Innovative biomass distribution module for increased productivity and reduced losses in crop harvesting

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Abstract: *This article is based on the project "Establishing the Production of an Efficient and Innovative Biomass Distribution Module to Enhance Productivity and Reduce Losses of the Productive Part of Agricultural Crops". The grain industry in Kazakhstan is dominated by three major producers: Zernovoy Konsortsium Kazakhstana LLP, Atameken Agro JSC, and Olja Agro LLP, collectively managing over one million hectares of agricultural land. To enhance support for the agricultural sector, the Grain Corporation of Kazakhstan must revise its quality standards for grain production. This study introduces an innovative approach aimed at minimizing crop losses and improving grain quality during the harvesting process. The proposed solution is an advanced biomass distribution module (BDM), designed to meet both structural and operational requirements for efficient and high-quality crop harvesting. The module integrates modern sensor technologies for real-time biomass identification and adaptive distribution mechanisms and is compatible with existing harvesting equipment. The BDM is engineered to optimize harvest efficiency while reducing losses of productive crop biomass, aligning with the goal of improving the economic and environmental sustainability of agricultural operations. The technology is poised to support the production of high-value agricultural products with significant export potential. The company "Activator Obmolota" plans to implement these innovative Kazakhstan-based technologies, which have been patented in nine countries. This article details the design, functionality, and projected impact of the biomass distribution module on improving agricultural productivity, reducing crop losses, and promoting sustainability within the sector.*
Keywords: *AGRICULTURAL INNOVATION, GRAIN PRODUCTION, HARVESTING TECHNOLOGY, BIOMASS DISTRIBUTION MODULE, CROP LOSS REDUCTION, SUSTAINABILITY*

1. Introduction

The agricultural sector in Kazakhstan plays a vital role in the national economy, with grain production being a cornerstone of this industry. Despite the country's vast land resources and adoption of modern agricultural practices, significant challenges remain in optimizing crop yields and reducing harvest losses. Among the critical factors contributing to these challenges are inefficiencies in the harvesting process, which result in the loss of productive biomass, affecting both the quality and quantity of harvested grain.

In light of these challenges, a number of proposals have been put forward regarding the protection and support of small businesses in grain production, particularly within the Kostanay region (2023). These proposals include:

- Revising the quality standards for grain, as the current requirements set by the Food Corporation do not align with the actual conditions faced by farmers.
- Increasing the impurity indicator for class 4 grain, which is currently set at 5% for bakery and pasta flour, but only 15% for wheat used in compound feed and alcohol production. A revision to increase this limit for class 4 grain is suggested to better support farmers.
- The removal of specific requirements for grain quality, such as those relating to gluten levels or the sprouted grain indicator, which do not reflect the realities faced by farmers and complicate their ability to meet procurement standards.
- The opportunity for farmers who store grain in warehouses to participate in direct purchase programs, which is currently restricted to those who store grain in elevators.
- The increase of the purchase quota to close gaps in procurement and enable a more sustainable grain market.

These issues are critical in shaping the future of grain production and agriculture in Kazakhstan. The project "Establishing the Production of an Efficient and Innovative Biomass Distribution Module to Enhance Productivity and Reduce Losses of the Productive Part of Agricultural Crops" is directly aligned with the country's strategic goals of improving agricultural productivity and ensuring sustainable development within the sector.

This project aims to address some of the key challenges identified, particularly the loss of productive biomass during harvest, through the development and implementation of an innovative biomass distribution module (BDM). The BDM is designed to enhance the efficiency of the harvesting process, minimize crop losses, and improve the overall quality of harvested grain. By integrating cutting-edge technologies such as real-time biomass identification and adaptive distribution systems, the module aims to optimize the harvesting process and increase the sustainability of agricultural practices.

In the context of Kazakhstan's goal to double agricultural production within the next five years, and to turn the agro-industrial complex into a more technological and innovative sector, the introduction of modern agricultural technologies such as the biomass distribution module is crucial. This innovation not only contributes to the reduction of harvest losses but also strengthens Kazakhstan's position in the global grain market by enhancing the quality and efficiency of its grain production.

2.1. Preconditions and Means for Resolving the Problem

Research Methods: Laboratory, Field, Information, and Analytical Methods

In the context of improving grain harvesting processes and reducing losses, several methods and devices have been developed. One such approach involves a mechanical and technological principle for reducing losses during the collection of grain, which includes pre-threshing leveling in harvesting machines featuring an inclined chamber (Newspaper "World of Quality" // www. Standard. KZ,www. Quality-managers.org, No. 8 (138), August 2016). However, the main limitation of this method lies in a decrease in the leveling coefficient, which ultimately causes both quantitative and qualitative losses of grain. Furthermore, the design of the devices employing this method requires the replacement of the bottoms of the inclined chamber when necessary, a process that is not feasible in the field due to the complexity of having a set of bottoms available for such replacements.

Another method known for grain collection involves processing the mown grain mass within the inclined chamber of a grain harvester. The grain is progressively moved along the preliminary grating-separating surface of the inclined chamber, where it undergoes sifting and separation. The separated grain is then directed for further cleaning. A key design feature of this method involves a conveyor with transverse bars on a belt, which aids in the collection of the separated grain. The working surface of the inclined chamber bottom is typically corrugated, and the corrugations are made up of active elements with a W- and V-shaped profile, arranged in a branching form on the surface of the bottom. In the receiving zone of the conveyor, a removable grating-separating grate is connected to the grain collector (patent EAPO 002420, class A01D 41/00, A01D 41/12, A01D 45/30).

The primary limitation of this method is the insufficient active leveling and multi-layer lateral displacement for effective grain separation. This issue leads to a reduction in the leveling coefficient, ultimately contributing to both quantitative and

qualitative losses in the harvested crop. Notably, damage to the grain embryo is a significant factor, with studies showing that it can lead to a reduction in the yield of cereal crops by 7.1 to 15.3 c/ha. The presence of damaged seeds further exacerbates this issue, decreasing the yield by an additional 2-3 c/ha or more. Additionally, the design of the device does not provide optimal lateral displacement or efficient leveling of the grain mass along the inclined chamber bottom, which reduces the quality and yield of the harvested grain. Furthermore, if the active elements of the device need replacement, it becomes necessary to replace the bottom of the inclined chamber, contributing to the increased metal content and complexity of maintenance due to the metal corners used in the W- and V-shaped profiles.

Innovative Developments: The Kazakh National Agrarian Research University has played a significant role in advancing innovative solutions in grain harvesting technology. The university has created numerous innovations, supported by hundreds of inventions, and has been awarded several prestigious honors, including the Orders "FOR LABOR AND VALOR" from the Eurasian Union of States, "FOR PROGRESS AND ACHIEVEMENTS," and many Gold Medals. Additionally, the university's contributions have received the State Prize named after K.I. Satpayev, among other recognitions. These innovations have been internationally acknowledged, confirming their relevance and demand on a global scale. One notable innovation is the THRESHING ACTIVATOR, which was recognized as one of the "TOP-10" innovative companies in Kazakhstan.

Scientific and Technical Novelty. The scientific novelty of this project lies in the development of new scientific and methodological principles for designing loss-reducing harvesting machines. These principles are based on a range of mechanical and technological strategies that aim to reduce losses during the harvesting process. One such breakthrough involves identifying and establishing patterns of the loss reduction process and determining the dependence of both quantitative and qualitative losses of the productive part of the crop on the leveling coefficient of the grain mass before and after threshing.

The technical novelty is demonstrated through the design and implementation of these innovations, which meet the criteria for patentability, including world novelty, inventiveness, and industrial applicability. The innovations have shown promise in addressing critical challenges in grain harvesting, offering significant improvements in both yield and quality of the harvested grain.

Implementation and Export Potential.To support the widespread implementation of these innovations, it is necessary to establish operational headquarters for monitoring and resolving implementation issues, ensuring the scaling of the technology across all regions of Kazakhstan. The goal is to create a distribution framework for the new-generation threshing activators, customized for specific types of crops and harvesting machines. This framework will be structured based on the needs of various districts and agricultural entities, facilitating the adoption of these innovations. At the national level, it is essential to formulate a strategy to combat grain losses by establishing clear plans for the deployment and utilization of these advanced technologies, including increasing the purchase quotas and creating incentives for farmers to adopt modern machinery.

2.2. Solution of the given problem

For the technology of processing grain mass in a harvesting machine, an innovation is proposed, which can be used when harvesting cereals, legumes, forage, oilseeds, industrial crops, and the productive part of medicinal plants. In the method for processing mown grain mass in a harvesting machine, including feeding the initial mass, leveling, collecting separated grain using active elements in an inclined chamber, according to the invention, the grain mass is processed in the inclined chamber of the harvesting machine using active elements installed in the bottom of the chamber in the form of modules with screw surfaces. The method is carried out using modules with screw surfaces made on a 3D printer. In the device for implementing the method for processing mown grain mass, including an inclined chamber with a bottom having active elements on the working surface, a conveyor, according to the invention, the active elements installed on the working surface of the bottom are made in the form of modules having an upper screw surface in the form of a helicoid, conoid, cylinder, and a lower surface - flat. In the device, the active elements are made on a 3D printer [1, 2]. The technology ensures effective displacement, leveling of grain mass and elimination of quantitative and qualitative grain losses due to this. In the device for implementing the method - creation of active elements, ensuring the possibility of their removal, improvement of wide operational capabilities with the selection of modules necessary depending on the type and characteristics of the processed material, reduction of metal consumption (Fig. 1-3).

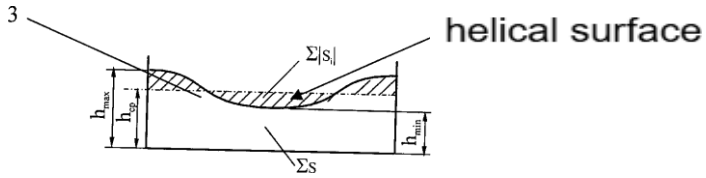

Figure 1 *– Helical surface of the module*
Note – compiled by the authors based on the source [1,2]

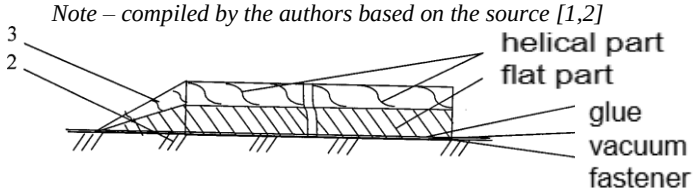

Figure 2 *– Module design*
Note – compiled by the authors based on the source [1,2]

For pre-threshing separation of plant panicles and their distributed feed to the thresher of a grain harvester, a broom distributor for harvesting machines has been created, comprising an inclined chamber with a bottom, a working surface of which is made corrugated, wherein the corrugations have a V- and W-shaped profile with continuously located pulling apart branches, a slatted conveyor and a drive, here, behind the last corrugation in the area of the ejection edge, the bottom is equipped with a panicle descent distributor; the working elements of the panicle descent distributor are made in the form of a conical edge inclined downwards at a certain angle α, where for the movement of the distributed unit of plant panicles, the angle α must satisfy condition (1). In this case, the division of the panicle units must be completed at point a before the plants approach the ejection edge at a distance not less than the value C horizontally; the height H of the location of point a is different for different crops. In addition, the placement of the working elements of the broom distributor is determined by formulas (2 and 3). Depending on the yield, variety and fragility of

the panicles of the harvested crop, the width of the base of the conical edge of a single panicle distributor is set equal to **ℓ'= 2ℓm**, and in the case of low yield and low panicle fragility, equal to **ℓ'= 3ℓm** [3].

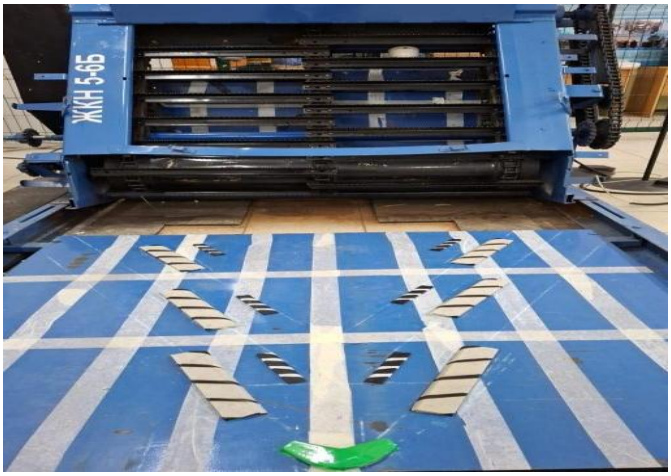

Figure 3 *– Laboratory samples of threshing activators*
Note – compiled by the authors based on the source [1,2]

Harvesting paniculate crops with the proposed broom distributor has its own obvious advantages: the ability to obtain high-quality seed grain directly in the field, including in non-seedgrowing economic entities; the introduction of a V- or W-shaped corrugation profile on the bottom and its supply in the area of the ejection edge with panicle distributors stabilizes the supply of biomass to the threshing device, provides an effect due to increased labor productivity; the thresher of a combine with a broom distributor has a throughput capacity at the level of the same total losses greater than the thresher of a combine without it and provides uniformity of loading of the threshing machine due to the effect of pre-threshing division and distribution of plant panicle units on the unloading edge of the inclined chamber and better leveling of the biomass; an increase in the thickness of the biomass layer under the floating conveyor of the combine's panicle distributor (section - convexity, sinusoid) leads to an increase in the torque on the shaft of the threshing drum. In the invention, the thickness of the biomass layer from a sinusoid is transformed into a uniform flow (by width), providing conditions for thin-layer threshing, which helps to reduce the torque on the shaft of the threshing drum and reduce the required engine power for threshing; in addition, an increase in the intensity of separation due to thin-layer threshing of the biomass will reduce the length of the straw walker, sieve mill, i.e. the dimensions of the combine, etc. With such a broom distributor design, which provides a more complete division before threshing and distribution of plant panicle units across the width of the thresher, the load on the straw walker and cleaning of the combine, which limits its productivity, is significantly reduced. All other things being equal, this increases the productivity of the combine.

2.3. Results and Discussion

The development of the Threshing Activator represents a significant technological advancement in the field of agricultural machinery, specifically designed to address the challenges of grain harvesting. As part of the ongoing efforts to enhance efficiency and reduce crop losses, the Threshing Activator has been rigorously evaluated for its effectiveness in improving harvesting outcomes. This section presents a detailed analysis of its key advantages, based on empirical data from laboratory and field tests, and discusses how these innovations can significantly enhance agricultural productivity, reduce operational costs, and foster the development of the domestic agro-industrial sector.

Advantages of Using the Innovative Threshing Activator [4]:

Minimization of Crop Losses: The Threshing Activator ensures minimal losses of the productive part of the harvested crop, significantly increasing yield efficiency and reducing waste during the harvesting process.

Ease of Operation: Designed with user-friendliness in mind, the device simplifies the operation, making it accessible to operators of varying levels of expertise in agricultural machinery management.

- Replaceability of Active Elements: The Threshing Activator is equipped with interchangeable active components, facilitating quick repairs and replacements in the field, thus minimizing downtime and improving operational continuity.
- Reduction in Metal Consumption and Faster Equipment Repair: The advanced design of the system reduces metal usage, lowering production costs and making the machinery lighter. This also enhances the speed and ease of repairs, reducing both labor and material costs.
- Simple Design and Versatility: Its straightforward construction and adaptability make the Threshing Activator suitable for a wide range of crops, including grains, oilseeds, and forage crops, while also ensuring cost-effectiveness and ease of deployment across diverse agricultural practices.
- Cost Efficiency via 3D Printing: Thanks to the use of 3D modeling and printing technologies, the biomass distributor module and other device components can be produced at lower costs, improving the overall affordability and scalability of the innovation.
- Educational Integration: The modular nature of the device, with 3D-printed components, allows for educational institutions to incorporate the technology into their curricula, thus fostering a stronger link between research, engineering education, and the practical demands of the agricultural industry.
- Reduction of Technological Dependence: The Threshing Activator reduces Kazakhstan's reliance on foreign-developed technologies, promoting self-sufficiency and technological independence within the domestic agricultural industry.
- Enhanced Efficiency of Harvesting Equipment: By improving the operation of harvesting machinery, the Threshing Activator directly contributes to better performance, reducing losses and improving overall harvesting productivity.
- Potential for Continuous Improvement: The device is designed with future enhancements in mind, ensuring that it can evolve alongside agricultural practices and technological advancements, maintaining its relevance in the long term.
- Compliance with International Standards: Meeting international quality standards, the Threshing Activator is positioned to compete in global markets, enhancing Kazakhstan's competitiveness in the international agricultural machinery sector.
- Adaptability Across Agro-Climatic Zones: The Threshing Activator is versatile and can be used in various agro-climatic zones and fields with different levels of yield, ensuring its broad applicability.
- Compatibility with Grain Harvesters: The device is designed to be compatible with most grain harvesters, with throughput capabilities ranging from 3 to 15 kg/s and headers with working widths of up to 8 meters, ensuring widespread usability across diverse harvesting systems.
- Improved Biomass Layer Management: The implementation of the Threshing Activator reduces the biomass layer in the combine drum, leading to higher throughput and reduced energy consumption, which enhances operational efficiency and sustainability.
- Export-Oriented and Import-Substituting: The Threshing Activator not only serves as an innovative solution for the domestic market but also represents an opportunity for Kazakhstan to establish itself as a key player in the global

agricultural technology market, contributing to the country's export potential and reducing its reliance on imported technologies.

The Threshing Activator stands as a pioneering solution that addresses several critical challenges in grain harvesting. Its innovative design improves the efficiency of harvesting equipment, reduces crop losses, and provides significant cost savings through its low metal consumption and ease of repair. Moreover, its versatility in application across various crop types and agro-climatic zones, along with its compatibility with existing harvesting machinery, ensures broad adoption potential.

By reducing technological dependence on foreign machinery, promoting local innovations, and supporting the educational sector, the Threshing Activator aligns with the strategic goals of modernizing Kazakhstan's agricultural industry. This technology not only enhances domestic productivity but also positions Kazakhstan as an emerging leader in the global agricultural machinery market. The continued development and implementation of such innovations will significantly contribute to the sustainability and growth of the agricultural sector, benefiting both local farmers and the broader economy.

2.4 Conclusion

The development of an innovative biomass distributor module for harvesting machinery, aimed at minimizing crop losses and enhancing productivity, addresses critical issues in modern agricultural practices. As part of the project "Organization of the production of an efficient and innovative Biomass Distributor Module," this new Threshing Activator design presents a significant advancement in the efficiency and quality of grain harvesting operations.

The proposed design is scientifically grounded in principles of mechanical and technological optimization. By improving the leveling coefficient of the grain mass before and after threshing, the Threshing Activator effectively reduces both quantitative and qualitative losses of the productive part of the harvested crop. This ensures that a larger proportion of the crop is retained, contributing to better yields and a higher quality of harvested grain.

Moreover, the innovative design enhances the distribution of plant material, such as heads and stems, across the threshing width, reducing stress on critical components like the straw walker and cleaning systems. This results in a more balanced and efficient operation of the harvester, ensuring that the equipment's throughput is maximized without excessive wear or strain on individual systems. The reduced load on the cleaning and separation units further contributes to a higher-quality final product with minimal contaminants, thus improving the overall performance and reliability of the harvesting process.

From a mechanical perspective, the Threshing Activator is designed for ease of operation and maintenance. The replaceability of active elements in the device not only reduces metal consumption but also improves the durability and repairability of the machine. Additionally, the simple and modular design allows for cost-efficient production and easy integration into existing harvesting machines, enhancing their performance across a wide variety of crops, including grains, oilseeds, and forage crops.

The innovation introduced by this module has broader implications for reducing Kazakhstan's technological dependence on foreign developments. With domestic production capabilities bolstered by this innovation, Kazakhstan's agricultural sector will be better equipped to meet the growing demands of both local and international markets. Furthermore, the utilization of advanced modeling techniques, including 3D printing of component modules, ensures that the manufacturing process is both cost-effective and scalable. This method also opens opportunities for academic institutions to incorporate the technology into educational curricula, fostering stronger connections between scientific research, engineering education, and practical business applications.

The Threshing Activator complies with international quality standards, ensuring its compatibility with a wide range of harvesting machines, with throughput capacities ranging from 3 to 15 kg/s and header widths of up to 8 meters. This versatility makes it suitable for use across various agro-climatic zones and fields with different yield potential, addressing the diverse needs of farmers and agricultural enterprises.

In terms of operational efficiency, the application of this innovative technology can significantly reduce the biomass layer in the threshing drum, which not only increases the harvester's throughput but also leads to a reduction in energy consumption. By improving the overall efficiency of the threshing process, the Threshing Activator contributes to the reduction of operational costs and supports sustainable farming practices. Additionally, the thinning of the biomass layer facilitates a more efficient separation of the grain, reducing the need for extended processing times and improving the overall productivity of the equipment.

The introduction of the Threshing Activator holds the potential to revolutionize the grain harvesting process, particularly in Kazakhstan's context, where agriculture plays a critical role in the national economy. By minimizing losses and enhancing efficiency, the technology provides clear benefits for the local agricultural sector, ensuring that the country can maintain its competitiveness in the global grain market. Moreover, the mass production of this innovation will create new jobs, stimulate technological advancement in the agricultural machinery sector, and enhance the export potential of Kazakhstan's agricultural products.

The innovative nature of this project not only promises to strengthen Kazakhstan's domestic industry but also provides a sustainable and export-oriented solution that addresses the global demand for more efficient and environmentally-friendly agricultural technologies. The implementation of this biomass distributor module is a significant step toward transforming the agro-industrial sector into a more technologically advanced and innovative component of Kazakhstan's economy.

In conclusion, the Threshing Activator is a breakthrough in agricultural engineering that aligns with the project's goals of improving productivity, reducing crop losses, and enhancing the efficiency of harvesting processes. The successful integration of this technology into Kazakhstan's grain production system would not only contribute to higher yields and better-quality crops but also establish the country as a leader in agricultural innovation. Future research and development efforts should focus on further optimizing the design, expanding its applications to other crop types, and ensuring its scalability for widespread adoption across diverse farming environments.

2.5. Literature

1. Sadykov Zh.S., Makasheva E.D. Method for processing mown grain mass in a harvesting machine and device for its implementation // Eurasian patent. Patent number: 044624. Date of publication and issue of the patent 2023.09.18. https://www.eapo.org/, Moscow

2. Sadykov Zh.S., Makasheva E.D. Method for processing mown grain mass in a harvesting machine and device for its implementation // Patent for invention KZ No. 36876, published.. 23.08.2024 // National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan, Astana

3. Sadykov Zh.S. and others. Broom-distributing device for a grain harvester // Description of the invention to patent KZ No. 25772.

4. Threshing activator. Links to the website of the Eurasian Union of States: - https://rosorgkomitet.ru/content/nominees/354; - https://rosorgkomitet.ru/content/comp