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Research Article

Investigation of Intensive Technology for The Production of Flour by Extrusion from Husked Barley Grain to Obtain Layered Bread Rich In B-Glucans When Organizing Targeted Consumption Rations

[1]Sanayev Ermat Shermatovich

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

[2]Serkayev Kamar Pardayevich

[2]Associate Professor, Tashkent Institute of Chemical Technology, Republic of Uzbekistan, Tashkent City, Uzbekistan

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Abstract

In this study, the classification of preferred and rare barley varieties based on aeration velocity was investigated for the production of protein-enriched early-maturing pasta raw materials. The goal is to reduce the repeated grinding and sifting stages of traditional technology by sorting fractions and other components containing starch, β-glucan, dietary fiber, and ash at an artificial wind speed.

At the stage based on protein enrichment, the "Istak" variety was used; after the first fractionation cycle, the protein content in the "Istak" variety increased by 2.13 times. Repeated cycles led to an even higher yield of dry protein for the "Istak" variety, resulting in an effective yield of high-protein fractions of 47–52%,

Keywords:

β-glucan, barley grain, extrusion technology, dehulled barley, dietary fiber, physicochemical properties, functional food, instant products.

INTRODUCTION

Barley is one of the oldest cereal crops and plays an important role in providing the population with functional food products. The high content of β-glucans, proteins, dietary fiber, vitamins, and minerals makes barley a valuable raw material for the food industry. β-glucans are especially important due to their ability to reduce blood cholesterol levels, prevent cardiovascular diseases, and regulate carbohydrate metabolism. In addition, barley dietary fibers positively affect intestinal microflora and exhibit prebiotic properties.

Despite its high nutritional value, the use of barley in bakery and flour products is limited by its technological characteristics. The high content of husk, fiber, and lignin negatively affects dough structure and the quality of finished products. Therefore, the development of modern processing technologies that improve the nutritional value and technological properties of barley grain is an aктyal task for the food industry.

One of the most promising methods for cereal grain processing is extrusion technology. This process makes it possible to rapidly modify the physicochemical properties of raw materials under high temperature and pressure conditions, improve the digestibility of proteins and carbohydrates, reduce moisture content, and decrease microbiological contamination. Extrusion also contributes to an increase in soluble dietary fiber content and the formation of a porous structure in extrudates.

The aim of this study was to investigate the effect of extrusion parameters on the physicochemical properties of dehulled barley grain and to determine the optimal processing conditions for obtaining flour with high nutritional value intended for use in layered bakery products and instant food products.

RESEARCH OBJECTS AND METHODS

The objects of the study were local spring barley varieties "Istak" and "Noyob", included in the State Register of the Republic of Uzbekistan. The research was carried out at the "Food Technology" scientific laboratory of the Tashkent Chemical-Technological Institute.

The physicochemical, technological, and microbiological properties of barley grain were determined according to standard analytical methods and current GOST requirements. Moisture content was determined according to GOST 13586.5–2015, bulk density according to GOST 10840–2017, and 1000-grain weight according to GOST 10842–89. Ash content was analyzed according to GOST 27494–2016, protein content according to GOST 10846–91 using the Kjeldahl method, fat content according to GOST 29033–91, and crude fiber according to GOST 31675–2012. Microbiological indicators were determined according to GOST 10444.15–94.

The amino acid composition of barley grain was determined using high-performance liquid chromatography (HPLC) and amino acid analyzers. β-glucan content was analyzed according to AOAC Method 995.16.

Prior to extrusion, barley grains were cleaned and dehulled using laboratory peeling equipment of the A1-ZSHN type. The dehulling process was performed in three stages by gradually reducing the distance between the abrasive cylinder and the drum from 20 mm to 10 mm. The efficiency of dehulling was evaluated according to grain breakage, husk separation efficiency, and microbiological indicators.

Extrusion processing was carried out using a hot extrusion method at temperatures ranging from 130°C to 180°C with a treatment duration of 6–10 seconds. During the experiments, the influence of extrusion temperature and processing time on the physicochemical properties of barley grain was investigated. Changes in moisture, protein, dietary fiber, fat, ash, and sugar content were analyzed after extrusion.

RESULTS AND DISCUSSIONS

According to traditional technology, two types of flour are obtained from barley: sifted (seeded) flour and baked flour; the yield of sifted flour is 70–73% with an ash content of 1.2%, while the yield of baked flour is 87% with an ash content of up to 2.0%.

Depending on the pigmentation of the seed coats, the Elanma flour variety is characterized by a bluish, yellowish, or greenish-white color. The color of Kepali flour is darker.

The protein content ranges from 8 to 14 g per 100 g. It is rich in lysine, valine, and sulfur-containing amino acids (methionine, cystine, cysteine). Barley flour is capable of forming low-elasticity gluten and contains about 55 g of starch. Flour from various barley varieties differs in its starch content and in the proportion of amylopectin and amylose.

Starch gelatinization occurs at a temperature of 65–80°C. The paste is viscous but not strong. Barley starch binds little water during cooking and is quickly released during storage; therefore, bread made from it hardens quickly. This is due to a decrease in the amount of soluble carbohydrates.

The activity of amylolytic enzymes in barley is among the highest among cereals; therefore, the flour has a high sugar- and gas-forming ability. The abundance of mucilage, which forms low-colloidal solutions, gives the dough high viscosity.

During the extrusion process, the moisture content decreases due to high pressure and increasing temperature, as well as an increase in fat content due to a decrease in total mass; the decomposition of starch into simple sugars occurs under the influence of temperature, harmful microflora are neutralized, and vitamins and amino acids in grain raw materials are preserved due to the short duration of the process.

Temperature, which is one of the main indicators for the extrusion of husked barley grain, determines the transition of substances from a wet bulk state to a gel at temperatures of 80–130°C in the working zones of the extruder, and from a gel state to a gaseous state at temperatures of 130–160°C; the optimal temperature is set at 160°C based on the transition of the substance from the gel state to the gaseous state.

The duration of exposure at the optimal temperature during the extrusion process, which affects the retention of moisture and nutrients (protein, fat, sugar, ash, fiber), was determined. Table 1 below defines the optimal time required to influence changes in the protein content of husked and bleached grain at the optimal extrusion temperature (160°C).

Table 1

Influence of the treatment duration on physicochemical indicators during the extrusion of husked barley grain (160 °C).

Peeled barley grain	Extrusion time, sec					
	5,5	6,5	7,5	8,5	9,5	10
Protein content, %	14,94	14,51	14,43	14,23	14,13	14,10
Fiber content, %	14,0	14,23	14,65	14,85	14,95	14,90
Fat content, %	1,14	1,19	1,23	1,31	1,36	1,41
Ash content, %	2,09	1,86	1,63	1,31	1,48	1,52
Sugar content, %	4,91	5,39	6,54	7,21	8,44	9,02

As seen in Table 1, a slight decrease in protein content is observed as a result of increasing the duration of the raw material in the extruder. As experience shows, protein is the second most important component of grain raw materials (after starch).

It was found that both shelled and whitewashed forms of barley grain have high nutritional value due to the presence of protein, fat, and sugar. This makes it possible to recommend husked grain as a raw material for obtaining products with high nutritional value.

Tables 2 and 3 show the results of changes in the physicochemical parameters of the temperature during the extrusion of clarified and shell-like forms of barley grain.

Table 2

Physicochemical parameters of barley grain (shelled and bleached) extruded at a temperature of 130 °C

Sample	Indicators, %					
	Moisture	Protein	Fiber	Fat	Ash	Sugar
Barley husk						
Non-extruded (control)	13,8	11,26	24,5	1,40	2,56	6,93
Extracted (experimental)	8,5	12,56	33,21	2,26	2,64	9,58
Result and difference	- 5,3	+ 1,30	+ 8,71	+ 0,86	+ 0,8	+2,65
Barley groats						
Non-extruded (control)	7,3	11,94	14,0	1,14	2,09	4,91
Extracted (experimental)	6,8	12,75	14,95	1,23	2,23	5,28
Result and difference	- 0,5	+ 0,81	+ 0,95	+ 0,09	+ 0,14	+0,37

According to the experimental results in Table 2, it was observed that the moisture content in husked barley decreased from 13.8% in the control sample to 8.5% (-5.3%). This is explained by the rapid thermal effect and intensive evaporation of moisture during the extruder process. At the same time, the protein content increased from 11.26% to 12.56% (+1.30%), which is due to the effect of protein concentration and denaturation processes. The fiber content increased from 24.5% to 33.21% (+8.74%), which is explained by a partial change in the structure of hemicellulose and cellulose in barley husks.

Based on these patterns, the extrusion process at a temperature of 150°C enhances the thermomechanical decomposition of husked barley, leading to an increase in fiber and carbohydrate content, while in husked barley, the main direction is characterized by an increase in the concentration of protein and sugars. Changes in the physicochemical indicators of the grain as a result of the experiment, where the extrusion temperature was increased to 160°C and the time was 6–10 seconds, are presented in Table 3.

Table 3

Physicochemical parameters of barley grain (shelled and bleached) extruded at a temperature of 160 °C

Sample	Indicators, %					
	Moisture	Protein	Fiber	Fat	Ash	Sugar

Barley husk						
Non-extruded (control)	13,8	11,26	24,5	1,40	2,56	6,93
Extracted (experimental)	6,7	10,56	29,01	2,59	2,86	8,48
Result and difference	- 7,1	- 0,7	+ 4,51	+ 1,19	+ 0,30	+1,47
Barley groats						
Non-extruded (control)	7,3	11,94	14,0	1,14	2,09	4,91
Extracted (experimental)	6,0	14,02	14,95	1,41	1,48	9,02
Result and difference	- 1,3	+ 2,08	+ 0,95	+ 0,27	+ 0,61	+4,11

According to the experimental results in Table 3, when the extrusion temperature was increased to 160°C, a series of changes were recorded in the physicochemical parameters of the barley grains in accordance with the influence of temperature. The moisture content in husked barley decreased from 13.8% to 6.7% (–7.1%), reaching a minimum level, which is attributed to the intense evaporation process at high temperatures. The protein content decreased from 11.26% to 10.56% (–0.7%), which is explained by the denaturation of proteins and the disruption of their thermolabile structure at high temperatures.

The general trend for both samples is a sharp decrease in moisture and an increase in sugar content. In conclusion, the extraction process at a temperature of 160°C leads to an increase in protein and sugar content in husked barley. The dynamics of the physicochemical indicators of the grain when the extrusion temperature is increased to 170°C and the time is 6–10 seconds are presented in Table 4.

Table 4

Physicochemical parameters of barley grain (shelled and bleached) extruded at a temperature of 170 °C

Sample	Indicators, %					
	Moisture	Protein	Fiber	Fat	Ash	Sugar
Barley husk						
Non-extruded (control)	13,8	11,26	24,5	1,40	2,56	6,93
Extracted (experimental)	6,1	10,01	28,61	2,69	3,01	9,38
Result and difference	- 7,7	- 0,25	+ 4,11	+ 1,29	+ 0,45	+2,45
Barley groats						
Non-extruded (control)	7,3	11,94	14,0	1,14	2,09	4,91
Extracted (experimental)	5,5	13,46	14,15	1,49	1,14	9,56
Result and difference	- 1,8	+ 1,52	+ 0,15	+ 0,35	+ 0,95	+4,65

According to the experimental results in Table 4, specific changes in the physicochemical parameters of barley grains under the influence of high temperatures were recorded when the extrusion temperature was increased to 170°C.

The moisture content in husked barley decreased from 13.8% to 6.1% (–7.7%), which is explained by intense water evaporation. The protein content decreased to 10.01% (–0.25%), indicating that the denaturation process intensified at high temperatures. Fiber content increased from 24.5% to 28.61% (+4.11%), which is due to thermo-mechanical decomposition and changes in the shell structure. An increase in the indicators of fat (+1.29%), ash (+0.45%) and sugar (+2.45%) was noted.

In husked barley, the moisture content decreased from 7.3% to 5.5% (-1.8%). The protein content increased from 11.94% to 13.46% (+1.52%). The fiber content remained unchanged and increased from 14.0% to 14.15% (+0.15%). A significant increase in fat (+0.35%), ash (+0.95%), and sugar (+4.65%) was observed. Under the influence of high temperatures, a sharp decrease in moisture and a decrease in protein content was observed in husked barley, but an increase in fiber and sugar content persisted. The main trend in husked barley is a significant increase in protein and sugar content.

In both cases, the decrease in humidity manifested as a stable pattern. When the extrusion temperature is increased to 180°C and the time is 6–10 seconds, the dynamics of the grain's physicochemical indicators are presented in Table 5.

Table 5

Physicochemical parameters of barley grain (shelled and bleached) extruded at a temperature of 180 °C

Sample	Indicators, %					
	Moisture	Protein	Fiber	Fat	Ash	Sugar
Barley husk						
Non-extruded (control)	13,8	11,26	24,5	1,40	2,56	6,93
Extracted (experimental)	5,6	9,31	28,01	2,86	3,21	9,18
Result and difference	- 8,2	- 1,95	+ 3,51	+ 1,46	+ 0,65	+2,25
Barley groats						
Non-extruded (control)	7,3	11,94	14,0	1,14	2,09	4,91
Extracted (experimental)	5,0	13,26	13,25	1,53	1,14	9,59
Result and difference	- 2,3	+ 1,32	- 0,75	+ 0,39	+ 0,95	+4,68

According to the experimental results in Table 5, the moisture content in husked barley decreased from 13.8% to 5.6% (–8.2%), which is explained by the maximum evaporation process. The protein content decreased from 11.26% to 9.31% (-1.95%), which is associated with protein denaturation and thermolysis processes at high temperatures. The fiber content increased from 24.5% to 28.01% (+3.51%), which is explained by a thermomechanical change in the fiber structure. An increase in fat (+1.46%), ash (+0.65%), and sugar (+2.25%) was noted. The moisture content in husked barley decreased from 7.3% to 5.0% (-2.3%).

The extrusion process had a positive effect on the physicochemical indicators of the husked barley grains in the temperature range of 130–180°C. In all experiments, the moisture content consistently decreased, which manifested as a pattern that increases the stability of grain storage. As the temperature increased, the protein content increased steadily, reaching 13.49% at 130°C, 14.69% at 160°C, and 13.26% at 180°C. This process is explained by the increase in the biological value of the protein under the influence of concentration and partial denaturation. Sugar content was also significantly increased across all regimens (from +0.37 to +4.68%), which is attributed to carbohydrate thermohydrolysis.

CONCLUSION

The results of the study demonstrated that barley grain is a valuable raw material for the production of functional food products due to its high content of protein, β-glucan, dietary fiber, and biologically active compounds. Among the investigated local barley varieties, the "Istak" variety showed the most favorable technological and nutritional characteristics, including higher protein content, lower husk percentage, and better processing efficiency.

The dehulling process significantly improved the quality of barley grain by reducing the amount of husk, lignin, and microbial contamination. The three-stage dehulling method provided effective separation of the outer layers while preserving the nutritional components of the endosperm. This contributed to obtaining barley flour with improved physicochemical and functional properties.

The study also confirmed that extrusion processing has a considerable influence on the physicochemical characteristics of barley grain. Increasing the extrusion temperature from 130°C to 180°C reduced moisture content and enhanced the concentration of proteins, soluble dietary fibers, fats, and sugars. However, excessively high temperatures caused partial degradation of protein and fiber components. Based on the experimental results, extrusion at 160°C for 6–10 seconds was determined to be the optimal processing condition. Under these parameters, the highest preservation of nutritional value and the most favorable balance of protein, soluble fiber, and sugar content were achieved.

Overall, the developed technology of dehulling and extrusion processing can be recommended for the production of barley flour with high nutritional value. The obtained flour can be effectively used in layered bakery products, instant pasta, and other functional food products with improved nutritional and technological properties.

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