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THE EFFECT OF HYDROTHERMAL TREATMENT ON THE MICROBIOLOGICAL SAFETY OF BARLEY GRAIN DURING PROCESSING AND STORAGE

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ABSTRACT

Barley flour is a promising functional ingredient for developing nutritionally enriched cereal-based products due to its dietary fiber, β-glucan, minerals, and bioactive compounds. However, its quality may deteriorate during storage as a result of moisture migration, enzymatic activity, lipid oxidation, and microbial growth. This study evaluated the effects of heat-moisture treatment and packaging conditions on the microbiological stability and toxicological safety of barley flour obtained from hulled Abu G'ofur and hull-less HM-140 barley varieties. The grains were cleaned, steam-treated at 0.4 MPa for 6 min, adjusted to different moisture levels, dried, milled using a Pin Mill, and sieved through a 250 μm mesh. Flour samples were stored for up to 360 days at 40±1.0 °C in sack and plastic packaging. The results showed that heat-moisture treatment reduced the growth of mesophilic aerobic and facultative anaerobic microorganisms and molds compared with untreated samples. Plastic packaging provided better microbial stability than sack packaging, while treated samples of both varieties maintained lower microbial counts throughout storage. Toxicological analysis confirmed that lead, arsenic, cadmium, and mercury levels did not exceed regulatory limits, and pest infestation was not detected. Overall, heat-moisture treatment combined with appropriate packaging improved the microbiological safety of barley flour and extended its storage stability beyond the conventional four-month period.

Key words

barley flour, heat-moisture treatment, microbiological safety, storage stability, packaging, mold, toxicological safety

INTRODUCTION

Barley flour is of great importance as a functional raw material in the food industry, as it contains β-glucan, dietary fiber, minerals, and biologically active compounds. In particular, β-glucan found in barley, as both soluble and insoluble dietary fiber, has a positive effect on human health and plays an important role in reducing blood cholesterol levels, lowering the glycemic index, and improving digestive processes. Therefore, barley flour is considered a promising raw material for increasing the nutritional value of bread and other flour-based products when used as part of composite flour by partially replacing wheat flour.[1], [2]

However, during the storage of barley flour and composite flour mixtures prepared from it, their quality may deteriorate under the influence of various factors. The moisture content, free fatty acids, enzymatic activity, and storage conditions of flour directly affect product stability. In particular, oxidative enzymes present in cereal products can cause lipid degradation, an increase in the amount of free fatty acids, and, consequently, the development of rancidity and unpleasant odors in the product. Therefore, ensuring the storage stability of barley flour and monitoring its physicochemical and microbiological quality indicators are important scientific and practical issues.[3], [4]

The development of microorganisms during the storage of barley flour is also one of the main factors that negatively affects product quality and safety. In particular, under conditions of high humidity, yeasts and molds can develop rapidly, reducing the organoleptic properties, nutritional value, and shelf life of flour. As a result of microbial activity, microbiological spoilage, mold growth, and problems related to biological safety may occur in the product. Therefore, the application of rapid and effective thermal methods, such as microwave treatment, is considered relevant for extending the shelf life of barley flour and barley-based composite flours, limiting microbial growth, and preserving the nutritional value of the product.[5], [6]

RESEARCH OBJECTS AND METHODS

The experimental design was developed to comparatively evaluate changes in barley flour samples under the influence of technological processing factors. Hulled barley variety Abu G‘ofur and hull-less barley variety HM-140, harvested in 2024 and grown at the Research Institute of Rainfed Agriculture, were selected as the main research objects. The samples were divided into untreated control and heat-moisture-treated groups.

Before treatment, the barley grains were cleaned to remove foreign impurities and, where necessary, separated from hull fractions. The prepared grains were subjected to steam treatment at a pressure of 0.4 MPa for 6 min. The moisture content of the samples was then adjusted to 15, 25, and 35%, followed by drying at 90, 110, and 130 °C for 2 h. After cooling, the treated samples were milled using a Pin Mill and passed through a 250 μm sieve to obtain uniform flour fractions for further analyses.

The prepared barley flour samples were used for subsequent physicochemical, enzymatic, structural, microbiological, and toxicological investigations. The safety indicators of the samples were determined in accordance with the requirements established by the O‘zDSt 3113:2016 standard.

RESULTS AND DISCUSSIONS

According to the requirements of SanPiN No. 0366-19, the total count of mesophilic aerobic and facultative anaerobic microorganisms in cereal flours should not exceed 5.0×10^4 CFU/g, while the permissible level of molds should not exceed 200 CFU/g. Compliance with these microbiological limits is essential for ensuring the sanitary quality and safety of flour intended for food production. An increase in microbial load during storage may lead to deterioration of flour

quality, changes in sensory properties, and a reduction in technological suitability. In addition, excessive development of microorganisms, especially molds and spoilage-associated microflora, can contribute to the occurrence of defects in bakery and flour-based confectionery products after baking, thereby negatively affecting product quality and consumer safety. In practice, flour products are commonly stored in paper or polypropylene bags, and the effectiveness of these packaging materials depends on their ability to limit moisture exchange and reduce favorable conditions for microbial growth. According to the established O‘zDSt 3113:2016 standard, the recommended shelf life of barley flour is generally limited to four months; therefore, improving its microbiological stability during storage remains an important scientific and practical issue.

Based on this, the effect of heat-moisture treatment on the microbiological safety indicators of flour produced from barley grain was evaluated (Table 1). The study was conducted during a storage period of 0–360 days to assess changes in the microbiological quality of barley flour.

The study examined how heat-moisture treatment affects the microbiological properties of barley flour, utilizing two barley varieties: Abu G‘ofur and HM-140. The findings revealed that samples subjected to heat-moisture treatment exhibited significantly lower levels of mesophilic aerobic and facultative anaerobic microorganisms during storage compared to untreated control samples. This reduction can be attributed to the redistribution of free moisture within the product, which limits conditions favorable for microbial growth, thereby enhancing the microbiological safety of the raw material through the applied treatment.

Effect of packaging methods on the microbiological safety indicators of barley flour during storage

Table 1.

Storage condition	Storage period (days)	MAFAnM, O‘zDSt 3113:2016 (×10³ CFU/g)	MAFAnM, HMT-treated (×10³ CFU/g)		Mold, O‘zDSt 3113:2016 (CFU/g)	Mold, HMT-treated (CFU/g)	
			Abu G‘ofur	HM-140		Abu G‘ofur	HM-140
40±1.0 °C, sack packaging	0	2.0	1.0	1.0	ND*	ND*	ND*
	30	2.2	1.2	1.1	10	ND*	ND*
	60	2.4	1.4	1.3	10	ND*	ND*
	90	2.7	1.6	1.5	20	ND*	ND*
	120	3.0	1.9	1.9	20	ND*	ND*
	150	3.2	2.1	2.0	20	10	10
	180	3.5	2.5	2.4	20	10	10

	210	3.8	2.7	2.7	30	10	10
	240	4.0	2.9	2.8	30	20	10
	270	4.3	3.1	3.0	30	20	20
	300	4.5	3.2	3.2	40	20	20
	330	4.8	3.3	3.3	40	20	20
	360	5.0	3.5	3.5	40	20	20
	0	2.0	1.0	1.0	10	ND*	ND*
	30	2.1	1.0	1.0	10	ND*	ND*
	60	2.2	1.1	1.1	10	ND*	ND*
	90	2.3	1.2	1.1	10	ND*	ND*
	120	2.5	1.4	1.3	10	ND*	ND*
	150	2.7	1.4	1.4	10	10	10
40±1.0 °C, plastic packaging	180	3.0	1.5	1.5	10	10	10
	210	3.1	1.7	1.6	20	10	10
	240	3.2	1.8	1.8	20	10	10
	270	3.3	2.0	1.9	20	20	10
	300	3.4	2.2	2.2	20	20	20
	330	3.4	2.3	2.4	20	20	20
	360	3.5	2.5	2.5	20	20	20

Note: MAFAnM — mesophilic aerobic and facultative anaerobic microorganisms; CFU — colony-forming units; HMT — heat-moisture treatment; ND* — not detected.

According to the analysis of Table 1, the microbiological stability of barley flour at 40±1.0 °C was significantly influenced by both the packaging method and heat-moisture treatment. In untreated samples, the counts of mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM) and molds increased steadily with storage time, reaching the highest values after 360 days, particularly under sack packaging conditions. In contrast, microbial growth was considerably

slower in the heat-moisture-treated Abu G‘ofur and HM-140 samples, and mold was almost not detected during the first 120–150 days of storage. The application of heat-moisture treatment maintained better microbiological safety compared with the control samples in both sack and plastic packaging. At the same time, plastic packaging was more effective than sack packaging, ensuring lower levels of MAFAnM and mold in both barley varieties. Although the Abu G‘ofur variety showed slightly higher stability than HM-140 at some storage periods, both varieties demonstrated a generally positive trend. Based on the obtained results, it was scientifically substantiated that the combined use of heat-moisture treatment and appropriate packaging can improve the microbiological safety of barley flour and practically extend its shelf life from 4 to 6 months.

After the recommended storage period of barley flour, a slight increase in MAFAnM and mold counts was observed; however, their levels did not exceed the permissible limits established by SanPiN No. 0366-19.

In addition to microbiological safety, the toxicological safety of food products is also of great importance. In particular, the presence of heavy metals in agricultural products determines their potential risk to human health.

It is known that metals such as Pb, Cd, Hg, and others can have adverse effects on living organisms and are among the most common environmental pollutants. Excessive intake of these microelements may negatively affect the health of both humans and animals. On the one hand, plants possess physiological and biological barriers that limit the excessive accumulation of toxic elements; on the other hand, many plant organisms are capable of accumulating heavy metals. This factor should be taken into account when locating agricultural production areas, especially near industrial enterprises. Therefore, it is necessary to conduct studies to determine the toxicological safety indicators of the investigated raw materials.

Toxicological safety indicators of flour obtained from barley grains

Table 2.

Indicator	Indicator value, mg/kg		
	Maximum permissible level according to ND*	Abu G‘ofur	HM-140
Toxic elements:			
Lead	0.50	0.10	0.10
Arsenic	0.20	0.10	0.10
Cadmium	0.10	0.005	0.005
Mercury	0.03	0.01	0.01
Toxic impurities and pests:			
Pest infestation	Not permitted	Not detected	Not detected

Note: *ND — normative document.

According to Table 2, the concentrations of toxic heavy metals in the studied barley grain samples did not exceed the established regulatory limits, and no harmful impurities were detected. The obtained data indicate that the investigated raw material complies with the toxicological safety requirements specified in Appendix 3 of the “General Technical Regulation on Grain Safety,” approved by Resolution No. 99 of the Cabinet of Ministers of the Republic of Uzbekistan dated March 31, 2016, which defines the maximum permissible levels of toxic elements in grain intended for food purposes.

Conclusion

In conclusion, the results demonstrated that heat-moisture treatment combined with appropriate packaging is an effective approach for improving the microbiological stability and safety of barley flour during prolonged storage. Treated samples of both Abu G‘ofur and HM-140 varieties showed lower counts of mesophilic aerobic and facultative anaerobic microorganisms and molds compared with untreated controls, with plastic packaging providing better protection than sack packaging. Although a gradual increase in microbial load was observed during storage, the values remained within the permissible limits established by SanPiN No. 0366-19. In addition, toxicological assessment confirmed that the concentrations of lead, arsenic, cadmium, and mercury did not exceed regulatory limits, and no pest infestation was detected. These findings indicate that heat-moisture treatment and suitable packaging can enhance the microbiological and toxicological safety of barley flour and support the extension of its practical shelf life beyond the conventional four-month storage period.

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