CHAPTER-1

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an ancient and important cereal grain ranking fourth in the world and occupies about 9.4% of the total world area under cereal production (FAO, 2007). In India barley is the most important cereal crop in winter with a total production of 16.89 lakh tonnes (2008-09) and average yield of 2390 kg/hector. The major barley producing states are Rajasthan (878000 tonnes) followed by Uttar Pradesh (376000 tonnes) and Haryana (185000 tonnes) (Verma et al., 2010). In Punjab the production of barley is 55000 tonnes. It has been an important food source in many parts of the world, including the Middle East, North Africa and Northern and Eastern Europe (Iran, Morocco, Ethiopia, Finland, England, Denmark, Russia and Poland) and in Asia (Japan, India, Tibet and Korea) (Chatterjee and Abrol, 1977; Ryu 1979). Barley used to be a crop as important as wheat and corn but later wheat became more popular as human food and barley became important as animal feed and for malting purposes.

Barley is classified as spring or winter type, two row or six row type, hulled or hulless type and malting or feed type. Based on grain composition, barley is further classified as normal, waxy or high amylose starch type, high lysine, high β-glucan and proanthocynidine free (Baik and Ullrich, 2008). The predominant type of barley cultivated is hulled having a tough fibrous husk and is used as a malting and brewing grain and as cattle feed. The other type is the hulless or naked barley in which the hull is easily removed during threshing similar to wheat.

Naked barley is grown to a lower extent as compared to hulled barley due to low yield, weak straw and because of its unsuitability as a malting grain. Barley was presumably first used as human food but evolved primarily into feed and into a malting and brewing grain. Presently about two third of the barley crop is used for feed and one third for malting purpose (Newman and Newman, 2006). Barley grain is preferred for malting because of the presence of a hull that protects the grain during germination and that serves as a filter bed during mashing and because of the type and amount of enzymes produced during germination. Barley is today considered a healthy grain and an excellent
source of β-glucan, B-complex vitamins, tocotrienols and tocopherols (Bonoli et al., 2004; Madhujithand and Shahidi, 2006).

Unfortunately, at present only about 2% of the barley is utilized as a human food (Baik and Ullrich 2008), the highest per capita consumption of barley (68 kg/year) in Morocco has been reported by Bhatty (1991). The major reasons that make barley unpopular as human food are the presence of a husk that is difficult to remove and the fact that barley lacks gluten protein therefore it cannot be used in leavened bakery products (Sharma and Gujral, 2010a). Barley grain contains considerable amount of polyphenol oxidase (Quinde et al., 2004; Baik and Ullrich, 2008; Sharma and Gujral, 2010b). Polyphenol oxidase reacts with phenolic compounds to produce o-quinones which further react with other phenolic compounds or amino acids to give discoloration in different foods made from barley (Saper, 1993). The discoloration in foods by polyphenol oxidase is another reason that limits the use of barley in food (Lagasse et al., 2006).

Among cereals barley has one of the highest levels (up to 6%) of β-glucan, a water soluble polysaccharide nutritionally classified as soluble dietary fiber. It is a linear chain of β-glucopyranosyl unit; about 70% are linked (1→4) and about 30% (1→3). The (1→3) linkages occur singly and are separated by sequence of generally two or three (1→4) linkage (Izydorczyk and Dexter, 2008). Within the brewing industry barley β-glucan is thought to be responsible for several technological problems such as retardation of malting, decreased brew-house yield during mashing, increased viscosity of wort and beer and formation of haze and gelatinous precipitates in stored beer (Dendey and Dobraszczyk, 2000). Therefore, in the malting industry barley low in β-glucan is desirable. However, today β-glucan has achieved functional status and has beneficial physiological effects. The effectiveness of barley β-glucan in lowering blood cholesterol (Newman et al., 1989; Behall et al., 2004) and glycemic index (Wood et al., 1990; Cavallero et al., 2002) has been reported in numerous publications and is widely accepted (Pins and Kaur, 2006). The Food and Drug Administration (FDA) have allowed whole grain barley and barley-containing products to carry a claim that they reduce the risk of coronary heart disease (FDA News Release, 2005). Barley contains many phenolic compounds in the free and bound form including benzoic and cinnamic acid derivatives,
proanthocyanidins, quinones, flavonols, chalcones, flavones, flavanones, and amino phenolic compounds which are concentrated in the outer layers of the barley grain (Goupy et al., 1999). Recent findings revealed that cereals also contain phenolic compounds that have antioxidant activity and prevent diseases in humans (Madhujith and Shahidi, 2007). The risk imposed by the consumption of free radicals and oxidation products towards various forms of cancer and cardiovascular disease could be lowered by the intake of dietary phenolics. The natural antioxidants in cereals may function as reducing agents, free radical scavengers, single oxygen quencher and potential complexer of prooxidants (Sharma et al., 2012). Therefore, the consumption of barley should be encouraged as a human food.

Morphologically, barley grain contains husk 7 to 15%, endosperm 75%, testa 1 to 3%, aleurone and nucellar layer 7 to 12% and embryo 2 to 5% (Dendey and Dobraszczyk, 2000) while chemically, barley contains 10 to 17% protein, starch 65 to 68%, 4 to 9% β-glucan, 2 to 3% lipids and 1.5 to 2.5% minerals (Czuchajowska et al., 1998; Izydorczyk et al., 2000; Quinde et al., 2004; Sharma and Gujral, 2010a; Sharma et al., 2011).

Since hulled cultivars of barley are more widely cultivated and available, its milling to remove husk would be the first step before it is utilized in human food. The hulled barley should first be subjected to dehusking to remove the fibrous husk by abrasion or by pearling and further the dehusked barley should be pearled to remove desired levels of bran before being milled into flour (Sharma and Gujral, 2010a). Dehusking removes the hull with minimum damage to the kernel while the pearling gradually removes the branny layers. Barley flour because of its nutraceutical advantage should be made available for use in food products. Barley meals and fractions are now gaining renewed interest for the production of functional foods due to their content of bioactive compounds.

Considering the health benefits of barley β-glucan and phenolic compounds, the human consumption of barley should be encouraged by utilizing it in foods with attractive sensory characteristics. The acceptability of the food supplemented with barley also depends on the barley variety and the processing treatments applied to the grains (Izydorczyk et al., 2000). Processed foods these days require the presence of bioactive
ingredients to satisfy the demands of health conscious consumers. Roasting is a simple and convenient process that uses dry heat for short periods of time for improving grain characteristics. Roasted grains exhibit improved texture, enhanced crispiness and volume due to puffing (Hoke et al., 2007; Gujral et al., 2011). Roasting also improves colour, extends shelf life, enhances flavor and reduces the antinutrient factors of cereals and legumes (Gahalawat and Sehgal, 1992). Moreover, roasting of grains leads to the gelatinization of starch and denaturation of proteins thus improving their digestibility. In India roasted barley commonly called sattu, has been consumed for ages and is considered a traditional health food. Barley after roasting is ground into flour and is mixed with water along with sugar and consumed as a refreshing drink. It is possible that the thermal treatment of the barley grains modifies the content and properties of the β-glucan, which have great influence in determining the utilization of barley for food purposes (Sharma et al., 2011). Moreover, it has been reported that the minimal processed foods have more health benefits as compared to processed foods (Shahidi, 2009). Grain roasting is traditionally done in hot sand (250-300°C) but can be replaced by modern processing methods such as microwaves, which has its advantages like shorter cooking time, better temperature control and no contamination with sand (Sharma and Gujral, 2011).

Extrusion is another rapid processing method involving high temperature and pressure and short time and is used to prepare a variety of processed foods like baby foods, snack foods, ready-to- eat breakfast cereals and pet foods (Singh et al., 2007; Sharma et al., 2012).

The extrusion process is unique because it performs several unit operations simultaneously. The raw material is subjected to heat and shear during transportation along the extruder barrel under controlled conditions (Arhaliass et al., 2009). Consumer preference of extruded foods is mainly due to convenience, attractive appearance and texture and utilizing barley in extruded foods would increase consumer acceptance as it contains bioactive functional components. Even though extrusion is a short time cooking process the temperatures and shear force encountered by the raw material in the barrel of the extruder is enough to bring about changes in the major and bioactive components. The most significant changes are brought about in the cereal starch and protein that
contribute to form structure, texture, mouth feel and bulk density. The food ingredients undergo many order-disorder transitions, such as starch gelatinization, protein denaturation, and complex formation between lipids and amylose and are finally shaped at the extruder die (Yu et al., 2012) altering the physical and chemical properties of the extruded products (Lai and Kokini, 1991; Nwabueze and Iwe, 2009). The extent of modification upon extrusion is influenced by feed moisture content, residence time, temperature, screw configuration and die diameter (Thymi et al., 2005). Extrusion is also appropriate for the production of fiber-rich foods through the use of combination of temperature, moisture, shear, and mixing conditions (Vasanthan et al., 2002; Santillan-Moreno et al., 2011). The functional properties of fiber rich materials may be modified by extrusion cooking (Camire and King, 1991). The extrusion variables especially temperature and feed moisture will have significant effects on the β-glucan in barley.

Utilization of barley in baked products such as cookies, chapattis and breads can also open a path to exploit the health benefits of barley in human foods. Efforts have been made to utilize barley in bread (Gill et al. 2002a, b; Jacobs et al., 2008; Skrbic et al. 2009; Sullivan et al., 2011; Kinner et al., 2011) in cookies (Skrbic and Cvejanov, 2011; Frost et al., 2011) in chapattis (Gujral and Gaur, 2002, 2005; Thondre and Henry, 2009) and in noodles (Izydorczyk et al., 2005; Hatcher et al., 2005). β-glucan has increased applications due to its unique characteristics such as water solubility, water absorption capacity, viscosity and gelation properties (Lazaridou and Biliaderis, 2007). FDA recommends daily intake of 3g of β-glucan from barley or oat and this reduces the risk of coronary heart disease (Wood, 2007). Baked products may be a good vehicle for the delivery of β-glucans since they are eaten almost regularly, world wide (Frost et al., 2011).

Among the baked products, cookies may be a more convenient baked product to supply the barley bioactive compounds because they have long shelf life and the very low gluten content of barley does not pose a technological challenge in cookie making as compared to bread making. Cookies are also a low specific volume baked product where the gluten content is not very important therefore, cookies may be a more convenient baked product to utilize barley and supply the bioactive compounds of barley. In this regards, Frost et al. (2011) prepared the chocolate chips cookies with upto 70% barley
flour. Recently, Skrbic and Cvejanov (2011) also prepared cookies with barley flour and sunflower seeds.

Chapattis are a good option for utilizing barley in baked foods because they have been a staple food of the Indian subcontinent and parts of the Middle East for hundred of years (Gujral et al., 2004; Gujral et al., 2008). In India most of the wheat is (~90%) consumed in the form of chapatti while the remaining is consumed in the form of bread, biscuits and cakes (Ghodke et al., 2009). The quality and quantity of gluten is very essential in making good quality bread where as this is not an essential requirement in chapatti making as it is a low specific volume product. The texture of chapatti should be soft, pliable, non-sticky and easy to tear and should not be brittle or leathery until it is consumed. However, chapatti becomes stale and difficult to chew soon after baking, which poses a problem especially to geriatrics and infants (Gujral and Gaur 2002, 2005).

The staling of chapatti may be prevented by addition of different hydrocolloids such as xanthan, guar-gum and locust bean gum, which bind or retain more water and keep the chapatti pliable and soft for longer time (Gujral et al., 2004; Mandala and Sotirakoglou, 2005; Shaikh et al., 2008). It has also been reported that the addition of barley flour and β-glucan delay the staling and keep the bread fresh for longer time (Gujral et al., 2003; Trogh et al., 2004; Izydorczyk et al., 2008; Sullivan et al. 2010a; Rieder et al., 2012). Keeping in view the health benefits of barley, in India chapatti may be the best source for delivering the bioactive components of barley. Diet containing barley decreases the glycemic index due to its β-glucan content (Knuckles et al., 1997; Wolever et al., 2003). Wheat bread with increased level of β-glucan has been prepared successfully by incorporating barley flour or β-glucan (Bhatty, 1986; Cavallero et al., 2002; Gill et al., 2002a, b; Andersson et al., 2004). However, little work has been done to prepare chapattis with higher level of β-glucan or barley flour (Gujral and Pathak, 2002; Gujral and Gaur, 2005; Thondre and Henry, 2009). Incorporating barley flour in wheat flour during chapatti making may also improve the phytochemical composition especially phenolic compounds (Liu and Yao, 2007). Increased level of phenolic compounds increases the antioxidant potential thus reducing the risk of diseases (Fardet et al., 2008).

Considering the beneficial effects of barley from its bioactive compounds the present investigation was carried out with the following objectives-
1. To study the dehusking, pearling and milling behavior of barley cultivars.
2. To study the physical properties of grains and physiochemical properties of barley flour.
3. Quantification, extraction and purification of β-glucan in different barley cultivars.
4. To study the total phenolic compounds and antioxidant activity of barely cultivars.
5. To study the roasting behavior of barley cultivars.
6. To study the effect of extrusion on the extractability of β-glucan.
7. To study the utilization of barley and wheat flour blends in making baked products like chapatti and cookies.