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Influence of Germination on Nutritional Properties of Hulled Barley Flour

Vaishnavi*and Anupama Sandal

Department of Food Science, Nutrition and Technology, College of Community Science
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidalaya, Palampur-176062, India

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Abstract

This study investigates the impact of germination on the nutritional characteristics of hulled barley flour. Barley grains were germinated at 25 ± 3°C for 48 hours, followed by drying at 55°C and milling to produce flour. Both germinated and non-germinated barley flours were analyzed for their nutritional composition. Germination significantly increased crude protein and crude fiber content, with values of 12.66% and 5.18% in germinated barley flour compared to 11.07% and 4.17% in non-germinated barley flour. Additionally, antioxidant activity and total flavonoid content were notably enhanced in the germinated samples. These findings indicate that germination improves the nutritional value of barley flour.

Keywords: Barley, Raw, Germination, Nutritional, Antioxidant

Barley (*Hordeum vulgare*) is the fourth largest cereal crop in the world, accounting for seven per cent of global cereal production. It belongs to the family Poaceae and the subfamily Pooideae. Barley is closely related to two other small-grain cereal species, wheat and rye. Barley is widely planted and recognized as one of the important cereal crops after wheat, rice, and corn. In Himachal Pradesh, barley is the second most important *rabi* cereal crop after wheat (Verma *et al*. 2022).

Barley grain is considered as sacred grain since it is used in many religious rituals for worshiping deities; performing *yagas* and it is associated with different ceremonies from birth to the death in Hindu religion. It can be grown in wide range of environment than any other cereal. The plant is suitable for both tropical and subtropical climate (Geng *et al*. 2021). Notably, barley holds a significant position as a *rabi* cereal, next to wheat, both in terms of area and production, in Himachal Pradesh. This versatile crop finds its adaptability well-suited to all twelve districts of the state, however it is more prevalent in upper temperate areas with a maximum consumption in Lahaul and Spiti. In India, barley holds a prominent place in traditional cuisine, particularly in fermented foods like *pinni, bhaturu, marchu, pakk, chhangpa, murjag* and *jhanchang* enjoyed in the tribal regions of Himachal Pradesh's high-altitude areas (Kanwar *et al*. 2018).

In comparison with other cereal crops, such as wheat, rice, and maize, barley is characterized by higher barren, salt, and drought tolerance, allowing it to have wide environmental adaptability and distribution across the world. Barley genotypes have been classified as hull less and hulled and majority of the barley cultivated around the world is hulled type as this is more suitable for malting purpose. The hull of barley accounts for 10 to 20 per cent of barley grain and the average husk content depends upon cultivars and growing conditions (Lukinac *et al*. 2022).

Barley is now recognized as a healthy grain and an excellent source of -glucan, B-complex vitamins, tocotrienols, and tocopherols. Unfortunately, only about 2 per cent of the global barley production is used as food due to unacceptable organoleptic characters. Therefore, continuous modifications are ongoing either to develop new cultivars for different purposes, or novel processing methods to improve its organoleptic characters. Different processing treatments can significantly enhance the functional, nutritional, and sensory properties of barley thereby contributing to healthier dietary options and innovative food solutions (Luithui *et al*. 2018).

Germination is an ancient practice used to enhance

*Corresponding author: vaishnavirana704@gmail.com

the nutritional profile of grains by improving digestibility, increasing nutrient bioavailability, and reducing antinutritional factors. The malting of barley is one of the most well-known applications of controlled germination, primarily used for brewing and various food products. Germination induces significant biochemical changes in grains, including the breakdown of storage macronutrients and the synthesis of bioactive compounds, thereby improving their nutritional and functional qualities. Germinated grains exhibit higher antioxidant activity and phenolic content than their non-germinated counterparts. These transformations also enhance the flavor profile, making the grains more suitable for various culinary applications (Warle *et al*., 2015). This study focuses on the nutritional changes in barley flour due to germination, aiming to highlight the benefits of this process in improving the nutritional profile of the grain.

Materials and Methods

Hulled Barley grains were procured from the Hill Agricultural Research and Extension Center, Bajaura, Kullu, Himachal Pradesh. The procured barley grains were cleaned manually for removing adhering dirt, dust and foreign particles along with shrunken and broken grains. Grains were spread on a damp muslin cloth and were kept at room temperature (32°- 35°C). Regular sprinkling of water was carried out to keep the seeds moist. Seeds took 48 hrs for germination (about 1 – 1.5 cm long). Germinated hulled and hulless barley grains were then dried in tray drier at 55°C for 12 hrs. After giving the above treatments, the ungerminated and germinated barley grains were ground into a fine powder to pass through 60 mesh sieve. Milling was done to get fine flour using Stainless Steel Agri Pro 3HP Pulveriser flour machine and passed through a sieve with a sieve size of 60 (340 µm aperture size) and stored in airtight containers at room temperature for further analysis.

The proximate analysis of hulled as well as hulless barley variety for moisture, crude protein, crudefat, crude fibre and total ash was carried out in triplicate according to the standard methods of Association of Official Analytical Chemists (AOAC, 2010). Nitrogen was determined by the micro Kjeldahl method and was multiplied by the factor of 6.25 for converting it in to crude protein. Total carbohydrates content was determined by difference method.Total phenols in samples were determined by the method given by Swain and Hillis(1959). DPPH radical scavenging activity in samples was determined by the standardized method given by Sreeramulu *et al*. 2009. Total flavonoid content was determined using colorimetric method of Zhishen *et al*. (1999)with slight modification.

The experiments were carried out in triplicate and the data obtained was presented as mean± standard deviation. The obtained data were subjected to *t* analysis using OPstat software. The obtained data were interpreted at 5 per cent level of significance ($p \leq 0.05$).

Results and Discussions

Proximate composition

Proximate composition analysis provides an estimation of essential nutrients and serves as a fundamental basis for food analysis. The key components analyzed include moisture, ash, crude protein, crude fat, crude fiber, and total carbohydrate content. These parameters are crucial in the food industry for product development, quality control and regulatory compliance. The results are reported on a dry weight basis.

The results as shown in Table 1 indicated that germination led to significant improvements in moisture content from 6.33 per cent to 6.53 percent. Germination is a biological process that begins with soaking seeds to initiate sprouting. During this process, grains absorb water, but some of this water is used in metabolic activities, which can result in a slight reduction in moisture content compared to the initial soaking stage (Shewry, 2014). Total ash content of hulled barley on germination reduced from 2.56 to 2.14 per cent. The reduction during germination can be due to leaching of water-soluble minerals during soaking at the initial phase of germination. Similarly, Arif *et al*. (2011) observed a decrease in total ash content during germination, suggesting that mineral solubility and loss through leaching play a significant role. Youssef *et al*. (2013) also confirmed that germination decreased total ash content, with ungerminated barley flour showing a reduction from 1.59 to 1.39 per cent on a wet basis. Crude fat content of hulled barley on germination reduced from 1.97 to 1.68 per cent.

Table 1. Proximate composition of unprocessed and germinated hulled barley flour

Parameters	Raw	Germinated	Mean
Moisture (%)	6.330	6.537	6.433
Total Ash (%)	2.563	2.140	2.351
Crude Fat (%)	1.970	1.687	1.828
Crude Fiber (%)	4.170	5.181	4.67
Crude Protein (%)	11.073	12.663	11.86
Total Carbohydrate (%)	72.543	71.833	73.01

Means are significantly different at $p \leq 0.05$

Grewal *et al*. (2006) reported 2.60 per cent fat content in barley, lending further credence to the present results.Germination activates lipolytic enzymes like lipase, which break down triglycerides into free fatty acids and glycerol, leading to lower fat content. This trend was also observed in studies by Kaur and Asthir (2021) during germination in rice grains. Crude fiber content is defined as the residue left after sequential digestion of a sample with dilute acid and alkali, followed by loss on ignition. While crude fiber does not contribute directly to human nutrition, it plays a vital role in maintaining gastrointestinal health by promoting regular bowel movements and cleansing the digestive tract. Germination led to significant improvements in crude fiber content from 4.17 per cent to 5.18 percent. The increase in crude fibre content with processing treatments is likely due to the breakdown of other components, such as starch and protein, along with the synthesis of new cell wall materials during germination. Germination led to significant improvements in crude protein content from 11.07 per cent to 12.66 per cent. Kayisoglu *et al*. (2024) suggested that the respiratory activity during germination contributes to the biosynthesis of new amino acids, while reductions in carbohydrate content further enhance protein concentration. These findings align with other studies on seeds and legumes, which reported increased protein content following germination due to amino acid synthesis. Karuma *et al*. (2018) observed significant improvements in the nutritional and biochemical properties of oats and barley after germination. Lakshmipathy (2024) also noted that protein content increased with extended germination periods, reinforcing the consistency of these results.

The analysis confirmed that raw hulled barley had a significantly higher carbohydrate (72.54 per cent) content than germinated hulled barley (71.83 per cent). Likewise, Lakshmipathy (2024) noted a reduction in total carbohydrate and fat levels after germination. Warle *et al*. (2015) also observed a decrease in carbohydrate content during germination, with a decline from 72.02 per cent to 61.06 per cent. The reduction in carbohydrate content during germination can be attributed to the enzymatic activity that occurs as the seed prepares for sprouting. Amylase enzymes break down complex carbohydrates into simpler sugars, which are used to support seedling growth.

Table 2. Antioxidant content of unprocessed and germinated hulled barley flour

Parameters	Raw	Germinated	Mean
Total phenolic content (mg GAE/100g)	1.75	2.23	1.99
DPPH inhibition activity (%)	68.54	76.18	72.3
Total Flavonoids (mg CE/100g)	19.71	19.85	19.78

Means are significantly different at $p \leq 0.05$

The total phenolic content (TPC) in barley grain flour, was measured in mg GAE/100g, varied significantly with germination of barley grain. The total phenolic content in germinated hulled barley was 2.23 mg GAE/100g, while the lowest total phenolic content was found in raw hulled barley flour with the value of 1.75 mg GAE/100g. The increase in total phenolic content during germination can be attributed to the activation of endogenous hydrolytic enzymes, which release bound phenolic compounds. Germination process enhances the availability of phenolic compounds, contributing to higher total phenolic content (Arif *et al*. 2011).

DPPH inhibition activity, indicates the antioxidant capacity of the barley grains. The highest DPPH inhibition activity was observed in germinated hulled barley with the value of 76.18 per cent, while the lowest was in raw hulled barley with the value of 68.54 per cent. The enhanced antioxidant activity during germination is linked to the increased concentration of phenolic compounds and other antioxidants that are released or synthesized during the germination process (Nithyashree and Vijayalaxmi 2022).

Total flavonoid content (TFC), was measured in mg CE/100g, varied significantly with germination. The highest total flavonoid content was observed in germinated hulled barley with the value of 19.85 mg CE/100g, while the lowest was in raw hulled barley with the value of 19.71 mg CE/100g. The increase in TFC during germination can be due to enhanced synthesis of flavonoids, which serve as protective agents against oxidative stress during seed germination (Arif *et al*. 2011). Germination significantly enhanced the antioxidant activity and flavonoid content of barley, highlighting its role in increasing bioactive compounds. These improvements in nutritional and functional properties make germinated barley flour a valuable ingredient for the development of functional food products.

Conclusion

Germination significantly enhances the nutritional properties of barley flour by increasing crude protein, crude fiber, minerals, and antioxidant activity. The process also boosts bioactive compounds such as flavonoids, making germinated barley flour an excellent choice for functional foods. These findings suggest that incorporating germinated barley flour into food products can offer both nutritional benefits and improve stability.

Conflict of interest: The authors declare that there is no conflict of interest among the authors in this research paper.

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