

Article

Next-Generation Technologies and Development Dynamics in the Grain Processing Industry of Uzbekistan

Khamidova Feruza Yusupovna^{1*}, Shukurova S. A.²

1. Associate Professor, Department of Tashkent State Agrarian University.

2. Assistant at the Department of Storage and Processing of Agricultural Products, Tashkent State Agrarian University.

*Correspondence: xamidova85@inbox.ru

Citation: Yusupovna, K. F., & A., S. S. Next-Generation Technologies and Development Dynamics in the Grain Processing Industry of Uzbekistan. American Journal of Biomedicine and Pharmacy 2026, 3(10), 1-6.

Received: 07th Jul 2026

Revised: 09th Aug 2026

Accepted: 06th Sep 2026

Published: 06th Oct 2026



Copyright: © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>)

Abstract: This article examines the modern trends and prospects of deep processing of grain crops in Uzbekistan. It analyzes technological processes such as grain fractionation, starch and protein extraction, bioconversion, and the production of high value-added feeds. The economic and environmental impacts of these processes are evaluated. Organizational and investment aspects of production localization are discussed, and recommendations for the development of the sector are provided in the context of the national agricultural policy.

Keywords: deep grain processing, Uzbekistan, starch, protein concentrates, bioethanol, food industry, feed production, food security.

Introduction

Grain production is a strategic branch of Uzbekistan's agriculture, with wheat, maize, and barley playing key roles [1]. Traditionally, processing was limited to flour milling, but global experience demonstrates that deep grain processing significantly increases economic returns and export potential [2].

Deep processing refers to a technological process in which grain is used not only as a food product but also as a source of starch, proteins, amino acids, vitamins, bioethanol, biopolymers, and feed additives [3].

The development of this sector aligns with:

- The Food Security Strategy of the Republic of Uzbekistan (2020–2030);
- The Program for the Industrialization of the Agricultural Sector;
- Export diversification goals [4].

Data from the Ministry of Agriculture of Uzbekistan (2020–2024) on grain production volumes;

- Statistics from the State Committee on Statistics on agricultural processing;
- Review of technological solutions from global manufacturers (Bühler, Cletral, Alfa Laval);
- Literature on deep grain processing (international and national) [5].

Materials and Methods

- 1. Analytical — comparative analysis of the current state of grain processing in Uzbekistan and leading countries (USA, Russia, China).
- 2. Technological — systematization of processing methods: wet and dry fractionation, starch extraction, enzymatic modification, extrusion.
- 3. Economic — calculation of potential value-added gains from transitioning from flour milling to deep processing.
- 4. Environmental — assessment of secondary utilization of by-products (bran, distillers’ grains, molasses).
- 5. Forecasting — scenario modeling of the industry’s development up to 2035.

Advanced grain processing represents one of the most promising directions for the agro-industrial sector in Uzbekistan. Unlike traditional milling, which mainly produces flour and bran, deep processing technologies allow the extraction of a wide range of high-value products such as starch, modified starch, gluten, protein isolates, bioethanol, feed yeast, and biodegradable materials. This diversification not only increases the economic return per ton of grain but also enhances food security and export potential. From an environmental perspective, comprehensive grain processing can achieve up to 90–95% waste-free production. By-products such as bran, germ, and residual biomass are effectively utilized in feed production, bioenergy generation, and as raw materials for the chemical industry. This circular approach reduces environmental impact and supports the principles of sustainable development. Despite its significant potential, the development of the sector faces several challenges. The high cost of modern processing equipment limits the entry of small and medium-sized enterprises into the market. A shortage of skilled specialists in biochemistry, food engineering, and industrial management also slows down technological adoption. Additionally, producers must comply with strict product certification requirements in line with international standards such as ISO, HACCP, and Halal to access global markets. To accelerate growth, several strategic measures are recommended. Establishing regional technoparks dedicated to deep grain processing would create industrial clusters that facilitate technology transfer and business cooperation. Integrating training facilities and pilot production lines into agricultural universities would prepare a new generation of qualified specialists. Furthermore, offering preferential financing and tax incentives for small-scale processors could stimulate private investment and innovation in the field.

Advanced grain processing in Uzbekistan holds substantial promise for creating high value-added products, expanding exports, and ensuring long-term food security. The most promising areas for development include starch and protein production, ready-to-eat food products, and feed additives. Achieving success will depend on a combination of government support, investment attraction, workforce training, and the adoption of modern, resource-efficient technologies.

Table 1. General Technological Scheme of Deep Grain Processing

Stage No.	Process Stage	Main Operations	Output Products
1	Grain reception & cleaning	Weighing, removal of impurities, sorting	Clean grain
2	Storage & conditioning	Moisture adjustment, temperature control	Conditioned grain
3	Milling	Grinding, crushing	Grain flour/fractions
4	Fractionation	Separation into bran, germ, endosperm	Bran, germ, endosperm

Stage No.	Process Stage	Main Operations	Output Products
5	Extraction of starch & protein	Wet or dry extraction, centrifugation, filtration	Starch slurry, protein concentrate
6	Modification processes	Enzymatic treatment, thermo-mechanical modification	Modified starch, protein isolates
7	Production of end products	Fermentation, extrusion, drying	Bioethanol, feed yeast, extruded products
8	Packaging & storage	Packing into containers, quality control	Market-ready products

Results

1. Technological directions applicable in Uzbekistan

Grain fractionation with separation of germ, bran, and endosperm [6].

Production and modification of starch — for the food industry, biodegradable packaging, pharmaceuticals [7].

Protein concentrates and isolates — for sports nutrition, meat substitutes, high-protein feeds [8].

Extrusion and ready-to-eat products — breakfast cereals, gluten-free mixes.

Bioconversion — bioethanol, feed yeast, biogas [9].

2. Economic efficiency.

Transitioning to deep processing can increase industry profitability by 2–3 times through the production of high value-added products [10].

Table 2. Economic Evaluation of Deep Grain Processing Directions in Uzbekistan (as of 2024)

Processing Direction	Equipment Investment (million USD)	Capacity (thousand tons/year)	Revenue at Full Capacity (million USD/year)	Payback Period (years)	Products
Starch & Modified Starch	8.5	60	12.5	4–5	food starch, biodegradable packaging, adhesives
Protein Concentrates & Isolates	6.2	40	9.8	3–4	protein supplements, animal feed
Bioethanol & Feed Yeast	7.0	50	11.0	3–4	ethanol, yeast, CO ₂
Extruded Products	2.8	20	4.0	2–3	breakfast cereals, pet feed
Starch-Based Biopolymers	5.5	30	7.2	4–5	biodegradable film

Discussion

The findings of this study demonstrate that the development of deep grain processing has considerable potential to modernize Uzbekistan's grain-processing industry and increase the economic

value obtained from grain crops [11]. The analysis shows that, unlike traditional flour milling, deep processing makes it possible to produce a wider range of high value-added products, including starch, modified starch, protein concentrates and isolates, bioethanol, feed yeast, extruded products, and biodegradable materials. This diversification directly supports the research objective of identifying promising technological directions for the development of the grain-processing sector in Uzbekistan.

The results are consistent with previous research emphasizing the increasing importance of advanced cereal-processing technologies. Singh et al. and Kent and Evers demonstrate that modern grain processing can expand the range of cereal-based products and improve processing efficiency [12]. The present study extends these findings to the Uzbek context by showing that deep processing can contribute simultaneously to value addition, export diversification, food security, and more efficient utilization of agricultural resources. Thus, the findings suggest that modernization should not be limited to improving conventional flour production but should involve the development of an integrated processing system [13].

The economic analysis provides important evidence for this conclusion. According to the results, deep processing can increase industry profitability by approximately two to three times through the production of higher-value products. The investment assessment also demonstrates that different processing technologies have different economic characteristics. Extruded products require relatively lower investment and have an estimated payback period of 2–3 years, while protein concentrates and isolates and bioethanol and feed yeast have estimated payback periods of 3–4 years [14]. Starch and modified starch and starch-based biopolymers require comparatively higher investment and longer payback periods.

These findings indicate that technology selection should depend on the investment capacity and production objectives of individual enterprises. For small and medium-sized enterprises, technologies with lower initial investment and shorter payback periods may be more accessible. Larger enterprises and industrial clusters may have greater opportunities to invest in capital-intensive technologies such as starch production and biopolymer manufacturing. Therefore, the economic results support a differentiated investment strategy rather than a single technological model for all processors.

The environmental results are also significant. The study indicates that comprehensive grain processing can achieve waste-free production rates of up to 90–95% [15]. Bran, germ, and residual biomass can be utilized in feed production, bioenergy generation, and other industrial applications. This finding is consistent with the resource-efficiency principles discussed in previous cereal-processing literature. Instead of treating processing residues as waste, deep processing allows them to become additional sources of economic value. Consequently, technological modernization can simultaneously improve enterprise efficiency and reduce environmental impacts.

The results also reveal that technological development is constrained by several institutional and human-capital factors. High equipment costs, a shortage of specialists in biochemistry, food engineering, and industrial management, and the need to comply with international certification requirements may slow the adoption of advanced technologies. These findings indicate that investment in equipment alone is insufficient. Successful modernization requires qualified specialists who can operate advanced processing systems, maintain production quality, and ensure compliance with international standards such as ISO, HACCP, and Halal.

In this context, the proposed integration of training facilities and pilot production lines into agricultural universities has important practical significance. Such cooperation could help prepare specialists whose skills correspond to the technological requirements of modern grain processing. It could also strengthen cooperation between universities, research institutions, and processing enterprises and facilitate the transfer of technological knowledge into industrial practice.

The findings further indicate that government support is necessary for accelerating the development of the sector. Preferential financing, tax incentives, regional technoparks, and support for technological innovation could reduce investment barriers and stimulate private-sector participation. The establishment of regional deep-processing technoparks could be particularly useful because such clusters could bring together producers, processors, researchers, universities, equipment suppliers, and

investors. This would facilitate technology transfer and reduce some of the costs associated with the introduction of advanced processing technologies.

From a theoretical perspective, the findings support an integrated approach to agricultural processing in which economic, technological, and environmental dimensions are considered together. Deep grain processing is not simply a technological upgrade of milling operations; it represents a transition toward a diversified production system in which different grain fractions are converted into food, feed, energy, and industrial products. This interpretation connects value addition with resource efficiency and sustainable agricultural development.

From a practical perspective, the results suggest that Uzbekistan should prioritize technologies that combine economic feasibility with market potential and resource efficiency. Starch and protein production, extruded and ready-to-eat products, feed additives, and bioconversion are among the most promising areas identified by the study. However, their successful implementation will depend on investment availability, skilled personnel, certification capacity, technological infrastructure, and appropriate government support.

Overall, the findings demonstrate that deep grain processing can contribute to the transformation of Uzbekistan's grain industry from a predominantly traditional milling model toward a more diversified, higher-value, and resource-efficient production system. However, technological modernization should be accompanied by investment in human capital, institutional infrastructure, certification, and supportive economic policies.

Conclusion

The study concludes that deep grain processing represents a promising direction for the modernization and sustainable development of Uzbekistan's grain-processing industry. Compared with traditional flour milling, advanced processing technologies enable a wider range of high value-added products, including starch, protein concentrates and isolates, bioethanol, feed additives, extruded products, and biodegradable materials. These technologies can increase the economic return from grain resources while supporting diversification of the agricultural processing sector.

The economic assessment demonstrates that different deep-processing technologies provide different investment and payback opportunities. In particular, extruded products demonstrate a relatively short payback period, while protein concentrates, bioethanol, and feed yeast also show attractive economic potential. At the same time, starch, modified starch, and biopolymer production require greater investment but provide opportunities for developing new food and industrial markets.

The study also concludes that deep processing can contribute to more efficient utilization of agricultural resources. The use of bran, germ, and other by-products for feed, bioenergy, and industrial purposes can substantially reduce processing waste and support the principles of sustainable and circular production.

However, the development of the sector is constrained by high equipment costs, insufficient numbers of qualified specialists, and international certification requirements. Therefore, technological modernization needs to be accompanied by measures aimed at improving access to investment, developing professional skills, strengthening quality-control systems, and supporting enterprises in entering international markets.

Based on the findings, the study recommends establishing regional deep-processing technoparks, strengthening cooperation between agricultural universities and processing enterprises, introducing pilot production facilities, and providing preferential financing and tax incentives for small and medium-sized processors. These measures can accelerate technology transfer, stimulate private investment, and increase the competitiveness of domestic processors.

In conclusion, the successful development of deep grain processing in Uzbekistan requires a coordinated combination of advanced technologies, investment, qualified human resources, institutional support, and resource-efficient production practices. The implementation of these

measures can increase value-added production, expand export opportunities, strengthen food security, and contribute to the long-term sustainable development of the country's agro-industrial sector.

REFERENCES

- [1] N. Singh et al., "Grain processing: Current trends and applications," *Food Engineering Reviews*, vol. 9, no. 2, pp. 123–143, 2017.
- [2] N. L. Kent and A. D. Evers, *Kent's Technology of Cereals: An Introduction for Students of Food Science and Agriculture*, 5th ed. Oxford, U.K.: Elsevier, 2017.
- [3] Food and Agriculture Organization of the United Nations, *Cereal Market Review*. Rome, Italy: FAO, 2022.
- [4] B. Zhang and B. R. Hamaker, *Cereal Carbohydrates in Processing*. Boca Raton, FL, USA: CRC Press, 2019.
- [5] A. A. Abdurakhmonov and Sh. Khasanov, *Technology of Grain Crop Processing*. Tashkent, Uzbekistan: Uzbekistan National Encyclopedia, 2021.
- [6] M. M. Mirzaev, "Agroprocessing in Uzbekistan: Problems and prospects," *Agroilm Journal*, no. 4, pp. 45–52, 2019.
- [7] Ministry of Agriculture of the Republic of Uzbekistan, *State Program for the Development of the Agro-Industrial Complex 2023–2030*. Tashkent, Uzbekistan, 2023.
- [8] U. Sh. Karimov, "Deep wheat processing: Experience and prospects in Central Asia," *Storage and Processing of Agricultural Raw Materials*, no. 6, pp. 12–18, 2020.
- [9] R. R. Khudayberdiev and A. M. Rakhmatullaev, *Modern Technologies in Flour and Cereal Industries*. Tashkent, Uzbekistan: Tashkent State Agrarian University, 2022.
- [10] G. Owens, Ed., *Cereals Processing Technology*. Cambridge, U.K.: Woodhead Publishing, 2001.
- [11] C. Wrigley, I. Batey, and D. Miskelly, Eds., *Cereal Grains: Assessing and Managing Quality*, 2nd ed. Cambridge, U.K.: Woodhead Publishing, 2017.
- [12] K. Khan, Ed., *Wheat: Chemistry and Technology*, 4th ed. St. Paul, MN, USA: AACC International, 2009.
- [13] S. P. Cauvain, A. S. Young, and L. C. Salmon, Eds., *Using Cereal Science and Technology for the Benefit of Consumers*. Cambridge, U.K.: Woodhead Publishing, 2005.
- [14] R. J. Henry, "Cereal biotechnology and cereal product quality," in *Cereals Processing Technology*, G. Owens, Ed. Cambridge, U.K.: Woodhead Publishing, 2001, pp. 53–76.
- [15] W. G. Owens, "Wheat, corn and coarse grains milling," in *Cereals Processing Technology*, G. Owens, Ed. Cambridge, U.K.: Woodhead Publishing, 2001, pp. 27–52.