancers. Barley consumption has been associated with lower total & serum cholesterol, improved postprandial glucose & insulin response and reduced heart disease and colon cancer (Gamel & Abdel-Aal, 2012).

Barley has been found to have high antioxidant activity than other common cereals such as wheat and maize (Zielinski and Kozłowska 2000; Grausgruber *et al.* 2004; Zilic *et al.* 2011). Barley grains contain much greater amounts of phenolic compounds than other cereal grains (Goupy *et al.* 1999; Kim *et al.* 2007; Zhao *et al.* 2008). The coloured barley types have high anthocyanin content which are health promoting flavonoids. Purple and blue barley groups contain higher average contents of anthocyanins than black. The content of various phenolic compounds and antioxidant activity in barley are significantly

affected by the growing location, the growth year and the genotype. The malting process allows better release and/or extraction of phenolic compounds. Individual reports are also available in the literature regarding changes in the antioxidant activity and phenolic content in barley during malting (Maillard *et al.* 1996; Goupy *et al.* 1999; Leitao *et al.* 2012, Narwal *et al.* 2016). In beer, 70 to 80% of the phenolic constituents originate from malted barley. Polyphenols and phenolic acids present in malt are natural antioxidants, capable of delaying, retarding or preventing oxidation processes and therefore are thought to have a significant effect on malting and brewing as inhibitors of oxidative damage. Other processes like sand roasting also results in significant increase in antioxidant activity (Sharma and Gujral, 2010).

Since, direct use of barley as food is very limited, it has now been used in number of multigrain products due to its health benefits. Studies have shown that blending of barley in different food preparations significantly increases the level of the phenolics and other bioactive compounds. Blending of barley in wheat flour can enhance the nutritive value and the health benefits of wheat flour and its products like chapatti, bread and biscuit (Sharma and Gujral, 2014 a&b; Gupta *et al.* 2011; Narwal *et al.* 2017).

**Table 3:** Antioxidant activity and phenolic content in barley and wheat

	Fraction	Antioxidant Activity ( $\mu$ MTrolox Eq/g)	Total Phenolic Content (mg GAE Eq/g)
Wheat	Whole meal	2.0 – 10.0	0.2 – 1.2
	Bran	15-May	2.9 – 5.6
Barley	Whole meal	8.0 – 17.0	1.9 – 3.9

At ICAR-IIWBR, based on a two year study of 72 Indian barley varieties (Table 3), few varieties have been identified which showed high antioxidant activity in both the years using two different methods (BG-105, BH-75, BHS-380, BHS-352, BH-393, HBL-113, PL-172). Most of these are food barley varieties including one hullless variety BHS352. One barley genetic stock has also been registered for high antioxidant activity (Kasota, BCU5762). Hullless barley has been shown to contain the higher amount of phenolics. IIWBR (ICAR-Indian Institute of Wheat and Barley Research) has identified a hullless barley variety that has high beta-glucan content (Kumar *et al.* 2015), antioxidant activity and phenolics (Narwal *et al.* 2016). Narwal *et al.* (2017) used a hullless barley variety for blending with wheat flour. Significant increase in beta-glucan content, antioxidant activity and

total phenolic content of flour blends and their products was observed at 30% blending level. The processing of hulled barley is quite difficult and laborious. Therefore, the hullless barley can have the additional advantage of

the minimal requirement of the processing. At home, barley flour can be easily blended with the wheat flour in order to make more nutritious and healthy products for daily consumption.

**Table 4:** Effect of barley blending on antioxidant activity, total phenolic content and beta-glucan content of chapatti and biscuit.

Flour Ratio	Antioxidant Activity (% Dis-coloration)		Total Phenolic Content ( $\mu\text{g GAE/g}$ )		Beta-glucan Content (%)	
	100W : 0B	70W : 30B	100W : 0B	70W : 30B	100W : 0B	70W : 30B
Chapatti	9.5	14	238	288	0.6	2.34
Biscuit	1.3	10	64	135	0.18	1.46

### 3. Potential barley based health products:

**3.1 Multigrain Atta:** The hulled barley can be used to increase the soluble and insoluble fibre content of wheat *atta* (flour). This may bring down the glycemic index of chapattis, which is consumed as staple food especially in northern India.

**3.2 Multigrain biscuits & bread:** Incorporation of hullless barley may increase the health beneficial properties of both bread & biscuits. Preliminary trials conducted at ICAR-IIWBR has shown feasibility of barley based biscuits. Similarly barley malt can also be used to make flavoured biscuits.

**3.3 Barley flakes:** Hullless barley can be used to make breakfast cereals like flakes, however it needs to be flavoured to increase its palatability.

**3.4 Ready to drink Sattu:** *Sattu* is a traditional drink utilizing barley and/or gram flour, however if ready to drink flavoured barley based sattu is developed it can make a dent in health drinks.

#### Future Directions

Food barley can be an important area of research and development in India from the perspective of farmers, industry and consumers. If consumption of food barley increases, farmers may get better prices with lesser inputs as compared to other same season crop/s. However industry has to come forward to introduce barley based products in the market with aggressive information on its health benefitting properties. There is an urgent need to develop hullless or naked barley varieties with comparable yield to hulled barley, better quality traits and biotic and abiotic stress tolerance. There will be challenge as under subtropical climates the grain filling period is much shorter as compared to temperate climates of Europe. Spring barley is a summer crop in Europe having longer

photoperiod, congenial temperatures and longer growing duration of the crop. On the contrary in sub-tropical climates of India barley is a winter crop having relatively shorter photoperiod, externally lower temperatures sometimes frost, foggy weather with shorter growing duration. Availability of high yielding hullless barley, development/standardization of barley based products and popularization of health benefits of barley is one of the keys to increase the income of resource poor farmers and providing the healthy foods to the people.

#### References

1. Ames N, Storsley J and Tosh S . 2015. Effects of Processing on Physicochemical Properties and Efficacy of  $\beta$ -Glucan from Oat and Barley. *Cereal Foods World* 60: 4-8.
2. Anonymous. 2014. Progress Report of All India Coordinated Wheat & Barley Improvement Project 2013-14, Vol. VI. Barley Network. Eds. AS Kharub, D Kumar, J Singh, V Kumar, R Selvakumar, A Khippal, R Malik, A Verma, S Katare and I Sharma. Directorate of Wheat Research, Karnal, India. P. 327.
3. Anonymous. 2018. Annual Report 2017-18. ICAR-IIWBR, Karnal pp 75.
4. Baik BK and SE Ullrich. 2008. Barley for food: Characteristics, improvement, and renewed interest. *Journal of Cereal Science*, 48: 233–242.
5. Barabaschi D, Francia E, Tondelli A, Gianin Etti A, Stanca A and N Pecchioni. 2012. Effect of the *nud* Gene on grain yield in barley. *Czech Journal of Genetics and Plant Breeding*, 48: 10–22.
6. Behall KM, Scholfield DJ and J Hallfrisch . 2004. Diets containing barley significantly reduce lipids in mildly

- hypercholesterolemic men and women. *American Journal of Clinical Nutrition* **80**:1185-93.
7. Behall KM, Scholfield DJ and J Hallfrisch . 2005. Comparison of hormone and glucose responses of overweight women to barley and oats. *Journal of the American College of Nutrition* **24**:182-188.
  8. Fadela A, Mahmoud AM, Jason J, Lif, AW, Nga, YL and A Plunkett. 2018. Health-related effects and improving extractability of cereal arabinoxylans. *International Journal of Biological Macromolecules* **109**: 819-831.
  9. Fleury MD, Edney MJ, Campbell LD and GH Crow. 1997. Total, water-soluble and acid-soluble arabinoxylans in western Canadian barleys. *Canadian Journal of Plant Science* **77**: 191-196
  10. Gallegos-Infante JA, Rocha-Guzman NE, Gonzalez-Laredo RF and J Pulido-Alonso. 2010. Effect of processing on the antioxidant properties of extracts from Mexican barley (*Hordeum vulgare*) cultivar. *Food Chemistry* **119**: 903-906.
  11. Gamel T and ESM Abdel-Aal. 2012. Phenolic acids and antioxidant properties of barley whole grain and pearling fractions. *Agricultural and Food Science* **21**:118-131.
  12. Garg M, Sharma N, Sharma S, Kapoor P, Kumar A, Chunduri V and P Arora. 2018. Biofortified crops generated by breeding, agronomy, and transgenic approaches are improving lives of millions of people around the world. *Front. Nutr.* **5**:1-33.
  13. Goupy P, Hugues M, Boivin P and MJ Amio. 1999. Antioxidant composition and activity of barley (*Hordeum vulgare*) and malt extracts and of isolated phenolic compounds. *Journal of Agricultural and Food Chemistry* **79**: 1625-1634.
  14. Grausgruber H, Scheiblauber J, Schönlechner R, Ruckebauer P and E Berghofer. 2004. Variability in chemical composition and biologically active constituents of cereals. In *Genetic Variation for Plant Breeding* (J. Vollmann, H. Grausgruber and P. Ruckebauer, eds.) pp 23-26.
  15. Gupta M, Bawab AS and N Abu-Ghannam. 2011. Effect of barley flour and freeze-thaw cycles on textural, nutritional and functional properties of cookies. *Food and Bioproducts processing* **89**: 520-527.
  16. Idehen E, tang Y and S Shengmin. 2017. Bioactive phytochemicals in barley. *Journal of Food and Drug Analysis* **25**: 148-161.
  17. Izydorczyk MS and CG Biliaderis. 1995. Cereal arabinoxylans: Advances in structure and physicochemical properties. *Carbohydrate Polymers* **28**: 33-48.
  18. Izydorczyk MS and JE Dexter. 2008. Barley  $\beta$ -glucans and arabinoxylans: Molecular structure, physicochemical properties, and uses in food products—a Review. *Food Research International* **41**: 850-868.
  19. Keogh GF, Cooper GJ, Mulvey TB, McArdle BH, Coles GD, Monro JA and Poppitt SD. 2003. Randomized controlled crossover study of the effect of a highly beta-glucan-enriched barley on cardiovascular disease risk factors in mildly hypercholesterolemic men. *The American Journal of Clinical Nutrition* **78**: 711-718.
  20. Kim MI, Hyun JN, Kim JA, Park JC, Kim MY, Kim JG, Lee SJ, Chun SC and IM Chung. 2007. Relationship between phenolic compounds, anthocyanin content and antioxidant activity in coloured barley germplasm. *Journal of Agricultural and Food Chemistry* **55**:4802-4809.
  21. Kim H, Stote KS, Behall KM, Spears K, Vinyard B and JM Conway . 2009. Glucose and insulin responses to whole grain breakfasts varying in soluble fiber, beta-glucan: a dose response study in obese women with increased risk for insulin resistance. *European Journal of Nutrition* **48**:170-175
  22. Klopfenstein CF. 1988. The role of cereal beta-glucans in nutrition and health. *Cereal Foods World* **33**: 865-869.
  23. Kumar D, Verma RPS, Narwal S, Kharab AS, Malik R, Selvakumar R, Singh J, Kumar V and I Sharma. 2015. Barley lines with higher grain beta glucan content identified. *Indian Journal of Plant Genetic Resources* **28**: 346-347.
  24. Leitao C, Marchioni E, Bergaentzle M, Zhao M, Didierjean L, Miesch L, Holder, E, Miesch M and S Ennahar. 2012. Fate of polyphenols and antioxidant activity of barley throughout malting and brewing. *Journal of Cereal Science* **55**: 318-322.
  25. Li J, Kaneko T, Qin L, Wang J and Wang Y. 2003. Effects of barley intake on glucose tolerance, lipid metabolism and bowel function in women. *Nutrition* **19**: 926-929.
  26. Malcolmson L, Lukie C, Swallow K, Sturzenegger T and Han J. 2014. Using Barley Flour to Formulate Foods to meet Health Claims. *Cereal Foods World* **59**: 235-242.
  27. Madhujith T and F Shahidi. 2007. Antioxidative and antiproliferative properties of selected barley (*Hordeum vulgare* L.) cultivars and their potential for inhibition of low-density lipoprotein (LDL) cholesterol oxidation. *Journal of Agricultural and Food Chemistry* **55**: 5018-5024.
  28. Maillard MN, Soum MH, Boivin P and C Berset. 1996. Antioxidant activity of barley and malt: relationship with phenolic content. *Lebensmittel-Wissenschaft und -Technologie* **29**: 238-244.

29. Martinez VM, Newman RK and Newman CW. 1992. Barley diets with different fat sources have hypocholesterolemic effects in chicks. *Journal of Nutrition* **122**: 1070-1076.
30. Merritt NR. 1967. New strain of barley with starch of high amylose content. *Journal of the Institute of Brewing* **73**: 583-585.
31. McGuire S. 2015. FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO. *Advances in Nutrition* **6**: 623-624.
32. Narwal S, Kumar D and RPS Verma. 2016. Effect of genotype, environment and malting on the antioxidant activity and phenolic content of Indian barley. *Journal of Food Biochemistry* **40**: 91-99.
33. Narwal S, Kumar D, Sheoran S, RPS Verma and RK Gupta. 2017. Hulled barley as a promising source to improve the nutritional quality of wheat products. *Journal of Food Science and Technology* **54**: 2638 – 2644.
34. Priebe MG, Wang H, Weening D, Schepers M, Preston T and RJ Vonk. 2010. Factors related to colonic fermentation of nondigestible carbohydrates of a previous evening meal increase tissue glucose uptake and moderate glucose-associated inflammation. *American Journal of Clinical Nutrition* **91**:90-97.
35. Rodrigo S, Santamaría O, López-Bellido FJ and MJ Poblaciones. 2013. Agronomic selenium biofortification of two-rowed barley under Mediterranean conditions. *Plant Soil Environment*. **59**: 115–120.
36. Shah A, Gani A, Masoodi FA, Shoib MW, Bilal AA. 2017. Structural, rheological and nutraceutical potential of  $\beta$ -glucan from barley and oat. *Bioactive Carbohydrates and Dietary Fibre* **10**: 10-16.
37. Sharma P and HS Gujral 2014a. Cookie making behavior of wheat-barley flour blends and effects on antioxidant properties. *LWT - Food Science and Technology* **55**: 301-307.
38. Sharma P and HS Gujral. 2014b. Antioxidant potential of wheat flour chapattis as affected by incorporating barley flour. *LWT - Food Science and Technology* **56**: 118-123.
39. Sharma P and HS Gujral. 2010. Antioxidant and polyphenol oxidase activity of germinated barley and its milling fractions. *Food Chemistry* **120**: 673–678.
40. Shimizu C, Kihara M, Aoe S, Araki S, Ito K, Hayashi K, Watari J, Sakata Y and S Ikegami. 2008. Effect of high beta-glucan barley on serum cholesterol concentrations and visceral fat area in Japanese men—a randomized, double-blinded, placebo-controlled trial. *Plant Foods and Human Nutrition* **63**:21-25.
41. Talati R, William L, Baker Mary S, Pabilonia C, Michael W and Craig I Coleman. 2009. The Effects of Barley-Derived Soluble Fiber on Serum Lipids. *Annals of Family Medicine* **7**:157-63
42. Thomason WE, Brooks WS, Griffey CA and ME Vaughn. 2009. Hulled barley seeding rate effect on grain yield and yield components. *Crop Science*. **49**: 342–346.
43. Thondre PS and CJ Henry . 2009. High-molecular-weight barley beta-glucan in chapattis (unleavened Indian flatbread) lowers glycemic index. *Nutrition Research* **29**:4806
44. Yamanaka-Okumura H, Taniguchi A, Sakuma M, Ushida F and M Harada . 2009. Nutrition education from the perspective of human health. *Rinsho Byori*. **57**:797-805.
45. Zhao H, Fan W, Dong J, Lu J, Chen J, Shan L, Lin Y and W Kong. 2008. Evaluation of antioxidant activities and total phenolic contents of typical malting barley varieties. *Food Chemistry* **107**: 296–304.
46. Zielinski H and H Kozłowska. 2000. Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions. *Journal of Agricultural and Food Chemistry* **48**: 2008-16.
47. Zilic S, Sukalovic VH, Dodig D, Maksimovic V, Maksimovic Milan and Z Basic. 2011. Antioxidant activity of small grain cereals caused by phenolics and lipid soluble antioxidants. *Journal of Cereal Science* **54**: 417-424.