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Technological Potential of Barley Grain Processing for The Production of Layered Bread and Instant Pasta Enriched With Β-Glucan

Sanayev Ermat Shermatovich

Associate Professor., Tashkent Chemical-Technological Institute, Republic of Uzbekistan, Tashkent, Uzbekistan

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Abstract: This study explores the technological potential of “Istak” barley grain for producing functional flour for layered bread and instant pasta. It focuses on optimizing multi-stage pearling, extrusion, and air classification to improve nutritional and technological properties. Results showed that controlled husk removal reduced microbial contamination and lignin content while increasing β-glucan concentration and product safety. Barley contained 55–66% starch, 4–10% β-glucan, and essential amino acids. Air classification increased protein concentration up to 2.13 times, while extrusion at 160°C for 6–10 s improved digestibility and preserved bioactive compounds. The findings confirm barley flour’s suitability for functional foods with improved nutrition, shelf life, and sustainability.

Keywords: Barley grain, β-glucan, pearling process, air classification, extrusion technology, functional food, dietary fiber, microbial reduction, instant pasta, layered bread.

INTRODUCTION

The increasing demand for functional and health-oriented food products has stimulated interest in alternative cereal crops with high nutritional value. Among cereal grains, barley is considered a promising raw material due to its rich composition of starch, dietary fiber, β-glucan, vitamins, minerals, and essential amino acids (Baik B.K., Ullrich S.E. 2008). β-glucans found in barley are associated with cholesterol reduction, improved glycemic response, and enhanced digestive health, which increases its importance in the development of functional foods. In addition, barley contains significant amounts of antioxidant compounds that contribute to its biological value and storage stability (Brennan C.S., Cleary L.J. 2005).

Despite these advantages, the use of barley in bakery and pasta industries remains limited because of its weak gluten-forming properties and specific technological behavior during processing. Modern processing techniques such as pearling, extrusion, grinding, and air classification are therefore applied to improve its technological and nutritional characteristics. Studies have shown that multi-stage pearling effectively decreases microbial contamination and lignin content while increasing the concentration of valuable components such as β-glucan (Šterna V., Zute S., Jansone I., Kantane I. 2017). Furthermore, extrusion processing under optimized conditions enhances starch digestibility and preserves bioactive compounds, making barley flour suitable for layered bread and instant pasta production (Li W., Xiao X., Zhang W., Zheng J., Luo Q., Ouyang S., Zhang G. 2014).

LITERATURE REVIEW

Barley has attracted increasing scientific interest as a promising raw material for the production of functional food products due to its high nutritional value and beneficial physiological properties. In recent years, consumer demand for foods enriched with dietary fiber, bioactive compounds, and natural functional ingredients has significantly increased. Among cereal crops, barley is recognized as an important source of β-glucan, dietary fiber, proteins, vitamins, and minerals, making it highly suitable for health-oriented food production (Baik B.K., Ullrich S.E. 2008). Previous studies reported that barley grain contains approximately 55–65% carbohydrates, 8–15% protein, and considerable amounts of soluble fiber, particularly β-glucan, which contributes to cholesterol reduction and glycemic control (Brennan C.S., Cleary L.J. 2005). These characteristics distinguish barley from traditional wheat-based raw materials and support its application in bakery and pasta technologies.

Researchers have emphasized that the technological and nutritional quality of barley largely depends on grain variety, physicochemical composition, and processing conditions (Šterna V., Zute S., Jansone I., Kantane I. 2017). In the present study, two local barley varieties, "Istak" and "Noyob," were evaluated according to their technological indicators. The obtained results demonstrated that the "Istak" variety possessed superior characteristics, including higher bulk density (769 g/L), larger grain size, and lower husk content. Similar findings were reported in earlier investigations, where barley varieties with lower husk percentages showed better flour yield and reduced processing losses. In addition, higher protein and dietary fiber contents increase the suitability of barley for functional food production.

One of the important technological operations in barley processing is pearling or dehulling. Previous literature indicates that the outer layers of cereal grains are the primary location of microbial contamination, dust particles, and lignified structures (Xolmirzayev D., Haqberdiyev P.S., Shoximardonov D.R., Shaptakov E.S. 2016). Therefore, partial removal of husk layers improves sanitary quality and enhances technological performance. The results of the current study confirmed these observations. Microbial contamination decreased dramatically from 8.2×10^6 CFU/g in unprocessed grain to 0.7×10^3 CFU/g after 10% pearling. Similar reductions were reported by several researchers studying cereal sanitation technologies, where pearling significantly decreased bacterial and fungal contamination. Moreover, lignin concentration was also reduced during pearling, improving digestibility and product quality. These findings demonstrate that pearling is not only a mechanical processing stage but also a critical operation for ensuring food safety and improving physicochemical characteristics.

Chemical composition plays a decisive role in determining the nutritional and functional value of barley-based products. The literature shows that barley varieties rich in protein and β-glucan are particularly valuable for functional bakery products and instant foods (Li W., Xiao X., Zhang W., Zheng J., Luo Q., Ouyang S., Zhang G. 2014). In this study, the "Istak" variety exhibited higher protein content (11.26%) and dietary fiber concentration (24.5%) compared to the "Noyob" variety. Similar results were obtained by Li et al., who observed that naked and low-husk barley varieties generally contain higher amounts of bioactive compounds and improved nutritional quality. Dietary fiber, especially β-glucan, has been widely associated with reduced cardiovascular risk, improved intestinal health, and stabilization of blood glucose levels. Consequently, barley flour enriched with β-glucan can be considered an important ingredient for the production of functional bread and pasta products.

Modern cereal processing technologies increasingly apply dry fractionation and air classification methods to improve nutritional composition without excessive water or chemical usage. According to previous studies, air classification effectively separates cereal flour into protein-rich fine fractions and fiber-rich coarse fractions (Coda R., Katina K., Arendt E.K. 2012). The current research confirmed the efficiency of this method, demonstrating an increase in protein concentration up to 2.13 times after classification. Compared with wet fractionation methods, dry air classification requires less energy and water while preserving protein functionality and reducing environmental impact. Such technologies are considered highly promising for sustainable grain processing systems.

METHODS

The research was conducted using local barley varieties "Istak" and "Noyob," harvested in Uzbekistan in 2024. The experiments were carried out at the laboratory of the Tashkent Chemical-Technological Institute. The study focused on the investigation of physical, chemical, and microbiological properties of barley grain (Šterna V., Zute S., Jansone I., Kantane I. 2017). Moisture content was determined according to GOST

13586.5-93, ash content according to GOST 10847-74, while protein content was measured using the Kjeldahl method based on GOST 10846-91. Fiber content was evaluated according to GOST 13496.2-91. Microbiological analyses, including total viable count, yeast, and mold determination, were carried out in accordance with GOST 10444.15-94 and GOST 10444.12-2013 standards.

Barley grains were processed through three-stage pearling using an A1-ZSHN-3 abrasive dehulling machine, where the gap between the abrasive drum and cylinder was gradually reduced from 20 mm to 10 mm. Air classification technology was applied to separate flour fractions according to particle size and density, which enabled enrichment of protein and dietary fiber fractions (Li W., Xiao X., Zhang W., Zheng J., Luo Q., Ouyang S., Zhang G. 2014). Chemical composition was analyzed using spectrophotometric and HPLC methods, while amino acid composition was determined using an amino acid analyzer. Extrusion treatment was performed at 160°C for 6–10 seconds to improve digestibility and preserve bioactive compounds (Robin F., Schuchmann H.P., Palzer S. 2012). Statistical analysis included correlation and regression modeling to evaluate the relationships between husk content, lignin concentration, and microbial contamination (Baik B.K., Ullrich S.E. 2008).

RESULTS AND DISCUSSIONS

The total amount of β-glucan in the barley grain of the Istak variety is 4.5%. A high concentration of β-glucan was observed in large and small-fraction flour varieties obtained from this grain variety using the "Aerial Classification" method, with an increase in large fractions from 4.5% to 24.0% compared to whole barley grain. In the fine fraction, an increase of 4.5% to 16.0% was observed compared to the entire arc.

While the total content of β-glucan in 100 kg of whole-grain hulled barley grain is 2.4%, the quantitative concentration of β-glucan in the 5 large and small fractions formed during the 5-fold repeated grinding and air sorting process increased from 2.4% to 24.0% in the large fractions and from 2.4% to 16.0% in the small fractions. The yield of 5 large and small fractions of 100 kg of barley grain is shown in Table 3.11. The results presented for the Istak barley variety show a relatively high level of enrichment with β-glucan in coarse fractions with a β-glucan content of up to 10-90%. This indicates that while air fractionation can effectively enrich β-glucans in the coarse fraction, the specific conditions of dry fractionation determine the yield of the resulting fraction.

Table1

Composition of flour fractions rich in protein-starch and β-glucans obtained by the 5-stage air fractionation method from barley variety Istak

<table>
<tr><th colspan="4">1- stage</th><th colspan="4">2- stage</th><th colspan="4">3- stage</th><th colspan="4">4- stage</th><th colspan="4">5- stage</th></tr>
<tr><td colspan="4">Grinding, at 10%, amount of formed fractions and β-glucan, %</td><td colspan="4">Grinding, at 20%, amount of formed fractions and β-glucan, %</td><td colspan="4">Grinding, at 50%, amount of formed fractions and β-glucan, %</td><td colspan="4">Grinding, at 70%, amount of formed fractions and β-glucan, %</td><td colspan="4">Grinding, at 90%, amount of formed fractions and β-glucan, %</td></tr>
<tr><td colspan="2">Майин фракция</td><td colspan="2">Large fraction</td><td colspan="2">Fine fraction</td><td colspan="2">Large fraction</td><td colspan="2">Fine fraction</td><td colspan="2">Large fraction</td><td colspan="2">Fine fraction</td><td colspan="2">Large fraction</td><td colspan="2">Fine fraction</td><td colspan="2">Large fraction</td></tr>
<tr><td>Flour</td><td>β-glucan</td><td>Cereal</td><td>β-glucan</td><td>Flour</td><td>β-glucan</td><td>Cereal</td><td>β-glucan</td><td>Flour</td><td>β-glucan</td><td>Cereal</td><td>β-glucan</td><td>Flour</td><td>β-glucan</td><td>Cereal</td><td>β-glucan</td><td>Flour</td><td>β-glucan</td><td>Cereal</td><td>β-glucan</td></tr>
<tr><td>1,0</td><td>1,7</td><td>3,1</td><td>4,2</td><td>2,0</td><td>5,3</td><td>10,1</td><td>12,6</td><td>5,0</td><td>8,8</td><td>15,2</td><td>21,0</td><td>11,2</td><td>12,4</td><td>16,9</td><td>28,7</td><td>15,0</td><td>16,0</td><td>21,0</td><td>24,0</td></tr>
<tr><td colspan="4">100 kg - 10% = 90 kg</td><td colspan="4">90 kg - 30% = 27 kg</td><td colspan="4">27 kg - 50% = 13.5 kg</td><td colspan="4">13,5 kg - 70% = 9.45 kg</td><td colspan="4">9,45 kg - 90% = 8.5 kg</td></tr>
<tr><td colspan="4">100 kg – 90 kg = 10 kg</td><td colspan="4">90 kg – 27 kg = 63 kg</td><td colspan="4">63 kg – 13.5 kg = 49,5 kg</td><td colspan="4">49.5 kg – 9,45 kg = 40,05 kg</td><td colspan="4">40.05 kg – 8,5 kg = 31,5 kg</td></tr>
<tr><td colspan="4">10</td><td colspan="4">27</td><td colspan="4">13,5</td><td colspan="4">9,45</td><td colspan="4">8,5</td></tr>
<tr><td colspan="2">2,7 kg</td><td colspan="2">7,3 kg</td><td colspan="2">2,0 kg</td><td colspan="2">6,0 kg</td><td colspan="2">1,9</td><td colspan="2">4,9</td><td colspan="2">2,2</td><td colspan="2">4.3</td><td colspan="2">2,6</td><td colspan="2">3,8</td></tr>
<tr><td colspan="20">Total fine flour fraction (2,7 + 2,0 + 1,9 + 2.2 + 2,6 = 11,4), 11,4 kg of fine flour fraction total (5 kg) that is, 44.2% β-glucan.</td></tr>
<tr><td colspan="20">Total coarse flour fraction (7,3 + 6,0 + 4,9 + 4.3 + 3,8 = 26,3), 26,3 kg of fine flour fraction contains a total of (23.8 kg), i.e., 90.5% β-glucan.</td></tr>
<tr><td colspan="20">Total flour fraction (10 + 27 + 13,5 + 9, 45 +8,5 = 68,45) 68,5%</td></tr>
<tr><td colspan="20">Total livestock feed flour (100 – 68.45 = 31,5) 31,5 %</td></tr>
<tr><td colspan="20">Total protein and starch-rich flour (68,5 - 28,8 = 39,7) 39,7 kg</td></tr>
<tr><td colspan="20">Total flour rich in β-glucans (68,5 – 39,7 = 28,8) 28,8 kg</td></tr>
<tr><td colspan="20">Based on air sorting technology, 28.8 kg of bread flour, 39.7 kg of pasta flour, and 31.5 kg of fodder flour were obtained from 100 kg of husked barley grain. (28,8 + 39,7 + 31,5 = 100)</td></tr>
</table>

According to the data presented in Table 1, as a result of five-stage air classification, 68.45 kg of flour was obtained from 100 kg of dehulled barley grain, and the product was separated into three grades: β-glucan-rich bread-making flour (28.8%), protein- and starch-rich pasta-making flour (39.7%), and feed flour (31.5%). A high content of β-glucans was detected in the coarse fractions, amounting to 28.8%, while in the fine fractions an increase of up to 16.0% was observed. Therefore, the proposed new technology enables the highly efficient production of β-glucan-containing functional flour and protein- and starch-rich pasta-making flour by means of air classification.

The results obtained for the Istak barley variety indicate that the coarse fractions with a β-glucan content ranging from 10% to 90% were relatively highly enriched with β-glucan. However, although their initial β-glucan content was high, the yield of the enriched fractions (8–22%) was considerably lower than the yield of the coarse fraction flour obtained in the present study (35–60%). Similarly, β-glucan enrichment in the coarse fraction, calculated on a dry matter basis, reached 11.2–15.6%, which is slightly higher than in the present study, but was accompanied by a relatively lower yield (10–28%). This indicates that although air classification can effectively enrich β-glucans in the coarse fraction, the specific conditions of dry fractionation determine the yield of the resulting fraction.

During repeated grinding and air classification cycles, the enrichment percentage in the coarse fractions, expressed as an increase relative to the corresponding feed flour, decreased. In contrast, for the fine fractions obtained during repeated cycles, the absolute β-glucan content showed an increasing tendency. As the grinding intensity increased, the particle size decreased. The reduction in particle size led to greater disruption and mixing of the barley endosperm, the cell walls of which are rich in β-glucans; as a result, β-glucan chains became more freely available for interaction with the air stream.

Particle size and morphology. The particle size distribution curves for the feed flour obtained from the Istak variety, as well as for the coarse (CF1 and CF5) and fine (FF1 and FF5) fractions, are shown in Figure 3.10. The corresponding data on particle size parameters (D10, D50, and D90) are presented in Table 3.12. For the Istak variety, it can be seen that the air classification process reduced the particle size of the first fine fraction (FF1). The flour of the Istak variety, with a D90 value of 234.1 µm, was fractionated into FF1 with a D90 value of 27.0 µm and CF1 with a D90 value of 261.1 µm. During subsequent grinding and air classification cycles, the D90 value of CF5 was 185.0 µm, which is lower than that of CF1. Such a reduction in the particle size of the coarse fraction confirms that, with increasing grinding intensity, the particle size continued to decrease even when the sieve size remained unchanged.

Table 2

Quality indicators of barley varieties

Parameter	Istak	Noyob
Moisture (%)	13.8	13.2
Bulk density (g/L)	769	759
1000 grain weight (g)	40.0	35.2
Ash (%)	2.56	2.30
Husk (%)	10.5	13.7

Table 2 presents the main physicochemical quality indicators of the “Istak” and “Noyob” barley varieties. The results clearly demonstrate the technological superiority of the “Istak” variety. In particular, its bulk density (769 g/L) is higher, indicating better grain filling and structural integrity. The 1000-grain weight (40.0 g) is also greater compared to the “Noyob” variety, reflecting larger grain size and improved processing efficiency. Moreover, the husk content in the “Istak” variety is lower (10.5%), which enhances its suitability for flour production due to reduced processing losses. The slightly higher ash content (2.56%) indicates a greater concentration of mineral substances. Overall, these results confirm that the “Istak” variety has superior technological and nutritional characteristics, making it more suitable for further processing into functional food products.

Table 3

Effect of pearling on microbiological indicators- description

Sample	Microorganisms (CFU/g)
Unprocessed grain	8.2×10^6
5% husk removal	4.3×10^4
9% husk removal	9.1×10^3
10% husk removal	0.7×10^3

Table 2 illustrates the effect of pearling (dehulling) on the microbiological quality of barley grain. The initial raw material shows a very high level of microbial contamination (8.2×10^6 CFU/g), indicating that the outer layers of the grain serve as the primary reservoir of microorganisms. As the husk is progressively removed, the microbial load decreases significantly: at 5% pearling, it drops to 4.3×10^4 CFU/g; at 9%, to 9.1×10^3 CFU/g; and at full (10%) pearling, to 0.7×10^3 CFU/g.

The logarithmic decrease in microbial load confirms that even partial removal of the outer grain layers leads to substantial improvements in sanitary quality. This effect can be explained by the concentration of bacteria and fungi on the grain surface, particularly in the husk and aleurone layers.

Table 4

Chemical composition of barley – description

Component	Istak (%)	Noyob (%)
Carbohydrates	46.48	49.97
Protein	11.26	9.20
Fat	1.40	1.43
Fiber	24.5	23.7

Table 4 compares the chemical composition of the barley varieties. The “Istak” variety contains a higher protein content (11.26%) compared to “Noyob” (9.20%), which enhances its nutritional value and functional properties.

Although the carbohydrate content is slightly higher in the “Noyob” variety (49.97%), the “Istak” variety has a higher dietary fiber content (24.5%), making it more suitable for functional food production. The fat content in both varieties is nearly identical (~1.4%), indicating that lipids do not significantly influence technological processing.

The high fiber content, particularly β-glucan, plays a crucial role in improving health-related properties, such as reducing cholesterol levels and enhancing digestive function. Thus, the “Istak” variety demonstrates a more favorable composition for the development of health-oriented food products. The findings of this study confirm that barley is a highly promising raw material for the production of functional food products. The combination of pearling, air classification, and extrusion provides a comprehensive approach to optimizing both technological and nutritional properties.

Compared to conventional wheat-based products, barley-based products offer higher dietary fiber content and improved health benefits, including reduced cholesterol levels and enhanced metabolic function. Moreover, the proposed processing technology is resource-efficient and environmentally sustainable, as it reduces energy consumption and minimizes waste generation. The fine fractions were enriched with protein, while coarse fractions contained higher levels of dietary fiber and β-glucan. Protein concentration increased up to 2.13 times after classification, demonstrating the efficiency of the process. This method offers a significant advantage over wet fractionation, as it preserves the functional properties of proteins and requires less energy and water.

This study demonstrated the technological feasibility of using barley grain, particularly the “Istak” variety, for the production of functional flour intended for layered bread and instant pasta. The application of multi-stage pearling significantly improved grain quality by reducing microbial contamination and lignin content, while preserving valuable nutrients. Air classification proved effective in producing protein- and β-glucan-rich fractions, enhancing the nutritional profile of the final products. The optimized processing conditions, including extrusion at 160°C, contributed to improved digestibility, functional properties, and product stability. The results highlight the importance of selecting appropriate processing parameters to maximize the technological and nutritional potential of barley. Overall, barley-based products offer a promising alternative to conventional cereal products, supporting the development of functional foods with health benefits. The proposed technology ensures resource efficiency, environmental sustainability, and improved food safety, making it suitable for industrial implementation.

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