EFFECTIVE SIFTING OF FLAT SEEDS THROUGH SIEVE
/
ЭФФЕКТИВНОЕ ПРОСЕИВАНИЕ ПЛОСКИХ ЗЕРЕН НА РЕШЕТАХ

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DOI: 10.35633/INMATEH-58-02

ABSTRACT

The paper presents the methods and technical means to improve the efficiency of grain cleaning machines. The object of research is the process of sifting grain mixtures on sieves that implement the separation of components by size. The experience of using sieves with rectangular holes in the cleaning and sizing of grain mixtures of corn, pumpkin and other crops, where the separation is carried out according to the thickness, shows their low efficiency due to the flat forms of the latter. In the technological process of grain cleaning machines work, flat grains fall on a larger plane on the sieve. This greatly reduces the likelihood of their separation by thickness. To improve the efficiency of sieving grain mixtures with flat seeds, sieves with size activators, which have a riffle appearance, were proposed. Activators lift flat grains and orient them into the holes by their thickness. The grain mixture moving along the sieve is affected by activators and is divided into components. In order to determine the optimal parameters of activators, mathematical modeling and experimental studies were carried out. The movement of a flowing fluid mixture of pseudo-liquefied grain mixtures is considered as the dynamics of a bubbly liquid. This made it possible to obtain the velocity field of the grain mixture and the dependence of the performance of the sieves on their structural kinematic parameters. The obtained research results are universal and can be used to improve the efficiency of sieve sifting of agricultural crops grain mixtures on various grain cleaning machines.

РЕЗЮМЕ

В работе приведены методика и технические средства для повышения эффективности работы зерноочистительных машин. Объектом исследований являются процессы просеивания зерновых смесей на решетах, которые реализуют разделения компонентов по размерам. Опыт использования решет с прямоугольными отверстиями при очистке и калибровке зерновых смесей кукурузы, тыквы и др. культур, где разделение происходит по толщине, показывает их низкую эффективность из-за плоских форм последних. В технологическом процессе работы зерноочистительных машин плоские зерна ложатся большей плоскостью на решето. Это значительно уменьшает вероятность их разделения по толщине. Для повышения эффективности просеивания зерновых смесей с плоскими зернами предложены решета с объемными активаторами, которые имеют вид рифлей. Активаторы приподнимают плоские зерна и ориентируют их в отверстия по толщине. Зерновая смесь, двигаясь вдоль решета, испытывает воздействие активаторов и разделяется по компонентам. Для определения оптимальных параметров активаторов проведено математическое моделирование и экспериментальные исследования. Движение сыпучей псевдосжиженной зерновой смеси по виброрешетам рассмотрено как динамика пузырьковой жидкости. Это позволило получить поле скорости зерновой смеси и зависимости производительности решет от их конструктивно-кинематических параметров. Полученные результаты исследований являются универсальными и могут использованы для повышения эффективности решетного просеивания зерновых смесей с.х. культур на различных зерноочистительных машинах.

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INTRODUCTION

For grain mixtures cleaning and calibration, during their post-harvest processing, sieve grain-cleaning machines are used. The sieves consist of cross connections and round, rectangular (oblong) or triangular holes. The separation of grain mixtures occurs by size: thickness, width and length. However, the separation of flat grains of grain mixtures of corn, pumpkin and other crops have low productivity rates of grain cleaning machines. This is due to the difficult conditions for sifting flat grains by thickness through rectangular holes (Fig. 1). In practice, this is compensated by repeated passes of grain mixtures or an increase in technological capacity (the addition of grain cleaning machines). Repeated passes of grain mixtures through grain cleaning machines leads to injury to the grain, which in turn negatively affects the process of their storage and the biological potential of the seed stock. As a result, we have an increase in operating costs for cleaning or calibrating grain, reducing its quality.
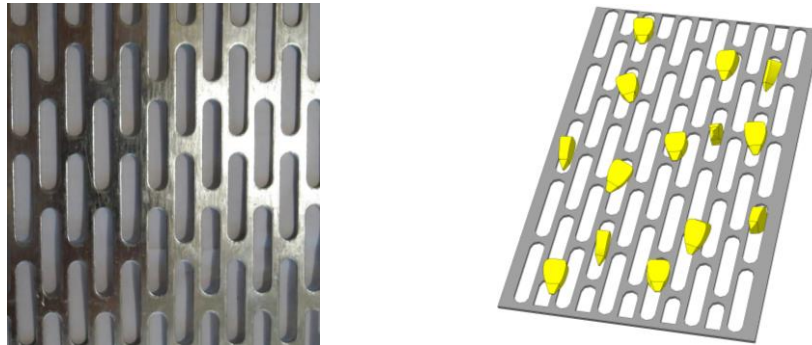

Fig. 1 - Basic sieve for the separation of the grain mixtures

In order to increase the efficiency of sifting grain mixtures with flat seeds, sieves with volumetric/size activators have been developed (*Kharchenko S.A., 2015*) (Fig. 2). Activators are made in the form of riffles; they orient the grains by their thickness, lifting them. The chess arrangement of activators makes it possible to provide multiple effects on the particle of grain mixtures. This allows you to increase the number of grains that are sifted through the sieve holes, while increasing its performance.
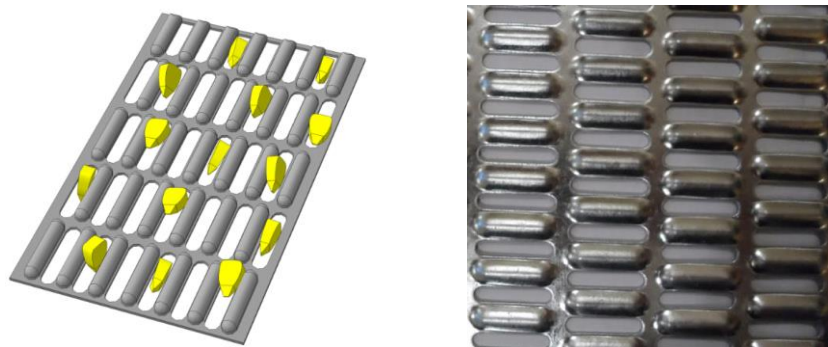

Fig. 2 - Sieve with the volumetric activators for the separation of grain mixtures with flat grains

The use of sieves with activators significantly improves the performance of grain cleaning machines, but the result is not constant and depends on a number of factors. As a result of theoretical and experimental studies (*Kharchenko S.O., 2017*), it was found that the following significant factors also influence the efficiency of vibrate-sieve sifting of grain mixtures: specific productivity (expressed in the thickness of the mixture layer); sieve type; kinematic and design parameters of sieves, activator parameters; properties of the mixture.

Thus, the specification of the parameters of the significant factors of the grain mixtures sifting process will make it possible to develop practical recommendations for the effective operation of sieves with activators for grain cleaning machines. The aim of the work is to study the influence of the grain shape on the screening process through the vibrating screen holes, to develop the means of the corresponding processes intensification.

MATERIALS AND METHODS

For describing the dynamic processes of bulk media in terms of vibro-sieves, in terms of the adequacy of the results, there are the following directions: analogies with hydrodynamic models (*Tishchenko L. N., Olshanskii V. P., Olshanskii S. V., 2011*); continuum mechanics (*Paolotti D., Cattuto C. at. al., 2002*); calculation of the probability of sieving particles by various methods, including the Monte Carlo method (*Pascoe R. at. al., 2015*); discrete element method (*Boac J. M. at. al., 2014*). However, these studies are not related to the dynamic processes of sifting various corn mixtures through the sieve holes and do not take into account the parameters of the sieves and the shape of the grains.

In order to study the dynamics of grain mixtures on flat vibrating sieves, mathematical models of a bubble pseudo-fluid mixture were obtained. For the basis we take the Navier – Stokes equation for a fluid, which is supplemented by a number of refinements and assumptions (*Tishchenko L. and Kharchenko S., 2013*). So, among such assumptions we can see: the grain mixture is considered as a bubble pseudo-liquid with two effective viscosity coefficients; the surface of a vibrating sieve is presented as a two-dimensional periodic structure with a period l_1 along an axis x_1 and with a period l_2 along an axis x_2; a basic cell of a sieve is a rectangle $-l_1/2 \le x_1 \le l_1/2$, $-l_2/2 \le x_2 \le l_2/2$, on which openings are located N with an area $S_1, S_2, ..., S_N$. Corresponding schemes for modeling have been adopted (Fig. 3). The periodic structure (vibrating sieve) is obtained by translation of the basic cell along the axes x_1 and x_2.

a   b
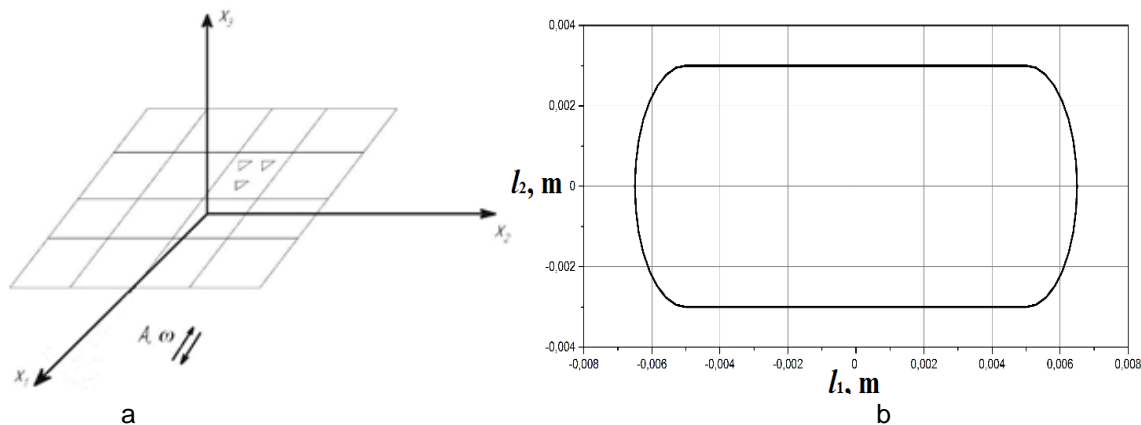
**Fig. 3 - Diagrams of a sieve (a) and its basic cell with the mathematical simulation
of grain mixtures sifting process (b)**

A sieve consists of basic cells (Fig. 3, b) of sizes l_1 and l_2 with openings of the area S. For the modeling of grain mixtures sifting on oblong openings, the parametric superellipse (Lame curve) equation is accepted with the parameters a_1=0.006 m and b_1=0.02 m.

As a result, equations were obtained that were solved using the following algorithm: initial basic equations, boundary and initial conditions; representation of the solution of equations in the form of Fourier series in basis functions with unknown coefficients; obtaining equations for unknown coefficients; using the Laplace transform for the equations in a time variable and obtaining ordinary differential equations (second order); obtaining equations in an explicit form (analytical form); the establishment of finite expressions for the velocity field of a bubble pseudo-environment using the Laplace transform and the residue method; numerical calculation of the dynamics of a bubble pseudo-liquid medium.

Sieve performance was theoretically determined by the expressions:

$$Q = Q_D + Q_P \tag{1}$$

where: Q_D, Q_P – performance of descent and passage fractions of bubble pseudo-medium:

$$Q_D = V_1^{av} h * H, \quad Q_P = V_3^{av} \overline{S}_P, \tag{2}$$

where: $h*$ – averaged thickness of grain mixture layer; H – the sieve width;

$\overline{S}_P$ – the area of «live» section (area of openings) of the sieve;

V_1^{av}, V_3^{av} – components of the speed averaged by the volume of the bubble pseudo-medium:

$$V_1^{av} = \frac{g \sin\theta h^{*2}}{3v} + \frac{A}{h^*}\sqrt{\omega v}\, \text{Re}\left[e^{i\left(\omega t - \frac{3\pi}{4}\right)} + h^*\left(\sqrt{\frac{\omega}{2v}}h^*(1+i)\right)\right] \tag{3}$$

$$V_3^{av} = \frac{V_0}{S_p l_1 l_2} \sum_{m,n=-\infty}^{+\infty} |B_{mn}|^2 D_{mn}, \tag{4}$$

where: S_p – the area of openings on the basic cell of a vibro sieve; g –acceleration of gravity; θ – angle of inclination of a flat sieve; V –average effective kinematic viscosity coefficient of bubble pseudo-medium: $v = \mu / \rho$, $\rho = \overline{\rho}(1-\delta_P) + \rho_P \delta_P$, where $\overline{\rho}$ – density of gaseous medium of bubbles; δ_p – volume concentration of solid particles of pseudo-medium; μ– effective coefficient of dynamic viscosity of the bubble pseudo-medium; A, ω– amplitude and frequency of sieve vibrations, respectively; V_0– average speed of passage of bubble pseudo-medium through openings of sieves, determined during the performance

(*Tishchenko L.N. et. al., 2016*); $D_{mn} = \dfrac{1 - \dfrac{2}{\gamma_{mn}h^*} + \text{th}(\gamma_{mn}h^*)}{\gamma_{mn}h^* + \text{th}(\gamma_{mn}h^*) - 1}$, $\gamma_{mn} = 2\pi\sqrt{\left(\dfrac{n}{l_1}\right)^2 + \left(\dfrac{m}{l_2}\right)^2}$;

B_{mn}–coefficient, considering the parameters of openings and activators: $B_{mn} = \displaystyle\int_{S_p} e^{-i2\pi\left(\frac{n}{l_1}x_1 + \frac{m}{l_2}x_2\right)}dx_1 dx_2$.

The effective coefficient of the dynamic viscosity of bubble pseudo-medium, which determines its properties, determined according to the expression (*Kharchenko S. A. and Tishchenko L.N., 2013*):

$$\mu = \frac{a^2(\rho + 2\rho_p)\omega C}{9(\overline{y}-a)B_1}\left(1 + \delta_B \frac{2{,}5\mu_B + \left(\dfrac{a^2(\rho+2\rho_p)\omega C}{9(\overline{y}-a)B_1}\right)}{\mu_B + \dfrac{a^2(\rho+2\rho_p)\omega C}{9(\overline{y}-a)B_1}}\right) \tag{5}$$

where μ_B – the coefficient of dynamic viscosity of a gaseous medium of bubbles (area between solid particles of grains); δ_B – the coefficient of volume concentration of bubbles; $B_1 = (3\xi fg\pi\rho\cos\theta)/4a$;

$C = \left(\dfrac{2(\rho_p - \rho)A\omega^2}{\pi}\right) - \sqrt{\left(\dfrac{2(\rho_p - \rho)A\omega^2}{\pi}\right)^2 - D^2}$;　　　$D = \dfrac{3\xi f\rho\pi y\cos\theta(h-a)}{4a} - \rho_p g\sin\theta$;

$\overline{y} = h - \dfrac{4a\rho_p \text{tg}\theta}{3\xi f\rho\pi}$; ξ – the coefficient taking into account porosity of the bubble pseudo-medium; f– coefficient of mixture internal dry friction; $a = k_f \cdot a^*$ and ρ_p – averaged radius and density of grain mixture grains, respectively; k_f, a^* – shape factor and real radius of grains, respectively; y – a coordinate by the thickness of the layer of a bubble pseudo-medium.

RESULTS

As a result, the dependences of volume productivity of sieves with activators (Fig. 4) during the separation of corn grain mixtures are obtained, which consider both the properties of the grain and design-kinematic parameters of the sieves. An example of calculation of one of the variants (Fig. 4) is carried out at the following parameters of the process: the amplitude and frequency of sieve oscillations (Fig. 3, a) A=0.0075 m, ω=48.12 rad/s; the basic cell size (Fig. 3, b) l_1=0.008 m; l_2=0.025 m; bubble concentration ratio (pores between solid grains) δ_B=0.36; density of grain mixture ρ =700 kg/m³; the shape factor k_f=1.8; average grain size a=0.0025 m; the opening's width and length a_1=0.006 m, b_1=0.02 m; the friction

coefficient f =0.55; inclination angle of a sieve θ=8°; the rate of mixture passage through the opening V_0=0.45×10^{-3} m/s; the sieve's length and width L=1 m, H=1 m.
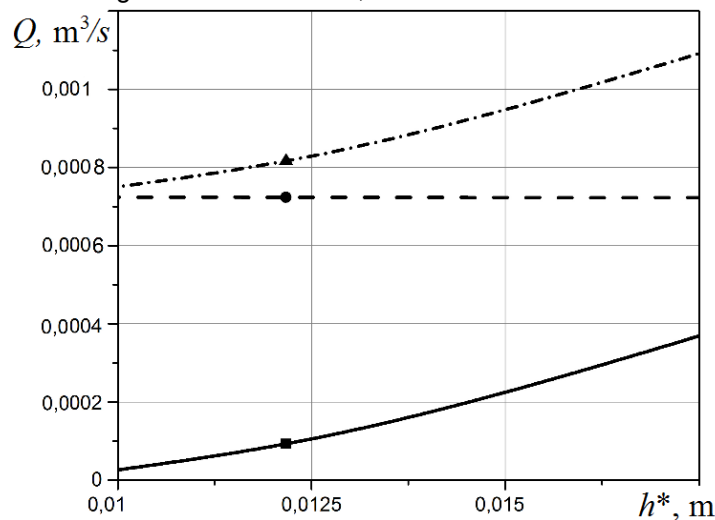
Q, m³/s

Fig. 4 - Dependences of volume productivity of a flat sieve with activators on average thickness of grain mixture layer:
— ■ — – productivity of descent fraction Q_D;
— ● — – productivity of passage fractions Q_P;
— ▲ — – overall productivity of sieves Q

By analyzing the simulation results (*Tishchenko L.N. at. El., 2011; Tishchenko L.N. at. El., 2014*), an increase in the performance of sieves with activators was obtained by separating corn grain mixtures by 25 ... 35% compared to basic sieves with rectangular holes.

As shown by numerical modeling, a significant factor that affects the efficiency of sieving is the shape of the mixture grains. It has been established that within the framework of a single crop, the shape of grains can vary depending on the variety, climatic conditions and the quality of the technological operations carried out when they are grown. According to the shape, the grains of various agricultural cultures differ. Thus, an elongated ellipsoid shape with a longitudinal groove is characteristic of cereal crops. The shape of most seeds of leguminous crops: sorghum, peas, chickpeas is considered to be spherical. The form of buckwheat seeds is close to a tetrahedron or triangular pyramid.

The analysis of the dimensional characteristics shows that the corn grains of various varieties and hybrids have a predominantly flat appearance (*Yeskova OV, 2005; Kirpa MY at. El., 2013; Kirpa MY at. El., 2012; Osokina NM and Kostetska KV, 2013; Babis L. at. El., 2013*). This also applies to pumpkin seeds and zucchini. The flat shape of the grains of these crops negatively affects their sifting through the rectangular openings of sieves, which requires additional study.

Taking into account the analysis, current and future production of crops in the world, the following grain mixtures were selected for experimental studies:

- "Kharkovsky 329" three-linear corn hydride: 1000 seeds weight - 290 g, grain unit - 750 g/l, density of the substance of grains - 1.31 g/cm³, humidity - 11.5%;

- middle-early hybrid of corn "Kharkovsky 291": 1000 seeds weight - 250 g, grain unit - 790 g/l, density of the substance of grains - 1.25 g/cm³, humidity - 12.1%;

- "Donor MV" ternary modified corn hybrid: 1000 seeds weight 300 g, grain unit 740 g/l, grain density 1.29 g/cm³, humidity 10.8%;

- corn hybrid "PR39A50": mass of 1000 seeds - 310 g, grain unit - 730 g/l, density of the substance of grains - 1.38 g/cm³, humidity - 10.1%;

- pumpkin variety "Volga Gray": the mass of 1000 seeds is 285 g, the humidity is 5.5%, the density of the substance is 360 kg/m³;

- a variety of zucchini "Kashnik": the mass of 1000 seeds is 135 g, humidity is 5.2%, the density of the substance of grains is 450 kg/m³.

The grain mixtures of agricultural crops selected for the study have a complex shape, which depends on the variety (hybrid), climatic conditions (humidity, temperature, intensive rainfall, etc.), the quality of agro-requirements for technological operations, etc.

The geometric characteristic of grain is defined by: linear sizes of grain, its volume V_g, area of external surface F_g, the shape of grain. The sphericity indicator ψ, used to estimate the shape of grain, represents the relation of the area of a sphere, equal on volume, to the area of the grain external surface. Different expressions are used for its determination (*Zaika P.M., 2006; Dufty James W., 2003*).

For example, for corn the area of grains and its volume are determined according to the expressions:

$$F_g = \pi R' \left[R' + \sqrt{l_g^2 + (R')^2} \right]; \quad V_g = ka_1a_2l_3 \tag{6}$$

where R' – equivalent radius of grain; k – coefficient considering features of the grain's shape: for wheat – 0.52; for corn – 0.55.

Then, taking into account the given mathematical expressions and the known data about the sizes of grains, geometric characteristics of grain mixtures are obtained (Table 1).

Table 1

Geometric characteristics of corn grains

Crop	Volume, mm^3	Area of external surface, mm^2	Sphericity
Corn	140-260	80-162	0.55-0.8

However, the use of the sphericity coefficient is justified only in the separation of grain mixtures components by width. For flat components of grain mixtures, the use of this coefficient is impractical. Especially when assessing the influence of the grains shape on the process of sifting them by the width through rectangular sieve holes.

The analogy of the corn shape to spherical used in the existing studies is not correct. An analysis of the studies of corn kernels size characteristics (Table 2) found that most seeds have a flat shape (*Yeskova O.V., 2005; Kirpa M.Y. at. el., 2013; Kirpa M.Y. at. El., 2012; Osokina N.M. and Kostetska K.V., 2013; Babis L. at. El., 2013*).

Table 2

Dimensional characteristics of corn seeds of some hybrids (grades)

Name of grade/hybrid	Sizes, mm			Flatness coefficient k_f	Reference
	width	thickness	length		
Kadr 267 MV	7.2	5.8	10	1.24	*Kirpa M.Y. at. el., 2012*
Dneprovsky 337 MV	7.8	6.9	11.1	1.13	
Kadr 443 CB	8.7	6	10.6	1.45	
Borozensky 277 MV	8	5.5	10.42	1.45	*Kirpa M.Y. at. el., 2013*
Solonyansky 298 SV	9.43	5.78	10.32	1.63	
Pyatikhatsky 270 SV	9.62	6.27	9.83	1.53	
Zbruch	9	6.98	9.25	1.44	
DKS 4685x1390	7.6	4.5	10.3	1.69	*Osokina N.M. and Kostetska K.V., 2013*
Dneprovsky 310 MV	7.35	4.39	0.4	1.67	*Yeskova O.V., 2005*
NS 640 (New Garden)	7.37	4.66	9.71	1.58	*Babic L. at. el., 2013*
NS 6010	7.43	4.31	10.43	1.72	
NS 4015	8.32	4.38	10.23	1.90	
ZP 434 (Zemun Field)	7.65	4.33	9.78	1.77	
ZP 677	7.04	3.87	11.25	1.82	
ZP 684	8.19	4.81	9.6	1.7	

In order to take into account the shape of grain mixtures components in mathematical models, it is proposed to use the flatness coefficient k_f.

Moreover, for flat grains it is proposed to use average flatness coefficient, which is the ratio of grain's width to its thickness (Table 2):

$$k_f = a_1/a_2 \tag{7}$$

where: a_1, a_2 – width and thickness of grains, respectively.

Determining seed size is a laborious operation and the most common method is direct measurement. The model method is assumed with the use of measuring tools: rulers, caliper, microscope, etc. When measuring the length, width and thickness, all the grains of the sample are measured. Along with great laboriousness, there is also a human factor, which ambiguously affects accuracy and labour productivity.

To determine the dimensional characteristics of corn mixtures components, a new method has been developed and implemented (*Tishchenko L.M.et. al., 2015*). The difference from the existing method is that image processing is performed using the developed computer program "ImgToVal", which automatically recognizes an object and splits it according to a given grid. Further, the program determines the maximum, minimum and average dimensions in millimetres in two mutually perpendicular planes. The program automatically recognizes the images of seeds from the camera and lays the grid on it with a given step. By setting the required quality (number of pixels) in each grid sector, the program automatically converts it to millimetres, while determining the size of the seeds with a given accuracy.

Determination of the size characteristics of corn hybrids, pumpkin and zucchini varieties, which were adopted for experimental studies, was carried out using the developed method with computer software "ImgToVal" with a sample of 100 pieces. The measurement accuracy of the developed method was up to 5 characters. The results are presented in Table 3.

Table 3

Average grain sizes of corn mixes, pumpkin, zucchini mixtures

Crop/hybrid	Width a_1, mm	Thickness a_2, mm	Length l_3, mm	Flatness coefficient, k_f
Corn DKS 4408	8.92322	4.31215	11.7308	2.08
Corn Donor MV	7.64948	4.29888	9.58465	1.78
Corn Podykh MV	7.98198	4.70482	10.7365	1.70
Corn PR39A50	7.80577	4.73105	10.8958	1.65
Pumpkin Volga gray	12.1763	4.0225	22.5423	3.03
Zucchini Kashnik	8.2724	2.6062	15.2388	3.17

Analyzing the obtained values of flatness coefficient (Table 3) and the results of the known studies (Table 2) it is established that the majority (68.5%) of corn hybrids have a coefficient of flatness k_f=1.65…2.08, and only 31.6 % – k_f <1.6. These results can be taken as initial ones in the mathematical modeling of processes of sieving grain mixtures through openings as basic sieves and developed with activators. As a result of experimental studies (Table 4) efficiency of grain mixtures components separation, expressed by the «completeness of separation» index is obtained depending on loading and shape of grains.

Table 4

Dependence of grain mixtures separation completeness on the specific load of sieves

Loading of sieve, kg/dm²h	Name of corn hybrid								Pumpkin «Volga gray»		Zucchini «Kashnik»	
	DKS 4408		Donor MV		Podykh MV		PR39A50					
	basic	with activators	basic	with activators	basic	with activators	basic	with activators	basic	with activators	basic	with activators
	k_f=2.08		k_f=1.78		k_f=1.7		k_f=1.65		k_f=3.03		k_f=3.17	
5	62	65.4	65	69.4	74	82.6	73	87.2	8.3	54.7	9.17	51.1
8	65	70	69	75	80	87	77	94	9.5	58.2	10.44	53.84
11	66	71.1	72	76.8	83	88.7	82	96.7	10.7	61.7	11.71	56.5

The completeness of the separation is the ratio of the component amount in the pass fraction to its amount in the initial mixture. At the same time, experimental data were obtained on the efficiency of sifting both through basic sieves and those developed with activators.

The analysis of dependencies revealed that the flat shape of the grains and the loading of the sieves significantly affect the efficiency of grain mixtures sifting. It has been established that the efficiency of the developed sieves with activators exceeds the efficiency of the basic ones by 1.52 ... 6.5 times, depending on

the grain shapes and loading. So, the ranges of completeness of grain mixtures separation on the developed sieves with activators were: for corn PR39A50 (k_f=1.65) 65.4…71.1%; for Podykh MV corn (k_f=1.7) 69.4…76.8%; for Donor MV corn (k_f=1.78) 82.6…88.7%; for corn DKS 4408 (k_f=2.08) 87.2…96.7%; for the pumpkin Volga gray (k_f=3.03) 51.1…56.5; for the Kashnik zucchini (k_f=3.17) 54.7…61.7%.

For the practical application of the obtained results, diagrams of the completeness of grain mixture separation from the coefficients of the grain shape and the loading of the sieves have been created (Fig. 5). So, after analyzing the form of the initial mixture (averaging the values) and accepting the specified sieve load, we can predict the complete separation of the mixture from the diagrams obtained.
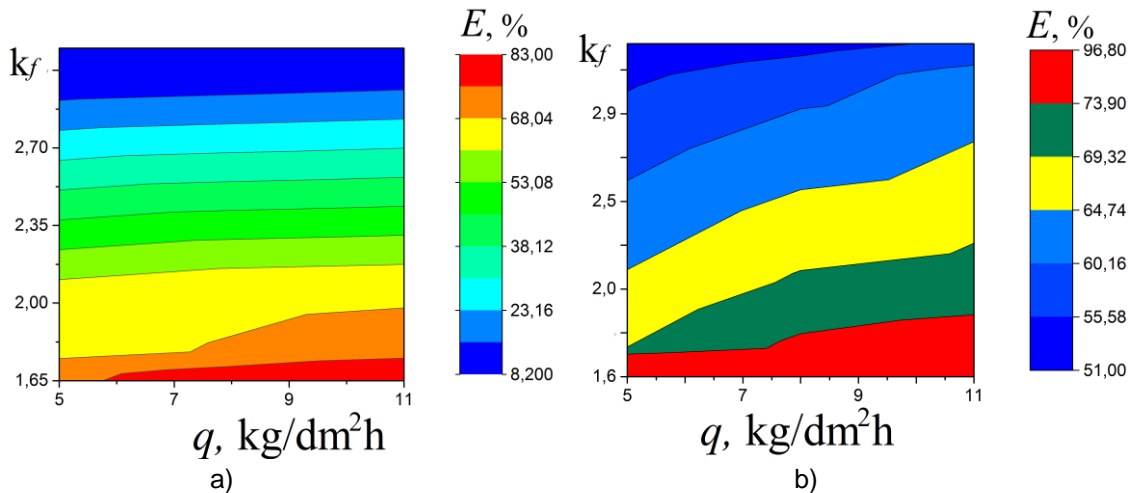

Fig. 5 - Dependences of the completeness of corn grain mixtures separation
on their shape factor and flat sieves load:
a – base sieves; b – sieve with activators

Thus, by analyzing the existing data and the obtained experimental results (Fig. 5), it was found that increasing the flatness of the grain shape within the studied range (k_f=1.65…3.17) results in a decrease in the separation efficiency of 10.1 times on the basic sieves and 1.9 times on the developed ones. This is due to the complicated conditions of grains sifting by thickness. It was also found that the use of developed sieves with volumetric activators, regardless of the values of the grain shape factor, leads to an increase in screening up to 6.5 times. This effect is due to the activation of the screening process using volume activators, which orient the grains into the holes and send pulses to the grain mixture, increasing the bubble concentration ratio (pores). The obtained dependences of the separation completeness allow us to predict the effectiveness of the process of sifting grain mixtures with flat grains, having previously determined their shape factor according to the developed method.

Thus, the developed methods allow us to determine the shape of the grains, on which the efficiency of the process of sifting grain mixtures on sieves significantly depends. The developed laboratory equipment and software can improve the quality of the measurement process (accuracy), take into account the peculiarities of the geometric shapes of the grains, significantly reduce labour costs and time for measurements.

To determine the effect on the efficiency of grain mixtures sifting process, experimental studies were carried out on a Cimbria DELTA 128 calibrator (Denmark) and PETKUS K 218 separator. During the tests of the developed sieves, based on the research program, we carried out adjustments of the separator load and determined the quality of the initial and output grain material in the certified laboratories.

Tests of developed sieves with activators for the separation of corn grain mixtures were carried out on the basis of the holding company Agrotrade (Kharkiv region, Ukraine) at the seed plant Cimbria on separator Cimbria DELTA 128 (Fig. 6, a). Separator Cimbria DELTA 128 is designed for sorting grain crops and seeds (Fig. 6). According to the manufacturer's recommendations, the separator productivity on cleaning corn grain mixtures is reduced by 1.25 ... 2.3 times, and is 6-12 t/h, compared to the cleaning of wheat mixtures (14-15 t/h). This confirms the relevance of research and indicates the problem of the separation of grain mixtures flat grains on sieves.

a)   b)

Fig. 6 - Experimental studies of the developed sieves
a) on Cimbria DELTA 128 separator on the base of the seed plant «Cimbria» Kharkiv region, Ukraine;
b) on PETKUS K 218 separator

When calibrating corn grain mixtures (hybrids Capital, Vimpel, Kristel), basic flat sieves with rectangular openings 6 × 25 mm are replaced with sieves with volumetric activators. For a given period, the modernized Cimbria DELTA 128 separator processed 60 tons of corn seed. Production tests have confirmed the increase in the efficiency of grain mixture sifting process: the completeness of separation on the developed sieves with volumetric activators increases when calibrating corn grain mixtures by 1.28 ... 1.35 times.

Production tests of the developed sieves with activators during the calibration of pumpkin and zucchini grain mixtures were carried out on a PETKUS K 218/1 separator (Fig. 6, b) based on the KHNTUA "Central" training field (Pershotravneve, Kharkiv district, Kharkiv region) with participation of employees of the Institute of Vegetable and Melon-Growing of the Ukrainian Academy of Agrarian Sciences.

Production tests confirmed an increase in the efficiency of the sifting process of grain mixtures: the completeness of separation on the developed sieves with activators increases during calibration of pumpkin grain mixtures by 4.8 ... 5.5 times, zucchini - 5.7 ... 6.5 times.

CONCLUSIONS

1. The possibility of increasing the efficiency by 1.5 ... 6.5 times by sifting grain mixtures through holes when using sieves with volumetric activators was confirmed.

2. A method has been developed for determining the shape of grain mixtures components, which, using laboratory and software tools, allows to determine the geometric parameters of grains with sufficient accuracy. The coefficients of the flatness of corn, pumpkin and zucchini were obtained. The grain flatness coefficients were experimentally obtained: corn k_f=1.65…2.08, pumpkin k_f=3.03, zucchini k_f=3.17.

3. It has been established that the effectiveness of sieves depends on the shape of the grains and the load. As a result of the research, it was established that the completeness of grain mixtures separation on the developed sieves with activators ranges: for corn PR39A50 65.4… 96.7%; for pumpkin Volga gray 51.1 ... 56.5; for Kashnik zucchini - 54.7 ... 61.7%.

4. The dependences of the separation completeness on the grain shape and the specific load of sieves, which make it possible to predict the separation efficiency of the components of grain mixtures on the sieve of grain cleaning machines, are established.

5. Long-term tests under production conditions revealed an increase in the completeness of the separation of corn grain mixtures by 1.28 ... 1.35 times, pumpkins by 4.8 ... 5.5 times, zucchini - by 5.7 ... 6, 5 times due to use of the developed sieves with activators..

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