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Зернові продукти і комбікорми

Зерновые продукты и комбикорма

Grain Products and Mixed Fodder's

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CONTENT

ЗМІСТ

Журнал „Зернові продукти і комбікорми" згідно до наказу МОН України № 1301 від 15.10.2019 (Додаток 8) входить до списку друкованих (електронних) періодичних видань, що включаються до Переліку наукових фахових видань України категорії Б, в яких можуть публікуватися основні результати дисертаційних робіт на здобуття наукових ступенів доктора і кандидата технічних наук спеціальності 181

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НАСІННЯ КУКУРУДЗИ КАЛІБРОВКА, НОВІ РЕШЕННЯ

Останні дослідження показали значимість двох параметрів, що впливають на врожайність кукурудзи - масаи 1000 зерен насіння і глибини сівби.

Узагальнені результати дослідження зазначеної залежності за три роки (2014 ... 2016 рр.) та по шести гібридам наведені на рис. 1.

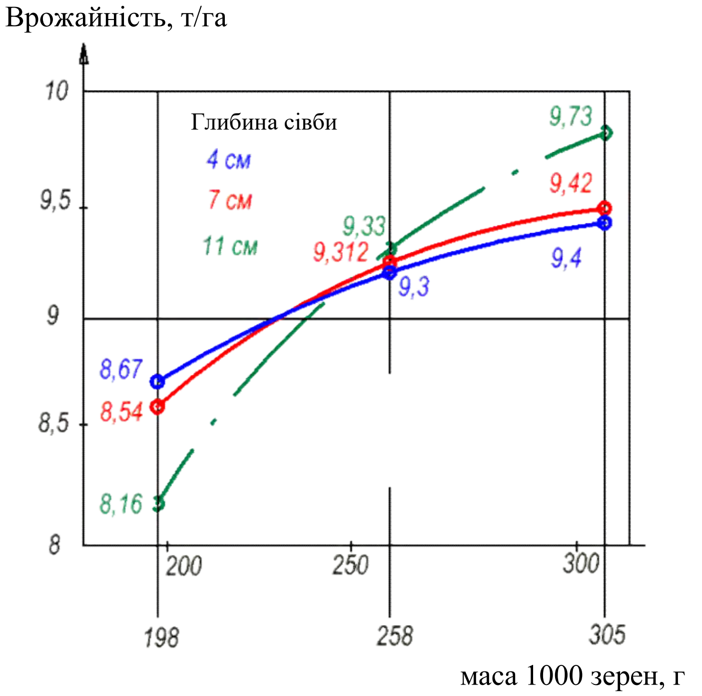


Рис. 1 - Залежність врожайності від маси 1000 зерен насіння кукурудзи та глибини сівби

Закономірності (рис. 1) легко пояснити: чим вище маса 1000 шт. насіння, тим вище врожайність, і велике насіння необхідно сіяти глибше (в експерименті 11 см). Це зрозуміло, оскільки на такій глибині велике насіння отримуює достатньо вологи для набухання, а кількість поживних речовин виявляється достатнім для дружного проростання з такої глибини.

Картина досліджень була б більш повною якби насіння кожної фракції, розділене по масі 1000 шт., було б розділено за формою - на округлі і на плоскі.

Насіння в качані кукурудзи (як насіння і у всіх інших рослин) отримує харчування вибірково. В першу чергу, харчування в процесі формування качана кукурудзи в повній мірі надходить до насіння в середині качана.

Незважаючи на те, що насіння середини качана поступається по крупності насінню в його нижній частині, у них є відмітна ознака - вони щільніше насіння нижньої і верхньої частини качана.

У цих насінь вище сила зростання і вище продуктивність. Саме це насіння ми називаємо сильними (рис. 3).

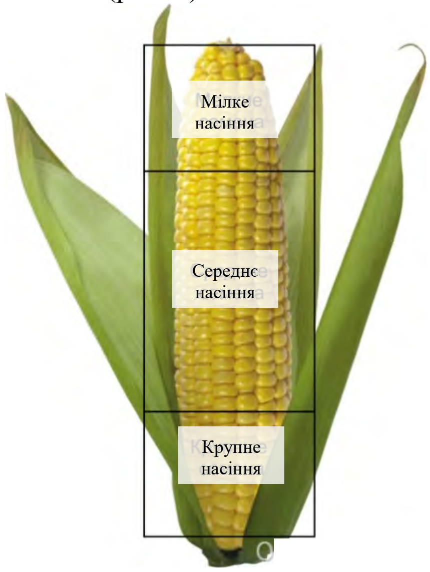


Рис. 2 – Розподіл насіння кукурудзи в качані по крупності

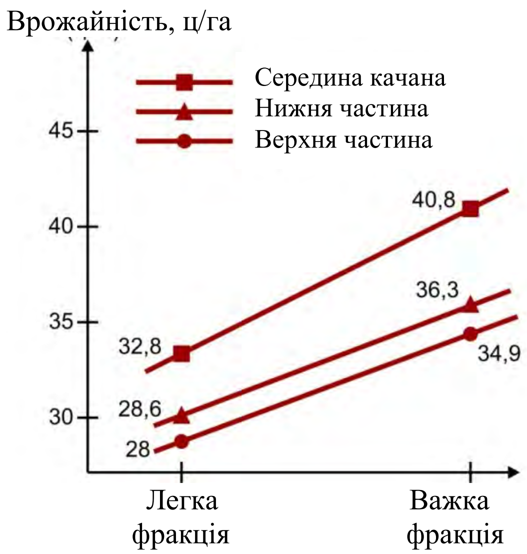


Рис. 3 – Залежність врожайності кукурудзи від щільності насіння і місця їх розташувавння в качані (Макрушин М.М., 1994 р.)

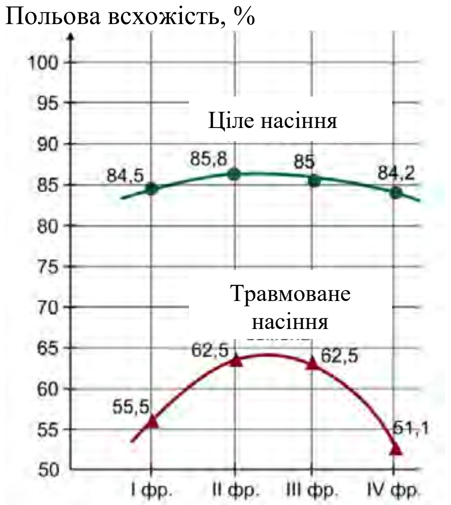


Рис. 4 - Польова всхожість цілого і травмованого насіння кукурудзи (гибрид) ВИР-25 (Строна І.Г. 1972 р.)

Рис. 5 - Форма насіння кукурудзи з різних участків качана

Польова всхожість насіння кукурудзи також підтверджує кращі посівні якості насіння центральної частини качана (рис. 4).

Подібні дослідження проводилися ще 25 років тому.

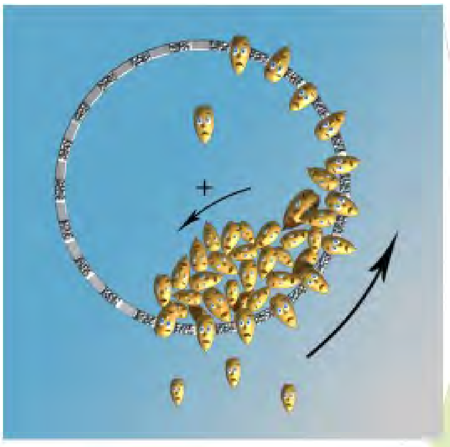


Рис. 6 - Робочий процес калібровки насіння кукурудзи у барабанному сепараторі

Деякі фахівці рекомендують для калібрування насіння кукурудзи застосовувати барабанні сепаратори (рис. 6).

Категорично з цим не згоден з двох причин:

1. Барабанний сепаратор травмує насіння. В процесі пересипання маси насіння в такому сепараторі «рушієм» є зерна, що застрягли в отворах як штифти, і кожна семянка під дією купи навантажується на вигин і на злам, як затиснена балка.

2. За такою технологією отримати чітку калібровку насіння кукурудзи неможливо.

Якщо ми розглянемо форму насіння, то побачимо, що саме сильне насіння має більш плоску форму, в порівнянні з насінням нижньої і верхньої частини качана.

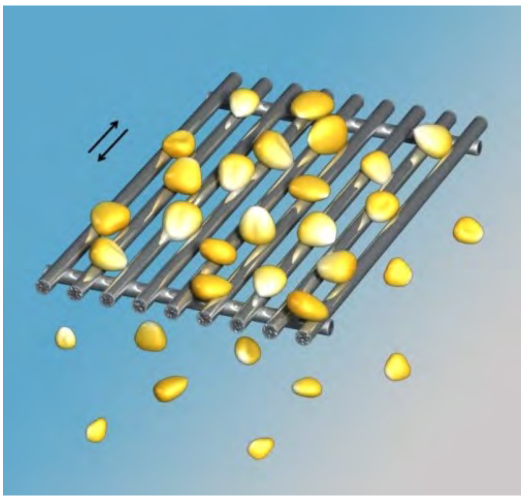


Рис. 7 - Калібровка по виконаності кукурудзи

Саме тому, ми пропонуємо технологію підготовки насіння кукурудзи, а точніше лінію з калібрування насіння, яка дозволяє відібрати по формі найбільш продуктивне насіння. Частка цього насіння в качанах складає близько 75 %.

На верхній ярус розсівів, що калібрують, встановлюються сита Фадєєва (з гексагональними отворами), проникність яких набагато вище, ніж на ситах з круглими отворами, а на нижній ярус розсівів, що калібрують, встановлюються сита Фадєєва, на яких насінина кукурудзи повертається і приміряється до калібра сита товщиною. Плоскі проходять, округлі сходять. І так кожна фракція по ширині ділиться на округлі і плоскі по товщині (рис. 7).

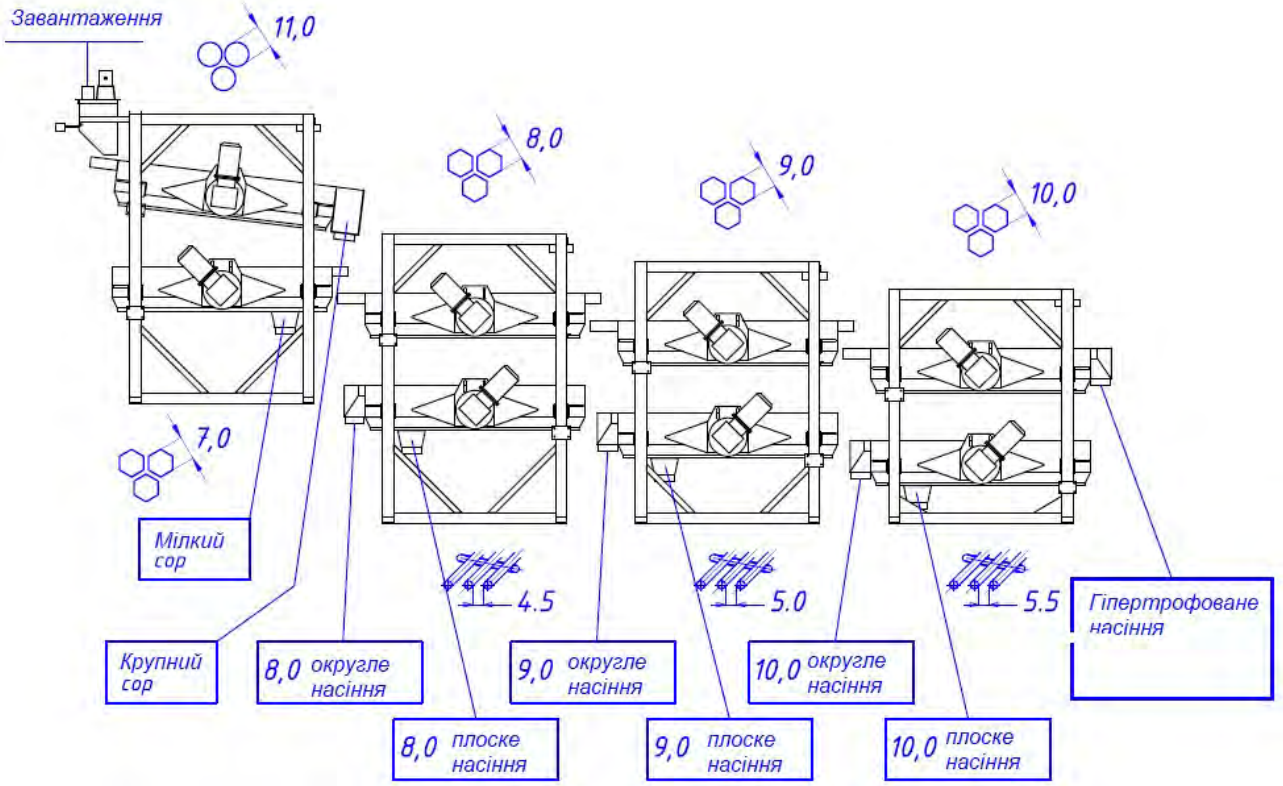
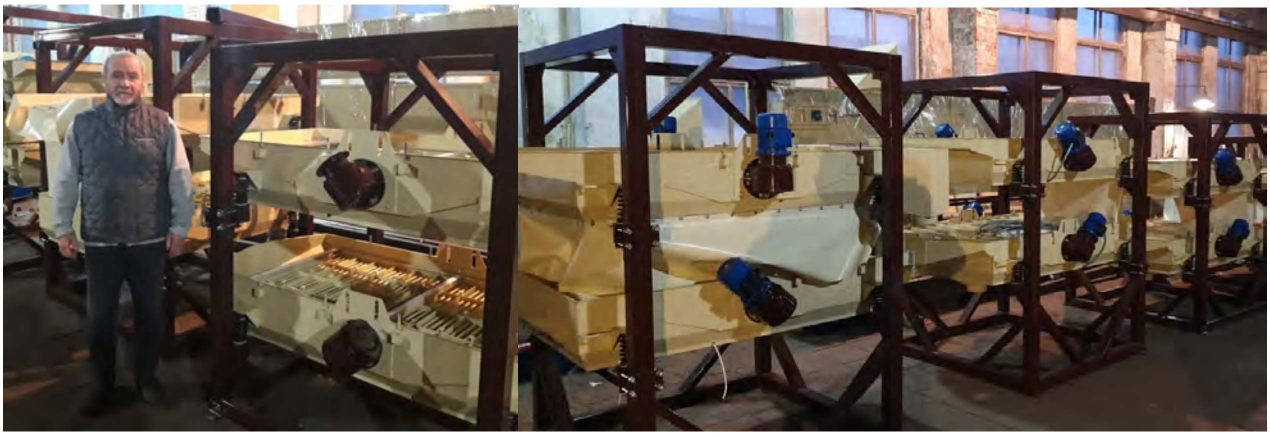


Рис. 8 - Схема компоновки лінії по очищенню і калібруванню насіння кукурудзи



Обладнання готове до відвантаження замовнику

На сьогоднішній день комплекс вже встановлений і працює.

Таким чином, на запропонованій нами лінії калібрування кукурудзи (рис. 8), з кожної фракції насіння, еталонних за розміром ширини насіння на верхніх ситах, будуть повністю вилучено щупле (низькопродуктивне) насіння на ситах нижнього ярусу розсівів. Саме тому така компоновка калібраторів представляється перспективною.

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INVESTIGATION OF CHARACTERISTICS OF THE GRAIN RECEIVING FROM RAILWAY TO THE GRAIN TRANSSHIPMENT TERMINAL

Abstract

In the future, in Ukraine it is planned to increase the sown area for cereals, legumes and oilseeds, to increase the gross grain harvest to 80 million tons, and its export abroad was increased twice. Intensive construction in the southern ports of Ukraine of grain transshipment terminals with large metal silos will solve the problem of increasing grain export in the future. At these powerful terminals, the bulk of the grain comes mainly by rail, and is shipped to water.

The aim of the work was to study the characteristics of the grain receiving from railway transport to the grain transshipment terminal of LLC "Ukrelevatorprom" in order to improve its works efficiency. The object of the study was the development of technology of grain receiving at the grain transshipment terminal; the subject of research is cereals, legume sand oil crops, as well as data from daily volumes of receiving and dispensing operations at the grain transshipment terminal of LLC "Ukrelevatorprom" for 2015-2016.

The studies were carried out on the basis of processing data from the consignment notes for 2015-2016, according to which there was a summed amount of grain (net) daily transported by the railway. Further processing of the obtained data was carried out by a combined graphoanalytical method, for which, on the basis of tabular values for each studied year, the corresponding histograms and graphs were built and the necessary indicators were determined.

Analysis of the structure of grain crops supplied by railway to LLC "Ukrelevatorprom" in 2015 and 2016 and their ratio showed that the main share was occupied by cereal crops (78.0 % and 73.1 % respectively), which were mainly represented by corn, share which was significantly dominated by other crops (wheat of various classes and barley) and amounted to 45.8 % and 44.5 %, respectively, which can be explained by its high demand in the international grain market, in which Ukraine occupies a leading position. Oilseeds (rapeseed) were taken in accordance with 19.1 % and 14.9 %, and legumes (soybeans) — 2.9 % and 12.0 %.

An analysis of the timing of the unloading of grain wagons (hopper cars) showed that the total duration of this process, depending on the crops, averages 37...59 minutes. The longest steps for unloading wagons are to determine the grain quality indicators, especially rapeseed, and to spill grain from the wagons, therefore, to reduce their duration, it is necessary to form feeds of wagons with grain batches of the same quality and use more modern express analyzers to determine grain quality indicators, which will increase the productivity of the grain receiving line from the railway. According to the research results, the enterprise has the potential to increase by about 30 % the volume of grain intake.

It was established that the periods of the grain receipt at the enterprise in 2015-2016 amounted to 349 and 353 days, respectively, the actual coefficients of the daily irregularity K_{daily} for the grain receipt from the railway in these years are equal to 1.47 and 1.52, and the monthly irregularity K_{month}, respectively 1.33 and 1.21, does not exceed the standard values K_{daily} = 2.5 and K_{month}= 2.0. This made it possible to clarify the database from the actual characteristics of the process of grain receiving by railway and can be used in design and verification calculations of equipment in technological lines for receiving grain from railway transport, and will contribute to increasing the efficiency of grain transshipment terminals.

Key words: *grain crops, grain receipts by railway, grain wagons, hopper car, timekeeping, uneven coefficients.*

Formulation of the problem

The development of the global crisis, as well as Ukraine's entry into the World Trade Organization, caused a need for a search for ways to improve the quality and volume of export of grain and food products. Ukraine accounts for 8.7 % of the world's area of black soil [1], which allows it to solve this problem. Already today Ukraine occupies a worthy place among world grain exporters.

In the future, in Ukraine it is planned to increase the sown area for cereals, legumes and oilseeds, to expand the gross grain harvest to 80 million tons, and to enlarge its export abroad in two times. Such a forecast makes the burning issue of a building new, as well as a reconstructing and expanding existing grain receiving enterprises (GRE) and elevators for various purposes, which are operated for 30 years or more.

However, the intensive construction in the southern ports of Ukraine of grain transshipment terminals with large-capacity metal silos will only solve the problem of exporting grain, which has been put in perspective, but not its post-harvest processing. Most of terminals receive the dry food grain from automobile and railway transport according to its commodity classification, such that it has already passed the post-harvest processing.

The total capacity of granaries in Ukraine, according to experts, is at least 35 million tons. Elevators account for about 40 % of the total grain storage capacity or 14 million tons of one-time storage. In the overall structure of the elevator industry, one tenth of all volumes of one-time grain storage is related to port capacities (approximately 3,500,000 tons). At the same time, port capacities for one-time storage of 200 thousand tons of grain are in state ownership (at Odessa and Nikolaev port elevators). A number of investors who entered the Ukrainian grain market began their own construction of the production facilities. Modern highly mechanized port elevators and terminals were built, the vast majority of which were metal silos only, oriented to export operations. Now in Ukraine more than 40 elevators of this type with a capacity of 15 to 200 thousand tons of one-time storage have been commissioned. The bulk of the grain goes to these elevators by railway, and is shipped to water transport [2].

The grain industry of Ukraine over the past decade has significantly increased exports. In the 2013/2014 marketing year (MY), it amounted to more than 30 million tons, which allowed to surpass Canada, Brazil, Argentina and enter the top three leading world grain exporters with the USA and the EU [3]. In the marketing season 2015-2016, Ukraine has exported 39.4 million tons of grains, which is 13 % more than during the previous 2014-2015 MY [4]. Over the past 10 years, Ukraine has record growth in grain exports up to 56.7 million tons in 2019, which is 4 times higher than grain exports in 2010 [5]. According to experts, by 2022 the volume of the grain production in Ukraine will increase to 100 million tons, and exports will reach 70 million tons [6]. Therefore, for further development of grain exports abroad, it is absolutely necessary to pay particular attention to grain terminals — to increase the efficiency of existing ones and to build modern new ones.

The purpose and objectives of the study

The purpose of the research was to study the characteristics of grain receiving from the railway transport to the grain transshipment terminal, which will improve its efficiency.

To accomplish this, the following tasks were required:

– to investigate the quantitative and qualitative characteristics of crops coming to the terminal;

– to conduct timing of the process of unloading grain from the railway and to determine the actual duration of unloading of hopper cars (hopper wagons);

– to determine the average daily actual productivity of grain reception by the railway and the coefficients of daily and monthly irregularity of grain intake for the studied period.

Object and subject of research

The object of the study was the development of technology of grain receiving at a new transshipment terminal; *the subject of research* was cereals, legumes and oilseeds grain, as well as data from daily intake operations at the grain transshipment terminal of LLC “Ukrelevatorprom” for two calendar years from January 1, 2015 to December 31, 2016.

The terminal was built as a modern enterprise; it is equipped with the latest technology. Part of the territory was created artificially, as is customary in the world practice of building elevators located on the seashore and where ships have recently moored, now unload wagons. The work of two sections that receive grain from road and railway transport provides high productivity — 120 hopper wagons (8400 tons of grain) and 200 hopper trucks (5000 tons of grain) per day.

Research methods

To determine the patterns of the quantitative and qualitative grain inflow to the terminal from the railway transport, the statistical material was collected, in which there was a summed amount of grain (net) daily transported by railway, it was based on the analysis and processing of data from consignment notes for 2015-2016. Summary results were entered in the table for each year of the grain receiving. Further analysis was carried out using the construction and analysis of histograms and graphs constructed on the basis of statistical data of the enterprise for the period from 01/01/2015 to 12/31/2016. When conducting research, methodological guidelines were used, which were developed at the Department of Grain Storage Technology of Odessa National Academy of Food Technologies [7].

To carry out timekeeping of the elevator’s external work in unloading grain-carrier hopper wagons (hopper cars), a number of successive steps were identified: installing a feed wagon at the “point” for unloading it, removing fillings from loading hatches, taking the grain samples from the wagon, performing analyzes and providing an enable signal for unloading grain from the wagon, removing seals from hatches under the wagon, opening latches under them, hanging panels of grain from the wagon and cleaning the wagon, closing the latches of hatches, cleaning the wagon from the “point‖” un-loaded. Timing of the unloading of the wagon was carried out by the method of “current time”, that is, fixing the time of the beginning and end of the each stage. The duration of the each stage was determined as the average value from the results of unloading at least 10 hopper wagons.

Processing of the obtained tabular data was carried out by a combined graphoanalytic method, for which, on the basis of the tabular values of the daily grain supply for each studied year, histograms and graphs were constructed that gave a visual representation of the patterns of grain supply.

The unevenness coefficients of daily K_{daily} and monthly K_{month} of grain supply to the enterprise by railway were determined in the following sequence.

The average monthly and average daily grain supply for a particular year was calculated by the formulas:

$$A_{\text{aver.month}} = A_{\text{total.annual}} / P_{\text{m}} \quad (1)$$

$$A_{\text{annual.day}} = A_{\text{total.annual}} / P_{\text{d}}\ , \quad (2)$$

where $A_{\text{aver.month}}$, $A_{\text{aver.daily}}$ — average monthly and average daily volumes of grain supply, t/month, t/day;

$A_{\text{total.annual}}$ — total annual grain supply, t;

P_{m}, P_{d} — summer periods of grain receipt at the enterprise, months, days.

Further, from the total annual period of grain supply, three months of intense (maximum) grain supply were selected. For each of these months, three days of maximum grain supplywere also chosen. According to the data obtained, the maximum average monthly and average daily values of grain supply for each year were calculated according to the formulas:

$$A^{3\,max}_{aver.month} = A_{3month}/n\,; \qquad (3)$$

$$A^{3\,max}_{aver.day} = A_{3\,day}/n\,, \qquad (4)$$

where $A^{3\,max}_{aver.month}$, $A^{3\,max}_{aver.day}$ —maximum monthly and average daily grain supply, t/month, t/day;

A_{3month}, A_{3day} — the total amount of grain supply in accordance with 3 months and 3 days of its maximum receipt, t/month, t/day;

n — the number of days of maximum grain supply (respectively $n = 3$ months or days).

The coefficients of monthly and daily irregularities in the supply of grain were determined by the formulas:

$$K_{month} = A^{3\,max}_{aver.month}/A_{aver.month}\,, \qquad (5)$$

$$K_{daily} = A^{3\,max}_{aver.daily}/A_{aver.daily}\,, \qquad (6)$$

where $A_{aver.month}$, $A_{aver.daily}$ — average monthly and average daily grain supply for a particular year, t/month, t/day.

Research results

At the first stage of the study, the quantitative and qualitative composition of grain that was supplied by railway to LLC "Ukrelevatorprom" from 01/01/15 to 12/31/16 was analyzed. The results are presented in the form of histograms that show the distribution of volumes individual crops have been studied for years, as well as their ratio according to the main groups of crops (Fig. 1).

After analyzing the histograms of the grain receipt of various crop groups by railway at LLC "Ukrelevatorprom" for 2015-2016 (Fig. 1), it can be noted that the main share of revenue in 2015 and 2016 was occupied by cereals — 78.0 % and 73.1 % respectively (a decrease of almost 5 %). Further, according to the annual supply, there were oilseeds (rapeseed 1 and the highest class were 19.1 % and 14.9 %, respectively). Least of all the company received legumes (soybeans) — 2.9 % and 12.0 %, although it is clear that soybean receipts in 2016 increased by 9.1 % (more than 3 times). A significant share of the reception and, consequently, the subsequent export of cereals can be explained by their high demand in the international grain market, in which Ukraine occupies a leading position.

If we consider the supply of individual crops at the enterprise, it can be seen (Fig. 1) that cereals in 2015 and 2016 were mainly represented by corn grain, the share of which was significantly dominated by other crops (wheat of different classes and barley) and amounted to 45.8 % and 44.5 % respectively. Second place of volumes of supply after corn in 2015-2016 consistently occupied class 3 wheat (15.7 % and 12.3 %, respectively), and together with other classes, wheat occupied 26.2 % and 21.2 % over the years, respectively. As for wheat of other classes, their supply was significantly less (in %, respectively, in 2015 and 2016): 6 classes — 6.4 % and 5.3 %; 2 classes — 2.4 % and 2.3 %; classes 1 and 4 of wheat were in the range of 0…0.2 % (and in 2016 there was no class 4 wheat at all). Another cereal crop, barley, in those years occupied 6.0 % and 7.5 % of the total grain supply by railway, respectively.

At the next stage of the study, the unloading of wagons with grain of different crops was timed, the results of which are shown in Fig. 2. It can be seen that the longest operation with the unloading of wagons is the analysis to determine the quality of rapeseeds, which lasts 28.2 minutes and differs significantly from the analysis for other crops (corn, wheat and barley), which last much less — 4.6...9.1 minutes, moreover, twice as much time is spent on wheat (9.1 minutes) than on corn and barley (4.6...4.8 minutes).

It is known that the determination of grain quality indicators can take different times — it all depends on the culture, its quality, the methods used to equip the laboratory with instruments, and the human factor etc. If, for example, a grain sample has an increased moisture content that does not meet the requirements of the standard, then the moisture content must be determined by the standard method using an oven, not an express analyzer, which significantly prolongs the analysis time. When the grain will have a high content of weed impurities, then, for example, for rapeseed, the duration of determining the clogging will be much longer. Crops such as corn and soybeans can have an increased amount of damaged or spoiled grains, and then you need to have extra time to cut a significant amount of grains for analysis. When taking wheat grains, it is necessary to determine the quantity and quality of gluten. This is usually done using express analysis, but if necessary, more accurate results are done according to GOST 13586.1-68 "Grain. Meth-

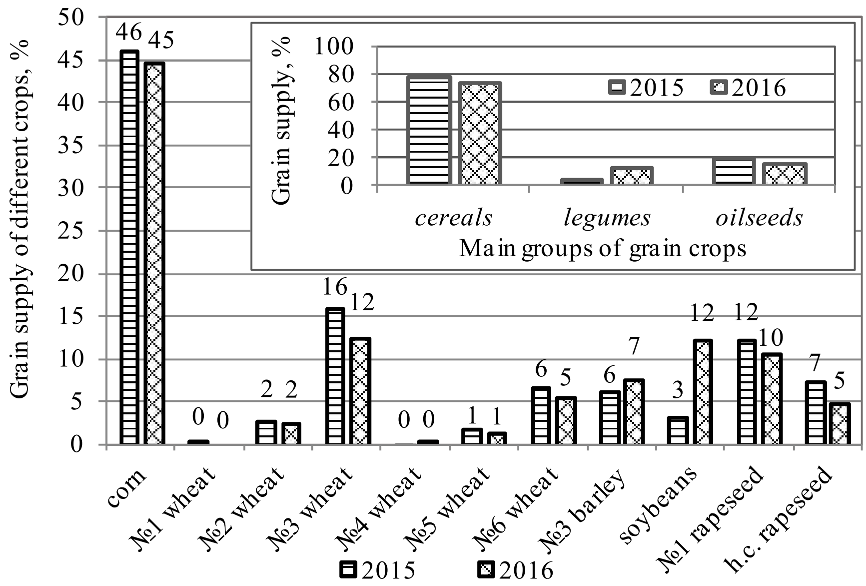

Fig. 1 – Histograms of the distribution of the crops supply by railway and their ratio by crop groups

ods for determining the quantity and quality of gluten in wheat", it is much longer by the manual method. Some crops (rapeseed, soybeans) in addition to the main quality indicators require checking for the presence of GMOs, it can take more than 20 minutes.

The second-longest operation is the grain unloading from wagons, which lasts 16...21 minutes depending on the crop, with rapeseed falling faster and corn lasting longer, due to their physicomechanical properties, primarily flowability.

Third in duration is sampling to determine grain quality indicators, which takes 6.4...7.2 minutes. The initial operation (installation of the wagon) and the final (cleaning grain from the unloading point) take 3.2...5.0 minutes. It takes a little time to open the gate valves — 1.5...3.7 minutes, and the short operation is to remove the seals — 0.7...1.1 minutes.

Thus, the timing showed that to increase the volume of grain acceptance, the most bottleneck is the duration of determining the grain quality. Despite a significant portion of the wheat grain supply, it is also advisable to reduce almost twice the duration of the analysis of its quality indicators — by improving the organization of analysis and the use of modern express devices.

Despite the considerable duration of the unloading of grain from the wagon, it is practically impossible to significantly reduce it, because it is determined by the flowability of the grain, which in turn depends on many factors — crop, its moisture content, shape and condition of the grain surface, and others that cannot be influenced.

There is little potential in reducing the operations of installing and cleaning hopper cars (wagons), removing seals and opening hatches, the duration of which is determined primarily by the human factor and weather conditions, but their share in the total duration of unloading hopper wagons is very small.

Using the results of the timing, it is possible to determine the total duration of unloading of the one wagon with grain of different crops entering the enterprise. Considering that the enterprise has 2 receiving streams of grain recepion from the railway, then 4 hopper wagons can be unloaded on them at the same time. Then, it is possible to assess the potential of the enterprise to receive grain of various crops by railway. The results of the calculations are shown in table 1.

The actual monthly number of grain hopper cars (hopper wagons) unloaded in 2015-2016 during the above-mentioned months of maximum grain intake was respectively 3422… 3491 and 2744… 3016 items.

Thus, the enterprise has the potential to receive and unload significantly more carloads and, accordingly, increase grain exports by about 30 %.

Table 1 – Summary calculations from the timing of unloading hopper wagons with different crops

Crops	Duration of unloading of the one hopper wagon, minutes			The number of hopper wagons that can be unloaded, items	
	minimum	maximum	average	for day	for month
Corn	35.6	39.5	37.5	154	4608
Wheat	40.7	45.6	43.1	134	4009
Barley	37.1	38.5	37.8	152	4571
Rapeseed	56.8	61.9	58.9	98	2934

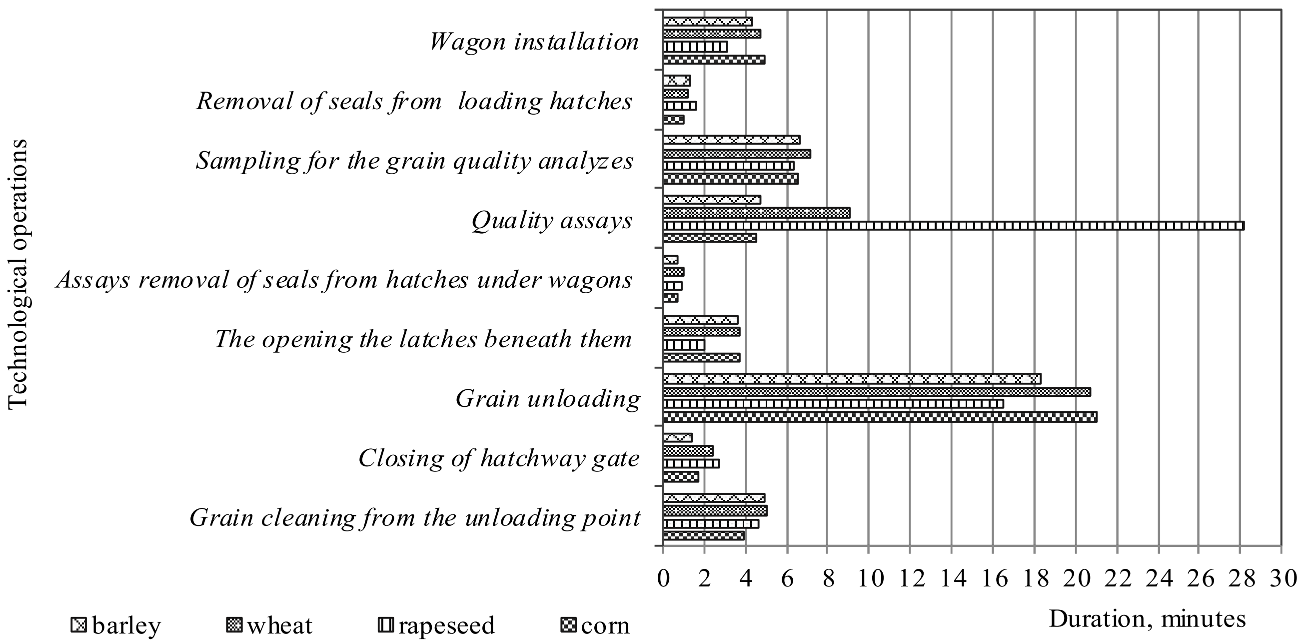

Fig. 2 – Histograms of the duration of individual technological operations when unloading wagons with grain of different crops

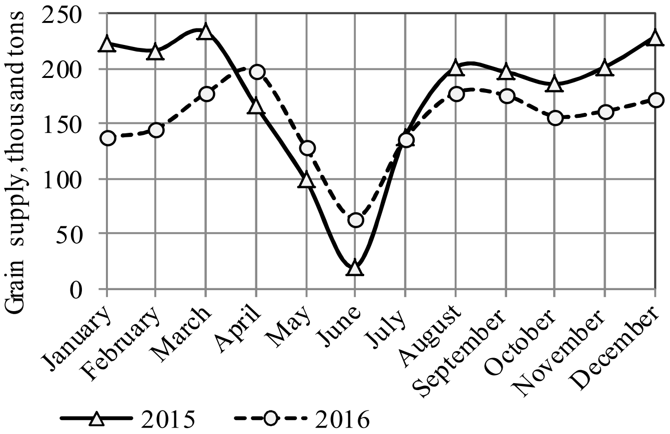

Fig. 3 – Grain volumes supplied to the enterprise by rail in 2015-2016

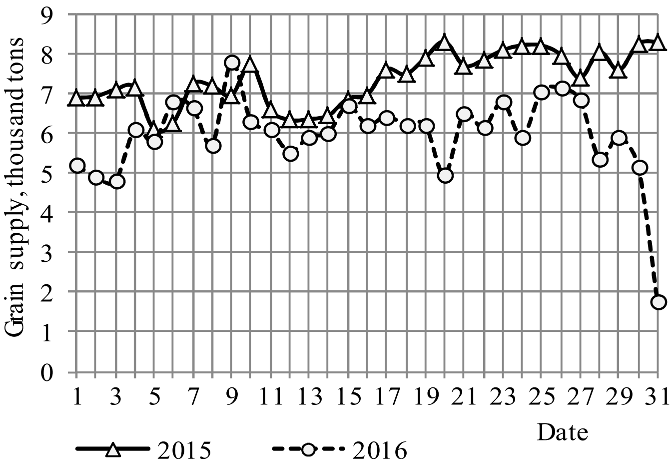

Fig. 4 – Dynamics of the averaged (for the busiest 3 months of work) daily grain supply by railway

Next, studies were carried out on the total grain volumes that arrived at Section 1 by railway during 2015-2016, the results of which are shown in Fig. 3, it clearly shows the monthly distribution of grain volumes over the years studied. From the graphs it can be seen that the volume of grain receipts by railway in 2015 was more than in 2016.

Further, for each year studied, based on the analysis of monthly grain receipts, the 3 most intense months of grain intake were determined.

The analysis of these graphs showed the following: January, March and December were the busiest months of grain receiving, with the largest volumes of its arrival at the railway company in 2015 and April, August and September in 2016; the smallest volumes of grain inflow were observed in 2015 — in May, June and July, and in 2016 — in January, May and June.

Studies also showed that the pattern of the monthly distribution of hopper wagons that delivered grain in the 2015-2016 study fully coincides with the pattern of the receipt of grain volumes, which is shown in Fig. 3, because the volume of grain is directly proportional to the number of hopper cars, if you do not take into account minor fluctuations in their carrying capacity.

So, the largest number of hopper cars (wagons) arrived at the enterprise in 2015, in particular, the busiest months of their reception were (items): in January 3422, March — 3491 and December —3460. In 2016, more hopper cars arrived (items): in April — 3016, August — 2744 and September — 2744 items.

Based on the above data of the 3 months of the most intense grain supply, the average daily maximum grain inflows for both years studied were determined. Using the data obtained, graphs were constructed (Fig. 4), they give a visual representation of the flow dynamics of the average daily intake of grain by railway over the months of 2015-2016. From the above graphs, it is seen that in the month of maximum volumes of supply, the grain was received quite unevenly. Fluctuations in the volumes of grain supply on the most stressful 3 days in 2015 were in the range of 6099...8317 tons, and in 2016 it amounted to 4802...7795 tons (excluding the anomalous August 31, when only 1758 tons of grain arrived).

A characteristic of fluctuations in the volume of grain supply both daily and monthly is usually the unevenness coefficient. Their actual values should be taken into account when analyzing the work, designing or reconstructing the enterprise, in particular, when substantiating the necessary performance of the transport and technological equipment for grain receiving lines, ensuring uninterrupted reception and processing of grain arriving at the terminal.

Using the method described above, we determined the coefficients of daily and monthly unevenness of the grain supply to the grain terminal in 2015-2016. The obtained calculation results are given in table. 2.

As can be seen from the data obtained, the coefficients of the daily and monthly irregularities in the flow of grain to the grain terminal do not exceed the normative (literary) values.

At the final stage, the average daily actual productivity of the receiving station from the railway in the busiest months of grain inflow was calculated, which amounted to 301 t/h in 2015 and 247 t/h in 2016, in contrast to the passport capacity of 500 t/h. Thus, the company has the technical capabilities to increase the volume of the grain reception from the railway and, accordingly, the grain export.

Conclusions

1. Analysis of the structure of grain crops supplied by LLC "Ukrelevatorprom" for 2015-2016 by railway and their ratio have showed that the main share was occupied by cereals (78.0 % and 73.1 %, respectively), which were represented in mainly corn, whose share was significantly dominated by other crops (wheat of the different classes and barley) and amounted to 45.8 % and 44.5 % in 2015 and 2016, respectively, which can be explained by its high demand in the international grain market, in which Ukraine occupies a leading position. Oilseeds (rapeseed 1 and highest classes) were received 19.1 % and 14.9 %, and legumes (soybeans) — 2.9 % and 12.0 % respectively.

2. An analysis of the timing of the unloading of grain wagons (hoppers cars) showed that the total duration of this process, depending on the crops, averages 37...59 minutes. The longest stages of unloaded wagons are the determination of grain quality indicators, especially rapeseed, and the precipitation of grain from wagons, therefore, to reduce their duration, it is necessary to

Table2 – The results of the study of the grain supplyby railway to the grain terminal

Name of indicators	Experimental data		Regulatory data [8]
	2015 year	2016 year	
The annual period of the grain supply, P_r, days	349	353	–
The total amount of the annual grain supply, $A_{total.annual}$, t	2066116	1821567	
The average daily grain supply, $A_{average.day}$, t/day	5920	5160	
Maximum daily average grain supply, $A^{3\,max}_{aver.day}$, t/day	8699	7864	
Average monthly amount of grain supply, $A_{aver.month}$, t/month	172176	151797	
Maximum average monthly grain supply, $A^{3\,max}_{aver.month}$, t/month.	228304	183878	
Coefficient of daily irregularity, K_{daily}	1.47	1.52	2.5
Coefficient of monthly irregularity, K_{month}	1.33	1.21	2.0

pre-form the supply of wagons with identical grain batches and use more advanced express analyzers to determine the grain quality indicators, this will increase the productivity of the grain receiving line from the railway. Now the enterprise has the potential to take and unload significantly more wagons and, accordingly, to increase grain exports by about 30 %.

3. It was established that the periods of grain receipt at the enterprise in 2015-2016 were 349 and 353 days, respectively, the actual coefficients of daily irregularity K_{daily} for the receipt of the grain by railway transport was 1.47 and 1.52 in these years, respectively, and the monthly irregularity K_{month}, respectively was 1.33 and 1.21, it does not exceed the standard values K_{daily}= 2.5 and K_{month}= 2.0. This made it possible to clarify the database from the actual characteristics of the process of the grain receiving by railway, and perhaps the design and verification calculations of the equipment in the technological lines for the receiving grain from railway transport will contribute to increasing the efficiency of the grain transshipment terminals.

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ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИК ПРИЙМАННЯ ЗЕРНА ІЗ ЗАЛІЗНИЧНОГО ТРАНСПОРТУ НА ЗЕРНОВИЙ ПЕРЕВАНТАЖУВАЛЬНИЙ ТЕРМІНАЛ

Анотація

У перспективі в Україні планується збільшити посівні площі під злаковими, бобовими і олійними культурами, збільшити валовий збір зерна до 80 млн. тонн, а його експорт за кордон — удвічі. Інтенсивне будівництво в південних портах України зернових перевантажувальних терміналів з металевими силосами великої місткості дозволить вирішити завдання збільшення у перспективі експорту зерна. На ці потужні термінали основна маса зерна надходить переважно залізничним транспортом, а відвантажується на водний.

Метою роботи було дослідження характеристик приймання зерна із залізничного транспорту на зерновий перевантажувальний термінал ТОВ «Укрелеваторпром», що дозволить підвищити ефективність його роботи. Об'єктом дослідження була технологія приймання зерна на зерновому перевантажувальному терміналі; предметом досліджень – злакові, бобові та олійні культури, а також дані з добових об'ємів приймально-відпускних операцій на зерновому перевантажувальному терміналі ТОВ «Укрелеваторпром» за 2015–2016 рр.

Дослідження проводили на підставі обробки даних журналів накладних за 2015–2016 рр., за якими була підсумована кількість щодобово перевезеного залізницею зерна (нетто). Подальшу обробку отриманих даних проводили комбінованим графоаналітичним методом, для чого на основі табличних значень для кожного дослідженого року будували відповідні гістограми і графіки та визначали необхідні показники.

Аналіз структури зернових культур, що надходили залізничним транспортом на ТОВ «Укрелеваторпром» за 2015 і 2016 роки та їх співвідношення показали, що основну частку займали злакові культури (78,0 % та 73,1 % відповідно), які були представлені в основному зерном кукурудзи, частка якої значно переважала інші зернові культури (пшеницю різних класів та ячмінь) та складала відповідно 45,8 % і 44,5 %, що можна пояснити її високим попитом на міжнародному ринку зернових, у якому Україна займає провідні позиції. Олійних культур (ріпаку) було прийнято відповідно 19,1 % та 14,9 %, а бобових (сої) — 2,9 % та 12,0 %.

Аналіз результатів хронометражу вивантаження вагонів-зерновозів показав, що загальна тривалість цього процесу залежності від культур складає в середньому 37…59 хв. Найбільш тривалими етапами при вивантажені вагонів є визначення показників якості зерна, особливо ріпаку, та висипання зерна з вагонів, тому для зменшення їх тривалості необхідно попередньо формувати подачі вагонів з однаковими за якістю партіями зерна та використовувати більш сучасні експрес-аналізатори для визначення показників якості зерна, що дозволить збільшити продуктивність лінії приймання зерна із залізниці. За результатами досліджень у підприємства є потенційна можливість збільшення приблизно на 30 % обсягів приймання зерна.

Встановлено, що періоди надходження зерна на підприємство у 2015–2016 рр. склали відповідно349 та 353 діб, фактичні коефіцієнти добової нерівномірності $K_{доб}$ надходження зерна із залізниці у ці роки дорівнюють відповідно1,47 та 1,52, а місячної нерівномірності $K_{міс}$ відповідно 1,33 та 1,21, що не перевищує нормативних значень $K_{доб}$ = 2,5 та $K_{міс}$ = 2,0. Це дозволило уточнити базу даних з фактичних характеристик процесу приймання зерна залізницею та може бути використано при проектних і перевірочних розрахунках обладнання у технологічних лініях приймання зерна з залізничного транспорту, що сприятиме підвищенню ефективності роботи зернових перевантажувальних терміналів.

Ключові слова: *зернові культури, надходження зерна залізницею, вагони-зерновози, вагони-хопера, хронометраж, коефіцієнти нерівномірності.*

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CHANGE OF STRESS CRACK IN CORN KERNEL DURING ITS PREPARATION FOR PROCESSING

Abstract

The article presents the results of the study of the influence of stress crack in corn kernel on the change of its mechanical properties, namely, on the strength of kernel and its ability to grind during the technological process of preparation for processing. The research was conducted at the Dnipro Food Concentrates Plant.

It is established that percentage of damage, i.e. grain impurities and foreign material (impurities), when receiving grain at the production elevator is within the norms of State standards of Ukraine (DSTU 4525:2006) – up to 7 % and not more than 1.0 %, respectively. But in the process of grain transportation this index is increasing. The maximum level of grain impurities (9.1 %) in corn grain can be observed before its preliminary cleaning on the separator BSH-100, then this indicator decreases significantly to 1.8 % in the cleaned grain, but then increases again in the technological process. Moreover, before sending grain into the degerminator the level totals 4.8 % - almost as much as when receiving grain from vehicles. One can say the same regarding the level of foreign material. Its minimum amount in the grain after pre-cleaning (0.5 %), and the maximum – at the end of the cleaning stage (7.4 %), which is much more than when receiving grain.

The increase in the amount of broken grain (including that relating to impurities) in the technological process is accompanied by higher number of stress cracks in the corn kernel. During receiving, the studied grain has already had a high stress crack – 68 %. At the same time, there was more corn kernel with one crack (41 %). After transportation by a belt conveyor and the main high-performance bucket elevator, although the total stress crack increased not significantly – up to 75 %, but there were changes in the number of cracks: the number of kernels with one crack decreased to 22 %, but the number of kernels with many (three or more) cracks increased from 8 to 33 %, respectively. During further transportation and processing of corn kernel, the stress crack increased to a maximum value of 78 % (before separation on SAD-10-01), and then decreased to 72 % in the grain entering the degerminator.

It is established that the decrease in corn kernel strength is influenced by both the total stress crack and its nature, i.e. the number of stress cracks in each kernel. The maximum required force for the corn kernel damage was observed exactly for grain entering the intake pit – 3.6 kg / 50 kernels. Here you can find more corn kernels stressed by only one crack (single) – 41 % or without cracks – 32 %. And the minimum effort – 3,0 kg / 50 kernels - for cleaned grain after conveyor and elevator No. 1, where the share of kernels with multiple stress crack (3 or more cracks) totaled 43 % (only 22 % of kernels were without cracks). A high inverse correlation of -0.84 was established between the number of stressed kernels with three or more cracks and the effort to break corn kernel.

Based on research, it is recommended to use the index of stress crack in corn kernel to assess its quality when accepted for further processing, as this indicator is directly related to the yield of finished products.

Key words: *corn, corn kernel, stress crack, mechanical properties, percentage of damage*

Introduction

Today, corn grain ranks first in the gross grain crop. So, the study of its mechanical properties and the factors that determine them, as well as changes in the properties of grain during storage, transportation, processing, is relevant.

Mykola Kyrpa's research established that there is too great loss of corn grain in the process of its storage in the wet state, during drying, cleaning, placement, various conditioning, storage in the post-harvesting period. At the stage of harvesting and post-harvest processing of wet grain, the losses are approximately 14-20 %, depending on the technology and material and technical base; for dry grain – 3.4-6.9 % [1].

The level of grain damage, foreign grain and foreign material, in the process of harvesting corn depends on many factors, such as the method of harvesting and grain moisture, the state of sowing and harvesting equipment, varietal characteristics of the hybrid. In most cases, when harvesting cob corn, the total percentage of grain damage (mechanical and thermal) does not exceed 15-17 %, depending on the moisture and the botanical group of corn. When harvesting corn kernel the damage significantly increases (up to 60 %), there is a significant amount of broken grain (up to 5-20 %) [1].

Increased volumes of corn production cause higher operating modes of harvesting and post-harvest processing. In addition, the drying of grain at high temperatures can reduce specific energy consumption by 15-20%, so it is widely used in practice. At the same time, due to rapid moisture evaporation, the percentage of stressed kernel increases to 70-80 %. As a result, its strength decreases and the content of broken grain increases during its movement, loading and unloading.

You should also take into account the different moisture-yielding ability of different types of corn – dent, flint, sweet, in the drying process. Sweet and dent corn give off moisture faster than flint. As a result, they are less damaged during drying, their stress crack is 18-40% less. Therefore, it is recommended to use milder drying regimes for grain of high humidity and early forms of ripeness of flint type of corn [1, 2].

Thus, corn kernel, due to its hardness and glassy nature, is characterized by high stress crack, which certainly affects its structural and mechanical properties [1, 3–5]. Therefore, it is easy to assume that in the process of grain receiving, drying, transportation, cleaning, the content of fine kernels in the grain mass of corn increases, but this assumption is still not sufficiently studied.

Materials and methods

In order to study the change in the content of broken grain and its stress crack at different stages of the technological process of its acceptance, storage and cleaning, they run the analysis of its mechanical properties at the Dnipro plant of food concentrates. For analysis, they took the samples of corn grain at the characteristic "critical" points of the technological schemes of the elevator and groats mill: 1 – Grain entering the intake pit; 2 – Grain after the belt conveyor; 3 – Grain after bucket elevator № 1 (el.); 4 – Cleaned grain after the separator BSH-100; 5 – Cleaned grain after bucket elevator №4 (el.) and scales; 6 – Cleaned grain after conveyor and bucket elevator № 1 (mill); 9 – Main grain before degerminator.

During the testing, the corn grain of type V was processed: semi-dent yellow (yellow or orange color; the shape is transitional from dent to flint with a slightly depressed kernel tip or without indentation/depression). The analysis of quality indicators (grain impurities, foreign material), distribution by size fractions was performed in accordance with DSTU 4525:2006 [6] and GOST 30483-97 [7]. The sieves with holes Ø 8.0; 4.5 and 2.5 mm were selected for this analysis: the sieves Ø 8.0 mm and Ø 4.5 mm received the fraction of the main corn grain – large and small kernel, respectively, and Ø 4.5 mm – broken and wrinkled corn kernel (except for other foreign grain and material).

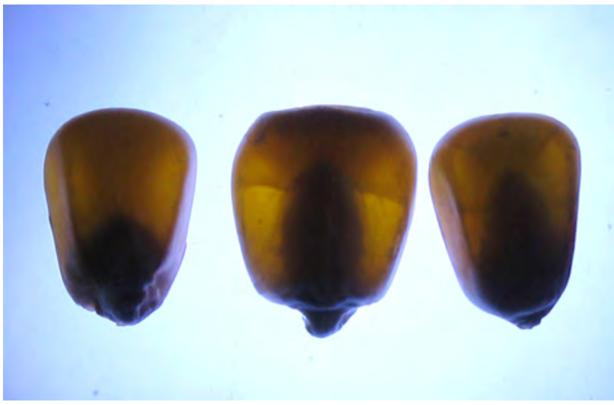
Corn stress crack was determined according to the USDA method [8]. 100 whole kernels were selected from the samples, which have no visible damage. Each corn kernel was examined for cracks. All stressed kernels were divided into 3 groups: kernel with one stress crack; with double stress cracks; with multiple stress cracks (Figure 1).

In order to determine the effect of stress crack on the reduction of kernel strength, they measured kernel breaking force using a breaking machine with a maximum load of 50 kg. For inspecting, they took whole grains in a row from the general weighing batch (without determining the stress crack percentage) in the amount of 50 pcs. and crushed on a bursting machine with a constant loading speed.

Results and discussion

The Table 1 and Figure 1 shows the results of the analysis of corn kernel quality indicators at different stages of the technological process.

The data show that the amount of grain impurities and foreign material when receiving grain at the production elevator is within the norms of DSTU 4525:2006 – up to 7 % and not more than 1.0 %, respectively. But in the process of grain transportation they increase. The maximum level of grain impurities (9.1 %) in corn grain is observed before its preliminary cleaning on the separator BSH-100, then it significantly decreases to 1.8 % in the cleaned grain, but then increases again in the process, and before the degerminator this



A B C

Fig. 1 – Corn kernel:
A – kernel without cracks; B – kernel with double stress cracks; C – kernel with multiple stress cracks (three or more)

level totals 4.8 % – almost as much as when receiving grain from vehicles (this does not apply to individual fractions of products 7 and 8, which after their separate processing are combined before being sent to the degerminator).

The same applies to the level of foreign material. Its minimum amount in the grain is after pre-cleaning (0.5 %), and the maximum – at the end of the cleaning stage (7.4 %), which is much more than when receiving grain. The largest increase in foreign material is observed after grain fractionation in the pneumatic separator SAD-10-01 due to damage of lighter corn kernels. The total number of damaged kernels (together mainly in the basic grain and foreign grain) in the light fraction (trays 3 and 4) reaches a maximum value of 87.7 %, on the contrary, for the heavier fraction – a minimum value of 22.4 %.

The increase in the number of broken kernels in the technological process is accompanied by an increase in the number of stress cracks in the corn kernel (Figure 3). The inspected grain already had a high stress crack percentage when receiving to plant – 68 %, which is obviously due to suboptimal modes during its harvesting and post-harvest processing. At the same time, the largest share accounted for corn kernel with single stress crack (41 %). After transportation by a belt conveyor and the main high-performance bucket elevator, the total stress

Table 1 – Indicators of corn kernel quality at different stages of the technological process

Sample No.	Basic grain, %			Grain impurities, %	Foreign material, %
	total	large –/Ø8.0	fine Ø8.0/Ø4.5		
1	95.1	72.0	23.1	4.3	0.6
2	94.1	69.0	25.1	5.1	0.8
3	88.6	73.6	15.0	9.1	2.3
4	97.9	79.4	18.5	1.6	0.5
5	97.0	77.8	19.2	1.8	1.2
6	93.7	72.9	20.8	4.6	1.7
7	97.8	85.8	12.0	0.8	1.4
8	48.4	10.4	38.0	20.3	31.3
9	87.8	70.4	17.4	4.8	7.4

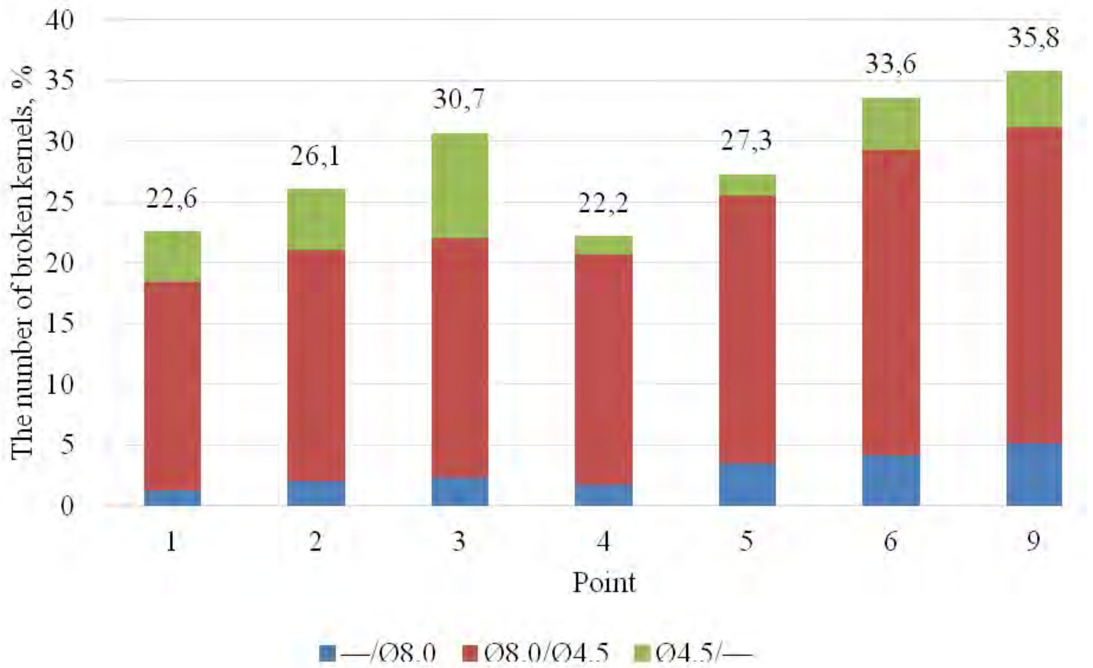


Fig. 2 – The number of broken kernels by fractions in corn kernel at different stages of the technological process:
A – in large grain; B – in fine grain; C – in grain impurities

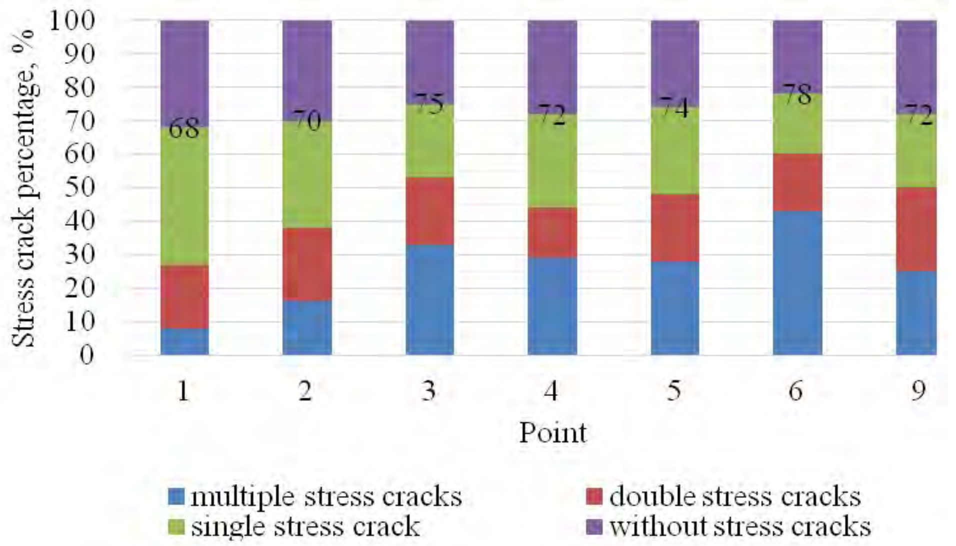


Fig. 3 – Stress crack percentage of basic grain at different stages of the technological process:
A – multiple stress cracks (three or more); B – double stress cracks (two); C – single stress crack; D – without stress cracks

crack percentage did not increase significantly – up to 75 %, but there were changes in the number of stress cracks: the number of kernels with single stress crack decreased to 22 % (at point 3 – before pre-separation) and increased number of kernels with multiple (three or more) stress cracks – from 8 to 33 %. During further transportation and processing of corn grain, the stress crack percentage increased to a maximum value of 78 % (at point 6 – before separation on SAD-10-01), and then decreased to 72 % in the grain entering the degerminator (point 9). It can be explained by the fact that when the kernel was divided into heavy and light fraction on this separator, a part of the basic grain (mainly in the light fraction) with multiple stress cracks (two or more) was broken.

When analyzing the effect of stress crack on the reduction of grain strength (Table 2), it was found out that the transportation of corn kernel and its processing on the technological equipment leads to changes in both total stress crack in corn kernel and an increase in the total number of stress cracks, which together affects the ability of corn kernel to damage. The maximum required force for corn kernel damage is observed for point 1 (grain entering the intake pit) – 3.6 kg / 50 kernels, where corn kernels with single stress crack – 41 % or without stress cracks – 32 % dominated, and the minimum required force for corn kernel damage – 3.0 kg / 50 kernels were observed for point 6 (cleaned grain after conveyor and bucket elevator No. 1 to SAD), where 43% were grains with multiple stress cracks (3 or more) (only 22 % of kernels were without cracks).

Table 2 – Strength of corn grain at different stages of the technological process

Sample No.	Damage force, kg / 50 corn kernels		
	min	max	average
1	1.4	6.5	3.6
2	1.3	6.6	3.5
3	1.0	6.2	3.5
4	1.3	6.3	3.4
5	1.2	6.1	3.5
6	0.9	5.5	3.0
7	1.3	6.5	3.4
8	1.1	6.2	3.1
9	0.9	5.8	3.5

The correlation analysis of stress crack percentage and damage force showed a high direct relationship between the number of kernels with single stress crack and the minimum and average required force to damage the kernel – 0.62 and 0.76, respectively. On the contrary, with an increase in the number of kernels with multiple stress cracks (three or more), the damage force decreases, i.e. an inverse correlation is established between these indicators – -0.84. But the correlation of the total stress crack with the corn damage force (reverse) is average – -0.45, i.e. the ability of the kernel to damage is more influenced by the nature of the stress crack, rather than its overall value. It is clear that for the inspected samples of corn kernel from different stages of the technological process, there is a very high inverse correlation – -0.93 between the number of kernels with single stress crack and the number of kernels with multiple stress cracks (three or more). It indicates that the mechanical action of transport and technological equipment causes the increase in number of stress cracks in each kernel.

CONCLUSIONS

When studying the technological (mechanical) properties of corn kernel, we found out that its stress crack is an important indicator of quality, which must be taken into account when receiving corn grain for processing. Due to its structure, after harvesting and post-harvest processing, stress crack in corn kernel reaches 70-80 %, which reduces the strength of the kernel and leads to an increase in the amount of broken grain (damaged kernels) in the process of receiving and preparing grain for processing. Also during the technological process the total stress crack in corn kernel increases as well as its nature changes, i.e. the number of stress cracks in each kernel: the number of kernels without cracks or with single stress crack decreases by increasing the number of kernels with multiple stress cracks (three or more). All this leads to lower kernel damage force, i.e. impaces on the yield of finished products: cereals, groats, groats for production of corn curls etc. Therefore, based on research, it is recommended to use the index of stress crack in corn kernel to assess its quality when receiving for further processing.

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ЗМІНА ТРІЩИНУВАТОСТІ ЗЕРНА КУКУРУДЗИ ПРИ ЙОГО ПІДГОТОВЦІ ДО ПЕРЕРОБКИ

Анотація

У статті наведено результати дослідження впливу тріщинуватості зерна кукурудзи на зміну його технологічних властивостей, а саме, на міцність зерна та його спроможність подрібнюватись у ході технологічного процесу підготовки зерна до переробки. Дослідження проведені на Дніпровському комбінаті харчоконцентратів.

Встановлено, що кількість зернової та сміттєвої домішок при прийомі зерна на виробничий елеватор находяться в межах норм ДСТУ 4525:2006 – не більше 7 % та не більше 1,0 %, відповідно, але у процесі транспортування зерна збільшуються. Максимальний рівень зернової домішки (9,1 %) у зерні кукурудзи спостеріга-

ється перед його попереднім очищенням на сепараторі БСХ-100, потім цей показник суттєво зменшується до 1,8 % у очищеному зерні, але далі знову збільшується по ходу технологічного процесу, та перед направленням зерна у дежермінатор складає 4,8 % – майже стільки ж, як при прийомі зерна з автотранспорту. Це же стосується і рівня сміттєвої домішки. Її мінімальна кількість у зерні після попереднього очищення (0,5 %), а максимальна – в кінці етапу очищення (7,4 %), що значно більше, ніж при прийомі зерна.

Зростання кількості битого зерна (у т.ч. того, що відноситься до домішок) по ходу технологічного процесу супроводжується зростанням кількості тріщин у зерні кукурудзи. При прийомі досліджено зерно вже мало високу тріщинуватість – 68 %, при цьому в ньому більшу кількість складало зерно кукурудзи з однією тріщиною (41 %). Після транспортування стрічковим конвеєром та основними високопродуктивними норіями елеватору хоча загальна тріщинуватість зросла не суттєво – до 75 %, але відбулися зміни у кількості тріщин: зменшилось кількість зерен з однією тріщиною до 22 %, але зросла кількість зерен з багатьма (три та більше) тріщинами – з 8 до 33 %, відповідно. При подальшому транспортуванні та обробці зерна кукурудзи тріщинуватість зростала до максимального значення 78 % (перед сепаруванням на САД-10-01), а потім зменшилась до 72 % у зерні, що поступає на дежермінатор.

Встановлено, що на зменшення міцності зерна впливає як загальна тріщинуватість, так і її характер, тобто кількість тріщин у кожній зернівці. Максимальне необхідне зусилля для руйнування кукурудзи спостерігалось для зерна, що поступає у завальну яму, – 3,6 кг/50 зерен, у який превалюють зерна кукурудзи тільки з однією тріщиною – 41 % або без тріщин – 32 %, а мінімальне зусилля – 3,0 кг/50 зерен – для очищеного зерна після транспортеру та норії № 1, у який 43 % складали зерна з 3-ма та більш тріщинами (без тріщин було тільки 22 % зерен). Між кількістю зерен з трьома або більше тріщинами та зусиллям на руйнування зерна кукурудзи встановлено високий зворотний кореляційний зв'язок – -0,84.

На підставі досліджень, рекомендовано використання показника тріщинуватості кукурудзи для оцінки його якості при прийомі на подальшу переробку, так як цій показник прямо пов'язаний з виходом готової продукції.

Ключові слова: *кукурудза, ядро, тріщина, механічні властивості, вміст битого зерна.*

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EFFECT OF WATER-HEAT TREATMENT ON SPELT GRAIN FLOUR QUALITY

Abstrakt

Studies have shown that the ash content of products after the first grinding was lower compared to the the second grinding. This is due to a decrease in the quality of intermediate product coming to the second grinding. The variation coefficients of analytical replicates for the results after the first grinding varied from 4,65 to 14,18, and for the results after the second grinding - from 2,44 to 13,43. This indicates little or slight variation. Therefore, the average data from the study results can be used for mathematical modeling.

The theory of correct distribution of the sample data was rejected, and therefore the relationship between the parameters of water-heat treatment and ash content of flour was carried out using nonparametric statistics (determining Spearman correlation coefficient).

With 95 % probability, it can be argued that there was an inverse correlation between the water-heat treatment parameters and ash content.

The lowest ash content of flour after the first grinding of spelt grain can be obtained with the highest grain moisture content and the maximum duration of its softening. The correlation and influence of the factors were determined using beta and partial correlation coefficients. For the first grinding, the highest moisture content and influence on the flour ash content had the grain moisture content before grinding. The effect of moisture on milling products during the second pass resulted in a greater impact compared with softening duration. In general, flour ash content in a production using two milling systems is mostly influenced by grain moisture content. Obviously it can be explained by the fact that the formation of microcracks in a bruchid endosperm depends on the tensile forces between water and its structural parts. Moisture increase weakens the bonds between shells and endosperm of grain, which helps them to better separate during the second grinding.

Therefore, the response of spelt wheat grain to water-heat treatment is similar to the known regimes for the soft type of soft wheat grain.

The tendency of flour whiteness change, depending on the modes of water-heat treatment, varied similarly to the ash content.

Key words: *spelt wheat, flour, water-heat treatment, ash content, flour whiteness.*

Introduction

Wheat is the most widely grown crop in the word because of its unique protein characteristics. Now there is an active 'search', revival, improvement and introduction into production of 'antique cereals' – forgotten grain cereals. One of these species is spelt wheat (*Triticum spelta L.*), an ancient, almost extinct species of wheat with a hexaploid chromosome set (2n = 42) [1, 2]. Spelt wheat is undemanding to growing conditions, so it is common in organic farming in most Western European countries (Germany, Belgium, Switzerland, France, Spain) and the United States. [3, 4]. The high adaptive properties of this culture have been confirmed by studies of 22 research institutes in nine countries of the European Union participating in SESA project [5].

Spelt wheat is almost a perfect combination of the vitamins, minerals, proteins, carbohydrates and fats essential for human body. Compared to soft wheat, it is richer in proteins, unsaturated fatty acids and dietary fibers [6, 7]. Organic substances contained in spelt have a high level of solubility, so they are easily and quickly absorbed by the human body [8]. Its grain contains special soluble carbohydrates – micropolysaccharides, which are able to strengthen the immune system, lower cholesterol and regulate blood coagulation processes [9, 10]. The peculiarity of spelt wheat grain is the balanced placement of valuable components in the shells and endosperm, which makes it possible to use simple and complex grain grindings [11, 12].

Literary review

Compared to soft wheat, spelt wheat grain has thicker shells that are less tight to the aleurone layer [13]. However, the groove of spelt wheat grain is wide and reaches about half of the cross section of endosperm and is relatively big in the top part [14, 15].

Spelt flour is inferior to wheat by the baking quality, but it can be useful in the manufacture of bakery products of improved chemical composition, for dietetic nutrition [16, 17]. High quality characteristics and soft-grain consistency of spelt grain provide high quality confectionery and grits with excellent taste properties. Thus, the complex of useful features and properties of spelt wheat determined its widespread practical use and encouraged for different scientific researches [18]. Flour quality depends on the technological properties of grain. Yield and quality of flour vary depending on weather and agrotechnical conditions of cultivation [19]. The conversion of spelt wheat into flour will help to expand the range of this product. In addition, it has high biological value [9, 12].

In a context of market economy, the main indicator of effective enterprise performance is the demand for products, which is formed to a greater extent by the quality of manufactured products. Marketing techniques and promoting of low quality products can only produce short-term sales improvements. Therefore, the optimization of flour production from new varieties of spelt wheat grain was carried out taking into account the main indicators of flour quality (ash content and linen), which predetermine the quality of the manufactured bakery products.

Formulation of the problem

The aim of the study is to determine the effect of water-heat treatment on the quality of spelt wheat flour.

To solve this goal, the following tasks were set: to conduct literature review and scientific experiment, make a statistical analysis of the obtained data, make mathematical models, establish the optimal parameters of water-heat treatment depending on flour quality.

Materials and methods

The experimental part of the work was carried out in the laboratory of 'Quality evaluation of grain and grain products' of the Department of Technology of Storage and Processing of Grain of Uman National University of Horticulture. For research, we used spelt winter wheat grain of Zoria of Ukraine variety. Flour quality was investigated depending on water-heat treatment (Table 1). To do this, the grain was used with a moisture content of 13,0 % to 17, 0% with an interval of 0,5 %, softened from 5 h to 30 h with an interval of 5 h.

Table 1 – Experiment scheme 'Moistening and softening effect of spelt wheat grain on yield and quality of flour

Indicator	Levels and step variation								
Grain moisture	13,0	13,5	14,0	14,5	15,0	15,5	16,0	16,5	17,0
Duration of softening, h	–	–	–	–	5; 10; 15; 20; 25; 30				

For laboratory grinding of spelt wheat grain, MVR-000342.90 roller machine was used, which allows to obtain wheat flour in accordance with DSTU 46.004-99 of wheat flour. The technical characteristics of the roller machine are shown in Table 2. The minimum weight of grain sample should be 1 kg.

The principle of roller machine operation is that grain after water-heat treatment is loaded into the receiving hopper 2 (Fig. 1). Through the feed valve 3 grain is directed to the roller 4.

Table 2 – Technical characteristics of roller machine

Indicator	Value
Productivity (raw), kg/h	320–350
Installed power, kW	7,5
Weight, kg	350
The yield of flour,%	75–85

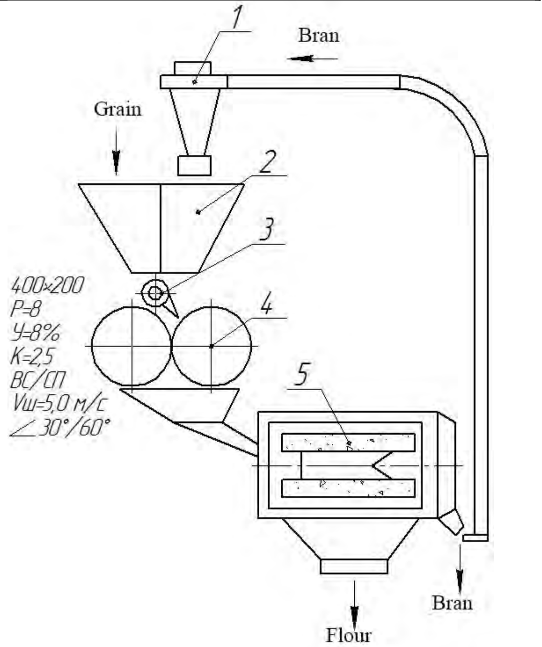

Fig. 1 - MBR-000342.90 flow diagram

After grinding the receiving product is separated on a sieve separator 5 of a drum type. The separator descent, if necessary, is directed to re-treatment through the pneumatic conveyor system 1.

The relationship between quality indicators of spelt wheat flour was determined by correlation (Multiple Regression, Correlation matrices) and variance (ANOVA) methods using Statistica 10 and Microsoft Office 2010. To properly evaluate the relationship power, Cheddock correlation coefficient was used: 0,1–0,3 – insignificant relationship; 0,3–0,5 – moderate; 0,5–0,7 – significant; 0,7–0,9 – high; 0,9–0,99 – very high; 1 – functional.

Measurements accuracy and data reliability were mathematically substantiated at each stage of the research. The replicates of each experiment were treated with descriptive statistics to determine variation coefficient. In case of poor data variation of the samples of each experiment, their average was determined, which was used for mathematical modeling. The arrays of data, obtained from the averages, were checked for correct distribution. Correctly distributed data were processed by basic statistics methods and incorrectly distributed – by non-parametric ones. Correlation and regression analyses were used during statistical processing. Obtained functional dependencies were checked for the absence of autocorrelation by Darbin–Watson statistics method [20].

Due to the duplication of experiments, the reproducibility of experimental data was checked. The hypothesis of noise dispersion persistence was tested using the Kohren criterion [20]. Testing of this hypothesis allowed to assert the homogeneity or heterogeneity of a number of variances. Mathematical modeling used data in which the number of variances was homogeneous.

The method of full factorial experiment is based on the assumption that any continuous function under study $y=f(x_1, x_2,...,x_n)$ with all derivatives at a given point with $x_{01}, x_{02}, ..., x_{0n}$ coordinates can be decomposed into Taylor series:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_H x_H + \beta_{21} x_1 x_2 +$$
$$+ \beta_{(n-1)} x_{(n-1)} x_n + \beta_{11} x_1^2 + \beta_{22} x_2^2 + ... + \beta_{nn} x_n^2, \quad (1)$$

where β_0 – the value of response function at the origin $x_{01}, x_{02}, ..., x_{0n}$ [15].

Results and discussion

Studies have shown that ash content of the products after the first grinding was lower than after the second one. This is due to a quality deviation of the intermediate product coming into the second grinding.

The variation coefficients of analytical replicates for the results after the first grinding varied from 4,65 to 14,18, and for the results after the second one – from 2,44 to 13,43. This indicates little or minor variation. Therefore, the average data from the research results can be used for mathematical modeling. The theory of correct distribution of sample data was rejected, and therefore the relationship between the parameters of water-heat treatment and flour ash content was carried out using nonparametric statistics (determining Spearman correlation coefficient).

With 95 % probability, it can be stated that there was an inverse correlation between the parameters of water-heat treatment and ash content (Table 3).

Table 3 – Correlation coefficients Spearman

Indicator	Duration of softening, h.	Grain moisture, %
Ash content in flour after first grinding, %	-0,664552*	-0,739161*
Ash content in flour after second grinding, %	-0,636434*	-0,886380*

Note: Significantly $p < 0{,}05$.

The relationship between water-heat treatment and flour ash content can be described by the following linear dependencies:

$$Z_1=1{,}641249–0{,}061686X_1–0{,}005239X_2 \quad (2)$$

$$Z_2=1{,}813573–0{,}064253X_1–0{,}003174\ X_2 \quad (3)$$

where Z_1 and Z_2 – ash content after the first and second grindings;

X_1 – grain moisture, %

X_2 – duration of softening, min.

An important indicator of mathematical model quality is the presence or absence of autocorrelation of residuals. As a result of statistical analysis, the Darbin-Watson method found a positive autocorrelation of the residuals of the 3d function. This meant that the selected model was incorrect or lacked of a statistically significant relationship. For the first equation, the autocorrelation of residuals was not detected.

Taking into account the high statistical reliability of first equation, the corresponding dependence can be represented graphically (Fig. 2). The lowest flour ash content after the first grinding of spelt grain can be obtained with the highest grain moisture content and the maximum duration of its softening.

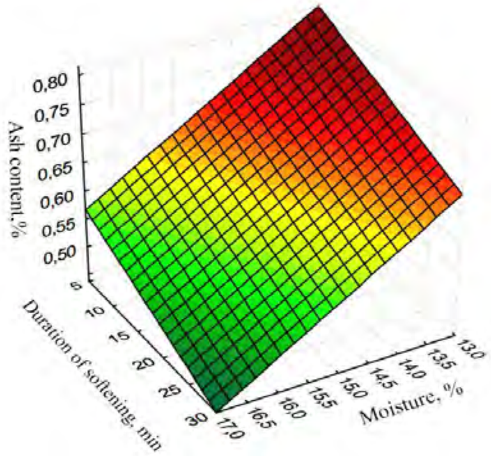

Fig. 2 – Relationship between parameters of water-heat treatment of spelt wheat grain and flour ash content after the first grinding

The correlation and influence of the factors were determined using beta and partial correlation coefficients (Fig. 3). For the first grinding, grain moisture content before grinding had the highest influence on flour ash content.

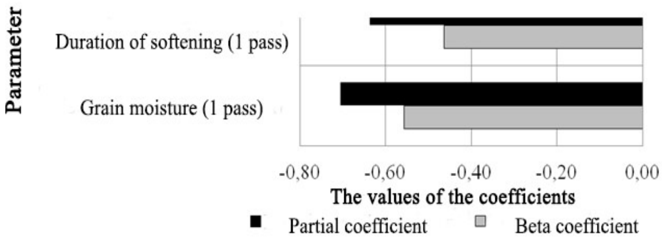

Fig. 3 – Results of correlation analysis of dependencies between the parameters of water-heat treatment and ash content after the first grinding

The parameters dependence of water-heat treatment and ash content after the second grinding was shown by the second-order equation according to Taylor's theory:

$$Z_2=3{,}346981–0{,}257682X_1–0{,}014978X_2+0{,}006044X_1^2+0{,}00076X_1X_2. \quad (4)$$

The theory of residuals autocorrelation of the 4th function was rejected because DW_U (1,58045) <DW (1,854882) <4-DW_U (1,58045) statement was true and all others were false. High reliability of the 4th function was statistically proved (Multiple R = 0,989562227, Multiple R^2 = 0,979233402, Adjusted R^2 0,975525081, $F(5,28) = 264{,}063812$, $p = 1{,}2063897\ 10^{-22}$).

After graphical representation of the 4th function, it was found that the effect of moisture and the duration of its effect on grain during the second grinding were similar to the first one (Fig. 4). The influence of moisture on the milling products during the second pass resulted in a greater effect than the duration of softening. In general, flour ash content in a production using two milling systems is most influenced by grain moisture content. Obviously it can be explained by the fact that the formation of microcracks in grain endosperm depends on forces between water and its structural parts. Moisture content increase weakens bonds between shells and grain endosperm, which helps them to separate better during the second grinding.

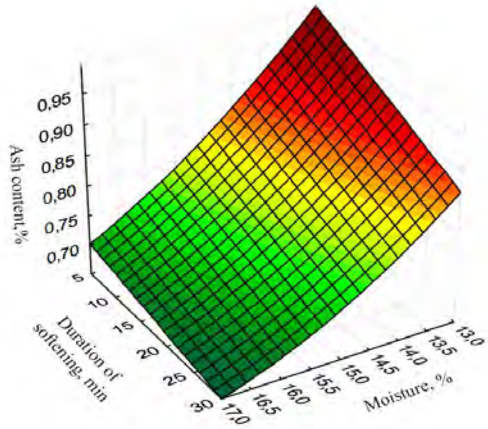

Fig. 4 – Relationship between the parameters of water-heat treatment of spelt wheat grain and flour ash content after the first grinding

Therefore, the reaction of spelt wheat grain to water-heat treatment is similar to the known regimes for soft-milled wheat grain type.

The tendency of flour whiteness change depending on the modes of water-heat treatment varied similarly to ash content. Due to the fact that the sample data were not correctly distributed, the relationship between factors was found using non-parametric statistics methods (Table 4). According to Cheddock scale, the relationship between flour whiteness and the duration of softening was directly noticeable, and with grain moisture content - straight high, which made it feasible to carry out further studies.

Table 4 – Spearman correlation coefficients

Indicator	Grain moisture, %	Duration of softening, h
Flour whiteness after first grinding, unit in.	0,833471*	0,585085*
Flour whiteness after second grinding, unit in.	0,894232*	0,579903*

Note: Significantly p <0,05.

The theory of linear dependence between these indicators was rejected because the residuals of obtained models had autocorrelation. After interpreting the dependencies in the form of second-order functions, it was found that the formula of the dependence of flour whiteness after the first grinding, moisture content and duration of softening had autocorrelation of residuals similar to linear. This indicates that relevant models may have unaccounted for significant variables that influenced the process, model cycle, process performance could respond to delayed conditions, and so on. Therefore, to calculate partial correlation coefficients for the corresponding dependence, look for relationships and the power of effect was inappropriate.

The mathematical relationship between flour whiteness of spelt wheat and the parameters of water-heat treatment is given in the 5 formula.

$$W = -149,516+19,324X_1+2,229X2–0,484X_1^2–0,01X_2^2–0,112X_1X_2. \quad (5)$$

де W – flour whiteness, unit in.;

X_1 – grain moisture, %;

X_2 – duration of softening, h.

The graphical representation of function shows that the duration of softening had the greatest influence on flour whiteness at the lowest grain moisture content (Fig. 5). At the moisture content of 14,0–17,0 %, the effect of softening duration decreased.

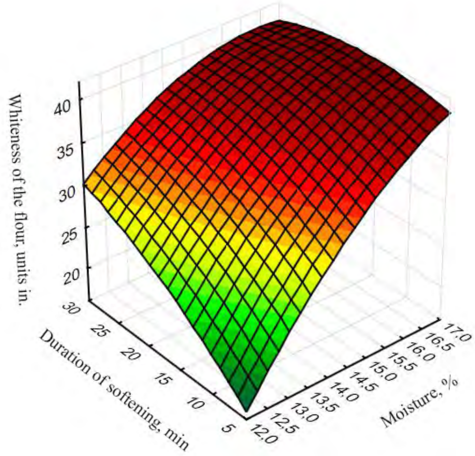

Fig. 5 – Relationship between the parameters of water-heat treatment of spelt wheat grain and flour whiteness

The research results were unevenly distributed, so the use of non-parametric statistics was a priority. It was assumed that there was a straight line connection between the coefficient of endosperm use (Coef. U) and the duration of softening, whereas the tendency to change depending on moisture content was curvilinear. Curvilinear dependencies were also observed between the parameters of water-heat treatment and complex efficiency criterion (Complex U). Therefore, the approximation was performed using second- and third-order polynomials.

Moisturizing and the duration of softening of spelt wheat grain influenced the flour yield. So, at 13,0–14,5 % grain moisture content, flour yield was 82,0–83,3 %. Grain moisturizing to the content of 15,0 % increased its yield up to 83,9 % during 5–hour softening, but it was the highest for 10–15 hours of moistening – 84,2–85,3 %. A similar tendency was found for grain moisturizing up to 15,5 %. Moisturizing of spelt wheat grain to 16,0–17,0 % moisture content reduced flour yield to 81,3–83,0 %. Therefore, it is optimal to moisten grain to 15,0–15,5 % moisture content and with softening for 5–10 hours. As a result of regression analysis, statistically significant regression coefficients were determined and mathematical models were formed:

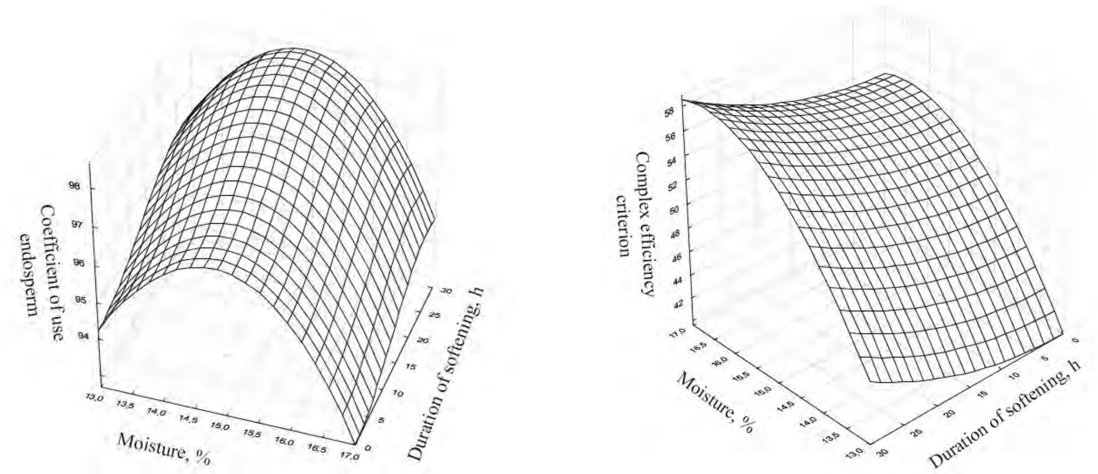

Fig. 6 – Relationship between the parameters of water-heat treatment and efficiency of flour milling

Coef. $U = 41{,}22451+0{,}75545X_1^2+0{,}00874X_2^2-0{,}03397X_1^3-0{,}00022X_2^3$ (6)

Complex

$U=-67{,}3908+1{,}3336X_1^2+0{,}0059X_2^2-0{,}0539X_1^3$ (7)

where X_1 – grain moisture, %; X_2 – duration of softening, h.

Graphical representation of 2^d and 3^d functions is shown in Fig. 6.

It has been proved that the greatest effect on the performance of flour production was due to grain moisture content. Thus, increasing moisture content from 13,0 % to 15,0 % rose endosperm use coefficient from 94,5 % to 99,0 or more by 4,5 points. High endosperm use coefficient was at 15,5 % spelt wheat grain moisture content. Further increase in moisture content to 16,0–17,0% had a negative effect on this indicator, as it decreased to 93,7–95,6 %. In all studied samples, increase in the duration of softening at grain moisture content of 15,0–15,5 % increased the endosperm use coefficient.

Conclusions

Therefore, there is high correlation between the parameters of water-heat treatment of spelt wheat grain and flour quality. The use of water-heat treatment significantly influences the complex criterion of flour milling production efficiency. Grain moisturizing and softening contribute to an increase in the complex criterion by 22–40 % compared to 13 % moisture content (40,8 %). Its largest value was recorded by the longest duration of softening – 57,0–57,2 %. It is the lowest in grain moisture content before grinding – 13,0–14,5 % – 40,8–46,8 %.

The use of water-heat treatment causes an improvement in spelt wheat grain flour production process. It improves the processing of spelt wheat by classic technology. According to the performance indicators of flour milling production in low productivity enterprises, moisturizing of spelt wheat grain is optimal up to 15,0–15,5 %, followed by its softening for 10–15 hours. It is advisable to further study the effect of crushing and water-heat treatment parameters of the developed flour milling process on spelt wheat grain.

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ВПЛИВ ВОДНОТЕПЛОВОЇ ОБРОБКИ НА ЯКІСТЬ БОРОШНА З ЗЕРНА ПШЕНИЦІ СПЕЛЬТИ

Анотація

У результаті проведених досліджень встановлено, що зольність продуктів після першого розмелювання була нижчою порівняно із другим розмелюванням. Це зумовлено зниженням якості проміжного продукту, що надходить на друге розмелювання. Коефіцієнти варіаціювання аналітичних повторностей для результатів після першого розмелювання змінювались від 4,65 до 14,18, а для результатів після другого розмелювання – від 2,44 до 13,43. Це свідчить про невелике або незначне варіювання. Отже середні данні результатів досліджень можна використовувати для математичного моделювання. Теорію правильного розподілення даних вибірок було відхилено, а тому встановлення зв'язку між параметрами водотеплового оброблення та вмістом золи у борошні здійснювали методами непараметричної статистики (визначення коефіцієнта кореляції Spearman). З ймовірністю 95 % можна стверджувати, що між параметрами водотеплового оброблення та вмістом золи існував обернений кореляційний зв'язок.

Найнижчий вміст золи у борошні після першого розмелювання зерна спельти можна отримати за найвищої вологості зерна та найбільшої тривалості його відволожування. Зв'язок і вплив чинників встановлювали за допомогою бета та парціальних коефіцієнтів кореляції. Для першого розмелювання найвищий зв'язок та вплив на вміст золи у борошні мала вологість зерна перед розмелюванням. Дія вологи на продукти розмелу під час другого проходу зумовлювала більший вплив порівняно з тривалістю відволожування. У цілому на вміст золи у борошні на виробництві, що використовує дві розмельні системи найбільший вплив зумовлює вологість зерна. Очевидно це пояснюється тим, що утворення мікротріщин в ендоспермі зернівки залежить від сил натягу між водою та структурними її частинами. Збільшення вологості послаблює зв'язки між оболонками й ендоспермом зерна, що сприяє кращому їх відділенню за другого розмелювання. Отже, реакція зерна пшениці спельти на водотеплове оброблення подібна до відомих режимів для м'якозерного типу зерна пшениці м'якої. Тенденція зміни білизни борошна залежно від режимів водотеплового оброблення змінювалась подібно вмісту золи.

Ключові слова: *пшениця спельта, борошно, водотеплове оброблення, вміст золи, білизна борошна.*

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PECULIARITIES OF NAKED OAT GRAIN AS A CEREAL CULTURE

Abstract

Archaeological excavations show that oats were known as early as the Bronze Age, from about 1500-1700 BC. According to various historical data, the homeland of the oat culture forms is Southern Europe, Northeast China and Mongolia. The first archeological findings of oat grain were discovered in Germany and date back to the I-VI c. In Kievan Rus oats began to grow from about the VI. For many centuries, oats have been an important feed and foof grain,and with the beginning of the twentieth century there is an increase in its use in agriculture and processing. Widespread products of oat processing in different countries of the world are groats, cereals, flour and food bran, in addition to traditional products produce instant cereals, muesli, various intended semi-finished products. Oats are also widely used in other industries: it is additionally used in the production of beer, oat milk, ice cream, bread, cookies, baby food, etc.

In Ukraine, oats are grown mainly as ancillary technical culture. The area of crops is from 5000 to 6000 km2. The main production is concentrated in Polissia and Forest-Steppe, mainly spring oats are grown, to a lesser extent semi-winter and winter forms. According to the State Statistics Service of Ukraine, the gross grain harvest in the last 5-7 years has increased and is at the level of 458 ... 616 thousand tons of grain per year. Over the past 20 years, oat production in Ukraine has been declining, due to the fact that most of it is grown for cereals, with a relatively small crop yield and high cultivation costs, even with the use of state-of-the-art agrotechnology. About 60,000 tonnes of oats are used annually to meet the needs of the domestic groats industry. Breeders have received new grains that have increased nutritional and technological value. Considering new varieties of oats, it is possible to distinguish naked forms of Avena nuda (naked oats).

In the world, naked oats is a valuable crop that has a consistently high nutritional value that allows it to be used in various industries. This type of oat is derived by the method of individual selection from a cross-hybrid population. The variety of this oat is inermis, morphologically different from the hull varieties by the structure of the spikelets, which determines the peculiarities of its quantitative and qualitative indicators

The peculiarity of naked oats is the absence of flower hulls firmly bound to the grain surface (20 ... 40% in oat hulled forms), which significantly improves its properties. The hulls in the naked varieties are soft, do not cover the grain very tightly and are almost completely separated in the process of grain harvesting and threshing.

Key words: *naked oats, technological properties, groat production, absence of flower hulls, varieties.*

Introduction. Formulation of the problem

In the modern world conditions, the development and implementation of new technological solutions is which are replacing the old and the less efficient, energy-intensive, extended technological processes that took place in the second half of the 20th century.

The existing technologies of the Ukrainian grain industry have been virtually unchanged since their first widespread publication and use, and the varieties of cereals that have served as a guide in their development cannot be compared with the modern ones in their yield and basic properties.

The use of a long technological process in combination with unstable physico-chemical indicators of grain raw materials does not contribute to the stabilization of high quality indicators of finished products.

At the same time, the population's demand for groat products is much lower than for bread products (the basis of which is wheat bread making flour), which also affected the backwardness of introducing new types of raw materials and assortment. This can be traced to the fact that, for example, the total gross grain yield of oats in a certain period (in 1990) reached 1400-1500 thousand tons per year, while for nutritional needs (production of groats, flakes, flour, other products) up to 60 are used according to various estimates., although the greatest value of this grain is appear as food and for many years in the world is used not only for the creation of classic groat products, but also used as a raw material for breakfast cereals, muesli, bars, combined cereal products Components for functional foods and dietary gradual production of whose in Ukraine began only in the second half 2000.

Since the early 21st century, there has been an increase in the proportion of small businesses in the groats industry, which are increasing today. The majority of such enterprises do not allow the use of existing extended full grain processing technologies, there is a reduction in the number of basic technological operations, often not sufficiently substantiated, which affects the quality of the obtained products, which does not always responds all the basic rules of the regulations on the finished products.

High efficiency of cereals processing, expanding the range of products and improving its quality properties is traditionally achieved due to new, breeding varieties of traditional grain that have better properties - higher yields, lower hoodness, better chemical composition (more protein, β-glucan vitamins), which allows for a gradual reorientation of the processing plant to higher quality standards, with economic costs being minimal as a rule and technological schemes and equipment for their implementation remain virtually unchanged, the main adjustment occurs with the modes of operation of the most energy-intensive stages that are available available during processing and are considered irrational for the processing of new grain.

The current level of development of breeding technologies and the need for more efficient technologies and raw materials contribute to the emergence of new promising varieties of cereals that are increasing their potential every year. These breeding varieties include the naked (unhulled) varieties of crops, the processing of which, compared to the most promising and modern hulled varieties, has the most significant advantages in:

- ✓ energy efficiency;
- ✓ reduction and stabilization of the main links of the technological process;
- ✓ improving the quality and values of yield of end products;
- ✓ Opportunities in creating a new range of products.

With all these advantages, the use of naked grain does not require a complete restructuring of technological processes and special conditions, for the production of a standard range of products using a certain technological process, adjust the modes of operation of the necessary stages, others exclude completely.

The greatest perspective of completely replacing the conventional hulled varieties in the groats industry is the newest naked varieties of oats, which by botanical classification belong to the sowing oats Avena sativa L. of the subspecies Avena nudisativa. In terms of distribution and prevalence, naked varieties of oats are get behind the hulled ones, but their high perspective for different branches of the grain processing industry and the active work of breeders have led to the growing number of varieties every year and today they can be found on almost all continents.

The largest breeding centers for breeding new and adapting existing varieties of naked oats are located in technologically developed countries - Germany, France, Finland, USA, Canada, in the post-Soviet space one of the leading places is occupied by Russia and Belarus, in recent years, increasing attention has been paid to breeding naked oats in Ukraine. Considering the features of naked oats traditionally excrete 5-7 basic botanical varieties: *var.inermis; var.chinensis; var.maculate; var. mongolica; var.sibirica; var.gymnocarpa; var.affinis.*

Each subspecies has its own peculiarities and distribution. Among others in the world, including in Ukraine, the highest prevalence of varieties of naked oats is var. inermis. In the European countries there are also naked varieties classified as var. chinensis, in Mongolia and China - var. maculate and var. mongolica. The uniqueness of the varieties of naked oats is determined not only by the prevailing technological properties and chemical composition, but also by the fact that the known varieties of naked oats do not contain genetically modified organisms, which significantly expands the scope and, if necessary, allows them to be used even in the production of baby food.

For Ukraine, naked oats grain are not a fundamentally new crop. Naked grains variety Abel (Czech country of origin, originator Selgen, AS) were first registered in the State Register of Varieties of Plants Eligible for Distribution in Ukraine in 2000. Since that time, the number of varieties of naked oats in the country has only increased. In 2007, after passing the state variety tests, high-quality food varieties of the naked oats of German breeding "Salomon" and "Samuel" (originator of GSS Zaattsucht Saltsmünde GmbH) were registered.) and the first domestic variety "Skarb Ukrayiny". In 2015-16, varieties of naked oat "Diyetychnyy" and "Timbre" were registered (the originator ***Ukrainian Scientific Institute*** of Plant ***Breeding***" (VNIS)).

Despite the fact that naked oats grain in Ukraine was first officially registered 20 years ago, its widespread use in the production of grain products is practically excluded, there is no official separate statistics on the parts of its cultivation, there are no general state regulations and restrictive norms for the cultivation of this type of grain. Existing standards, in particular in force in Ukraine DSTU 4963: 2008 «Oats. Specifications." Does not allow, from a practical point of view, to evaluate naked oats, for example by, indicator of volume weight, the grain of naked oats, even shrunken and shriveled (which is by no means recommended for the production of groats), will prevail hulled the varieties for which the limit is set at least 450-520 g / l, with other indicators of impurity content, moisture content (which does not depend on the grain itself) may be full compliance with the values characteristic of food varieties of hulled oats.

The state regulation in force in Ukraine since 1998 ("Rules for conducting and organization of technological process at groats factories") for the implementation of cereals processing does not contain recommendations on the use of naked varieties of oats, while the features of naked oats do not allow efficient technological the process of production of groats products when applying separate modes defined for the hulled grain, which include water-heat treatment, pearling, control operations, etc. All this leads to the fact that the potential processing of naked oats in Ukraine is unprofitable and does not respond basic criteria due to which this grain is widely popular in the world.

The main value of naked varieties of oats is the high nutritional value of grain and, accordingly, the products obtained during its processing, as well as excellent physical properties, so that the technological process can be carried out according to a flexible structure, which allows not to depend on the existing conditions at the processing plant and technological equipment for the implementation of one or another stage of production and extends the possibility of its use for implementation in almost of any existing enterprises.

In morphological structure, the grain of naked oats is practically no different from the hulled varieties, while growing the kernel surface of the naked varieties are similarly covered with hard floral hulls, but in the hulled grain the flower films have a strong bond with the kernel and at one point and when harvesting and threshing grain without the use of special peeling equipment, their removal is not possible, the naked grain flower hulls do not have a strong bond with the kernel, is a component that is easily removed without the use of any technology equipment, depending on the varietal characteristics of grain and agrotechnical conditions of its cultivation, most of the flower hulls (up to 95-97 % of all the grain, without impurities) is removed in the process of harvesting and threshing (similar to modern naked wheat varieties).

Ukrainian naked varieties of oats have a declared average yield of 25-35 c / ha, which is lower compared to the stated characteristics of hulled varieties - 45-50 c / ha. Within the limits of these values for hulled varieties of oats, including hard flower hulls which, by their structure, practically do not contain components important for human nutrition, the technological process is carried out with the aim of their complete removal, the proportion of which, depending on the variety features may be 20-40 % which adds weight and increases yields. The naked oats do not have the hulls and yield characteristics considered without them into account as kernel, which together with the potential yields that can reach 40-45 c/ha brings the naked varieties closer to the hulled.

The naked oats grain like hulled kernel, is characterized by an elongated cylindrical shape; a distinctly crease is present on the ventral side of the grain. The kernel surface is smooth with a glossy shade of traditionally light color which, depending on the varietal features, can change from white to light yellow or light brown. On the surface of the bran parts there are trichomes, which similarly hard flower hulls need to be removed in the technological process. Comparing the pearled kernel of tradirional hulled oats and naked by the amount of trichomes naked contains much less, which is due to their removal during harvesting and threshing.

According to the anatomical structure, the naked oats grain, like all cereals, consists of three main parts – the bran, the endosperm and the embryo. The bran are divided into fruit and seed, in the upper layer of the endosperm is located aleurone layer. Endosperm has the highest proportion of grains, and bran the smallest.

Due to the absence of hard flower hulls, the geometric characteristics of the naked oat grain are smaller than the hulled grain of the traditional oat, although with the hulled kernel the main dimensional characteristics are almost identical: thickness 1.5-2.5 mm, width 2.0-3.5 mm , length 7-9 mm. Due to this, the grain size of this type of oats is relatively smaller compared to the grain in the hulls, but due to the lack of flower hulls, the naked grain has greater uniformity, which increases the efficiency of grain processing. It is recommended to divide the hulled grain during processing into fractions at the stage of cleaning and preparation, which increases the number of necessary process equipment of any range of products by twice, respectively energy costs, the number of service the staff, etc.

This has led to the fact that today, to save resources, the processing of traditional oats is in most cases carried out without fractionation, however, this leads to deterioration of the quality of end products. Naked oats grain does not have this problem and the technological process does not have to be fixed within two fractions; high processing efficiency without loss of quality achieved in processing a grain without fractionation by one stream.

By indicators of the volume weight and 1000 grains weight (additionally characterizing the size and evenness of the grain, its varietal features), the naked grain has the opposite of the traditional oat trends. Volume weight, of hulled grain owing to its convex-acute shape has the least value of this indicator among other cereals, at DSTU 4963: 2008 «Oats. Specifications.» for food used oats (minimum 3 class), volume weight is determined not less than 460 g/l, for naked oats grain due to absence of flower hulls contributes to a more dense packing of grain in a certain volume, which allows to obtain high values of volume weightindicator 580-700 g/l.

According to the 1000grains weight, by contrast, due to the presence of flower hulls, the grain of hulled oats is characterized by a sufficiently high 1000 grains weight of 30-45 g, while for the naked grain there are smaller values of this indicator of 25-30 g.

The relatively low values of 1000 grains weight do not reduce adaptability of naked oats grain and on the contrary emphasize the possibility of obtaining a high yield of end products during its processing.

The hoodness of naked oats grain in the almost complete absence of hard flower hulls is not a characteristic indicator, however the residual presence of hulls on the kernel surface depends entirely on the agroclimatic conditions of grain cultivation and the degree of threshing during harvesting.

To ensure high technological efficiency of processing naked oats grain, it is recommended that it be threshed in order to maximize the extraction of hard flower hulls, with the total proportion of untreshed and hulled (traditional oats) grain not exceeding 10%. Exceeding 10% reduces the efficiency of use of this type of grain, which is accordingly reflected in the decrease in the values of yield of end products and its quality properties.

The content of fine grains in accordance with the current standard determines the suitability of oat grain for food production, the amount of which is determined by the passage of a sieve of 1.8 × 20 mm (hulled grain), for grains of 1-2 grades no more than 3 %, 3 classes and for malt production - no more than 5 %. Such restrictions are important in terms of the ratio of the content of endosperm and hulls, in the fine grain the proportion of endosperm is small, the hulls contain more (compared to the main grain) its removal will not lead to abuse of the technological process and reduce the quality of production. By its dimensional characteristics, the grain of naked oats is smaller than the hull grain, so the use of the recommended sieve of 1.8 × 20 mm is recommended for batches of large grain, in other cases the sieve (1,6 - 1,7) × 20 mm with the mass fraction of the removed grain from the sieves should not exceed 5 %.

According to other indicators defined in the current standard indicators of moisture content, content of impurities, acidity naked oats grain intended for food production should satisfy the limiting values of these indicators. Only a humidity exceeding 0.5 % of the specified requirements is allowed.

Naked oat grain has all the advantages of the chemical composition that are inherent in traditional hulled grain. The anatomical parts of the basic chemicals are unevenly distributed. The main component of the endosperm is starch and protein, the upper layer (aleurone) contains part of the protein, minerals and β-glucans and other fibers, the germ parts contain main mass fraction of fat and a certain amount of protein, the bran layer are mainly consists of difficult to digest fiber and particles of minerals. The absence of hard floral hulls in the naked oats which are the main components of fiber and other hard-to-digest components as a result of the differences in the chemical composition of the hulled and naked grains. For the production of high quality groat products that meet the restrictive of current standards content of proteins and their value for the human body is important.

Naked oats may contain a high protein content compared to other cereals, which may reach maximum levels of 21-22 %, however, for most varieties there is a lower indirect protein content of 14-16 %, Ukrainian varieties of naked oats characterized by a protein content of 12 to 16 %. Such significant differences within protein content values are the result of agro-climatic growing conditions depending on which the mass fraction of protein in the grain is capable of increasing or decreasing by 1.5-2.0 %, even within one defined variety. Among the varieties of naked oat recommended for growing in Ukraine, the highest protein content has the varieties of German breeding "Salomon" and "Samuel" - up to 16 %, the least promising can be called the Czech breed "Abel" and the Belarusian variety "Marathon" - up to 14 %. According to the amino acid composition of proteins, the grain of naked oats is complete for the human body, contains all the necessary eight essential amino acids - lysine, tryptophan, methionine, threonine, valine, phenylalanine, leucine, isoleucine.

Naked oat grain, similarly to hulled, contains a high proportion of lysine, the amount of which, when consumed with 100 g of oat products, satisfies the body's needs for this amino acid. The presence of partially substituted amino acids, arginine and histidine, allows the use of naked oats to create baby foods.

From a technological point of view, it is important for proteins, their structure, digestibility has water-heat treatment and its modes. The process of denaturation of proteins begins with the process of steaming, roasting, cooking, which are an integral part of the technological processes of grain processing when reaching a temperature of +110-120 ° C. As a result, their structure is destroyed. This affects the fractional composition, which increases the proportion of insoluble residue (scleroproteins) that is not absorbed by the human body, while accordingly reducing the number of available water-soluble fractions of protein (albumin and globulins). In addition, long-term heating of the grain undergoes amino acid reactions and free sugars (Maillard reaction), which darkens the grain surface due to the formation of melanoidins, which are also not absorbed by the human body. In aggregate, it reduces the total amount of protein and its and its suitability for nutrition.

Starch is the main energy substance in oat grain, in the endosperm is placed in the form of granules of various shapes with size characteristics from 3 to 10 microns. Oat grain starch is enclosed in a protein matrix and fats may be present on the surface of the starch grains in bound or free state. The constituents are amylose and amylopectin, which is characterized by a much higher proportion of amylopectin than amylose which does not exceed 20-25 %. It is the properties of amylopectin that determine the viscosity of oat products and their pasteurization. Naked oat grain is characterized by higher starch content than hulled grain, which, depending on the varietal characteristics and conditions of grain cultivation, is in the range of + 55-65 %. In the process of water-heat treatment under the action of moisture and temperature, the starch changes its physicochemical properties, at a temperature of +55 to 60 ^{o}C the hydrolysis processes begin, which is the result of reducing its amount in the grain or products.

A particular dietary component of the carbohydrate complex of some cereals is β-glucan. This substance is present in sufficient quantity only in barley, oats and wheat grains. In addition to cereals, β-glucan is also found in some species of algae, fungi and yeast. The substance has not been found in the human body, so its absence in most foods does not adversely affect the body, such as the absence of proteins, individual amino acids, minerals, vitamins etc.. By its structure and effect on the human body β-glucan can be attributed to valuable dietary fiber. It has been determined that β-glucans are difficult to absorb by the digestive system, and are able to excrete harmful substances from the body, which gives them biotic properties. The β-glucans of cereals are significantly different in structure from those found in mushrooms and yeast, the structure of which includes D-glucose having β-1-3 bonds; β-1-6, while cereal β-glucan is characterized by β-1-3 bonds; β-1-4. In the grain of the naked oat, β-glucan is located mainly in the aleurone layer, which is the upper layer of the grain close to the bran parts.

The mass fraction depends on the varietal characteristics and agrotechnical conditions of cultivation, while in quantitative terms, the naked grain exceeds the hulled content of β-glucan indirectly by 2-3 %. Intermediate values of the content of this component in valuable food varieties of naked grains reach up to 7%, while the value of 4-5% is characteristic of hulled grain.

In 1997, the US Food and Drug Administration identified β-glucan as a useful, 3 g daily substance for human health, combined with low saturated fat intake, to reduce the risk of cardiovascular disease, lower blood cholesterol, strengthen the immune system. Given the full nature of this component of the harmful effects of its excessive consumption was not detected.

From a technological point of view, the modes of pearling important for the preservation of β-glucan in end products in the processing of naked oats. Incorrectly selected mode will not only remove excess bran parts but also remove β-glucans, which reduces the potential value of the obtained products. The influence of water heat treatment modes on quantitative-qualitative changes in cereals β-glucan has not been sufficiently investigated, the vast majority of results indicate that the change of steaming modes on the quantitative fraction of β-glucan has no significant effect, the main changes are related to changes in solubility and viscosity.

For naked varieties of oat grains, similar to hulled, there is a significant mass fraction of fat in comparison with other cereals, which is one of the main advantages and disadvantages of oat grain. The advantages include the composition of oat fat, which has high biological efficiency, which is manifested in the presence in its composition of unsaturated fatty acids that are not synthesized by the human body and get to it only with food. The main constituents of the complex are linoleic, oleic and palmitic fatty acids, with a polyunsaturated fatty acid content of up to 75 %. At the same time, this is the main disadvantage of oat products - a significant proportion of polyunsaturated fatty acids that are unstable leads to a rapid deterioration in the quality of grain and products. If the uncessed grain is closed due to the integrity of the bran parts to the action of oxygen on the inner layers, which contributes to a certain equilibrium in the oxidation processes, the products of its processing, regardless of the assortment, are produced with a required defection of the integrity of the bran parts, which opens oxygen and accelerates the oxidation processes which is reflected in the relatively small shelf life of oat products – 4-6 months The mass fraction of fat in naked oats is higher than the value characteristic of the hulled grain and, depending on the varietal characteristics, may reach 12 %.

The major mass fraction of fat is in the embryo parts in the endosperm. Technologically, the stabilization of the processes in the fatty acid complex is achieved through the conduct of water-heat treatment, and if consider such a product as flakes, water-heat treatment is carried out twice - at the stage of preparation of grain for dehulling and preparation of groats for flaking. As a rule, the effectiveness of the processes is evaluated by the activity of lipase - an enzyme that is a catalyst for fat hydrolysis, and it is proved that the steaming of the grain/ groats at a saturated vapor pressure can reduce its activity by 7-10 times. It is technologically inappropriate for the grain of naked oats to apply the modes of water-heat treatment existing for hulled varieties, as steaming at the recommended modes (especially in the production of flakes) will lead to negative reactions in the carbohydrate and protein complexes of the grain, reducing the nutritional value of the product with no significant effect on the product. Therefore, for processing naked oat grain, it is important to choose the modes of water-heat treatment of the grain / groats, which at a sufficient level stabilize the fatty acid complex, but there are no negative reactions in other grain complexes, with special attention to be paid to pearling modes, which aim at softening or complete elimination of steaming is the effective removal of germ parts, potentially contributing to the stability of products during storage.

Fiber is a difficult to digest human body component of grain, in the production of cereal products with high quality and nutritional properties, the content of this substance is reduced at different stages of the technological process, so the content of fiber (its extraction) is structured and built technological processes. In the oat grain, the main mass fraction of the fiber is placed in the hard flower hulls and upper bran parts of the grain, trichomes.

Conclusion

For naked varieties of oats, the absence of flower hulls on the kernel surface, and the smaller number of trichomes, is the result of significantly lower content of fiber than in the hulled grain. The very low fiber content, combined with other physical and chemical benefits, is a key factor in making effective use of these benefits, as the removal of flower hulls and subsequent pearling(processing hulled grain) is accompanied by excessive formation of flour, which, except fiber, has a high protein content, β-glucans , fat, vitamins, minerals, which reduces the content of these biologically active substances and accordingly reduces the nutritional value and quality properties of the final product. Increase the availability of fiber and achieve its absorption in the body by conventional methods that can be used in groats production is not possible, for example, during the stage of water-heat treatment, which significantly changes the characteristics of the quantitative and qualitative characteristics of proteins, fats and carbohydrates practically does not change, no reactions its hydrolysis to other substances, only its swelling is observed, its mass fraction does not change.

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ОСОБЛИВОСТІ ЗЕРНОВОЇ КУЛЬТУРИ У ВИГЛЯДІ ГОЛОЗЕРНОГО ВІВСА

Анотація

Археологічні розкопки показують, що овес був відомий ще у бронзовому віці, приблизно у 1500-1700 рр. до н.е. За різними історичними даними батьківщиною культурних форм вівса є Південна Європа, Північно-Східний Китай та Монголія Перші археологічні знахідки зерна вівса посівного були виявлені в Німеччині та відносяться до I-VI в. н.е. У Київській Русі овес почали вирощувати приблизно з VI ст. н.е. На протязі багатьох століть овес був важливою зернофуражною та продовольчою культурою, а з початком XX ст. відмічається зростання об'ємів його використання у сільськогосподарському виробництві та переробній промисловості.

Широко розповсюдженими продуктами переробки вівса в різних країнах світу є крупи, пластівці, борошно та харчові висівки, окрім традиційних продуктів виробляють крупи швидкого приготування, мюслі, різні за призначенням напівфабрикати. Овес також широко використовується іншими галузями переробної промисловості: його додатково використовують при виробництві пива, вівсяного молока, морозива, хліба, печива, дитячих харчових продуктів тощо.

В Україні овес вирощують переважно як допоміжну технічну культуру. Площа посівів становить від 5000 до 6000 км^2. Основне виробництво сконцентровано на Поліссі та Лісостепу, вирощують переважно яровий овес, в меншому ступені напівозимі та озимі форми. Валовий збір зерна за даними служби державної статистики України за останні 5-7 років збільшується і знаходиться на рівні 458...616 тис. тонн зерна на рік. За останні 20 років виробництво вівса в Україні зменшувалося, що пов'язано з тим, що його більшість вирощується на зернофуражні цілі, при цьому культура має відносно невелику врожайність та потребує великих затрат на вирощування, навіть при застосуванні найсучасніших агротехнологій. Для забезпечення потреб вітчизняної круп'яної промисловості щорічно використовується близько 60 тис. т. вівса. Вчені-селекціонери отримали нові зернові, які мають підвищену харчову та технологічну цінність. Розглядаючи нові сорти вівса можна виділити голозерні форми Avena nuda (голозерний овес).

У світі голозерний овес є цінною культурою, яка має стабільно високу харчову цінність, що дозволяє використовувати його у різних галузях світової промисловості. Зазначений тип вівса виведено методом індивідуального відбору з безкросованої гібридної популяції. Різновид цього вівса інерміс, морфологічно відрізняється від плівчастих сортів будовою колоска, що обумовлює особливості його кількісних та якісних показників

Особливістю голозерного вівса є відсутність жорстких квіткових плівок, міцно зв'язаних з поверхнею зернівки (20...40 % у плівчастих форм вівса), що значно покращує його властивості. Плівки у голозерних сортів м`які, не щільно охоплюють зернівку і практично повністю відокремлюються в процесі збирання та обмолочування зерна

Ключові слова: *голозерний овес, технологічні властивості, виробництво крупи, відсутність квіткових оболонок, сорт.*

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ASSESSING THE QUALITY OF HOMOGENEITY OF PET FOOD USING FERROMAGNETIC MICROTRACERS

Abstract

Obtaining highly homogeneous mixtures is an urgent task in many areas of feed production, as it is associated with the need for even distribution of particularly important and valuable components. Manufacturers of animal feed are using several different methods for performing homogeneity studies to check their mixer performance.

This paper is devoted to the use of nontraditional markers such as ferromagnetic Microtracers to evaluate the homogeneity of the final feed. Microtracers have successfully been used in a mixer testing program in the USA since 1985 and in Europe since 2006. They represent a major improvement over traditional analytical procedures for evaluation of mixer performance involving the use of cobalt or manganese salts. The authors described the quantitative results of determination and identification of Microtracers in two sets of 20 samples of pet food manufactured by Kormotech LLC with using a proprietary Rotary Detector procedure developed by Micro-Tracers Inc (San Francisco, California). It was shown that analysis of 150 g samples at level of Microtracer addition of 20 g per metric ton of pet food allowed a magnetic retrieval of the number of ferromagnetic particles from 61 to 101 which was sufficient for application of Poisson and Chi-squared statistics. The obtained results from two tests performed with different time of mixing were interpreted in accordance with the requirements of the GMP + BA2 standard. It was determined that mixing within 3 min leads to the marginal mixing with the calculated probability value of 1.12%. The prolonged mixing within 4 min leads to complete mixing with the calculated probability value of 5.93%. The use of ferromagnetic Microtracers in a mixer testing program is justified for such tasks as comparison of mixers with each other, as well as identifying the changes in the technical characteristics of the mixers and their performance occurring during their exploitation. In addition, using microtracers can quickly determine the quality of the mixing equipment when it is purchased.

Keywords: *mixing, compound feed, food quality, microtracers, markers, pet food, the Rotary Detector.*

Introduction. Formulation of the problem

Despite the rapid growth of the global pet food market, the domestic market demonstrates the untapped potential [1, 2]. Conducting basic scientific research in the direction of developing new formulations and technologies for the manufacture of finished feeds [3] include the following: studying their usefulness, quality and safety, improving existing and developing new methods for monitoring quality [4]. The results of this basic research are able to contribute to improving competitiveness and increasing the share of domestic producers in the industrial feed market for unproductive animals

An effective method for the production of pet food based on meat and vegetables using poultry offal for meat and bone meal is described in study [5]. The formulation of the combined meat and vegetable pet food developed and optimized by the authors meets the physiological needs of the animal's body and meets the established regulatory requirements.

European law tightens the use of slaughter by-products, and since 2002, the EU has banned the use of secondary poultry products for animal feed and pet food [6]. The lack of adequate dietary protein is a problem in feeding domestic animals.

The market of pet food today is developing dynamically and its annual growth averages at level of 12-25% [7]. Such countries as Germany, France, Great Britain, the USA and China are among the most significant producers and importers of pet food. Due to the current political and economic situation in the world, many importers have reduced supply volumes. On the other hand, an increase in the population of domestic animals causes a natural increase in pet food intake. Thus, a favorable situation is currently developing for the development and promotion of new pet food products which consist of numerous important and valuable ingredients.

Obtaining highly homogeneous mixtures of these ingredients is an urgent task in many steps related to the pet food production. Therefore, the manufacturers of these products must have a solid evidence of the high quality of their materials based on accurate dosing and uniform mixing of all components [8].

To our time, there is no single methodology for determining the quality of mixing adopted in Ukraine. The methodology for determining the quality of mixing refers to the international standard [9], the practical application of which is very time-consuming and costly.

It is believed that Ukraine is in 8th place in the TOP 10 fast-growing pet food markets. However, foreign producers dominate the Ukrainian feed market, in particular from countries such as Hungary, Russia, the USA, France and others.

In 2003, the company Kormotech LLC has been founded in Ukraine. Today this company has become the leading domestic producer of pet food, entering the TOP-50 of the largest European manufacturers, arranging the export of its products to 18 countries [10]. Kormotech LLC produces its products under the following brands: Optimeal TM, Club 4 Paws TM, Meow TM, Gav TM and Private Cable. Each type of pet food developed by Kormotech's specialists is based on their innovative approach called "IMMUNITY SUPPORT MIX". Implementation of this approach allowed to create a pet food enriched with a number of components necessary to maintain animal immunity. At the same time, the developed rations fully comply with the basic safety criteria of FEDIAF (European Federation of Pet Food Producers) and ISO 22000. Currently Kormotech LLC is interested in the preparation of their facility to the certification audits in accordance with GMP+ FC requirements [9]. One of the important steps in this process includes performing several tests of its mixers according to GMP + BA2 using ferromagnetic Microtracers to assess the quality of mixing pet food products.

In this paper, the authors described the use of safe markers such as ferromagnetic Microtracers for assessing the quality of the feed mixture homogeneity. For preliminary and qualitative results on the determination and identification of Microtracers in the analyzed sample the Mason Jars [11, 12] should be used. To quantify the quality of mixing and assess the level of contamination of feed mixtures, the use of a Rotary Detector is recommended [13, 14].

Microtracers™ have been reported as a tool for evaluating mixer performance and uniformity in feed materials [15-17].

Microtracers F -series consist of iron grit particles colored with food-grade water soluble or water insoluble (lake) food dyes and are designed to be used in premixes and complete feeds. They can be retrieved from feed materials via magnetic separation. The particle count is approximately 25 000/g and the particle size range is 150–300 micron.

When analyzing particle count data, it is standard to assume an underlying Poisson distribution [9,18,19], with the shape and location of the distribution described by a single parameter, λ. In this study, the focal data are counts of Microtracers particles in individually pet food samples that may or may not have been produced uniformly. If the pet food samples are sufficiently uniform, then repeated items in the production run will reflect a Poisson distribution around a mean value (λ) that is the count of tracer particles that were originally added in pet food samples, scaled to mass.

A goodness of fit test such as the Pearson's Chi-square test is an appropriate tool to evaluate Microtracer counts by testing if observed count distribution is significantly different from what may be expected from a truly random Poisson distribution [13, 19]. The *P* value result of the Chi-square test estimates the probability that the set of observations were drawn from a uniform population and that the variation observed between pet food samples is solely due to random Poisson variation.

Materials composed of particles with discernible differences in physical properties (e.g., particle size, density, rigidity, or surface properties) have a tendency for segregation of particles [15, 19]. Uniformity in particle size and limited particle size range are especially critical in limiting segregation. Thus, Microtracers particle size distribution should be comparable to the materials to which it is incorporated to achieve uniform distribution.

This study was undertaken to investigate the potential use of Microtracers F as a quality control tool to estimate the variability in the process used to manufacture pet food. Variability of test items was evaluated based on distribution of incorporated tracers. If tracers prove to be a useful tool for assessing the uniformity of pet food samples, they may be suitable as a routine quality control tool for laboratory proficiency testing schemes in accordance with ISO 17025 and in the accreditation of organizations providing proficiency testing schemes in accordance with ISO/IEC 17043.

Materials and methods

The following Base feed materials manufactured by Kormotech have been tested using Microtracers F-Series:

Woof!™ - dog food; Meow!™ - cat food; Club 4 Paws™ (former 4 Paws Club™) - top quality dog and cat feeds, Optimeal™ - top quality dog and cat feeds with prebiotics, berries and herbs aimed at enhancing the animal's immunity .

This particular paper includes only data related to the pet food of Optimeal™ brand.

Two Microtracer F-Series, namely F-Red #40 and F-Blue #1 manufactured Micro-Ttracers, Inc. (San Francisco, CA, USA) have been used in this study [20].

Apparatus

(a) Mixing Equipment: Hosokawa Micron Powder Systems Mikro Bantam Hammer and Screen Mill.

(b) Equipment for Microtracers recovery and counting.

- Rotary Detector™ magnetic separator;
- Scales technical WLC 0.2 / C / 1 (Radwag, Poland)
- Spray bottle containing 50% ethanol solution.

Tracer Recovery and Counting

Upon receipt at Kormotech., the test items were individually weighed, and tracer particles were recovered and counted. Ferromagnetic particles of Microtracers F-series were isolated from the six feed materials using a Rotary Detector magnetic separator. Recovered tracers were transferred from the small filter paper placed on the rotating magnet of the Rotary Detector to the surface of large filter paper (18 cm in diameter) wetted with 50% ethanol solution to dissolve the dyes from the tracer and yield colored spots. Individual tracer particles formed colored spots on the filter papers, which were dried and the spots counted manually or by scanning to a computer and automatically counting according to a program developed by Micro-Tracers, Inc. and posted on their website [21].

Results and discussion

Summary information, including Tracer Recovery, Mean, Standard deviation, Coefficient of variation (%), Coefficient of variation-Poisson (%), Chi-Square, Probability (%) is presented in Table 1 for two different batches of Optimeal™ pet food. Both batches were prepared on the same mixing equipment with using two different Microtracers F-Series, both with an average particle count about 25 per 1 mg The main differences between these batches was the time of mixing : 3 min for batch with results presented in Table 1 and 4 min for batch with results presented in Table 2.

Table 1 - Experimental results on evaluating the quality of mixing with using Microtracer F-Blue #1 , Sample Assayed -150 g, at loading of 20 g of Tracer/Metric Ton of Optimeal™ pet food. Time of mixing 3 min.

Number of Samples Analyzed, 20				Tracer Recovery	96,27
99	61	64	79	Mean	72,20
91	61	82	64	Standard deviation	11,44
56	84	63	68	Coefficient of variation (%)	15,84
70	77	71	87	Coefficient of variation-Poisson (%)	11,77
66	66	65	70	Chi-Square	34,42
Probability (%)					1,12
Conclusion: A Chance Probability between 1-5 % evidences a marginal mix for the blue tracer					

Table 2 - Experimental results on evaluating the quality of mixing with using Microtracer F-Red #40 , Sample Assayed -150 g, at loading of 20 g of Tracer/Metric Ton of Optimeal™ pet food. Time of mixing 4 min.

Number of Samples Analyzed, 20				Tracer Recovery	105,80
78	71	83	101	Mean	79,35
82	60	68	63	Standard deviation	10,85
76	80	94	69	Coefficient of variation (%)	13,67
75	100	83	82	Coefficient of variation-Poisson (%)	11,23
88	77	82	75	Chi-Square	28,19
Probability (%)					5,93
Conclusion: The chance Probability of more than 5 % evidences a complete mix for the red tracer					

From the content of Tables 1 and 2 that summarize the results of calculations and conclusions obtained by the program of Micro-Tracers Inc [20], it can be seen that the found number of MT particles in 20 analyzed samples turns out to be rather close in value to the average number of particles: 72 (Table 1) or 79 (Table 2). It is obvious as well that the values of the coefficient of variation provide some evidence that the uniformity of mix for batch after 4 min of mixing (CV ~13.7 %) is higher than for batch after 3 min of mixing (CV ~ 15.8 %).

This conclusion is in a good correlation with results of evaluating the quality of mixing according to the method developed by Micro-Tracers Inc [21]. It is known that in counting particles as evidence of mixing results are defined by the applicable Poisson statistics, currently accepted by majority of statisticians [9, 18, 22]. The critical property of the Poisson statistics is that a count will be defined with a standard deviation equal to its square root. If one counts 400 particles or in the case of Microtracers colored spots, and one had no analytical data and analyzed an infinite number of samples and mixing was "perfect", it is expected to obtain a standard deviation of 20 and a CV then of 20/400 or 5 %. Obviously, the larger amount of counts the lower value of CV is expected (Table 3).

Table 3 - Correlation between the counts and values of CV expected from applying Poisson statistics

Counts	The values of CV expected from applying Poisson statistics %
100	10,00
400	5,00
800	3,54

As it is clear from Table 3 that at count of 100, for example, the expected value of CV is around 10%. Considering as example the mean value of 79,35 (Table 3), it is easy to calculate the expected value of CV from applying Poisson statistics :

$(79,35)^{1/2} = 8,91$ and CV = (8,91/79,35) x 100 = 11.23%.

However, the experimental data presented in Table 2 show that CV =13,67 %. Therefore, the question becomes is the excesss CV is random noise or statistically significant. For this, the Chi-squared calculation should be applied which yield a Chance Probability (P). If we find a Chance Probability greater than 5 %, we judge the data could reasonably have come from a Complete Mix and we accept it as evidencing such. If we get a Chance Probability of between 1 % and 5 % is is "Probably statistically significant" and the mix is judged "Probably Incomplete", if the Chance Probability is less than 1% this is considered a statistically significant deviation and the mix is judged Incomplete.

This approach is in complete agreement with published document [9] GMP+ Good Manufacturing Practices - Certifications schemes describing using ferromagnetic Microtracers to evaluate animal feed uniformity. Results of $P \leq 0.01$ reflect insufficient uniformity, results of $P \geq 0.05$ reflect good uniformity, and results of $0.01 \leq P \leq 0.05$ suggest marginal uniformity, which may be suspect, and further investigation is warranted [9].

Thus, the results shown in Table 1 should be attributed to the case of marginal mix (P=1,12 %, i.e. $0.01 \leq P \leq 0.05$) and the results shown in Table 5 should be attributed to the case of complete mix (P=5,93 %, i.e. $P \geq 0.05$).

Numerous studies conducted in the USA, Serbia, Poland, Ireland, Italy, Russia and other countries show the high efficiency and speed of using ferromagnetic Microtracers to assess the uniformity of feed [12-16].

Their use is justified for solving specific problems, which include:

1. Comparison of the mixers based on the study of the efficiency of distribution of the Microtracer in them over the mixing composition;
2. Identification of changes in the technical characteristics of the mixer during operation over time,
3. Identification of changes in the composition or physical properties of the mixture on the distribution of the Microtracer in it.

It is important to point out that Microtracer should be added to the feed not by itself, but as a part of the mix with other conventional components of the feed. The amount of such a mixture in the studied feed should be similar to the amount of the component, which, in accordance with the formulation, is introduced into the feed in a minimum dose. The introduction of the Microtracer takes place in the same place as the introduction of other microcomponents of the feed. Then the results of the study will confirm the existing dosing and mixing procedures in the production of finished products.

Conclusion

Ferromagnetic Microtracers, such as Microtracers F-series can be used as an effective tool for determination of the quality of mixing processes and can be useful at the time of purchasing mixing equipment and for evaluation of every production run.

The detailed knowledge of the time and speed of mixing is especially important because the manufacturers of pet food waste energy, labor and capital when they run mixing too long. Besides, an excessive mixing may also lead to degradation such valuable components of pet food as vitamins, enzymes and medications. The required information can be obtained using Microtracers that are widely used in 66 countries of the world, not only for evaluation of mixing performance, but also for cross-contamination determination and for coding microingredients in pet food and animal feed.

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ОЦІНКА ЯКОСТІ ГОМОГЕННОСТІ КОРМІВ ДЛЯ ДОМАШНІХ ТВАРИН З ВИКОРИСТАННЯМ ФЕРРОМАГНІТНИХ МІКРОТРЕЙСЕРІВ

Анотація

Отримання високогомогенних сумішей є актуальним завданням в багатьох сферах виробництва кормів, так як воно пов'язане з необхідністю рівномірного розподілу особливо важливих і цінних компонентів. Від ступеня однорідності кінцевого продукту залежить ефективність його дії та безпечність при використанні. Тому одним із пріоритетних завдань виробників кормових сумішей - це підтверджена доказова база якості їх продукції, яка полягає в точності дозування та однорідності змішування всіх компонентів.

У даній роботі для оцінки якості однорідності кормової суміші пропонується використання нетрадиційних маркерів, таких як феромагнітні мікротрейсери. Автори представили кількісні результати ідентифікації мікротрейсерів у двох пробах по 20 зразків кожна кормів для домашніх тварин, виготовлених ТОВ «Кормотех» з використанням обертального детектора компанії Micro-Tracers Inc (Сан-Франциско, Коліфорнія). Показано, що аналіз 150 г зразків на рівні додавання мікротрейсерів 20 г на метричну тону корму для домашніх тварин дозволило отримати магнітне дослідження кількості феромагнітних частинок від 61 до 101 шт., що було достатнім для застосування статистики Пуассона та χ–квадрату. Отримані результати двох тестів, проведених з різним часом перемішування, інтерпретували відповідно до вимог стандарту GMP + BA2. Визначено, що змішування протягом 3 хв призводить до граничного змішування із розрахунковим значенням ймовірності 1,12%, а тривале перемішування протягом 4 хв призводить до повного змішування із розрахунковим значенням ймовірності 5,93%.

Застосування феромагнітних мікротрейсерів для оцінки однорідності кормів є виправданим для вирішення наступних завдань: порівняння змішувачів між собою; виявлення з плином часу технічних змін в характеристиках змішувача при експлуатації; виявлення змін складу або фізичних властивостей кормової суміші при розподілі в ній індикатору. Крім того, використовуючи мікротрейсери можна швидко визначити якість змішувального обладнання при його придбанні.

Ключові слова: *змішування, комбікорм, якість кормів, мікротрейсери, маркери, корм для домашніх тварин, обертовий детектор*

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DEVELOPMENT OF AN EXPERIMENTAL MODEL OF AVITAMINOSIS F

Abstract

The article analyzes the role of essential polyunsaturated fatty acids (PUFA), especially omega-3 series in humans and animals. The biosynthesis of essential PUFA in humans and animals is very limited, so they must be consumed with food (feed). The ratio of omega-3 and omega-6 PUFA is very important. Biomembranes of animal cells contain about 30% PUFA with a ratio of ω-6/ ω-3 1-2. As this ratio increases, the physicochemical properties of biomembranes and the functional activity of their receptors change. The regulatory function of essential PUFA is that in the body under the action of oxygenase enzymes (cyclooxygenase, lipoxygenase) are formed extremely active hormone-like substances (eicosanoids and docosanoids), which affect a number of physiological processes: inflammation, immunity, metabolism. Moreover, ω-6 PUFA form eicosanoids, which have pro-inflammatory, immunosuppressive properties, and ω-3 PUFAs form eicosanoids and docosanoids, which have anti-inflammatory and immunostimulatory properties. Deficiency of essential PUFA, and especially ω-3 PUFA, leads to impaired development of the body and its state of health, which are manifestations of avitaminosis F. Prevention and treatment of avitaminosis F is carried out with drugs that contain PUFA.

To create new, more effective vitamin F preparations, it is necessary to reproduce the model of vitamin F deficiency.

An experimental model of vitamin F deficiency in white rats kept on a fat –free diet with the addition of coconut oil, which is almost completely free of unsaturated fatty acids, and saturated fatty acids make up almost 99 % of all fatty acids was developed.

The total content of ω-6 PUFA (sum of linoleic and arachidonic acids), the content of ω-3 PUFA (α-linolenic, eicosapentaenoic and docosahexaenoic acids) in neutral lipids (triglycerides and cholesterol esters) defined. The content of ω-6 PUFA under the influence of coconut oil decreased by 3.3 times, and the content of ω-3 PUFA - by 7.5 times.

The influence of coconut oil, the content of ω-6 PUFA decreased by 2.1 times, and the content of ω-3 PUFA - by 2.8 times. The most strongly reduces the content of ω-3 PUFA, namely eicosapentaenoic, coconut oil, starting from 5 %. Consumption of FFD with a content of 15 % coconut oil reduces the content of eicosapentaenoic acid to zero, ie we have an absolute deficiency of one of the most important essential PUFAs, which determined the presence of vitamin F deficiency.

Key words: *essential fatty acids, coconut oil, vitamin F deficiency, ω-6 PUFA, ω-3 PUFA, fatty nutrition.*

Introduction

Avitaminosis F – is a deficiency of essential polyunsaturated fatty acids (PUFA), especially omega-3 series [1].It is known that the composition of PUFA includes fatty acids, the radical of which is two, three, four, five or six double bonds and which are divided depending on the location of the double bond in the third from the terminal methyl group of the carbon atom or in the sixth from the terminal methyl group of the carbon atom. Omega-3 PUFA include α-linolenic acid ($C_{18:3}$, ω-3), eicosapetaenoic ($C_{20:5}$, ω-3) and docosahexaenoic ($C_{22:6}$, ω-3). Omega-6 PUFA include linoleic ($C_{18:2}$, ω-6), γ-linolenic ($C_{18:3}$, ω-6), arachidonic ($C_{20:4}$, ω-6).

The biosynthesis of essential PUFA in humans and animals is very limited, so they must be consumed with food (feed).

Essential PUFA have two main functions: structural and regulatory. The structural function of PUFA is that they are necessary for the construction of biomembranes, without which there is no cell of the body. Moreover, the ratio of omega-3 and omega-6 PUFA is very important [2]. Biomembranes of animal cells contain about 30 % PUFA with a ratio of ω-6 / ω-3 1-2 [1]. As this ratio increases, the physicochemical properties of biomembranes and the functional activity of their receptors change.

The regulatory function of essential PUFA is that in the body under the action of oxygenase enzymes (cyclooxygenase, lipoxygenase) are formed extremely active hormone-like substances (eicosanoids and docosanoids), which affect a number of physiological processes: inflammation, immunity, metabolism [3].

Moreover, ω-6 PUFA form eicosanoids, which have pro-inflammatory, immunosuppressive properties, and ω-3 PUFAs form eicosanoids and docosanoids, which have anti-inflammatory and immunostimulatory properties.

Deficiency of essential PUFA, and especially ω-3 PUFA, leads to impaired development of the body and its state of health, which are manifestations of avitaminosis F. Prevention and treatment of avitaminosis F is carried out with drugs that contain PUFA.

To create new, more effective vitamin F preparations, it is necessary to reproduce the model of vitamin F deficiency.

The aim of our work was to develop an experimental model of vitamin F deficiency in white rats kept on a fat –free diet with the addition of coconut oil, which is almost completely free of unsaturated fatty acids, and saturated fatty acids make up almost 99 % of all fatty acids [4].

Materials and methods of research

White Wistar rats were used. Rats were fed a 30-day fat-free diet (FFD) supplemented with 5, 10, or 15% coconut oil. The content of ω-6 PUFA (linoleic and arachidonic) and ω-3 PUFA (eicosapentaenoic and docosahexaenoic) in gas and liquid chromatography was determined in neutral lipids of the liver and blood serum.

The experiments were performed on 24 Wistar rats (males, 3 months), which received a fat-free diet (FFD) [5], the composition of which is presented in table 1. All rats were divided into 4 equal groups:

Table 1 - The composition of the fat-free diet for rats [5]

№	Component	Content, g / kg
1	Maizestarch	660
2	Soybeanmealisdefatted	150
3	Ovalbumin	50
4	Sugar	90
5	Mineralmixture	40
6	Vitaminmixture	10

1st - control, which received FFD, 2nd received FFD with the addition of 5% coconut oil (instead of starch), 3rd received FFD with the addition of 10 % coconut oil and 4th - with the addition of 15 % coconut oil. The duration of the experiment was 30 days.After euthanasia, the animals were isolated liver and received serum. In the neutral lipids of all tissues, the content of PUFA was determined by gas chromatographic method [6].

Results and discussion

Consumption of coconut oil dose-dependently reduces the total amount of PUFA in neutral lipids of liver and serum. The content of ω-6 PUFA is reduced in the liver by 3.3 times and in the serum by 2.1 times when consuming a diet of 15 % coconut oil. The content of ω-3 PUFA is reduced in the liver by 7.5 times, in the serum by 2.8 times.

Under these conditions, the content of eicosapentaenoic acid decreased to zero.

The total content of ω-6 PUFA (sum of linoleic and arachidonic acids), the content of ω-3 PUFA (α-linolenic, eicosapentaenoic and docosahexaenoic acids) in neutral lipids (triglycerides and cholesterol esters) of rat liver is shown in the table 2, what does the content of ω-6 PUFA under the influence of coconut oil decreased by 3.3 times, and the content of ω-3 PUFA - by 7.5 times.

The ratio of ω-6 / ω-3 increases by 1.3 - 2.3 times and for the group with the addition of 15 % coconut oil is 43,0.

Similar figures, but for neutral serum lipids, are presented in table 3, which shows that under the influ ence of coconut oil, the content of ω-6 PUFA decreased by 2.1 times, and the content of ω-3 PUFA - by 2.8 times.

Table 2 - The total content of PUFA in neutral lipids of rat liver, whoreceived FFD with the addition of coconut oil (%)

№	Group	Σ ω-6 PUFA	Σ ω-3 PUFA	ω-6/ω-3
1	FFD	14,3±1,8	0,75±0,24	19,1
2	FFD + 5 % coconut oil	5,9±1,0	0,25±0,19	23,6
3	FFD + 10 % coconut oil	4,5±0,9	0,17±0,08	26,5
4	FFD + 15 % coconut oil	4,3±1,1	0,10±0,06	43,0

Table 3 - The total content of PUFA in neutral serum lipids of rats,who received FFD with the addition of coconut oil (%)

№	Group	Σ ω-6 PUFA	Σ ω-3 PUFA	ω-6/ω-3
1	FFD	14,6±2,0	0,78±0,23	18,7
2	FFD + 5 % coconut oil	10,2±1,4	0,72±0,24	14,2
3	FFD + 10 % coconut oil	7,6±1,1	0,40±0,19	19,0
4	FFD + 15 % coconut oil	6,9±0,9	0,28±0,14	24,6

The ratio of ω-6 / ω-3 increases by 1.32 times and for the group with the addition of 15 % coconut oil is 24,6.

The most strongly reduces the content of ω-3 PUFA, namely eicosapentaenoic, coconut oil, starting from 5 % (Fig. 1).

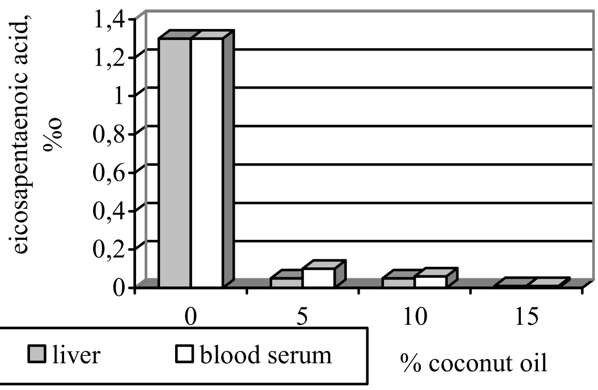

Fig. 1 - The effect of coconut oil on the content of eicosahentaenoic acid inneutral lipids

Consumption of FFD with a content of 15 % coconut oil reduces the content of eicosapentaenoic acid to zero, ie we have an absolute deficiency of one of the most important essential PUFAs, which determined the presence of vitamin F deficiency.

Conclusions

An experimental model of vitamin deficiency F (PUFA deficiency) was developed, which consists in feeding rats FFD with the addition of 15 % coconut oil for least 30 days. Fat-free diet does not eliminate the presence of PUFA in the body.

The consumption of coconut oil (in an amount of 15 %) in a fat-free diet causes the development of experimental deficiency of vitamin F.

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РОЗРОБКА ЕКСПЕРИМЕНТАЛЬНОЇ МОДЕЛІ АВІТАМІНОЗУ F

Анотація

У статті проаналізовано роль незамінних поліненасичених жирних кислот (ПНЖК), особливо групи омега-3 для людей та тварин. Біосинтез незамінних ПНЖК у людини і тварин дуже обмежений, тому їх необхідно вживати разом з їжею (кормом). Співвідношення омега-3 та омега-6 ПНЖК є дуже важливим. Біомембрани клітин тварин містять близько 30 % ПНЖК у співвідношенні ω-6 / ω-3 1-2. Зі збільшенням цього співвідношення фізико-хімічні властивості біомембран та функціональна активність їх рецепторів змінюються. Регулююча функція ПНЖК полягає в тому, що в організмі під дією ферментів оксигенази (циклооксигенази, ліпоксигенази) утворюються надзвичайно активні гормоноподібні речовини (ейкозаноїди та докозаноїди), які впливають на низку фізіологічних процесів: запалення, імунітет, обмін речовин. Більше того, ω-6 PUFA утворюють ейкозаноїди, які мають прозапальні, імуносупресивні властивості, а ω-3 PUFA утворюють ейкозаноїди та докозаноїди, які мають протизапальні та імуностимулюючі властивості. Дефіцит найважливішої ПНЖК, а особливо ω-3 ПНЖК, призводить до порушення розвитку організму та його самопочуття, що є проявами авітамінозу F. Профілактика та лікування авітамінозу F здійснюється препаратами, що містять ПНЖК.

Для створення нових, більш ефективних препаратів вітаміну F необхідно відтворити модель дефіциту вітаміну F.

В роботі було розроблено експериментальну модель дефіциту вітаміну F у білих щурів, що знаходились на жировій дієті з додаванням кокосової олії, яка майже повністю не містить ненасичених жирних кислот, а насичених жирних кислот становить майже 99 % усіх жирних кислот.

Визначено загальний вміст ω-6 ПНЖК (сума лінолевої та арахідонової кислот), вміст ω-3 ПНЖК (α-ліноленова, ейкозапентаенова та докозагексаєнова кислоти) в нейтральних ліпідах (тригліцериди та складні ефіри холестерину). Вміст ω-6 PUFA під впливом кокосової олії зменшився в 3,3 рази, а вміст ω-3 PUFA - у 7,5 раза.

Вплив кокосової олії, вміст ω-6 ПНЖК зменшився в 2,1 рази, а вміст ω-3 ПНЖК - у 2,8 рази. Найбільш сильно знижується вміст ω-3 PUFA, а саме ейкозапентаенової, починаючи з 5 % кокосової олії, Споживання корму з вмістом кокосової олії 15 % зменшує вміст ейкозапентаєнової кислоти до нуля, тобто ми маємо абсолютний дефіцит однієї з найважливіших незамінних ПНЖК, яка визначала наявність дефіциту вітаміну F.

Ключові слова: *незамінні жирні кислоти, кокосова олія, дефіцит вітаміну F, ω-6 ПНЖК, ω-3 ПНЖК, жирове харчування.*

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AGGREGATED COMPLEXES FOR RICE GRAIN PROCESSING

Abstract

The paper considers various designs of aggregated complexes for the processing of rice grain. Their technological schemes were built and analyzed, and a breakdown into modules was performed. This allowed us to group the various designs of units and summarize their technological capabilities. The general reduced technological scheme of rice grain processing is considered. The noted variations are as far as practical applications with and without a grain cleaning module. Various schemes of hulling of grain and selection of hulled grain from unlulled are presented. The technological schemes with various hulling machines are analyzed (the Engleberg hulling machine, with rubberized rolls, centrifugal action), which have their own characteristics. The differences in the use of paddy machines and trimers for sorting grain after hulling are considered. The cylindrical trieurs used to select the rice kernel have an original technological scheme (company Yanmar). This allows you to simplify technological communications and make the unit more compact. The units use more compact paddy machines (reduced size, number of tiers, etc.), which, of course, affects their performance.

The most common combined machine with a single-pass technological scheme (which was named after the first inventor and manufacturer, a hulling machine from Satake) is considered. In addition to laboratory equipment, centrifugal hulling machines are used in grain processing units, which gives additional advantages (a more compact scheme, due to the combination of several technological operations, hulling, transporting the grain stream, and air separation. For the majority of broken and unbroken grains sieve separators are used for simple circuits. Separators with vertical rotation axis, that allows to transport the rice to a predetermined height. This makes it possible to link this separator, for example with electronic scales.

Keywords: *stoner, separator, huller, grinding machine, polishing machine.*

Introduction

In many countries, along with powerful rice processing enterprises, there is integrated equipment for processing mainly 0.3 - 2 tons of rice per hour. This allows you to quickly use equipment to meet the demand of the population of both agricultural and areas remote from large industrial centers. In some cases, combined machines are used to perform hulling and grinding operations, as well as various stages of grinding. In some areas of Ukraine, farmers grow rice. Currently, the Ukrainian industry does not produce the necessary technological equipment for farmers' rice processing enterprises. The equipment that is imported into our country does not always satisfy consumers in terms of quality. Therefore, the authors provide an overview of modern technological equipment manufactured in various countries.

Analysis of recent research and publications

Unfortunately, there are few publications in the academic literature describing the design of aggregated complexes for the processing of rice grain. Also, there are no technological schemes by which these combined machines are built. The literature mainly describes comparative tests of various technological operations and equipment for their implementation [1-4]. Research is aimed at choosing the most optimal equipment for performing the basic operations of the technological process - hulling, separation at various stages, grinding and polishing. Optimization is performed to reduce energy costs, increase the percentage of finished products and improve the quality of the final product (for example, reducing the number of broken kernels). A large number of models of aggregated complexes for the processing of rice grain were reviewed, mainly leading companies that have a significant percentage of equipment sales on the international market [5, 6]. This made it possible with the help of technical documentation to compile and analyze various technological schemes of units and combined machines.

The aim of this work is the construction and analysis of structural schemes of existing structures of aggregated complexes for the processing of rice grain.

Research Methodology

The methodology of this study consisted in sequentially performing the following procedures in the analysis of constructive solutions for the processing of rice grain:

- structural division of structures into various technological modules;
- compilation and analysis of technological modules;
- development and identification of common features for classifying the design of technological modules;
- analysis of the advantages and disadvantages of the selected technological modules and assemblies in general.

Research results

Given the need for equipment mobility and its power from mobile diesel generators, the equipment is maximally compacted, performing part of it in the form of combined machines or as a universal installation made according to the general scheme. During the development of aggregated complexes, most of them refuse to weigh and rough clean grain (Fig. 1).

The grain mixture I elevator 1 raise for cleaning on the air separator 2. Dust and light aerodynamic impurities II are separated from the main stream III. Grain stream III enters the sieve separator 3, which emit large IV and small impurities V. Grain stream VI is directed to a stoner 4, where mineral impurities VII are selected. From the stoner, the cleaned grain VIII is lifted by a fan 5 to a certain height and fed to the hulling head 7. After hulling, rice and husk grain is fed to an air separator 8, which collects dust, flour and husk IX. The punctured grain X is also taken, and the grain mixture from husked and not hulled grains is fed to the paddy machine by fan 9. Unhulled grain XII is usually fed again by fan 5 to the husk head 7. The husked grain XIV is sent to the grinder 11. Stream XIII (the undivided mixture of husked and unhusked grain) is wrapped back in the paddy machine 10. In the grinding machine 11, due to the abrasive action of the rotor and the mesh shell, as well as due to frictional loading between the grains, the upper brown powder is removed, which leads to bleaching of rice grains. Grinding products XV are removed, and grain XVI with a fan 12 is usually fed to a combination machine, which consists of a screen separator 13 and electronic scales 14. In this machine, broken grain XVII is taken from a non-broken XVIII, which is weighed and packaged.

This technological scheme (excluding the grinder) is very common among Japanese, Chinese and other (Korea, India, Thailand, Malaysia) manufacturers of technological equipment for rice processing. The air separator 2 is very often mounted on the material pipe to feed the initial mixture into a complex unit consisting of the main technological equipment: a screen separator 3, a stoner 4 (sometimes not included in the diagram), a peeling head 7, an air separator 8 and a paddy machine 10. Separately install a combined machine, which consists of a screen separator and electronic scales.

Recently, there has been a tendency to replace the peeling head with two elastic rollers with a centrifugal hulling machine, which gives some advantages.

It should be noted that some firms install in the unit a cylindrical trieur, which selects the found grains. Recently, due to increased requirements for the quality of finished products, a scalper is installed separately at the beginning of the line.

A large percentage of rice processing units is performed without a grain cleaning section. Then the technological scheme takes the form shown in Fig. 2.

The unit becomes compact and mobile for operation in several locations. In some models, there is also no grinder 9. Consider an assembly consisting of a hulling head, an air separator and a trieur (Fig. 3). The cleaned grain I is loaded into the hopper 1, from which it enters the hulling head 2. After passing through the working zone between two rubberized rolls, the husk breaks off the grain and a mixture of husk, kernels and unhulled grains II is fed to the air separator 3. Inlet air stream III picks up husk and dust and carries them out of the separator in the form of a stream IV. The hollow grain changes the flight path and is also removed in the form of stream V. The cleaned grain VI is fed to the elevator 4, which picks it up and directs it to the trieur 5. Inlet VII is fed by a screw 6 to the opposite end of the trieur. On the meshed surface of the trieur, the flow changes its direction. Unhulled grains VIII, as a longer fraction, fall out of the cells first and remain on the alveolar surface or fall on screw 6. Rice kernel IX, as a short fraction, falls on the second stage and falls on screw 7.

The rice kernel is transported and removed from trieur in the form of stream IX, which is purged with fresh air XI. This air stream finally takes aerodynamic light impurities and flour, and is reused in the form of the previously considered stream III. Non-husked rice grains that could not rise and get onto screw 6 are removed from the trieur by flow X and sent for re-hulling in the hopper 1. The cleaned rice core (stream IX) is sent to elevator 8 and after rising goes to packing (stream XII), or for further processing.

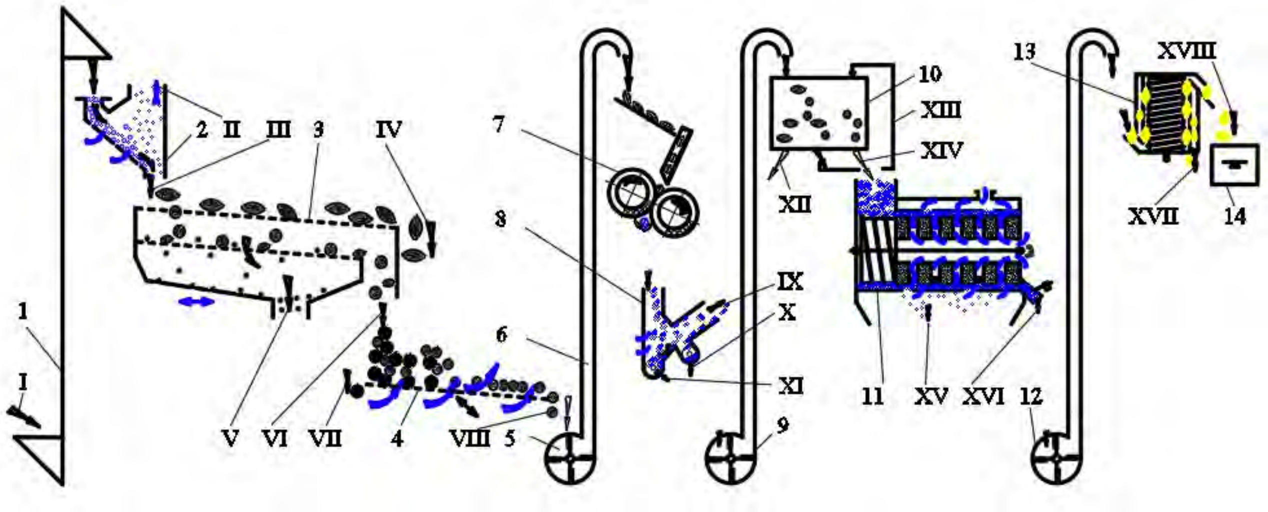


Fig. 1 - An abbreviated technological scheme of rice grain processing:
1 - elevator, 2, 8 - air separators, 3, 13 - sieve separators, 4 - stoner, 5, 9, 12 - fans, 6 - material pipe, 7 - hulling head, 10 - paddy machine, 11 - grinder, 14 - scales. I - XVIII - technological flows.

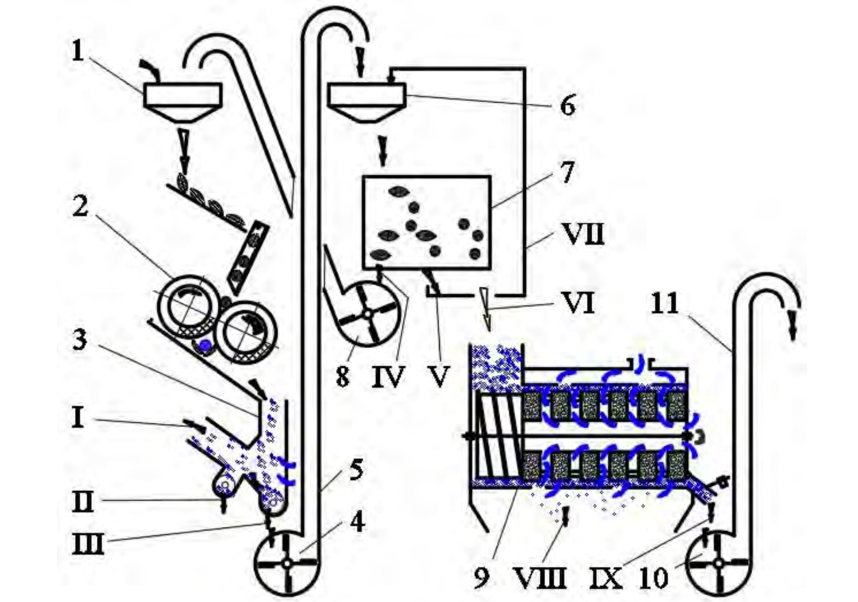


Fig. 2 - The technological scheme of rice grain processing without cleaning:
1, 6 - bins, 2 - peeling head, 3 - air separator, 4, 8, 10 - fans, 5, 11 - material pipelines, 7 – paddy-machine, 9 - grinding machine. I - IX - technological flows.

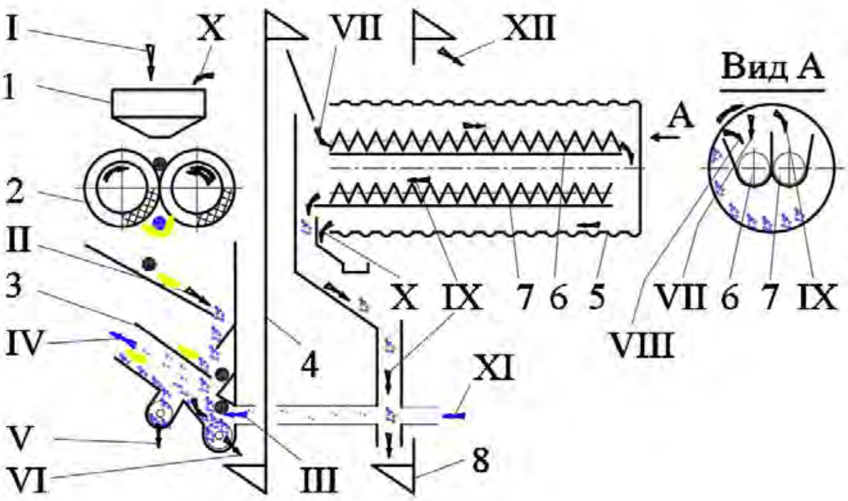


Fig. 3 - The technological scheme of rice grain processing using trieur:
1 - hopper, 2 - hulling head, 3 - air separator, 4, 8 - elevators, 5 - trieur, 6, 7 - screws. I - XII - technological flows.

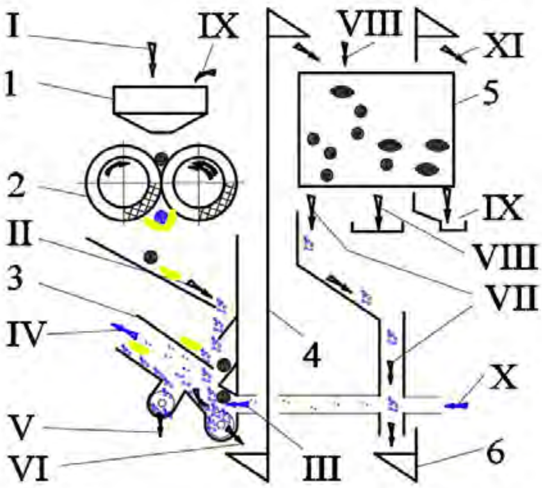


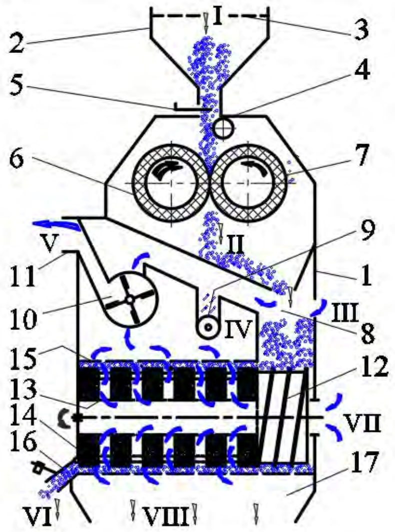
Fig. 4 - The technological scheme of processing grain rice with a paddy-machine:
1 - hopper, 2 - hulling head, 3 - air separator, 4, 6 - elevators, 5 – paddy-machine. I - XI - technological flows.

Instead of trieur, paddy-machines are also used in the hulling and separation modules (Fig. 4). The designations in the diagram are the same as in the previous diagram. They differ in the separation zone in which the paddy-machine 5 is installed. Three process streams emerge from this machine. Stream VII represents husked grain, which is finally blown through with air stream X and elevated by elevator 6 to supply the kernels (stream XI) for packing or further processing.

An inseparable mixture of hulled and unhulled grain (stream VIII) is wrapped at the entrance of the paddy-machine. Unhulled grain that flows in stream IX is returned to hopper 1 for re-hulling.

However, the most popular machines in rural areas of Southeast Asia are machines made according to the scheme developed by Satake back in the fifties of the last century, and which is shown in Fig. 5a. These are the so-called single-pass machines. They include a peeling head with two rubberized rolls 6 and 7, which can dramatically increase the efficiency of the hulling operation, an air separator 8 and a machine with abrasive disks 12 for a high-quality grinding operation. Such a combined machine allows you to get a fairly high-quality product at the output. True, sometimes instead of an abrasive machine for a grain, a friction action machine is used that performs the same technological operation.

Consider the technological scheme of a combined machine (Fig. 5a). The machine consists of a casing 1, over which a hopper 2 with an oscillating sieve 3 is mounted. In the casing 1 there is a feeder 4, which feeds the grain to the hulling head. When the machine is operating, the grain flow is manually controlled using the gate valve 5. The husking head is made with two rubberized rollers 6 and 7, which rotate in different directions at different speeds. An air separator 8 is located under the hulling head. A screw 9 is mounted to output the immature grain, and a fan 10 with an air duct 11 is installed to remove the husk.



а

б

Fig. 5 - Scheme a) and general view b) of a combined machine for peeling and grinding grain from Satake:
1 - housing, 2 - hopper, 3 - sieve, 4 - feeder, 5 - valve, 6 - fast-rotating roller, 7 - slow-rotating roller, 8 - air separator, 9 - auger for the withdrawal of immature grain, 10 - a fan, 11 - a nozzle for the output of husks, 12 - a forcing screw, 13 - a hollow perforated shaft, 14 - abrasive discs, 15 - sieve shell, 16 - cargo valve, 17 - collection. I - VIII - technological flows.

A grinding machine is also mounted in the housing 1. A feeding screw 12 is mounted on the hollow shaft 13 of this machine, creating grain back-up in the grinding zone, and abrasive wheels 14. A rotor representing the shaft 13 with abrasive disks rotates in the sieve shell 15. At the exit from the machine, a cargo valve 16 is mounted to regulate grain back-pressure, and under the sieve shell a collection for the flour 17.

Consider how the machine works. The grain stream I enters through the vibrating sieve 3 into the receiving hopper 2, coarse impurities remain on the screen surface. Then, by the feeder 4, the grain is fed to the rollers 6 and 7 rotating in different directions, where they grab the grain and, under the action of compression and shear forces, carry out the hulling operation. The mixed stream (husked grain, unhusked grain, husk particles and dust) in the form of stream II, is subjected to a purge of air (stream III). The air stream, picking up husk products and dust, carries them out and delivers them to the fan 10. The weaked rice grains are lost over the screw 9, which carries them out in the form of stream IV. Dusty air and husk exit the machine in the form of stream V through the nozzle 11. The husked grain by a feeding screw 12 is fed into the milling zone with abrasive disks 14, where additional layers are removed from the grain under the influence of the abrasive action of the disks and sieve shell 15 and the frictional effect of surrounding grains. Particles removed from the kernel are carried out of the working area by a stream of air VII entering the machine through a hollow perforated shaft and passing through a sieve the shell fall into the collection 17 (stream VIII). The main stream of polished grain, overcoming the resistance of the cargo valve 16 comes in the form of stream VI.

In aggregates of small capacity, centrifugal peeling machines are used (Fig. 6). In the housing 1, a centrifugal hulling machine 2 is installed, over which a hopper 3 is installed. A fan 5 is installed on the same shaft as the hulling machine 2, for air intake with rice hulls and for transporting hulls and dust from the machine (material pipe 6). This allows you to compactly place two process units and simplify the drive of the machine. A material pipe 4 departs from the hulling machine 2 for feeding the mixture into the air separator 7. After the air separator, an oscillating sieve 8 is mounted to separate the unshelled grains.

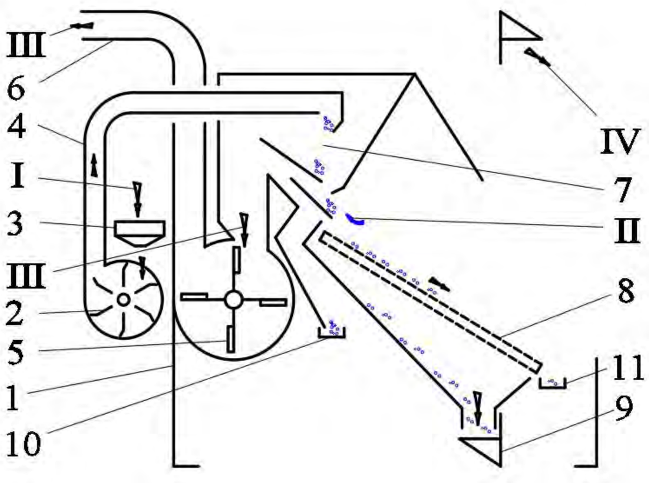


Fig. 6 - Scheme of a combined machine for hulling and sorting grain:
1 - case, 2 - hulling machine, 3 - hopper, 4, 6 - material pipelines, 5 - fan, 7 - air separator, 8 - sieve separator, 9 - elevator, 10 - tray for immature grain, 11 - tray for unhulled grain. I - IV - technological flows.

The machine operates as follows. Grain I is poured into hopper 3 and the valve controls the flow of grain to the rotor of the hulling machine 2. The grain is picked up by the blades of the hulling machine and, under the action of centrifugal forces, slides from the blades, strikes the inner surface of the shell, which is covered with a layer of polyurethane. The grain husk deforms and opens, and the kernel falls out of the shell. The elastic layer of polyurethane does not allow to split the rice kernel. Grain husking products, husk particles and dust are transported by the pumping air stream through the material pipe 4 to the air separator 7. When the mixture falls in this separator, dust and shells are captured by the inlet air stream II. The air with husk enters the fan 5 and, under the action of centrifugal forces, is discharged through the air duct 6 behind the machine (in some models, the air duct length is up to 30 meters). The immature grain deviates from the vertical trajectory and is sent to the tray 10. The main grain flow enters a sieve 8, designed to separate the unhulled grain, which is collected on the tray 11. And the selected kernel is sent to elevator 9 for feeding it (stream III) for subsequent technological operations or packaging. In some machine models, a broken core is also selected.

Consider the scheme of a machine for grinding a rice kernel of small productivity (Fig. 7). A shaft 2 with a screw 3 and a rotor 4 is located in the housing 1. The grain inlet to the working area is regulated by a valve 5. At the outlet of the working area, a lever 7 with a valve 8 and a handle 9 is mounted on the axis 6. The position of the valve 8 is fixed by the handle 9 on the gear sector 10. To unload the processed grain, a valve 11 is pivotally located on the axis 12. The lower part of the body in the working area is made in the form of a mesh 13, to remove the flour.

The machine operates cyclically as follows. In the hopper of housing 1, hulled rice grain is poured (stream I). The timer sets the time for processing a portion of grain. The drive of the machine is turned on, which drives the shaft 2 with the screw 3 and the blade rotor 4. The valve 5 is opened to feed grain into the working area of the machine. The grain is carried away by the screw 3 and is pumped into the area of the rotor 4. The blades pick up the grain and due to friction between the grains, grains and blades, as well as the net, the surface brown layer is removed from the grain of rice. The separated particles of the surface layer in the lower part of the working area are removed from the machine through the mesh 13 (stream II). The main grain flow rises again into the hopper, overcoming the resistance force of valve 8. By changing the position of valve 8, the resistance force of the valve and, as a result, the residence time and pressure of the grain in the working area are regulated. Grain for the specified processing time passes several times through the working area and part of the surface layers, which are mainly brown in color, are removed from it, the kernel remains with a good white color. After processing the rice kernel, the valve 11 is opened and the machine is unloaded (stream III).

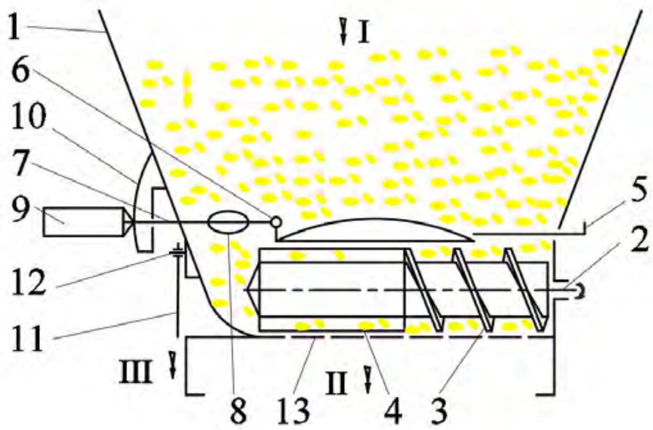


Fig. 7 - Diagram of a machine for grinding rice grains of small capacity:
1 - hopper, 2 - shaft, 3 - auger, 4 - blade rotor, 5 - valve, 6 - axis, 7 - lever, 8 - valve, 9 - handle, 10 - gear sector, 11 - valve, 12 - axis, 13 - sieve.
I - III - technological flows.

The machine is mainly used in catering with small volumes of production.

Conclusions

1. Aggregate equipment of small capacity is carried out mainly modular, which allows you to equip the base unit with the necessary modules (cleaning, grinding, polishing, separation and weighing).

2. The hulling module and the separation of hulling products have been adopted as the base module.

3. In such equipment, the percentage of hulling machines with centrifugal action has increased.

4. Instead of mechanical separation, a photo-separation module is installed, which separates the particles by color and shape.

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АГРЕГАТОВАНІ КОМПЛЕКСИ ДЛЯ ПЕРЕРОБКИ ЗЕРНА РИСА

Анотація

В роботі розглянуті різні конструкції агрегатованих комплексів з переробки зерна рису. Побудовано та проаналізовано їх технологічні схеми, і виконана розбивка на модулі. Це дозволило згрупувати різні конструкції агрегатів і узагальнити їх технологічні можливості. Розглянуто загальну скорочену технологічну схему переробки зерна рису. Зазначені її варіації що до практичного застосування як з модулем очищення зерна, так і без нього. Представлені різні схеми лущення зерна та відбору лущенного зерна від нелущенного. Проаналізовано технологічні схеми з різними лущильними машинами (лущильна машина Енглеберга, з гумовими валами, відцентрової дії), які мають свої особливості. Розглянуто відмінності застосування падді-машин і трієрів для сортування зерна після лущення. Циліндричні трієри, що використовуються для відбору ядра рису мають оригінальну технологічну схему (фірма Yantar). Це дозволяє спростити технологічні комунікації і виконати агрегат більш компактним. В агрегатах використовуються більш компактні падді-машини (зменшені габарити, кількість ярусів і т.д.), що, звичайно, відбивається на їх ефективності роботи.

Розглянута найбільш поширена комбінована машина з однопроходовою технологічною схемою (яка отримала назву від першого винахідника і виробника, лущильна машина фірми Satake). Крім лабораторного обладнання, в агрегатах для переробки зерна використовуються лущильні машини відцентрової дії, що дає додаткові переваги (більш компактна схема, за рахунок сумісництва декількох технологічних операцій, лущення, транспортування зернового потоку, і повітряної сепарації. Для виконання поділу битого і небитого зерна в більшості простих схем використовують ситові сепаратори. Також для підвищення продуктивності ситових сепараторів, в деяких моделях агрегатів їх виконують циліндричними з вертикальною віссю обертання, що дозволяє транспортувати ядро на певну висоту. Це дає можливість скомпонувати цей сепаратор, наприклад з електронними вагами.

Ключові слова: *каменевідбірник, сепаратор, лущильна машина, шліфувальна машина, полірувальна машина.*

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DIRECTION OF IMPROVEMENT OF THE WORKING BODIES OF HAMMER

Abstrakt

Among the many types of grinding machines used in enterprises of grain processing, food and other industries, an important place belongs to hammer crushers. This is explained by the possibility of their use for grinding materials of various origins (plant, animal, mineral, as well as various wastes of food production), various particle size distribution (lumpy, briquetted, granular, fibrous), having different strength properties (hard, medium hard, soft, brittle, viscous), capable of being crushed once or requiring double sequential crushing. In addition, hammer crushers are characterized by relative simplicity of design, and most importantly - they destroy materials in the most rational way - by impact loading as a result of two successive strokes: a hammer on a particle and particles on the surface of the deck.

The execution of these attacks at right angles creates the conditions for the intensification of the destruction process. However, the wear of the hammers leads to a rounding of their impact faces, which makes the angles of attack in the active zone of the hammers significantly different from the direct one. Under the influence of shock-frictional loads, their working surfaces quickly wear out, which leads to a decrease in productivity and crushing efficiency, to an increase in energy consumption, a disturbance in the balance of hammer rotors, an increase in the vibroacoustic activity of crushers, and other negative consequences

The invention of the "Hammer of the crusher" provides for the use of ring-shaped multi-toothed hammers, the durability of which, when using traditional materials and conventional heat treatment, is increased by 4...5 times, eliminates the need for periodic rearrangement of hammers, stabilizes the operation of crushers. The possibility of self-sharpening ring-shaped multi-toothed hammers after reversing the hammer rotor simplifies the maintenance of crushers, eliminates personnel errors when replacing worn hammers.

If multi-toothed hammers are subjected to liquid non-electrolysis boration and heat treatment using an optical quantum generator, then their durability can increase by more than ten times.

Key words*: hammer; wear of work surfaces; heat treatment of hammers; reversal of a hammer rotor; replacement of worn hammers; ring-shaped multi-tooth hammer; chemical heat treatment.*

Hammers of the hammer crushers during operation perceive intense shock-frictional loads, which lead to the rapid wear of their working surfaces. There is a decrease in productivity and grinding efficiency, an increase in energy consumption, an increase in the vibroacoustic activity of crushers and other negative phenomena.

Therefore, hammers are usually made of materials with high wear resistance - from alloy steels 30хгс, 30хгса, 35хгс and 35хгса, which require cementation and hardening, as a result of which the hardness of the impact part on both sides of the hammers from the edge to the hanging hole is equal to нгс 55...56.

Despite this, high tension concentrations occurring at the vertices of the right angles of plate hammers under shock loads cause specific wear of a set of hammers of 0.5...1.0 g/t, and the average operating time of one set does not exceed 300...340 hours.

Studies have shown [1] that the shape, size and thickness of hammers also affect the wear resistance of hammers. Now the prevailing form of hammers is considered rectangular. Rectangular plate hammers with two hanging holes are the most technologically advanced for reasons of manufacturing and consumption of scarce sheet steel. The length **a** of the hammers and the width **b** depend on the diameter **D** of the hammer rotor **a = 0.23d, b = 0.1d**. Recently, the thickness of hammers **Δ** has been predominantly taken equal to 6 mm.

The technical literature describes attempts to use cylindrical hammers with a diameter of 18 mm [1]. Their wear resistance increased by 1.5...1.8 times, which should be recognized as positive, but still insufficient. In this regard, the technology of chemical-thermal processing of hammers developed at the Moscow Technological Institute of the Food Industry [2] deserves attention. They developed and introduced the technology of liquid (non-electrolysis) boron and heat treatment of hammers using an optical quantum generator (OQG).

Liquid borating of hammers made of 3ОХГСА steel was carried out in a molten salt. A metallographic analysis of the microstructure and micro hardness of the surface layers showed that a boride layer 30...40 μm thick with a micro hardness of 8000 ... 12000MPa was formed on the surface of the hammers.

To prevent damage, boron hammers were subjected to heat treatment - high-temperature tempering in a high-vacuum installation, which led to a decrease in the structure of the transition zone material and a decrease in the heterogeneity of its structure and chemical composition.

X-ray and microstructural analysis showed that the phase composition, microstructure and micro hardness vary depending on the depth of the diffusion zone: the zone of iron borides FeB - has a thickness of 30 μm and a micro hardness of 12000 MPa; zone of iron borides Fe2B - 20 μm and 8000 MPa, respectively; the zone of a solid solution of boron in iron is 70 μm with a gradual decrease in micro hardness from the surface to the middle of 8000...2200 MPa. Under the influence of radiation from the generator, the solubility of boron in steel increases.

Chemical-thermal treatment allows obtaining a protective layer up to 1.5 mm thick on the surface of the hammer, which consists only of Fe2B, which reduces its brittleness.

Tests of boride coated hammers subjected to heat treatment with the use of laser showed that the wear resistance of the hammers of the A1-ДМИ-20 crusher increased by 3...4 times. However, this method has not yet received industrial distribution.

We have proposed the construction of a ring-shaped multi-toothed hammer [3], which when using traditional materials and conventional heat treatment increases the durability of hammers by at least 4-5 times. If the proposed hammers are subjected to the aforementioned chemical-thermal treatment, then their durability will increase even more.

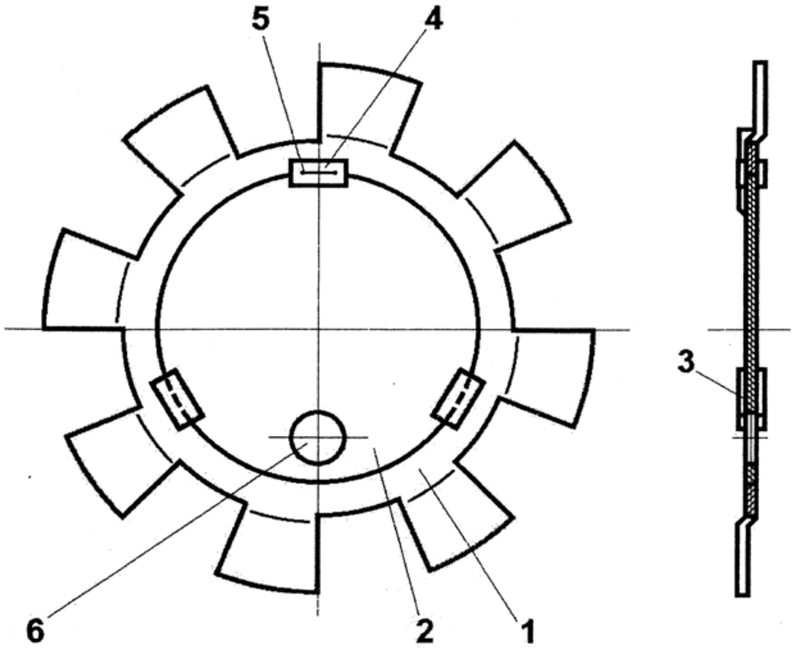

Fig. 1 - The scheme of the hammer crushers made in accordance with the invention No. 1764691:
1 - ring-shaped multi-toothed hammer; 2 - carrier disk; 3 - side plates; 4 - removable stop; 5 - closing link; 6 - suspension hole

The multi-toothed ring-shaped hammer **1** (Fig. 1) is freely mounted on the carrier disk **2**, which has three side plates **3**, one of which contains a removable stop **4** and a closing link **5**. The hammer is mounted on a suspended axis of the usual type, for which the carrier disk has eccentric pendant hole.

The invention is aimed at stabilization of the grinding process in time due to self-rotation of a multi-toothed ring-shaped hammer in such a way that at any time within the overhaul cycle, the least worn tooth appears in the shock position. This occurs under the influence of centrifugal inertia forces and forces of impact-friction interaction between the hammer and the grinding product.

If, for example, ten teeth are arranged along the perimeter of the ring, then, taking into account the reverse of the directions of rotation of the rotor, twenty working faces successively appear at the shock position, having the geometry originally provided, which ensures the maximum crushing effect. To increase the efficiency of crushing, the teeth are bent from the plane of symmetry of the ring: paired in one side and unpaired in the other by half the thickness of the hammer. So, for example, if the thickness of the hammer is 6 mm, then the teeth are bent 3 mm from the axis in different directions. This allows you to expand the crushing zone and eliminates the obstruction of the teeth from adjacent teeth (the effect of obscuring the cutting edges of the teeth by adjacent teeth is eliminated).

This provides a more uniform distribution of the cutting edges of the teeth in the working area of the crusher.

As a result, the number of simultaneously working cutting edges of the teeth increases, therefore, the productivity of the crusher increases when using hammers of a new design.

After all ten teeth have been wear to the maximum permissible state, the rotor of the crusher is subjected to reversal, which includes the work of the yet not worn opposite edges of the teeth. In this mode, the geometry of the worn edges of the teeth is partially restored due to self-sharpening, the effectiveness of which still needs to be confirmed during the practical use of multi-toothed hammers in real operating conditions.

Since a conventional rectangular-shaped hammer with four working faces (or eight, taking into account the reverse), the durability of a ten-pointed hammer with twenty working faces increases 2.5 times. If they are subjected to the above chemical-thermal treatment, then the durability can increase by 7.5...10 times. This fully compensates for the costs of increased consumption of sheet steel and its waste, which are created in the manufacture of hammers of an annular shape.

In the case of the use of multi-toothed ring-shaped hammers in hammer crushers with monolithic rotors, as provided, for example, in crushers of the Dutch company Van Aarsen, the design of hammers can become more advanced. In this case, the pads **3** (Fig. 1) become unnecessary, therefore the hammers **1** together with the carrier disks **2** are located inside the annular grooves (Fig. 2), the width of which can be δ+0.5 mm without bent the teeth. If the tooth bent is to be carried out, then on both sides of the carrier discs, when assembling the rotor, distance washers 3 mm thick should be installed, and the width of the grooves can be 12... 13 mm.

For balancing a hammer crusher on impact, according to the theory of M.M. Gernet [4], the square of the radius of inertia of the hammer ρ relative to the sus pension axis should be equal to the product of the distance from the suspension axis to the center of mass of the hammer c by the distance from the suspension axis to the impact line l, i.e.

$$\rho^2 = c \cdot l. \qquad (1)$$

The square of the central radius of inertia of the hammer, which is assembled in the form of a flat disk of mass m and radius r, we find

$$\rho^2 = \frac{I_z}{m}, \qquad (2)$$

where I - is the moment of inertia of the hammer relative to the z axis, that is, the product of the hammer mass m by the square of the distance from its center of mass r to this axis. Therefore, we have

$$I_z = m \cdot \rho^2. \qquad (3)$$

The square of the radius of inertia of the hammer relative to the suspension axis ρ^2 is determined by the Huygens-Steiner theorem (according to the parallel axis theorem)

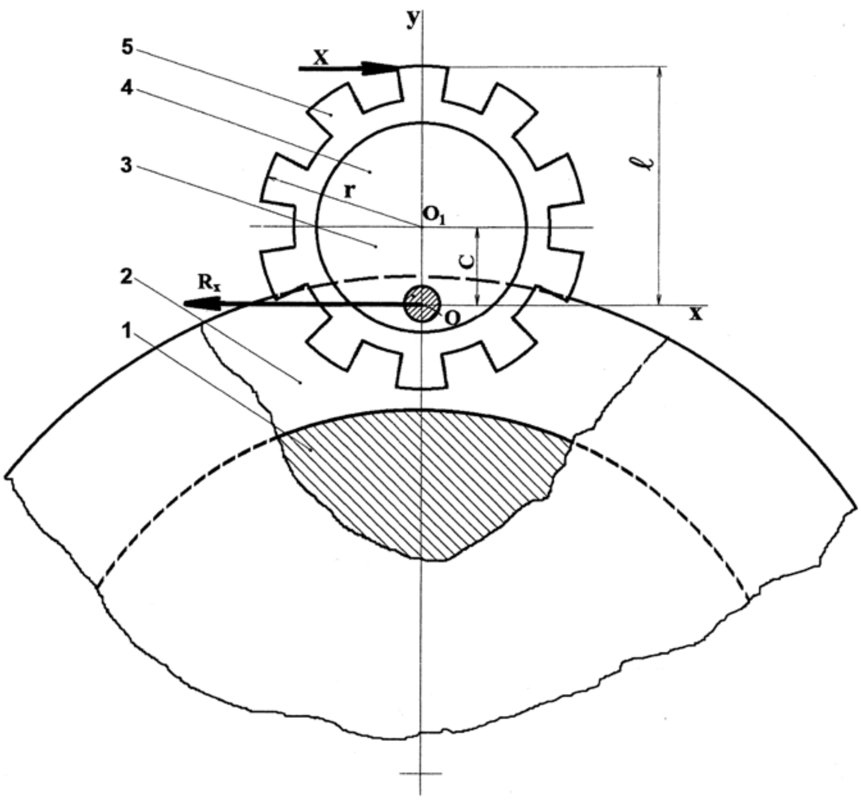

Fig. 2 - The scheme of the hammer rotor with ring-like multi-tooth hammers:
1 - monolithic rotor; 2 - ring-like groove; 3 - hanging rod; 4 - disk drive; 5 - ring-like hammer

$$\rho^2 = \rho_c^2 + c^2. \qquad (4)$$

Neglecting the presence of a suspension hole and hollows depressions between the teeth, we determine the square of the central radius of inertia of the hammer according to (2), taking $I_{cz} = m\frac{\rho^2}{4}$ from the tables of moments of inertia

$$\rho^2 = \frac{I_{cz}}{m} = \frac{\rho^2}{4}. \qquad (5)$$

The distance from the suspension axis of the disk hammer to the line of impact (Fig. 2) is

$$l = c + r. \qquad (6)$$

After transformations (4), (5) and (6), provided that the impact reaction on the axis of the suspension of the hammer is $R_X = 0$, we obtain

$$\frac{r^2}{4} + c^2 = c(c + r), \qquad (7)$$

where do we get

$$\frac{r^2}{4} + c^2 = c^2 + cr. \qquad (8)$$

Finally, find

$$c = \frac{r}{4}. \qquad (9)$$

Expression (9) allows you to construct a hammer so that the shock reaction on the axis of its suspension is zero, regardless of the force shock X and the acceleration created by it.

Ring-shaped hammers, in comparison with conventional plate hammers, also provide a significant reduction in the complexity and time spent on the readjustment and maintenance of crushers.

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НАПРЯМОК УДОСКОНАЛЕННЯ РОБОЧИХ ОРГАНІВ МОЛОТКОВИХ ДРОБАРОК

Анотація

Серед багатьох типів подрібнюючих машин, що застосовуються на підприємствах переробки зерна, у харчовій та інших галузях промисловості, важливе місце належить молотковим дробаркам. Це пояснюється можливістю їх використання для подрібнення матеріалів різного походження (рослинного, тваринного, мінерального, а також різних відходів виробництва харчових продуктів), з різним розподілом розмірів частинок (крупнокускових, брикетованих, зернистих, волокнистих), з різними міцностними властивостями (твердих, середньо-твердих, м'яких, крихких, в'язких), здатних подрібнюватися за один раз або вимагати подвійного послідовного подрібнення. Крім того, молоткові дробарки характеризуються відносною простотою конструкції, а головне - вони руйнують матеріали найбільш раціональним способом - ударним навантаженням в результаті двох послідовних ударів: молотком по частці і часткою на поверхні деки.

Виконання цих ударів під прямим кутом створює умови для інтенсифікації процесу руйнування. Однак знос молотків призводить до округлення їх ударних граней, що робить кути атаки в активній зоні молотків суттєво відмінними від прямих. Під впливом ударно-фрикційних навантажень їх робочі поверхні швидко зношуються, що призводить до зниження продуктивності та ефективності здрібнення, до збільшення енерговитрат, порушення балансу молоткових роторів, збільшення віброакустичної активності дробарки та інших негативних наслідків.

Винахід «Молоток дробарки» передбачає використання кільцеподібних багатозубчастих молотків, довговічність яких при використанні традиційних матеріалів та звичайної термічної обробки збільшується в 4...5 разів, що виключає потребу в періодичній перестановці молотків. Можливість самозаточування кільцеподібних багатозубчастих молотків після реверсування молоткового ротора спрощує технічне обслуговування дробарки, усуває помилки персоналу при заміні зношених молотків.

Якщо багатозубчасті молотки піддати рідинному не електролізному боруванню та термічній обробці за допомогою оптичного квантового генератора, то їх довговічність може зрости більш ніж у десять разів.

Ключові слова: *молоток; зношування робочих поверхонь; термообробка молотків; реверсування молоткового ротора; заміна зношених молотків; кільцеподібний багато зубчастий молоток; хіміко-термічна обробка.*

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ТЕХНОЛОГІЇ ЗЕРНА І ЗЕРНОВОГО БІЗНЕСУ

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- Брокерами на товарних біржах;
- Фахівцями з логістики;
- Експертами з зовнішньоекономічних питань;
- Експертами з оцінки та прогнозування діяльності зерноторгівельних підприємств та ін.

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