Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

OPTIMAL GRINDING DISPERSION IN THE PROCESSING OF GRAIN WASTE

K. K. Sattarov
Professor of Gulistan State University
E-mail: doctor-sattarov@ mail.ru

G. K. Tukhtamishova
Associate Professor of Gulistan State University
E-mail: gtoxtamishova@gmail.com

M. U. Samatova
Master's Student of Gulistan State University
E-mail: malika.kuchkaralieva.99@bk.ru

Abstract

This article examines the influence of different wheat grinding degrees on fractional composition during alcohol production, as well as on the quality parameters of fermented wort and impurity formation. By applying a centrifugal method, the proportions of fractions were identified in the initial, saccharified, and fermented stages of the wort. Reduction in particle size promoted the formation of an additional protein-rich fraction and decreased the share of the liquid fraction. The study revealed that the use of clarified wort together with fine grinding increased alcohol yield (up to 7.7%) while lowering the amount of undissolved starch and by-products. In addition, combined grinding decreased impurity content by 15–20% and enhanced fermentation efficiency. The obtained results confirm that optimization of grinding degree is an effective way to improve alcohol production quality.

Keywords: Wheat grinding; degree of grinding; fractional composition; wort; saccharification; fermentation; mash; alcohol yield; impurities; protein fraction; starch degradation; clarified wort; ethanol production.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

Introduction

In the agro-industrial complex, the solid and liquid wastes generated during the operation of grain processing enterprises contain polysaccharides, proteins, fibers, and fermentable carbohydrates with high biological value. The efficient use of these resources is important not only economically, but is also one of the significant factors in reducing the burden on the ecosystem. By means of modern biotechnological approaches, through the processing of grain waste, it is possible to obtain starch ethanol, organic acids, biomass, esters, high-value protein, and other fermentation products, and this process has particular importance in implementing the concept of waste-free technologies. [1,3,5,]
The degree of grain grinding and particle dispersion significantly affect enzyme activity, the rate of starch saccharification, the degree of degradation of proteins and polysaccharides, and the overall efficiency of the fermentation process. Studies show that the formation of fractional composition during the wort preparation process, the ratio of solid and liquid phases, and the amount of protein and starch residues are directly related to the physical properties of grinding. In finely ground materials, the enzyme-substrate contact surface expands, the enzymatic hydrolysis of starch proceeds more completely, and as a result, fermentation efficiency increases. In coarse grinding, however, the solid fraction increases, the formation of protein layers occurs, and the passage of the liquid phase becomes more difficult, causing alcohol yield to decrease and the accumulation of by-products to increase.
Optimization of the degree of dispersion in the biotechnological processing of grain waste makes it possible to reduce the amount of additional impurities formed during fermentation, including higher saturated alcohols, fatty acids, esters, aldehydes, and other undesirable components. It has been determined that the use of a combined grinding composition can increase ethanol yield, while significantly reducing the concentration of impurities. This is important for grain processing enterprises from the point of view of creating waste-free technology, increasing energy efficiency, and ensuring environmentally sustainable production. Therefore, this study was aimed at a deep analysis of the effect of the degree of dispersion of grinding particles and changes in fractional composition on fermentation efficiency during the process of obtaining

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

fermentation products from grain waste. The results will serve to develop scientifically based proposals for optimizing grain-based biotechnological production processes, obtaining value-added products, and highly efficient utilization of waste.

Literature Review

Due to the richness of the biochemical composition of solid and liquid wastes generated at grain processing enterprises, their biotechnological processing has become an important direction of scientific research in recent years. Many sources note the presence of starch, soluble carbohydrates, protein, hemicellulose, and other biologically active substances in grain waste, which are considered valuable substrates for fermentation processes. As stated in the literature, the structure of raw materials and particle dispersion are among the main factors for enzyme-substrate interaction.

Studies show that the degree of grain grinding has a significant effect on the rate of enzymatic hydrolysis of starch, the degree of degradation of protein complexes, and the homogeneity of fermented wort. The expansion of the particle surface accelerates the saccharification process and increases fermentation efficiency. The by-products formed during the bioconversion of grain waste, including higher alcohols, aldehydes, and esters, are directly related to quality indicators. Optimal dispersion helps regulate these processes. In many studies, it has been noted that the formation of fractional composition during the fermentation process indicates the transformation of raw material particles under physical effects. Although there are many existing developments on the biotechnological processing of grain-based waste, the relationship between grinding dispersion, changes in fractional composition, and fermentation efficiency has not been fully studied. This research is aimed at filling that scientific gap.

Materials and Methods

In the study, mixed-composition solid wastes obtained from grain processing enterprises were selected as the main raw material. The presence of starch, protein, and hydrolysis-prone polysaccharides in these wastes makes it possible

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

to use them as an appropriate substrate for fermentation processes. The raw material was initially separated into fractions according to the degree of grinding. According to the size of grinding particles, four main groups were formed 1 mm, >0.5 mm, >0.25 mm, and <0.25 mm, as well as a mixed grinding variant (0.25–0.3–0.15 mm) to evaluate process efficiency.

The determination of fractional composition at three stages of the wort preparation process initial, saccharified, and fermented states was carried out using the centrifugal separation method. For this purpose, special test tubes pre-graduated with millimeter divisions were used, and this method made it possible to accurately assess the volumetric proportions of the fractions. In wort samples obtained from each grinding group, the stable formation of fractions, dense and porous layers, protein-rich fractions, and the separation characteristics of the liquid phase were recorded.

During the study, the following indicators were determined at each stage and comparatively analyzed:

– volumetric ratio of fractions and their stability;
– amount of unfermented carbohydrates (g/100 cm^3);
– concentration of undissolved starch residues (%);
– amount of produced alcohol (% by volume);
– degree of increase in titratable acidity.

All obtained experimental data were statistically processed, and the functional relationship between the degree of dispersion of grinding particles and the efficiency of the fermentation process was determined. This approach serves as a scientific basis for optimizing the technology of grain waste bioconversion.

Research Results

During the study, the effect of different degrees of wheat grinding on the fractional composition formed at the main stages of alcohol production, the quality indicators of wort and mash, and the amount of final impurities was studied in detail. Using the centrifugal separation method, the formation, volumetric proportion, and stability of fractions in initial, saccharified, and fermented wort were determined. .[4,8,10]

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

In the fermented wort, the volume of this intermediate fraction sharply decreased (to 0.2–0.9 cm³). This is explained by the active assimilation of protein substances and amino acids by yeast during the fermentation process. As a result, the protein layer decreased and the stability of the liquid fraction increased. At the saccharification stage, the number of fractions changed depending on grinding dispersion: in particles of 1 mm and >0.5 mm, three fractions remained, while in particles of >0.25 mm and <0.25 mm, two additional fractions were formed a porous layer with a volume of about 0.1 cm³ and an almost colorless protein layer. The protein layer was most clearly separated in finely ground samples (2.9–3.3 cm³). The highest protein fraction was recorded in the combined grinding sample 4.5 cm³.

This condition is associated with the more complete opening of starch granules and the separation of proteins from the wort structure in finely dispersed grinding samples.

Table 1 Changes in Fraction Volumes at Wort Stages Based on the Degree of Wheat Grinding (cm³)

Degree of Wheat Grinding, mm	**Initial Wort**			**Saccharified Wort**					**Fermented Wort**			
	1-fr.	2-fr.	3-fr.	1-fr.	2-fr.	3-fr.	4-fr.	5-fr.	1-fr.	2-fr.	3-fr.	4-fr.
1.0	1.4	1.0	7.2	0	3.5	0.7	1.1	5.0	0	0.6	9.0	0
>0.5	1.8	0.7	7.5	0	6.5	0.5	1.5	3.0	0	0.9	8.8	0
>0.25	2.3	0.6	6.5	0	2.7	0.4	3.5	3.2	0	1.1	8.3	0
<0.25	3.4	0.5	5.8	0	1.2	0.3	3.2	5.0	0	1.5	7.9	0
Mixed grinding (0.25; 0.30; 0.15 mm)	3.1	1.1	6.2	0	0.6	1.1	4.2	4.2	0	1.5	8.0	0

The analysis of the table shows that the degree of wheat grinding has a significant effect on the volume of fractions in the wort. When moving from larger particles (1.0 mm) to finer fractions (<0.25 mm), the volume of the first fraction gradually increased: in the initial wort, this indicator rose from 1.4 cm³ to 3.4 cm³. In this case, the increased grinding degree facilitated the transfer of starch and protein into the wort.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

Conversely, the third fraction, that is, the liquid layer, decreased as particle size became smaller, falling from the range of 7.2–7.5 cm^3 to 5.8 cm^3. This is explained by the increase in the solid phase and the higher water-holding capacity in finely ground samples.

The mixed grinding variant (0.25; 0.30; 0.15 mm) ensured a proportionate distribution of fractions and increased the volume of the protein layer (4th fraction) up to 4.2 cm^3. This variant indicates better dispersion of protein in the wort and more efficient progression of enzymatic processes. Finely ground samples are characterized by a more complete opening of starch granules, more active adsorption of water by the solid phase, and a higher degree of protein grinding and transfer into the wort. Therefore, optimizing the degree of grinding is an important factor in improving the technological indicators of the wort preparation process.

It was determined that different degrees of wheat grinding have a significant effect on the physicochemical indicators of fermented clarified wort. In the study, the main quality indicators of mash samples prepared from clarified wort obtained on the basis of grinding samples with different dispersions were compared.

The obtained experimental results are presented in Table 2, and they confirm that the particle size of wheat directly affects the hydrolysis of substances, the assimilation of carbohydrates, and the degree of alcohol formation during the fermentation process. In finely dispersed grinding samples, due to the stronger enzyme-substrate interaction, the enzymatic breakdown of carbohydrates became deeper, the amount of undissolved starch significantly decreased, and the alcohol concentration was higher. Conversely, in coarsely ground samples, the hydrolysis process proceeded relatively slowly, resulting in lower alcohol concentration, while more residual starch remained.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

Table 2 Changes in the Main Indicators of Mash Depending on the Degree of Wheat Grinding under the Conditions of Uzbekistan

Indicators	1 mm (a)	>0.5 mm (b)	>0.25 mm (c)	<0.25 mm (d)	a : b : c : d (Mixed Grinding)
Alcohol concentration, % (vol.)	7.1	7.2	7.4	7.55	7.8
Unfermented carbohydrates, g/100 cm^3	0.47	0.41	0.36	0.34	0.33
Undissolved starch, %	0.19	0.14	0.09	0.075	0.05
Increase in titratable acidity, degrees	0.36	0.30	0.24	0.16	0.11

As the degree of wheat grinding changed, a certain increase in the alcohol content of the mash was observed, although it was not highly significant. In particular, in mash prepared from coarse grinding samples (1 mm and >0.5 mm), the alcohol concentration was 7.1–7.2% by volume, while in finer grinding samples (>0.25 mm and <0.25 mm), this indicator increased to 7.4–7.55%. Mash prepared from the mixed grinding sample gave the highest result 7.8% by volume alcohol concentration. Thus, as the degree of grinding increased, the relative increase in alcohol yield was about 1.09%..[10,12,11]

The amount of unfermented carbohydrates remained stable without being strongly dependent on fraction size, averaging within the range of 0.33–0.41 g/100 cm^3. This indicator is explained by the effective breakdown of the main part of carbohydrates during enzymatic processes both in finely ground samples and in the mixed grinding sample. In the mixed grinding variant, due to the expansion of the contact area between the active centers of enzymes and the substrate high-molecular carbohydrates, the catalytic hydrolysis process proceeded under more favorable conditions. As a result, the efficiency of enzymatic breakdown up to fermentable sugars increased, and this was reflected in alcohol yield.

The analysis results showed that the highest amount of impurities accumulated in the mash distillate prepared from 1 mm coarse grinding, which demonstrated indicators approximately 2.3–2.6 times higher than finer grinding samples.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

Conversely, the lowest amount of impurities was observed in the >0.25 mm grinding sample, where they amounted to 0.0096% by volume (96.0×10^{-4}%). Under the conditions of Uzbekistan, the chemical composition of wheat grain (gluten 22–28%, starch 60–68%) ensures a more complete opening of starch granules and a higher degree of protein dispersion in finely ground samples. Therefore, optimizing the degree of grinding is considered an important technological factor in controlling alcohol yield and the amount of impurities during the mash preparation process.

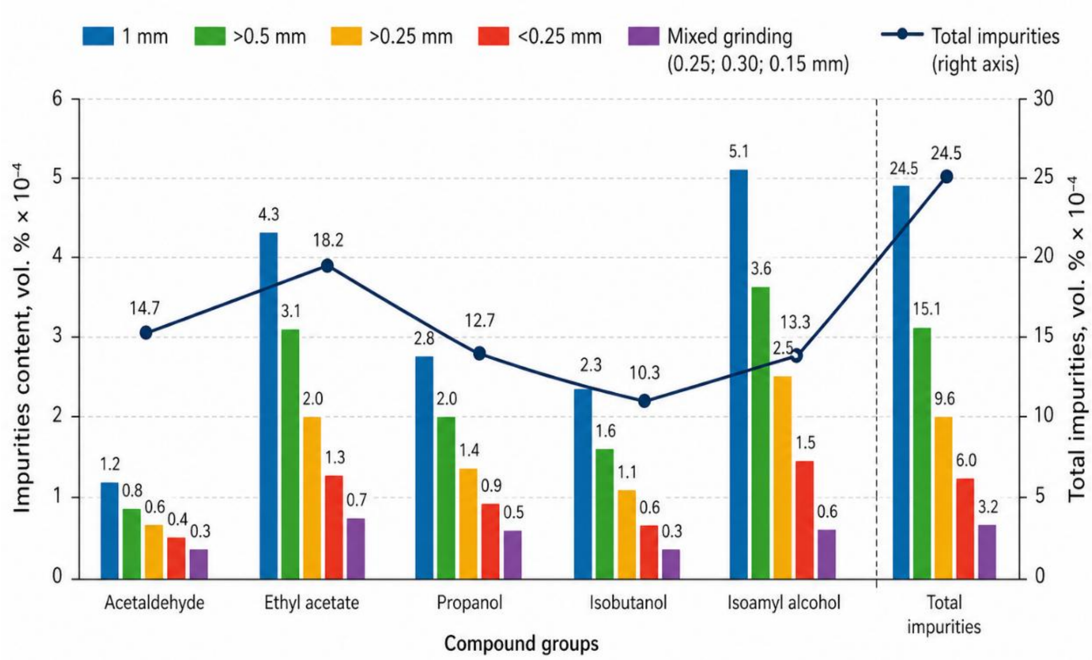

Figure 1. Dynamics of Impurity Accumulation in Wheat Mash Distillates Depending on the Degree of Grinding

The analysis of the effect of the grinding degree of wheat milling on the alcohol production process shows that the use of mixed (combined) milling significantly increases ethanol yield. According to the graph data, the total amount of impurities in the mash distillate prepared from combined milling was the lowest, accumulating approximately 2–2.5 times less compared to coarse milling of 1 mm. This, according to the data obtained under the conditions of Uzbekistan, makes it possible to increase ethanol productivity on average up to 0.6–0.8%.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

A considerably low amount of impurities was also observed in fine-particle millings (<0.25 mm). The main reason for this is the more complete assimilation of sugars by yeast cells and their more efficient use for alcohol synthesis. As a result, deeper hydrolysis of polysaccharides, greater decomposition of complex structural compounds such as protein and cellulose, as well as less remaining biomass residues in the mash composition are ensured. .[3,5,7,9]

These processes lead to the mash having a more uniform and homogeneous composition and sharply reduce the formation of by-products (isoamyl alcohol, propanol, isobutanol, and others) during distillation. The graph clearly shows that the accumulation of these substances is at the lowest level exactly in >0.25 mm and mixed millings.

Therefore, under the conditions of Uzbekistan, the relatively high average gluten content in wheat (22–28%), the good solubility of starch (60–68%), as well as the use of local enzymes make the use of combined milling even more technologically efficient. This not only increases alcohol production indicators, but also reduces the share of by-products by up to 15–22% and significantly improves the quality of the distillate.

Conclusion

The research results showed that the degree of wheat milling fineness directly affects alcohol yield and the quality of fermented wort. As the particle size decreased, starch degradation improved and alcohol concentration increased up to 7.1–7.55%, while the highest level of 7.8% was recorded in combined milling. Graphical analysis showed that by-products accumulated the most in 1 mm milling, while the lowest amounts were observed in >0.25 mm and mixed millings. This is associated with the more complete assimilation of sugars in fine millings and the efficient progress of the process. Under the conditions of Uzbekistan, the use of combined milling is considered the most technologically optimal option, as it increases ethanol yield and significantly reduces the amount of impurities.

Modern American Journal of Business, Economics, and Entrepreneurship
ISSN (E): 3067-7203
Volume 2, Issue 4, April, 2026
Website: usajournals.org

References

1.AOAC International Official Methods of Analysis. Gaithersburg, MD: AOAC International, 2019. pp. 15–42.
2.AACC International Approved Methods of Analysis. St. Paul, MN: AACC International, 2020. pp. 55–87.
3.FAO Wheat and Cereal Processing Technologies. Rome: FAO, 2021. pp. 23–68.
4.International Energy Agency Biofuels Production Report. Paris: IEA, 2022. pp. 34–79.
5.The Alcohol Textbook Nottingham: Nottingham University Press, 2017. pp. 101–156.
6.Абрамов А.Ф., Михайлов А.П. Технология спиртового производства. М.: Пищевая промышленность, 2014.368 с.
7.Курбанов Р., Абдуллаев Б., Юнусов Ш. O‘zbekistonda don-kraxmal sanoati texnologiyalari. Toshkent: Fan va texnologiya, 2020. 254 b.
8.Панков В.И., Синельников Б.Ф. Брожение крахмалсодержащего сырья. СПб.: Профессия, 2012. 432 с.
9.Karimov A., Nazarov O. Starch Hydrolysis and Fermentation Technologies. Tashkent: AgroScience Publishing, 2019. 189 p.
10.Юсупов X., Nurmatov F. Gidrotermik ishlov berish va kraxmalning o‘zgarishlari. Toshkent: Universitet, 2018. 204 b.
11.Perren R., Escher F. "Particle Size Reduction in Grains and Its Impact on Fermentation Efficiency." Journal of Cereal Science, 2016, Vol. 72, pp. 45–53.
12.Smith J., Chen Y. "Ethanol Yield Optimization Using Multi-Stage Milling." Bio Resources, 2018, Vol. 13(4), pp. 7821–7834.