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Fractional Technology and Tools for Post-Harvest Grain Treatment and Processing with Crushing

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Abstract. The use of fractional technologies for post-harvest treatment and processing of grain heap delivered from field with further special purpose use of grain fractions leads to a significant increase in grain production efficiency. (*Research purpose*) Developing a fractional technology for post-harvest treatment and processing of grain with crushing and preservation of feed grain fraction and designing a technological line and machines for it. (*Materials and methods*) The authors have analyzed the technological level and developed a fractional technology for grain post-harvest treatment and processing by crushing with subsequent preservation of the feed grain fraction. They have offered a technological line and presented the design and technological parameters of the corresponding technical means (МЗУ-20Д - grain cleaning universal machine, МПО-30ДФ - preliminary grain cleaning machine with fractionation, ПЗД-3,1, ПЗД-10 – two-stage grain crusher). (*Results and discussion*) The authors have designed, manufactured and tested a universal grain-cleaning machine МЗУ-20Д. It efficiently cleans grain material coming from the field after its threshing by combine harvesters, and divides it into fractions: seed and feed grain – 60-70 percent, waste material - up to 10 percent, grain fodder - up to 40 percent. Further on, the grain is sent for crushing (for wet grain), followed by preservation and hermetic storage of the products obtained before their feeding to animals. Tests have shown that the developed feed preparation machine efficiently performs the technological process. The authors have developed a two-stage grain crusher (ПЗД-3,1), performing the crushing of grain material in two stages by three rollers, followed by preservation (for wet grain) of the feed grain fraction. (*Conclusions*) It has been established that the use of the new fractional technology and equipment contributes to an increase in grain cleaning productivity – by 30-40 percent, and the estimated annual economic effect of the renovation is 400,000 rubles. The estimated annual economic effect of the use of the two-stage grain crusher (ПЗД-3,1) has proved to be more than 60 thousand rubles, and the level of production intensification has increased by 26 percent as compared to the MURSKA crusher produced in Finland.

Keywords: grain, fractionation, technology, preservation, foreign matter, crushing, cleaning.

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The use of fractional technology for post-harvest processing (or a technology for the special-purpose (targeted) use of products) of a grain heap coming from the field after combine harvesting to post-harvest grain processing stations with further targeted use of grain fractions and the production of finished products from them contributes to a significant increase in the efficiency of the entire grain production sector. In this respect, the reconstruction of grain cleaning and drying facilities, their technological lines and corresponding technical means is one of the important tasks of farm production modernization. To solve this problem, the designers of FASC together with those from North-East Farming Research Institute have been developing new technologies and technological lines, for example, fractional technology of post-harvest grain processing and technology for processing feed grain for the production of final products (ready-made animal feed) – crushed preserved wet grain, as well as technical means for the implementation of these processes - fractional grain cleaning machines and a grain crusher.

The study purpose is the development of fractional technology for crushing and preserving of feed grain, the technological line and technical means for its implementation; development of a machine for grain material fractionation with its cleaning from impurities and a two-stage conditioner for dry and wet grain.

Materials and methods. Existing stations and facilities of post-harvest grain processing do not provide the required deep processing, which is necessary in particular for the production of concentrated (grain) feeds for livestock that are directly suitable for feeding [1, 2]. In FASC North-East, a constructive technological

scheme for fractional processing and treatment of grain material (heap) has been developed, with the feed fraction being separated and its subsequent crushing and preserving (*Fig. 1*) [3-5]. It operates as follows. The grain heap is fed from a pit (ЗЯ) or an air duct into the grain pre-treatment machine (МПО), where it is cleaned from impurities by the air flow and on the grate mills, and is also divided into the main (seed and food grains, 60-70%), feed fraction (up to 40%) and waste material (5%). The main fraction – pure grain - is transported through grain lines to the hopper of the wet grain storage (БРВЗ), where it is further processed with common technologies. The cleaned feed fraction is fed to the wet feed grain hopper (БВФЗ).

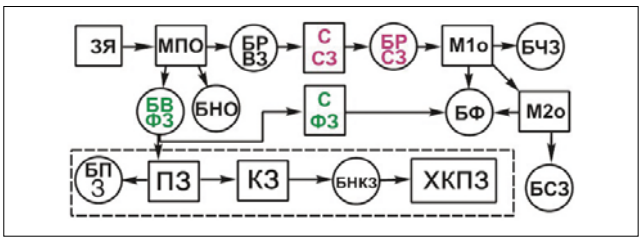

Fig. 1. Scheme of fractional technology of grain processing with its subsequent crushing: ЗЯ – dammed pit; МПО – grain cleaning machine; СС3, СФЗ – grain driers; М1о, М2о – dry grain cleaning machines; ПЗ – grain crusher; КЗ – grain preservation; БНО, БРВ3, БРС3, БФ, БЧЗ, БС3, БП3, БНКЗ – grain hoppers; ХКП3 – crushed grain storage

In accordance with the common technologies for post-harvest processing of grain heaps, wet feed grain is fed to a feed grain dryer (СФЗ) with a rigid drying mode or is preserved [4]. Waste material separated by МПО from grain material are sent to the unused waste hopper (БНО). The amount of feed grain received in the БВФЗ hopper makes up for 30-40% of the total amount coming from the field, and its quality must satisfy the livestock breeding requirements for the technology of preparation of concentrated forages and meet the requirements of GOST 9267-68, GOST 9268-90, GOST 18221-72.

In the proposed (new) technology, the feed grain fraction extracted from the impurities by the grain cleaning machine is fed through grain lines from the БВФЗ hopper for crushing, which is provided by a machine for preparing concentrated feeds – the grain crushing unit (ПЗ), and the feed products (crushed grain) produced by it must meet the requirements of TU8- 22-39-88. The obtained crushed grain is fed to the hopper-storage unit БПЗ, from which it comes as a full-value concentrated feed either for feeding animals or for preserving (КЗ). Crushed preserved grain is fed to the storage hopper БКПЗ, from which it is taken for storage.

Results and discussion. Increasing the efficiency of post-harvest grain processing requires the reconstruction of grain cleaning and drying lines of grain post-harvest processing facilities with a possibility of applying grain-crushing technologies [6]. To solve this problem, the designers of the North-East Farming Research Institute have developed a technological line (*Fig. 2*) installed at the grain processing facility in farm enterprise «Zarya», the Nagorsk district of the Kirov region.

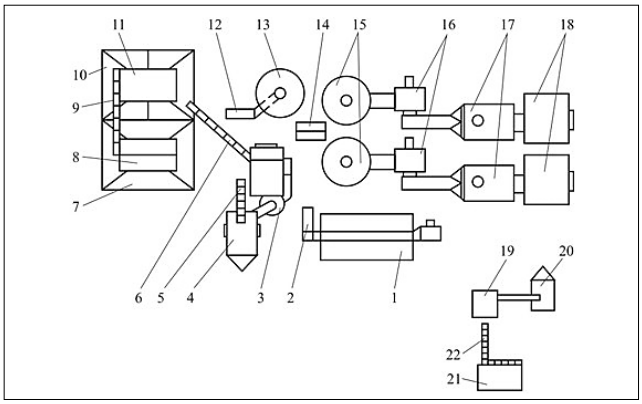

Fig. 2. Technological scheme of seed-cleaning and drying of complex post-harvest grain processing in the Zarya farm enterprise, the Nagorsk district of the Kirov region:
1 – air slide; 2, 12, 14 – cup-type elevators; 3 – grain pre-cleaning machine with fractionation (optional) МПО-30ДФ; 4 – waste material hopper; 5, 6, 9, 22 – transporters; 7, 10 – a pack of grain bins; 8 – screening separator; 11 – secondary cleaning machine; 13 – grain binning hopper; 15 – drying bin; 16, 17, 18 – dry grain processing machine; 19 – crusher; 20 – trailer; 21 – intake hopper

The technological process of the facility is a sequence of certain operations. The wet grain pile is unloaded into the receiving device with an air duct, from where it flows to the cup-type elevator, which feeds it to the grain pre-treater with a possibility of fractionation МПО-30ДФ. The cleaned grain is also fed by a scraper conveyor to the hopper of the wet grain section or gravity feed to one of the cup-type elevator sections that loads the drying hoppers. Further, the dried grain discharged into the second section of the cup-type elevator is sent to the hoppers for cooling and resting, and then fed by the cup-type elevator into the secondary cleaning machine. The separated grain is sent by the transporter to the screening cleaning and then to the pure grain hopper, from where it enters the storage area of finished products.

Feed waste from the screening unit and the secondary cleaning machine МВО-8Д are loaded into the dry feed grain section of the hopper. Grain material that enters the hopper section of wet grain is unloaded into vehicles and transported under a canopy to the receiving hopper and then fed into the crusher via a scraper conveyor. The preservative-treated crushed grain is loaded with a conditioner auger into the trailer and sent for storage or used for animal feed. It is also possible to crush dry feed grain from the hopper.

The use of the new fractional technology and equipment in the reconstruction of the grain cleaning and drying facilities located in the «Zarya» farm enterprise, the Nagorsk district of the Kirov region, has contributed to an increase in its productivity of up to 30-40%, and the estimated annual economic effect from the renovation of the considered facilities has accounted for 400 thousand rubles.

To increase the efficiency of agricultural technologies for post-harvest (including fractional) treatment and grain processing, the experts of the North-East Farming Research Institute have developed grain cleaning machines and grain crushers and started their production [7-10].

Taking into account the results of experimental studies of the post-harvest grain treatment and processing, as well as the analysis and monitoring of key indicators and corresponding technical means, the universal grain cleaner МЗУ-20Д (patents N2513391 RU, N2371262 RU) has been developed. The device is intended for fractionation of grain and seeds of different crops, their primary and secondary cleaning from impurities and can be used in practically all agricultural zones of the Russian Federation.

The operating principle of the technological scheme (*Fig. 3*) of the offered grain-cleaning machine is as follows. The grain mixture is fed through the grain line into the feeder, being evenly distributed by the scraping screw along the machine width, and then fed to the first pneumatic separating channel where the airflow from the cereal mixture carries away light impurities (chaff, straw particles, weed seeds, and dust). After cleaning in the first pneumatic channel, the material enters the upper screen of the screening mill, which separates larger impurities leaving the machine, while cleaned grain enters the middle grating sieve. The middle sieve separates large-sized pure grain (a fraction of seed and food grain), which falls into the second pneumatic separating channel, where light impurities are separated. On the lower sieve small impurities are separated and pass through the lower sieve and the bottom of the lower sieve mill and are discharged from the machine through the tray. Grain (the fraction of feed grain) going overtail is fed into the third pneumatic duct, cleaned rom impurities, and afterwards taken out and sent to the crushing unit. The air stream with light impurities from the first pneumatic channel is sequentially fed to the first dust-settling chamber, then to the second one and is fed by the diametric fan into the sediment chamber of the dust collector. The impurities trapped in the chambers are discharged by the screws outside the machine. Thus, the grain-cleaning machine МЗУ-20Д provides the output of the cleaned feed grain fraction (going overtail from the lower sieve) for its subsequent crushing and preserving (for wet grain).

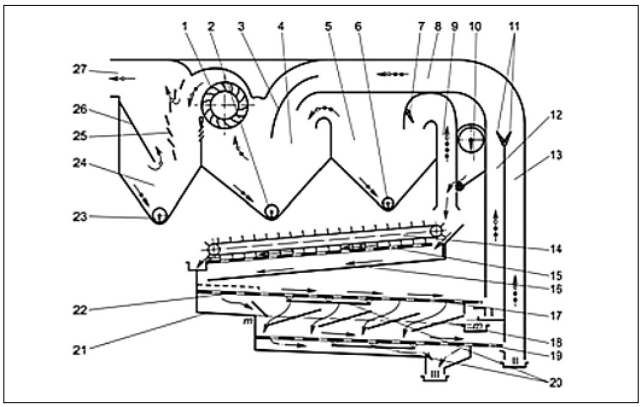

Fig. 3. Flow chart and general view of the universal grain cleaning machine (МЗУ-20Д):
1 – feeding device; 2 – first pneumatic separating channel; 3 – upper sieve; 4 – upper grating; 5 – average dividing sieve; 6 – second pneumatic separating channel; 7 – the bottom part of the lower grating mill; 8, 9 – first and second dust chamber; 10 – diametral fan; 11 – sedimentary chamber of the dust collector

An experimental model of the universal grain cleaning machine МЗУ-20Д has been made. Specialists of the Kirov machine testing station have conducted preliminary tests of the machine in the «Rassvet» farm enterprise of the Nema district of the Kirov region. According to their results, it has been established that this model qualitatively implements the technological process of grain material cleaning from light, large and small impurities, and its design and technological parameters comply with the requirements of technical design specification and ND, in particular, in terms of its designation, energy estimate and design safety. The machine meets the requirements of the technology of post-harvest processing of grain and seeds and can be successfully used in agricultural enterprises. The Kirov machine testing station recommends that the grain-cleaning machine MZU-20D should be subjected to acceptance testing.

For the production of crushed grain feed, including feed grain fraction extracted from the grain heap coming from combine threshing and cleaned from impurities by the aforementioned grain cleaning machines, a two-step grain conditioner (ПЗД-3.1) with

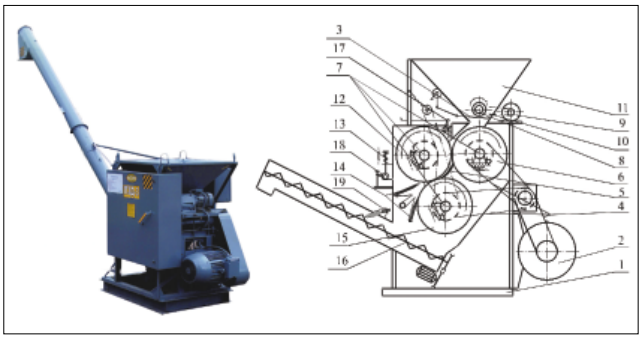

Fig. 4. General view and scheme of ПЗД-3,1 grain crusher: 1 – frame; 2, 9 – electric motor; 3 – flap; 4 – belt drive; 5 – cleaning knife; 6 – upper shaft; 7 – supports; 8 – feeder; 10 – chain drive; 11 – feed hopper; 12-side shaft; 13 – protective device; 14 – cleaning knives; 15 – lower shaft; 16 – discharge conveyor; 17, 18 – gap regulators; 19 – nozzle

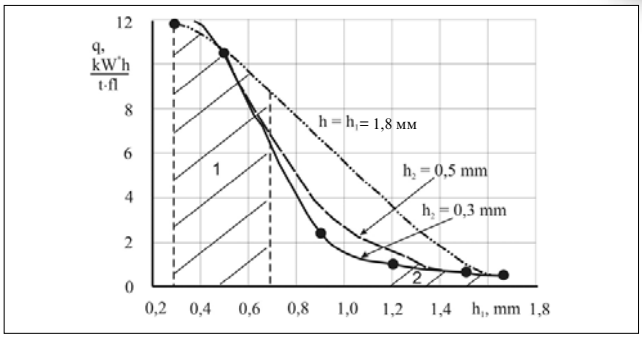

Fig. 5. Dependence of specific energy consumption change q on the input flange clearance h_1 of the first stage of crushing

a productivity of 3 t/h, a general view and a technological design scheme of which are presented in *Fig. 4*.

To determine a two-stage working process of producing crushed feed grain, experiments have been carried out for single- and two-stage grain crushing, which has made it possible to determine the influence of various design and technological factors on the throughput capacity, the power consumption of the roller machine (grain conditioner-crusher) and the quality of the finished product. This allows assessing the application feasibility of two-stage crushing as compared with the single-stage one.

Basing on the results of the experimental studies, graphs of the dependence of the change in the specific energy consumption q on the input interval face gap h1 of the first stage for single-stage and two-stage crushing have been plotted (*Fig. 5*).

Fig. 5 shows zone 1 for single-stage crushing and zone 2 for two-stage crushing, which determine the range of using the finished product that corresponds to the livestock breeding requirements, based on the output inter-roller gap. The analysis of these zones shows that the use of two-stage crushing as compared to the single-stage one reduces the specific energy consumption in several times (the difference in the areas of zones 1 and 2). In addition, the use of two-stage crushing allows the grain to be crushed by rollers with a smooth working surface of a larger capacity, with a lower energy intensity of the process, with the output of flakes meeting the livestock breeding requirements, which indicates the high efficiency of its application.

Taking into account these studies, a prototype of the grain crusher ПЗД-3.1 has been developed, manufactured and tested in production conditions. The authors provide the economic estimation of technical means for crushing grain of various crops with simultaneous application of preservatives. The analogue for the calculation of economic efficiency is a single-stage grain harvester with two grooved rollers with a possibility of simultaneous application of the MURSKA-350S preservative. According to the calculations, the annual economic effect of the use of a technical means for grain crushing with simultaneous application of preservatives ПЗД-3.1 (with an annual load of 1000 tons on the conditioner) is ЭГ = 60,833 rubles, and the level of intensification of agricultural production for ПЗД-3.1 has amounted to 26% as compared with MURSKA-350S crusher manufactured in Finland.

Conclusions. The task of increasing the efficiency of post-harvest treatment and grain processing is solved by the method of reconstructing grain cleaning and drying facilities. This will allow, for example, to use the fractional technology of crushing and preserving wet feed grain, to increase the productivity of the whole complex by 30-40%, and to obtain a crushed grain feed directly at the points of production and processing of raw materials.

The use of new air-screening machines in the post-harvest grain processing lines allows the efficient fractionation of the grain heap coming in for processing, and the obtained grain fractions are used for their technological purpose: obtaining seeds and food from high-grade grain and ready-made crushed feed for various groups of farm animals from forage grain. The use of a machine for producing crushed feed – a two-stage grain crusher (ПЗД-3.1) significantly reduces the cost of feed production, for example, the estimated annual economic effect of using a two-stage grain crusher (ПЗД-3.1) instead of MURSKA-350S amount to ЭГ = 60,833 rubles, and the level of intensification is expected to reach 26%.

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Conflict of interest.
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