IMPROVEMENT OF CEREAL PRODUCT PROCESSING TECHNOLOGY.

Aslonov Javlon Farmonovich
Asian International University, Bukhara, Uzbekistan.

Abstract: *The article describes the characteristics of separation of grain mixtures in different types of separators. Digitization in the grain processing industry enables the development of mathematical models of mass service distribution systems. Algorithms for the analysis of the physical properties of the grain mass have been developed. The study of wheat processing products is based on the analysis of milled grain using computer vision methods and artificial neural networks developed by software tools. The developed classification of grain grinding particles by their geometric properties allows to predict the technological characteristics of wheat quality, in particular, its grain hardness index, with high accuracy (estimation error no more than 3.7%).*

Keywords: *grain, wheat, grain processing, technology, microelement, research.*

СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИИ ПЕРЕРАБОТКИ ЗЕРНОВЫХ ПРОДУКТОВ.

Аннотация: *В статье рассмотрены особенности разделения зерновых смесей в сепараторах разных типов. Цифровизация в зерноперерабатывающей промышленности позволяет разрабатывать математические модели систем массового обслуживания-распределения. Разработаны алгоритмы анализа физических свойств зерновой массы. Исследование продуктов переработки пшеницы основано на анализе измельченного зерна с использованием методов компьютерного зрения и искусственных нейронных сетей, разработанных программными средствами. Разработанная классификация частиц помола зерна по их геометрическим свойствам позволяет с высокой точностью (погрешность оценки не более 3,7%) прогнозировать технологические характеристики качества пшеницы, в частности показатель ее твердозерности.*

Ключевые слова: *зерно, пшеница, переработка зерна, технология, микроэлемент, исследования.*

RELEVANCE

In the countries of the European Union, grain crops are highly dependent on the weather conditions of the year. Thus, 9.65 million tonnes were collected in the UK in 2020 [1]. This is 40.5 percent less than in 2019, which is explained by the reduction in planting of winter wheat by farmers after the wet fall of 2019. Also, the low wheat harvest was aggravated by the following dry spring. In 2020, the wheat harvest in Russia amounted to about 88 million tonnes. In the next five years, Russian farmers will expand the area sown by 40% due to the introduction of new wheat varieties and the modernization of production technologies. This allows to increase the production of durum wheat to 2 million tons per year [2]. Stimulation of durum wheat production is supported by subsidies at the federal level - an appropriate draft regulation was prepared on the allocation of subsidies for the cultivation of such grain [3].

Digitization of the selection of the operating mode of equipment for separating wheat grain is relevant. An important aspect of improving grain processing efficiency is the development of models of the separation process [4].

Modern developments in the field of information technologies allow to modernize existing information and measurement systems for grain processing and develop new ones by developing algorithms for analyzing the physical properties of grain mass [5].

Research materials and methods. 14 varieties of wheat from the Bukhara region participated in the study, their natural weight was from 720 g to 850 g, moisture content was from 12.5% to 14.7%, and vitreous content was from 45% to 100%.

Smoothing properties. Grain testing was done in a laboratory mill to obtain grain grinding samples. From each sample, 10 kg of grain was ground. Grinding was performed using five grinding systems with high flow selection [6], [7], [8].

Fractographic analysis of the milled particles was carried out using a laboratory device (SonyIMX digital camera, RaspberryPi4 mini-computer) to analyze the particle images using software created using OpenCV technical vision libraries and Deeplearning4 artificial neural network libraries [9].

Results and discussion. The result of separation of grain mixtures in the separator is determined by two types of accidents. The first (mass) is characterized by the interaction of particles with a high concentration in the separating organ, some particles prevent others from separating without obstacles. The second (individual) is determined in the absence of mass randomness, when single particles are separated at a very low concentration of the grain flow. In this case, the result of the separation is also unknown in advance, because the direction of the grain in the separator is random [10], [11], [12]. Within this approach, the probability distribution result naturally takes into account the effects of both components. When creating models of public service separation systems, the following is necessary:

- imagine the working element as a parallel-series system of separating elements that act as channels (devices) of separation systems (trier cells, sieve holes, elementary volumes of the air channel, etc.);

- expressing the intensity of incoming and outgoing grain flows through the technological characteristics of the separator, in particular, its productivity;

- determining the discipline of serving (allocating) grain particles (requests) in the elements of the working body: sequence, level of reliability, patience, priority, etc.;

- description of the possible states of the working element (there are no serviceable grains; one grain; two; three, etc.) [13].

The model defined in this way allows to obtain equations for calculating the probabilistic properties of the separation system using standard methods for mass service theory [14].

Research has shown that the outcome of separation naturally depends on the individual and mass components of the randomness of the separation process. However, it predicts the existence of two dissociative groups, one of which allows single-particle separation and the other does not. The first group includes most of the known types of separators (air, screen, electric, magnetic, optical, etc.), and the second group includes disk separators and high-density screen modules, which are distinguished by slightly larger screen opening sizes than only separated particles. In addition, it clearly reflects certain experimental dependences of the separation quality on the specific load and speed of the grain flow, productivity, etc. [15].

It is necessary to study the state of the separator system when its productivity tends to zero, which physically represents the separation of single particles, and therefore requires the use of classical models of known separators, that is, such models, which are nothing more than known equations of dynamics. The nature of such equations is determined by the initial conditions of motion, the physical properties of grain particles, and the operating modes of the separator. With sufficient computing power, it is possible to calculate the probability of extracting different components of grain mixtures at very low productivity for different types of separators in any mode. Thus, the proposed approach to modeling made it possible to practically calculate (predict) the required quality indicators (yield and composition of the mixture components in fractions) for various types of separators in any operating modes, including productivity.

Based on the models of individual separators, it was possible to predict the quality of the separation of mixtures in grain cleaning technological lines and to solve the following optimization problems:

- cleaning of the grain batch (the composition and composition of the mixture components are known) according to the fixed technological line (the number of separators, their type and installation sequence are known) in the specified operating modes of each separator; the model responds to how this mixture is purified and formed to meet the requirements of GOST;

- grain batch cleaning that meets GOST requirements in a strict technological line; the model determines whether all separators on this line should work in what modes, which fractions will be the main and what output, how much more than the main line;

- grain batch cleaning that meets GOST requirements on a flexible technological line; The model determines the number, type and sequence of separators in such a line, the main fractions and operating modes of each separator, the yield of refined grain and the excess amount compared to the main line.

The digitalization of the grain processing industry includes methods for assessing grain quality based on various physicochemical indicators. So, there are methods for assessing grain contamination and glassiness using computer vision algorithms. To increase the efficiency of grain cleaning machines, methods of separating impurities from grain according to their optical properties are used - photo separation or photo cleaning. High-speed scanning of the grain mass and subsequent processing of the image according to a preset algorithm (differentiating criterion) are used to separate the photographs. Grain can be sorted by size, color, shape, and other characteristics.

The raw grain in the stream is evenly distributed in one layer thanks to vibrating feeders, which allows scanning the image of each individual particle. The selection of particles is carried out with the help of air currents (due to the pneumatic ejector), by directing impurities or poor-quality grain to the waste container. Modern methods of separation of photos allow to sort raw materials according to the whole set of individual and general characteristics, to get a product with the best technological properties.

Additional information about the quality of the studied raw material can be obtained by using visible light instead of light. In the practice of the flour processing industry, grain vitreousness index is often used to classify grain, but this index does not fully describe the milling quality of different wheat varieties (genotypic factor). Variability of glassiness is also related to soil, climate and agrotechnical conditions (phenotypic factor). Considering this, it is proposed to use the grain hardness index to quantitatively assess the consistency and to determine the strength properties of the grain. Direct methods of determining this indicator using hardness tests require a lot of work and therefore have not been used in practice.

The study used computer vision and artificial neural networks to locate and classify grain grinding particles based on geometrical characteristics. The characteristics of the contours of images of grinding particles are taken into account.

Conclusion. Based on obtained mathematical models of grain processing, software tools have been developed to improve quality prediction and optimize grain separation. The characteristics of the formation of wheat firmness qualities were determined, and a methodology for grain hardness assessment was developed using modern digitization tools in the grain processing industry.

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