Journal of Cereal Research
Volume 18 (2): 340-349
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Hulless Barley as an Ingredient for Manufacturing Barley-Grits

Anuj Kumar, Narender Mohan, Dinesh Kumar, Joginder Singh, Manthn Sharma, Amit Sharma, Om Parkash Gupta, Chuni Lal, Sunil Kumar and Ratan Tiwari

ICAR-Indian Institute of Wheat and Barley Research, Karnal -132001, Haryana, India

Article history:
Received: 29 May, 2026
Revised: 29 Jun., 2026
Accepted: 29 Jun., 2026

Citation:
Kumar A, N Mohan, D Kumar, J Singh, M Sharma, A Sharma, OP Gupta, C Lal, S Kumar, R Tiwari. 2026. Hulless barley as an ingredient for manufacturing barley-grits. *Journal of Cereal Research* ***18 (2):*** *340-349.* *http://doi.org/10.25174/2582-2675/2026/178293*

****Corresponding author:***
E-mail: anuj19.ak@gmail.com

Abstract

Barley, an ancient and salubrious grain, has very high nutritional potential. The absence of a tightly attached hull in hulless barley makes it amenable for culinary uses. The present study focused on evaluating the physicochemical attributes, cooking behaviour, and sensory attributes of barley grits obtained from four distinct barley varieties, namely, DWRB 223, Karan 16, PL 891, and Geetanjali. The grits were obtained using a stone mill, with protein content between 10.28-15.28%, ash from 1.17-1.37%, and β-glucan from 4.12-5.03%. The whiteness index for grits, based on Hunter colour parameters ranged from 61.2 to 67.0. The by-product generated during grinding contained 13.48-19.49% protein, 2.56-2.90% ash, and 3.47-4.10% β-glucan, offering a potential option for further valorisation. The cooked-sweetened *dalia* in milk medium was 'liked moderately to very much' by the sensory panellists when served as a hot and cold dessert with overall acceptability scores ranging from 7.33-7.67 and 7.42-8.00, respectively. Hulless barley grits present themselves as a minimally processed food option and a unique attempt for value addition and product diversification aligned with climate-smart agriculture which could be beneficial in providing economic opportunities to women's self-help groups and farmer-producer organisations.

Keywords: Barley grits, cooking behaviour, hulless barley, physico-chemical properties, sensory evaluation

1. Introduction

The present-day consumer looks for minimally processed and healthier food products. The enhanced demand for health foods, possibly due to the increased burden of non-communicable diseases, due to urban lifestyle, has provoked the food industries to seek ingredients/ food formulations possessing unique physiological benefits for meeting consumers demands.

Barley is an ancient and salubrious food crop whose consumption is linked to various health benefits. Hulless barley is a type of barley during whose harvesting process, the hull loosens and detaches itself from the grain. The barley grain contains various phytochemicals i.e., beta glucan, phenolic acids, various flavonoids, lignans, tocols, phytosterols, folates etc. (Idehen *et al.,* 2017; Raj *et al.,* 2023). and bestows the grain with various physiologically important bioactivities. The health benefits of barley are indeed well documented (Geng *et al.,* 2022; Zhang *et al.,* 2023; Raj *et al.,* 2023). Furthermore, barley is considered an adaptable crop with high tolerance to abiotic stresses (Fatemi *et al.,* 2022; Elakhdar *et al.,* 2022; Shaveta *et al.,* 2019); thus, it has the potential to serve as an important climate-resilient food security crop. In India, barley is cultivated across approximately 0.57 million hectares, with an annual production of about 1.80 million tons (3rd advance estimate; 2025-26; https://upag.gov.in/dash-reports/statewiseapy?rtab=Area%2C+Producti on+%26+ Yield&rtype=reports; accessed on 23 June 2026). Although most common barley varieties are of covered types, the development of new hulless barley varieties in India, such as DWRB 223 (released in 2024; developed at IIWBR, Karnal) and PL 891 (released in 2020; developed at PAU, Ludhiana), has reignited interest among food technologists in their use for food product development. The absence of hull makes it readily usable, similar to the wheat grain, without subjecting the grain to the dehulling or pearling process to remove the inedible outer covering. The introduction of pearling/ dehulling step in the value chain leads to enhanced energy uptake, prolongs the processing duration and increases the expenditure. It also leads to the removal of nutrients from the outer layer. Thus, hulless barley is better suited for direct food uses. In our country, hulless barley has a good future as a diversification crop, where farmers look for alternatives. Its easy processing may act as a boon for its food usage at the household and cottage-level enterprises.

Dalia (grits) are cracked/ broken pieces of grain, generally prepared from wheat. The production of *dalia* (grits) from barley grains could indeed be helpful for cottage-level industries. The hulless barley could be directly processed into grits by merely grinding to appropriate levels, and thus it may be considered a suitable mode for value addition and product diversification. Various researchers have utilised combinations of grains for the development of *dalia*/ porridge. Rana *et al.* (2015) formulated multigrain *dalia* with germinated wheat, oat and green grain in the ratio of 50:20:30. Similarly, Mridula *et al.* (2015) developed multigrain *dalia* from sprouted wheat blended with a mix of barley (after pearling operation), sorghum and pearl millet grains. The *dalia* obtained by mixing sprouted wheat and the other three grains in 25:75 was recommended for getting an acceptable quality multigrain *dalia*. Bhatt *et al.,* (2022) prepared savoury ready to cook wheat-based porridge in combination with Bengal gram, green gram, dry yellow along with vegetables like spinach, beans, carrot and onions for utilization as breakfast item. Gupta *et al.,* (2025) developed) nutrient-dense instant porridge from the flours of germinated finger millet, green gram, semolina, amaranth seeds, and gingelly seeds. Yaqoob *et al.,* (2025) prepared multigrain porridge premix by utilizing soaked, germinated oat along with finger millet and mulberry fruit. Soaked, germinated oats, along with finger millet, in a 75:15 ratio were found to be best for preparing a nutritionally enriched porridge premix. Most of the work on *dalia* preparation has focused on utilising wheat grains alongside other cereals and legumes. Information on the production of barley grits from hulless barley is scarce. Therefore, the present study was designed to prepare grits from hulless barley varieties and to evaluate the physicochemical properties of grits and the sensory attributes of *dalia* prepared therefrom.

2. Materials and Methods

2.1. Raw materials

The hulless barley varieties viz., DWRB 223, Karan 16, PL891 and Geetanjali were collected from the Karnal farm (season 2024-25). All the chemicals (sulphuric acid, boric acid, potassium sulphate, copper sulphate) used during the analysis were of analytical reagent grade and procured from the standard manufacturers. The other ingredients viz., table sugar, full cream milk, *ghee* required during the experiment were procured from the local market.

2.2. Barley grits preparation

The barley grains were cleaned manually to remove the dust, debris, and other foreign material. The cleaned and dried grains were then milled using a small stone-based mill. The barley grits (sieved manually; mesh size 25), as well as the grit by-product (bran- like material), were collected separately in large polyethene pouches. The collected materials were then stored in airtight containers at ambient temperature (25°C) until analysis. Fig.1 depicts the barley grains of different varieties along with the corresponding grits and by-products obtained after milling.

2.3. Physicochemical properties

The various physicochemical parameters were determined according to Association of Official Analytical Chemists (2000). Briefly, the moisture content was determined gravimetrically after hot-air drying (105°C), and the ash content was determined by incinerating the sample to whitish-grey ash in a muffle furnace (550°C). The total nitrogen was determined using the Kjeldahl methodology (Pelican Equipment, Chennai) and then multiplied by a factor of 5.8 to obtain protein content. The colour values were expressed in terms of Hunter L*, a* and b* values (Hunter Colourimeter, Veston, USA) and whiteness index (WI) was calculated as per Kumar *et al.* (2016) by combining all three Hunter parameters. The pH of the barley grits after grinding was measured directly using a pH meter (Eutech 700, Singapore) (Nosa-Obanwonyi and Antai, 2019). β-glucan content of the samples having mixed linkage was measured using the Megazyme kit (K-BGLU, Mixed-Linkage β-glucan Assay) (McCleary and Codd, 1991).

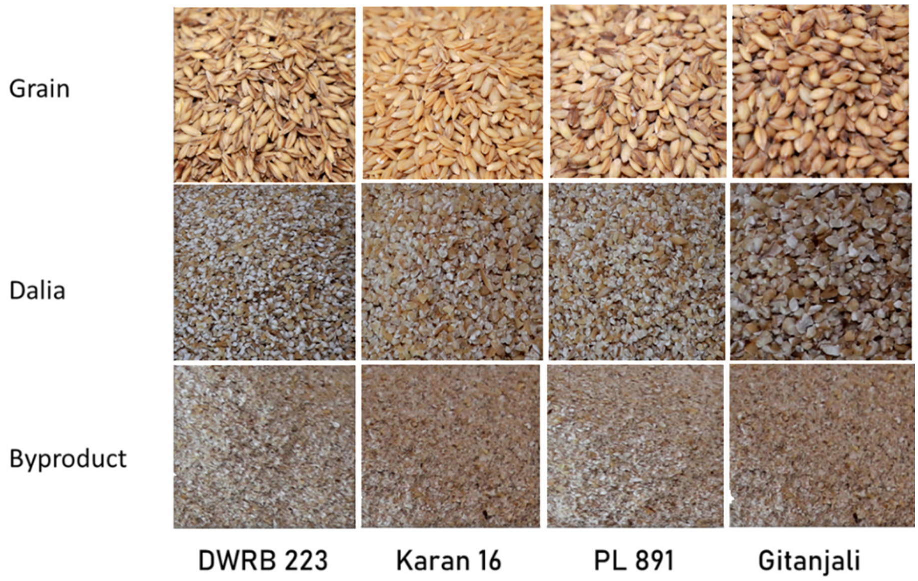

Fig. 1 Grits obtained from hulless barley grains and their corresponding by-products

2.4. Preparation of Dalia

Barley *dalia* samples were cooked as described by Mridula *et al.* (2015), with minor modifications. Briefly, barley grits (50 g) were roasted in ghee (5 g) for 5 min. Later, the *roasted grits were* allowed to cool to ambient temperature, then cooked in water and milk (200 ml each) for 20-25 min, and sweetened with table sugar (10 g). The sensory evaluation was conducted for *dalia*, served both as a hot- and cold- dessert item (Fig. 2) and rated on the 9-point Hedonic scale. For cold serving, the *dalia sample* was chilled at 5°C overnight.

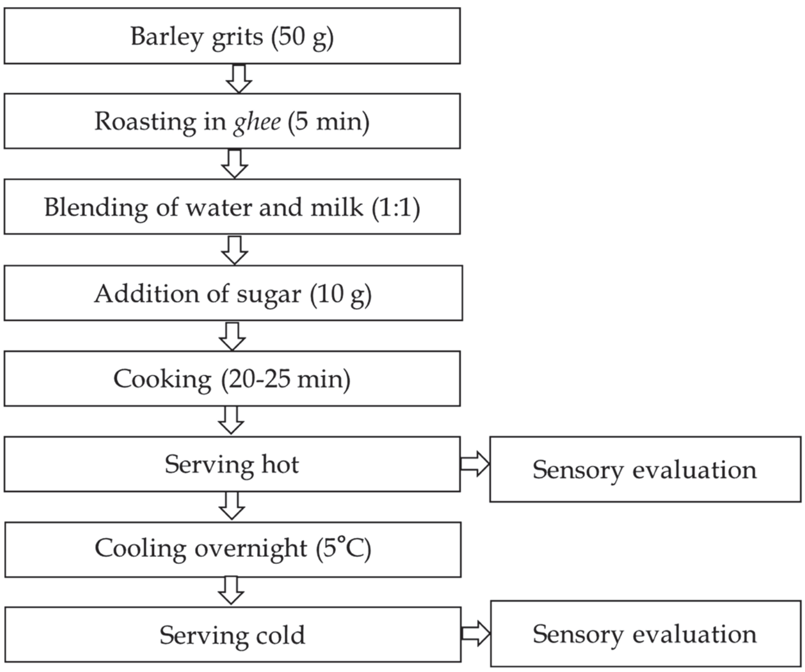

Fig. 2 Process flow describing the preparation of *dalia* samples for sensory evaluation

2.5. Sensory analysis

The sensory analysis of sweetened and cooked barley grits (*dalia*) (Fig. 2) was performed using colour, taste, consistency and overall acceptability score as descriptors on a 9-point Hedonic rating scale by a group of sensory panellists (three nos.) from the section. Before the sensory analysis, the panellists were informed about the product and its attributes to be evaluated. The samples were presented in coded format. The Hedonic scale sequence is as follows: Like extremely- 9, like very much- 8, like moderately- 7, like slightly- 6, neither like nor dislike- 5, dislike slightly- 4, dislike moderately- 3, dislike very much- 2, dislike extremely- 1 (Mridula *et al.,* 2015).

2.6. Cooking behaviour

The cooking properties, viz., rehydration ratio and cook loss, were determined by cooking in water according to Kumar *et al.* (2025) adapted from Prasert and Suwannaporn (2009). The rehydration ratio (RR) was determined by cooking ten grams of the grits in 200 ml water for thirty minutes. The cooked grains were collected employing a hand-held sieve. Further, the cook water was allowed to drip by tapping the sieve continuously and the rehydration ratio was calculated using the following equation:

$$\text{Rehydration ratio} = \frac{\text{Weight of cooked sample}}{\text{Weight of uncooked sample}}$$

Further, the cook loss (solids) in the cook water was determined gravimetrically by drying at 105°C for 5 hours. The analyses were conducted in duplicates. The results are expressed as the mean and standard deviation.

3. Results and Discussion

3.1. Physicochemical attributes

The barley grits obtained were analysed for moisture, protein and ash (mineral) contents and depicted in Fig. 3. The moisture content of the obtained barley grits ranged from 9.30% to 10.01%. The moisture content in food products impacts their shelf life and nutritional value. Since, drying of food to a lower moisture content helps in extending the shelf life, further drying can be carried out to enhance the shelf storage of *dalia.* Kumar *et al.* (2025) observed that the moisture content of the wheat grits varied from 9.09% to 9.62%. Sethy and Mogra (2020) observed that the moisture level of ready-to-cook *dalia* mix was 8.17%, comprising wheat, pearl millet, green gram and groundnuts in the ratio of 40:20:30:10. Hussain *et al.,* (2020) utilized buckwheat and barley grit along with apricot powder to develop instant multigrain porridge mix and observed moisture content of 12.04% in barley. Yiblet *et al.* (2024) observed the moisture levels in the barley grains ranging from 7.3-12.8%. It is recommended that barley grains be restricted to moisture levels of 13.5% for 9 months of storage and 12.5% for more than 9 months of storage (https://www.ndsu.edu/ agriculture/ag-hub/ag-topics/crop-production/crops/barley/control-moisture-natural-air-drying). It must be noted that storage humidity and temperature are also critical factors impacting the life of grain.

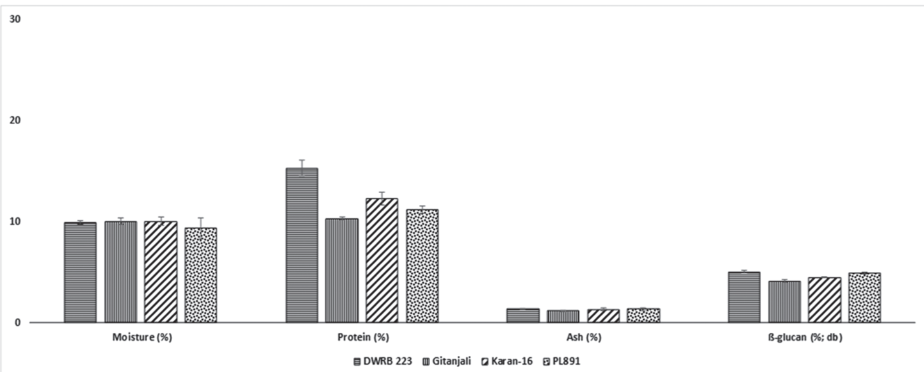

Fig. 3 Compositional attributes of barley grits

The protein content of grits ranged from 10.32% to 15.33%, and ash content varied from 1.17% to 1.37%. Beta-glucan, a soluble fibre found in barley, offers health benefits like lowering of cholesterol, regulation of blood sugar levels, and prevention of various lifestyle disorders. Beta-glucan content in barley grits ranged from 4.12-5.03%. Similarly, a variation in the grain protein and β-glucan content of various barley genotypes: 9.3-17.8% (db) and 4.8-7.3% (db) has been noticed (ICAR-IIWBR, 2025). Similarly, Abdel-aal and Choo (2014) noticed variation in protein content (11.9-20.4%) and ash content (1.8-2.3%) of hulless barley cultivars grown across different environments in Canada. Barley composition is significantly influenced by the environment, genotype, barley type, and their interactions. Environmental factors like nitrogen and water availability, temperature and stress factors determine the protein levels (Bertholdsson, 1999). Also, the ash content is impacted by the type of barley and the agronomic practices being carried out. Further, ash content denotes the mineral levels in a food product, and additional ingredients can be blended with barley grits to accentuate the mineral content. Sethy and Mogra (2020) found protein and ash levels to be 17.24% and 2.37%, respectively, in an optimised formulated multigrain *dalia* mix, while Mridula *et al.* (2015) observed protein and ash levels to vary from 9.32-10.26 % and 1.07-1.29% in various formulations of multigrain *dalia* mix. The protein and ash values ranged from 13.19-18.30% and 2.03-2.49%, respectively for formulations developed from wheat, green gram and oats (Rana *et al.,* 2015).

The colour value of the prepared grits was measured in the form of L* (lightness/ darkness), a* (redness/ greenness), and b* (yellowness/ blueness) values along with the whiteness index. L*, a*, b* and whiteness index (WI) values for various barley grit samples varied from 64.5 to 71.0, 3.70 to 4.50, 15.0 to 16.8 and 61.2 to 67.0 (Table 1). Whiteness index (WI) integrates in itself all three Hunter color parameters and denotes the 'empirical whiteness' or 'lightness' of the product as a single value and is directly correlated with Hunter L* value (Kumar *et al.,* 2016). A higher L* value, along with a higher whiteness index, could indicate a more desirable and visually appealing product. Lightness value and whiteness index was highest for grits from DWRB-223 (71.0; 67.0) and lowest for grits from Geetanjali (64.5; 61.2) variety. Lee *et al.* (2011) observed the colour of various pearled hulless barley cultivars and found that L*, a*, b* values varied from 63.3-72.9, -0.8-1.4 and 13.5-24.1, respectively. Mridula *et al.* (2015) observed instrumental colour coordinates of various multigrain *dalia* samples (wheat, barley, sorghum, pearl millet) and reported L, a and b values as follows: 74.60-76.90, 2.35-4.55 and 12.51-16.41, respectively. Further, Yaqoob *et al.,* (2025) noticed variation in multigrain porridge mix (oat, millet, milk powder and mulberry fruit). The colour values in terms of L*, a* and b* values varied from 76.36-89.9, 1.43-1.97 and 13.62-17.21, respectively,

pH, defined as the negative logarithm of hydrogen ion concentration, along with acidity, helps categorise foods. Low pH of a food helps in suppressing the growth of microbes and helps in designing food preservation technologies. The pH of the prepared barley grits ranged from 6.40 to 6.67 and may be put into the low-acid food category (Karastogianni *et al.,* 2016). Arora *et al.* (2010) reported that a barley-based, unprocessed probiotic food mix had a pH of 6.02, although it had whey and tomato pulp. The food products having pH in the low-acid range might require more severe heat processing (more lethality- higher temperatures for long periods of time) compared to the acidic counterparts, since the hurdle effect of pH is lacking. The water activity value of the barley grits obtained varied from 0.414 to 0.429 (Fig. 4). Water activity reflects the amount of free water available for microbial growth and chemical reactions and is a critical parameter for stability, safety, and processing behaviour. The water activity of grits might be influenced by the extraction efficiency of the milling process. Chia, quinoa, and rice-based porridge mix formulations were reported to have water activity of 0.21-0.45 (Goyat *et al.,* 2019) while Sivasubramaniyan *et al.,* (2024) observed the water activity of pearl millet porridge samples to be ranging from 0.32-0.42.

Table 1. Colour parameters of barley grits

Parameters	DWRB-223	Karan-16	PL-891	Geetanjali
L* value	71.0 ± 0.42^{a}	70.3 ± 0.71^{a}	68.5 ± 0.76^{b}	64.5 ± 0.84^{c}
a* value	3.7 ± 0.07^{b}	4.50 ± 0.21^{a}	4.4 ± 0.26^{a}	4.3 ± 0.32^{a}
b* value	15.4 ± 0.16^{b}	16.8 ± 0.56^{a}	16.7 ± 0.23^{a}	15.0 ± 0.18^{b}
Whiteness index	67.0 ± 0.34^{a}	65.6 ± 0.83^{b}	64.1 ± 0.55^{c}	61.2 ± 0.74^{d}

(Values are Mean ± SD, n=2; Means within different superscripts in a row are significantly different at P ≤ 0.05; Tukey's HSD test)

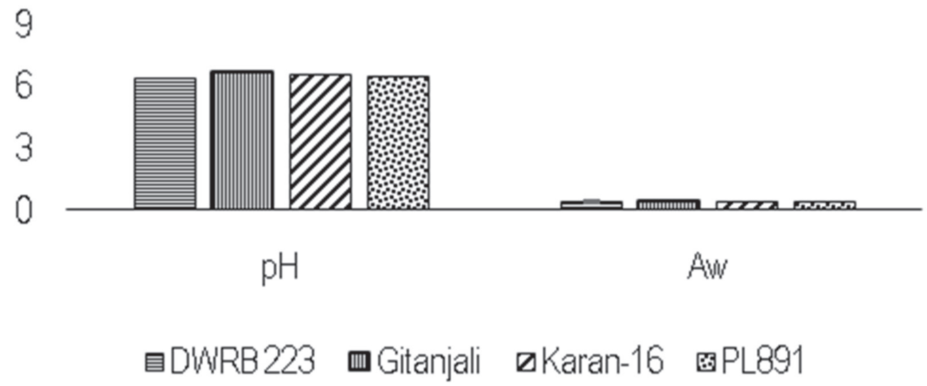

Fig. 4 pH and water activity of barley grit samples

3.2. Cooking properties

Cooking parameters viz., rehydration ratio (RR) and cooking loss (CL) of the four hulless barley grits are presented in Fig. 5. Rehydration ratio (RR), an index of water uptake and final cooked volume, ranged from 4.55 to 4.86. It was found highest in Karan-16 (4.86) barley grits and lowest in PL 891 and DWRB 223 (4.55). It might help in predicting the gelatinisation behaviour of the barley grits. The rehydration ratio signifies the porosity in the grits obtained, which helps in enabling the hydration and ultimately cooking it for consumption. It correlates well with the increase in volume (Prasert and Suwannaporn, 2009). The inner core of the grit should become soft for consumption; therefore, the rehydration ratio may also give an indication of the time of the cooking process. Further, the water absorption of the constituents (protein, starch, fibre) in barley grits may play a crucial role in impacting the rehydration ability. Cook loss, also described as solids loss in cooking medium (Mridula *et al.,* 2015) signifies the loss of starch and other soluble/ disintegrated material in the cooking matrix (cook water) during the cooking process. A low cook loss indicates good structural integrity and tight binding of starch molecules within the grains. The cook loss varied from 0.97% to 1.13%. It was lowest for the PL 891 and Karan 16; while DWRB-223, showed highest cook loss in the cook water. It should be noted that a longer cooking time may increase cooking loss. These cooking properties depend on the cohesion among the various components within the grains. The adhesion between components of DWRB-223 may have been less, which might have led to enhanced cook loss. These could possibly be altered by the dimensions of the barley grits, shape, volume of the cooking water, etc. The loss of solids during cooking may further increase the viscosity of the cooking medium, which could enhance the mouthfeel of the product. Cook loss becomes important during processing when the cooking medium needs to be drained out, since it would probably lead to a decrease in nutritional components.

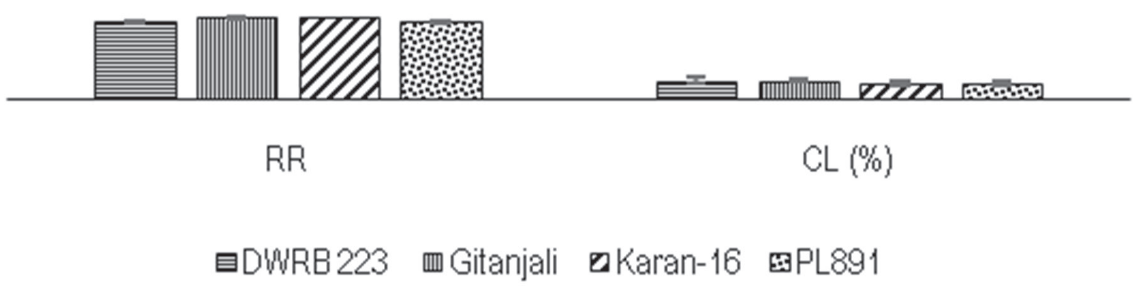

Fig. 5 Cooking properties of barley grits

Sensory analysis for cooked barley grits

Sensory analysis uses human senses to assess the food in terms of sensory attributes and is a valuable way to assess the suitability of food for human consumption and consumer preferences. The cooked barley grits were evaluated sensorially using the following descriptors: colour, taste, consistency and overall acceptability. Prior to sensory evaluation, grits were cooked as per the protocol mentioned in Fig. 2 and evaluated both as a hot and a cold dessert. The sensory scores are depicted as sensory radar charts. The sensory evaluation helps in assessing the product's attributes like colour, flavour and texture *via* human senses to determine the quality, acceptability, and consumer preference of the food item. Sensory analysis of sweetened cooked *dalia* was conducted while serving it hot and cold. The scores are displayed using a radar chart (Fig. 6 and Fig. 7). The sensory colour, taste, consistency, and overall acceptability score for the cooked and sweetened *dalia*, served as warm dessert, varied from 7.67-7.83, 7.25-7.58, 7.25-7.67 and 7.33-7.67, respectively. The overall acceptability of hot served *dalia* prepared from Geetanjali was lowest (7.33) while it was maximum for DWRB 223 (7.67); although both were in 'like moderately- like very much range'. The *dalia* served as a cold dessert scored higher and the scores varied from 7.33-7.83, 7.83-8.00, 7.50-7.83 and 7.50-8.00 for sensory descriptors, respectively. For cold served *dalia*, the overall acceptability scores of PL891 was minimum (7.42) and maximum for DWRB 223 (8.0); like moderately to like very much range. The setting of *dalia* gel upon cooling could have heightened its acceptability. The viscous character of fibre, β-glucan could play an important role in influencing the consistency of the products and may impart it a creamier mouthfeel. The overall acceptability score for all samples was in the range of like moderately to like very much on 9-point Hedonic scale, implying the preference for hulless barley *dalia*. Mridula *et al.,* (2015) reported the good sensory acceptability (overall acceptability scores of 7.50-8.49) of various *dalia* formulations. Likewise, Yaqoob *et al.* (2025) reported overall acceptability values of 7.94-8.74 for multigrain porridge premix containing mulberry. This implies that addition of any flavouring or fruit-based pulp/ powder could help accentuate the acceptability.

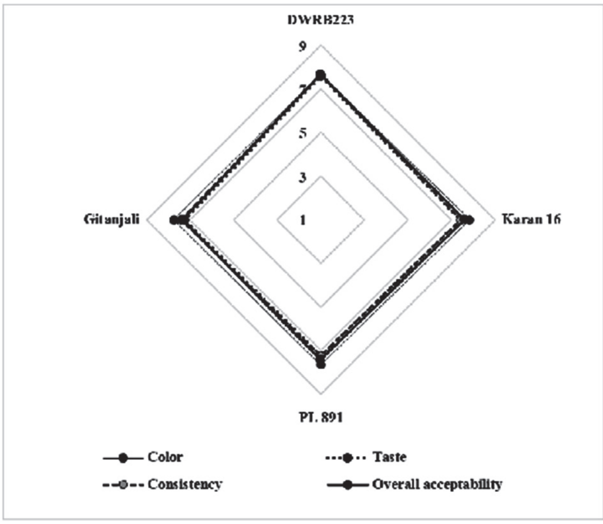

Fig. 6. Sensory analysis of *dalia* as a hot dessert

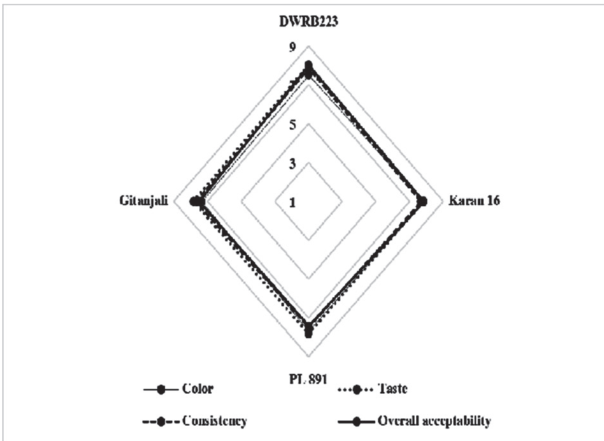

Fig. 7. Sensory analysis of *dalia* as a cold dessert

Compositional attributes of *dalia* by-product

During the grinding process to obtain barley grits, a by-product was generated that resembled coarsely ground bran in appearance. The by-product contains a significant amount of dry matter, including protein, minerals (ash content), and β-glucan. The dry matter content in the *dalia* by-product ranged from 90.4% to 90.9%. The protein and ash content ranged from 13.50% to 19.55% and 2.56% to 2.90%, respectively, while the β-glucan content in the by-product ranged from 3.47% to 4.10% (Fig. 8). This composition reflects the inclusion of nutrient-rich bran and germ in the by-product. The nutrient content of the by-product depends on the recovery of grits. Further, Mridula *et al.* (2015) reported barley *dalia* (size: 1.4-2.0 mm) recovery to be 69.77-78.9% for sprouted and unsprouted grains. Mridula *et al.* (2013) reported *dalia* (1.4-2 mm size) recovery to be in the range of 73.8-75.1% from wheat grains, while Kumar *et al.* (2025) reported the recovery of durum wheat grits to be 75%. It may be noted that the size of grit being manufactured may alter the composition of the by-product. Therefore, the grinding/milling process for barley grit production may be standardised with respect to parameters such as milling type and speed, feed material flow rate, and grinding material (metal/stone), etc., for obtaining *dalia* grits. Although a by-product of *dalia* preparation, this bran-rich product presents an opportunity for valorisation (food, feed, functional ingredient or any other) and for advancing the circular bioeconomy due to its nutritional components, including protein, minerals, and β-glucans.

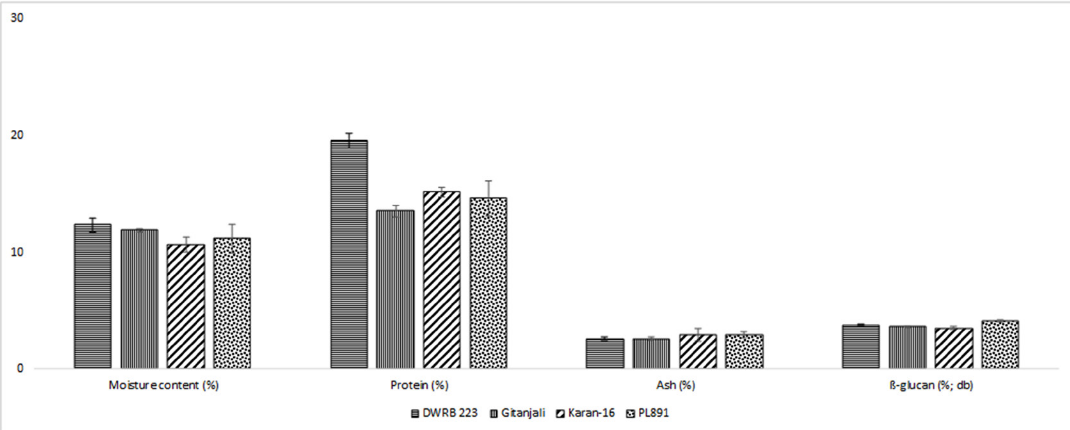

Fig. 8 Compositional attributes of barley *dalia* by-product

Conclusion

The climate resilience of barley makes it an important food crop in the present scenario. Hulless barley presents a great opportunity for its valorisation in food systems because of its ease in processing and salubrity. The *dalia* from various hulless barley varieties was sensorily acceptable. The preparation of grits appears well justified and offers a simple way to diversify the product. A suitable milling technique may be devised for enhancing the recovery of grits. Further, supplementation of barley grits with legumes, other cereals/ pseudo-cereal, dried fruits/ vegetables may boost the nutritional density and acceptability of barley grits. Future work, including rheological properties, microstructure evaluation, pasting behaviour and large-scale processing trials for *dalia* preparation, consumer preference studies, and glycaemic response studies, may further enhance the commercial significance of the hulless barley *dalia*. Furthermore, a larger set of barley genotypes from various locations may be assessed to determine the wider applicability of quality traits.

Acknowledgment

The authors are grateful to the Indian Council of Agricultural Research for supporting the research work.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

AK planned the experiment, prepared and edited the manuscript; NM, MS, provided the technical assistance; DK, JS, AS, OPG, CL, SK planned and edited; RT: Planning and guidance. All authors read, edited, and approved the final manuscript.

Ethical Approval

The article doesn't contain any study involving ethical approval.

Use of Generative AI or AI-assisted technologies

Authors declare that generative AI or AI-assisted technologies have not been used in the preparation of this manuscript

References

1. Abdel-Aal ESM and TM Choo. 2014. Differences in compositional properties of a hulless barley cultivar grown in 23 environments in eastern Canada. *Canadian Journal of Plant Science* **94**: 807-815.
2. AOAC International. 2000. Official Methods of Analysis. 17th Edition. Association of Official Analytical Chemists, Gaithersburg, Maryland, USA.
3. Arora S, S Jood and N Khetarpaul. 2010. Effect of germination and probiotic fermentation on nutrient composition of barley-based food mixtures. *Food Chemistry* **119**: 779-784.
4. Shaveta KH, S Kaur and S Kaur. 2019. Hulless barley: A new era of research for food purposes. *Journal of Cereal Research*, **11**(2):114-124.
5. Bertholdsson NO. 1999. Characterization of malting barley cultivars with more or less stable grain protein content under varying environmental conditions. *European Journal of Agronomy* **10**: 1-8.
6. Bhatt Y and AS Jyothi Lakshmi. 2022. Effect of processing treatments on digestibility and physicochemical properties of ready-to-cook breakfast mixes. *Journal of Food Processing and Preservation* **46**: e16324.
7. Elakhdar A, S Solanki S, T Kubo, A Abed, I Elakhdar, R Khedr, ... & CO Qualset. (2022). Barley with improved drought tolerance: Challenges and perspectives. *Environmental and Experimental Botany*, **201**: 104965.
8. Fatemi F, F Kianersi, A Pour-Aboughadareh, P Poczai and O Jadidi. 2022. Overview of identified genomic regions associated with various agronomic and physiological traits in barley under abiotic stresses. *Applied Sciences* **12**: 5189.
9. Geng L, M Li, G Zhang and L Ye. 2022. Barley: a potential cereal for producing healthy and functional foods. *Food Quality and Safety* **6**: fyac012
10. Goyat J, SG Rua, S Suri and SJ Passi. 2019. Nutritional, functional and sensory properties of ready-to-eat chia and quinoa mix enriched low amylose rice-based porridge mixes. *Current Research in Nutrition and Food Science* **7**: 399-410.
11. Gupta C, RD Khedkar, K Negi and K Singh. 2025. Optimization and development of nutrimix porridge flour for lactating mothers. In: Revolutionizing Agri-food Systems: Sustainability, Health and Innovation. Springer Nature Switzerland, Cham. pp. 205-224.
12. Hussain A. 2020. Characterization and Storage Studies of Instant Multigra in Porridge Made from Underutilised Crops of Ladakh. *International Journal of Food and Fermentation Technology,* **10**(2), 119-127.
13. ICAR-IIWBR. 2025. Progress Report of AICRP on Wheat and Barley 2024-25: *Barley Improvement.* Eds. Omvir Singh, C Lal, J Singh, L Kumar, AK Khippal, R Malik, OP Gupta, SK Bishnoi, R Kumar, OP Gangwar, AK Sharma, C Singh, Satyavir Singh, AK Verma and R Tiwari. ICAR-Indian Institute of Wheat and Barley Research, Karnal, India. p. 366.
14. Idehen E, Y Tang and S Sang. 2017. Bioactive phytochemicals in barley. *Journal of Food and Drug Analysis* **25**: 148-161.
15. Karastogianni S, S Girousi and S Sotiropoulos. 2016. pH: Principles and Measurement. In: Caballero B, P Finglas and F Toldrá (eds). *Encyclopedia of Food and Health.* Vol. 4. Academic Press, Oxford. pp. 333-338.
16. Kumar A, P Ramakumar, AA Patel, VK Gupta and AK Singh. 2016. Influence of drying temperature on physico-chemical and techno-functional attributes of elephant foot yam (Amorphophallus paeoniifolius) var. Gajendra. *Food Bioscience* **16**: 11-16.
17. Kumar A, M Sharma, P Verma, S Kumar, V Pandey, D Kumar and AK Sharma. 2025. Utilisation of durum grains for producing wheat grits for *dalia* preparation. *Journal of Cereal Research* **17**: 290-297.
18. Lee MJ, NY Lee, YK Kim, JC Park, ID Choi, SG Cho and HS Kim. 2011. Physicochemical properties of pearled hull-less barley cultivars with normal and low amylose content. *Food Science and Biotechnology* **20**: 55-62.
19. McCleary BV and R Codd. 1991. Measurement of (1→3), (1→4)-β-D-glucan in barley and oats: A streamlined enzymic procedure. *Journal of the Science of Food and Agriculture* **55**: 303-312.
20. Mridula D, M Sharma, MR Manikantan and RK Gupta. 2015. Development of quick cooking multi-

grain *dalia* utilizing sprouted grains. *Journal of Food Science and Technology,* **52**: 5826-5833.

21. Mridula D, M Sharma, MR Manikantan and RK Gupta. 2013. Development of quick cooking *dalia* utilizing sprouted wheat. *Journal of Agricultural Engineering,* **50**(4), 14:6520-6524.

22. Nosa-Obanwonyi RA and SP Antai. 2019. Microbial and proximate composition of fermented sorghum and barley malts during storage. *African Journal of Microbiology Research* **13**: 285-293.

23. Prasert W and P Suwannaporn. 2009. Optimization of instant jasmine rice process and its physicochemical properties. *Journal of Food Engineering* **95**: 54-61.

24. Raj R, R Shams, VK Pandey, KK Dash, P Singh and O Bashir. 2023. Barley phytochemicals and health promoting benefits: A comprehensive review. *Journal of Agriculture and Food Research* **14**: 100677.

25. Rana GK, MA Khan and Y Singh. 2015. Effect of germination on nutritional and organoleptic properties of multigrain *dalia. Indian Research Journal of Genetics and Biotechnology* **7**: 436-441.

26. Sivasubramaniyan V, N Govindarajan, NVK Senthilkumar and S Kabeer. 2024. Effect of drying methods on the biochemical and functional qualities of ready-to-mix traditional pearl millet porridge (*Pennisetum glaucum*). *International Journal of Nutrition, Pharmacology, Neurological Diseases* **14**: 337-342.

27. Yaqoob S, M Amir and S Ahmad. 2025. Impact of germination and soaking on the nutritional and functional profile of multigrain porridge premix. *Journal of Food Measurement and Characterization* **19**: 6727-6742.

28. Yiblet Y, W Misganaw and E Adamu. 2024. Nutritional and functional composition of barley varieties from Legambo district, Ethiopia. *The Scientific World Journal,* **2024**: 1367540.

29. Zhang J, H Deng, J Bai, X Zhou, Y Zhao, Y Zhu, DJ McClements and Q Sun. 2023. Health-promoting properties of barley: A review of nutrient and nutraceutical composition, functionality, bioprocessing and health benefits. *Critical Reviews in Food Science and Nutrition,* **63**: 1155-1169.