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RESULTS OF EXPERIMENTAL STUDIES OF A COLUMN-TYPE AERODYNAMIC SEPARATOR

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The development and implementation of technological lines for cleaning grain and sunflower seed mixture waste using aerodynamic separators, including column-type separators, play an important role in organizing modern solutions for primary grain processing, ensuring effective cleaning and sorting of grain through air flows.

Their relevance is due to low energy consumption compared to traditional mechanical separation methods. They have high productivity, allowing for the rapid sorting of large volumes of grain and seeds. They also demonstrate high efficiency in removing light impurities, dust, debris, and grain admixtures while being characterized by the absence of mechanical contact with the processed material, which reduces the risk of grain damage during processing. Additionally, they can be classified as universal machines since they are suitable for working with various crops (wheat, corn, sunflower, etc.).

Modern enterprises engaged in the primary processing of grain and seeds increasingly implement aerodynamic separators to enhance the efficiency of grain production and comply with international standards.

The experimental research results of the column-type aerodynamic separator presented in this article indicate that the model describing the dependence of the kernel and sunflower seed content in the kernel collection area is significant and adequate. Additionally, equations were derived to describe the relationships between the distribution coefficient and energy consumption based on research factors.

To achieve the efficient operation of the column-type aerodynamic separator, it is necessary to maximize the kernel and sunflower seed content in the kernel collection area, optimize the performance of the vibrating feeder, and minimize its energy consumption. The obtained dependencies were used to adjust the operating parameters of the column-type aerodynamic separator and achieve maximum operational efficiency.

Key words: *sunflower seed waste, separation, cleaning, airflow, cleaning efficiency, modeling, optimization.*

Eq. 11. Fig. 5. Table. 4. Ref. 13.

1. Problem formulation

Waste from sunflower seed processing contains a significant proportion of an oil-rich fraction (30 – 50 %), making it a valuable secondary raw material. However, the efficient extraction of this component is only possible through mechanical separation, which requires modern technical equipment. The existing equipment does not provide an adequate level of cleaning for sunflower seed processing waste while ensuring resource conservation [1].

Morally and physically outdated cleaning complexes lack modern automated control systems, leading to reduced process efficiency and increased energy consumption. These challenges highlight the need to search for and implement innovative solutions for extracting the oil-containing component from the waste mixture [2-4].

One such solution is the introduction of a column-type aerodynamic separator into the technological lines for cleaning sunflower seed mixture waste. However, to fully understand the process and enable its implementation, it is necessary to justify the rational structural and technological parameters of the column-type aerodynamic separator. The results of experimental research can serve as the basis for developing an industrial prototype of this separator [6, 8].

2. Analysis of recent research and publications

The development of the experimental prototype of the column-type aerodynamic separator aimed to reduce overall dimensions, material consumption, and energy costs while maintaining the efficiency of cleaning sunflower seed mixture waste [3, 5].

The column-type aerodynamic separator for fine cleaning of seed materials is equipped with a cylindrical sedimentation chamber. Sorting channels are positioned around the perimeter of the sedimentation chamber at an angle to its vertical axis, with the inclination angle determined based on the size of the vertical cross-section of the inlet pipe. Additionally, the sedimentation chamber is fitted with an automatic control system that regulates the inlet pressure for each sorting channel separately [7, 10].

This set of general and distinct characteristics, which differentiate the improved device from its closest analogs, is novel and sufficiently unique for all applications.

The achievement of the technical result in the development of the experimental prototype of the column-type aerodynamic separator included the following aspects:

- The vacuum chamber was designed in a cylindrical shape;
- The sorting channels are arranged around the perimeter of the sedimentation chamber at an angle to its vertical axis, with the inclination angle selected based on the size of the vertical cross-section of the inlet pipe;
- The unit is additionally equipped with an automatic control system for regulating the pressure at the inlet of the vacuum chamber [11, 12].

Thus, the combination of these essential features in the column-type aerodynamic pneumatic unit for fine seed material cleaning has allowed for a reduction in material usage for its manufacturing, as well as a decrease in the overall dimensions of the sedimentation chamber, while maintaining the efficiency of seed mixture sorting and impurity removal [13].

3. The purpose of the article

The aim of the experimental research is to empirically substantiate the rational structural and technological parameters of the column-type aerodynamic separator for cleaning waste from oilseed mixtures, particularly sunflower seeds.

4. Results and discussion

Considering previous theoretical studies and the justified structural and technological parameters, an experimental prototype of the column-type aerodynamic separator has been developed, with its general appearance shown in Fig. 1.

The machine is designed for cleaning, sorting, or calibrating sunflower seed mixture waste for further use in the oil and fat industry. It can also be integrated into technological lines for primary and secondary seed processing, installed at grain elevators, and used in storage facilities as part of specialized lines in all agricultural zones for monitoring and adjusting the main grain cleaning equipment.

The manufactured column-type aerodynamic separator operates as follows. The raw material is fed into the hopper of the vibrating feeder, then moves through a chute into the sorting channel. Upon entering the airflow zone created by the fan, the material is separated based on the floating velocity index of the seed mixture.

Particles with lower floating velocity, including dust, rise through the channel, where they are further divided into two streams. The aspiration dust and the main airflow exit through the upper outlet pipe, while all lightweight particles of the incoming material are discharged through the lower outlet pipe. The entire oil-containing fraction settles in the discharge pipe.

A sampling window is provided in the discharge pipe for collecting samples to monitor the separation process. If necessary, the separation process parameters can be adjusted via the control unit panel.

The selected research factors include the feed rate of sunflower seed mixture waste (q), the airflow velocity (V_a), and the content of kernels and sunflower seeds in the mixture (ψ_k). The variation levels of the research factors are presented in Table 1.

Fig. 1. The general appearance of the experimental prototype of the column-type aerodynamic separator

The feed rate of sunflower seed mixture waste was adjusted by changing the parameters of the vibrating feeder.

The airflow velocity was modified using a frequency converter for the centrifugal fan motor (Fig. 2).

The content of components in the seed mixture was adjusted by adding and mixing the missing component.

Table 1.

Variation Levels of Research Factors for the Column-Type Aerodynamic Separator Experimental Studies

Variation Level	Feed rate of sunflower seed mixture waste (q)	Airflow velocity V_a	The content of sunflower kernels and seeds in the mixture ψ_k
Lower (–1)	50	1	0,2
Zero (0)	100	3	0,6
Upper (+1)	150	5	0,8
Interval (Δ)	50	2	0,2

The criteria selected for the research include the distribution coefficient δ, the content of sunflower kernels and seeds in the kernel collector area $\eta_{k\text{-}k}$, and the consumed power P.

Based on the research conducted by Aliyev E.B. [9, 10], the qualitative criterion for evaluating the performance of the developed aerodynamic separator is the distribution coefficient δ, which is defined as the average content of waste components from the sunflower seed mixture in the respective collectors η.

The content of sunflower kernels in the kernel collector area ηk-k was determined by manually separating the collected samples and weighing them.

The consumed power P was measured using an electric meter over a specified time interval. The study was conducted following the Box-Behnken design for three factors at three variation levels, with a total of 15 experiments. The tests were repeated three times:

$$\delta = \frac{\eta_{h-h} + \eta_{d-d} + \eta_{k-k}}{3}. \quad (1)$$

The content of sunflower kernels in the kernel collector area $\eta_{k\text{-}k}$ was determined by manually separating the collected samples and weighing them.

The consumed power P was measured using an electric meter over a specified time interval.

The study was conducted according to the Box-Behnken design for three factors at three variation levels, with a total of 15 experiments. The tests were repeated three times.

Using the Wolfram Cloud software package, a second-order regression equation was obtained in coded form, describing the dependence of the content of sunflower kernels and seeds in the area of the kernel collector $\eta_{k\text{-}k}$ on the studied factors.

$$\begin{gathered}\eta_{k\text{-}k} = 0{,}947667 - 0{,}010625\,x_9 - 0{,}0112083\,x_9^2 + 0{,}04225\,x_3 - 0{,}00833333\,x_9x_3 - \\ - 0{,}0294583\,x_3^2 + 0{,}0069583\,x_8 - 0{,}00208333\,x_9x_8 - 0{,}0023333\,x_3x_8 + 0{,}0014583\,x_8^2,\end{gathered} \quad (2)$$

where $\eta_{k\text{-}k}$ is the content of sunflower kernels and seeds in the kernel intake area; x_9 is the coded value of the vibrating feeder capacity q; x_3 is the coded value of the air flow rate V_a; x_8 is the coded value of the content of sunflower kernels and seeds in the mixture ψ_k.

The calculated statistical indicators are presented in Table 2. The regression coefficients for which the calculated Student's coefficient is less than the table value are highlighted in grey. Since these coefficients are statistically insignificant, they will not be taken into account in further analysis. The calculated variances are homogeneous according to the Cochran criterion. The calculated value of Fisher's criterion exceeds the table value. This indicates that the null hypothesis can be rejected, and the model has a significant impact on the dependent variable.

After decoding and removing insignificant regression coefficients, we have (Fig. 2):

$$\begin{gathered}\eta_{k\text{-}k} = 0{,}748552 - 4{,}48333\cdot10^{-6}\,q^2 + 0{,}000934167\,q - 0{,}0000833333\,V_a\,q + \\ + 0{,}0736458\,V_a - 0{,}00736458\,V_a^2 + 0{,}0347917\,\psi_k.\end{gathered} \quad (3)$$

The analysis of the obtained equation shows that the performance of the vibratory feeder affects $\eta_{k\text{-}k}$ in a nonlinear manner: the linear term indicates a positive effect, i.e., with an increase in q, the number of kernels in the intake increases, but the quadratic term indicates the presence of a saturation point, after which further increase in performance leads to a decrease in selection efficiency.

Table 2.

Statistical indicators of the regression equation (2)

b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
0,94767	-0,01063	0,04225	0,00696	-0,00833	-0,00208	-0,00233	-0,01121	-0,02946	0,00146
Δb_0	Δb_9	Δb_3	Δb_8	Δb_{93}	Δb_{98}	Δb_{38}	Δb_{99}	Δb_{33}	Δb_{88}
0,00713	0,00437	0,00437	0,00437	0,00618	0,00618	0,00618	0,00643	0,00643	0,00643
b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
0,94767	-0,01063	0,04225	0,00696	-0,00833	0,00000	0,00000	-0,01121	-0,02946	0,00000
Cochrane criterion			G	G(0,05;2;15)		Result.			
			0,1943	0,3346		The variances are homogeneous			
Student's criterion				t(0,05;30)		$S_{вос}^2$		$S_{ад}^2$	
				2,04		$7{,}47778\cdot10^{-6}$		0,000167797	
Fisher's criterion			F	F(0,05;8;30)		Result.			
			22,4394	2,27		The model is adequate			

The interaction between the performance of the vibrating feeder and the airflow rate shows that at high values of V_a, an increase in q can have a negative effect, which is explained by the increased removal of light particles along with the nuclei. Airflow velocity also has a significant effect: at the initial stages, increasing it improves the separation efficiency, but at too high V_a values, a negative effect appears, which may be due to excessive particle removal.

The content of kernels and seeds in the initial mixture has a direct positive effect on the final result, which is quite natural, since the more kernels in the initial mixture, the more of them can be selected into the intake. In general, the analysis of the regression equation confirms that in order to achieve optimal efficiency, it is necessary to rationally combine the parameters of the vibratory feeder performance and air flow rate, taking into account their nonlinear effect on the final kernel selection rate. Under the condition of maximizing $\eta_{k\text{-}k} = 0.976$, we obtain the values of the factors q = 60.91 kg/h, V_a = 4.65 m/s, ψ_k = 0.8.

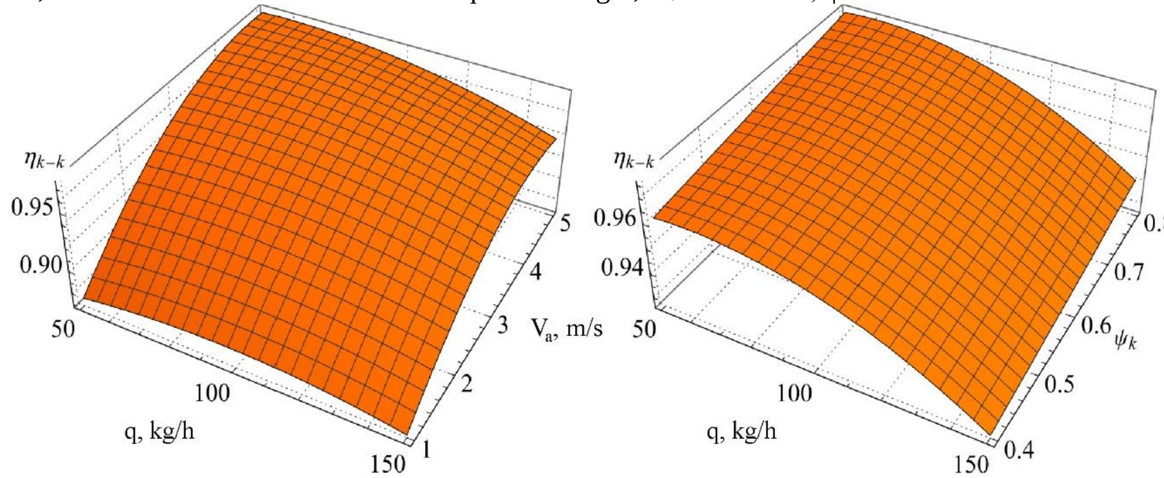

Fig. 2. Dependence of the content of sunflower kernels and seeds in the kernel collector area $\eta_{k\text{-}k}$ on the performance of the vibrating feeder q, air flow rate V_a and the content of sunflower kernels and seeds in the mixture ψ_k

Using the Wolfram Cloud software package, a second-order regression equation was obtained in coded form, which describes the dependence of the distribution coefficient δ on the factors under study:

$$\delta = 0{,}928111 - 0{,}0170833\, x_9 - 0{,}00868056\, x_9^2 + 0{,}0426667\, x_3 - 0{,}00991667\, x_9x_3 - \\ - 0{,}0266806\, x_3^2 + 0{,}0128333\, x_8 - 0{,}00475\, x_9x_8 + 0{,}00258333\, x_3x_8 + 0{,}00765278\, x_8^2, \quad (4)$$

where δ – the distribution coefficient.

The calculated statistical indicators are presented in Table 3. The regression coefficients for which the calculated Student's coefficient is less than the table value are highlighted in grey. Since these coefficients are statistically insignificant, they are not taken into account in further analysis. The Cochran test showed that the variances are homogeneous. The calculated value of the Fisher's criterion exceeds the tabulated value, which allows us to reject the null hypothesis and confirm the significant impact of the model on the dependent criterion.

After decoding and excluding insignificant regression coefficients, the following equation was obtained (Fig. 3):

$$\delta = 0{,}799747 - 0{,}000341667\, q + 0{,}0613542\, V_a - 0{,}00667014\, V_a^2 + 0{,}0641667\, \psi_k. \quad (5)$$

Table 3.

Statistical indicators of the regression equation (4)

b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
0,92811	-0,01708	0,04267	0,01283	-0,00992	-0,00475	0,00258	-0,00868	-0,02668	0,00765
Δb_0	Δb_9	Δb_3	Δb_8	Δb_{93}	Δb_{98}	Δb_{38}	Δb_{99}	Δb_{33}	Δb_{88}
0,01416	0,00867	0,00867	0,00867	0,01226	0,01226	0,01226	0,01276	0,01276	0,01276
b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
0,92811	-0,01708	0,04267	0,01283	0,00000	0,00000	0,00000	0,00000	-0,02668	0,00000
Cochrane criterion			G	G(0,05;2;15)		Result.			
			0,16579	0,3346		The variances are homogeneous			
Student's criterion				t(0,05;30)		$S_{вос}^2$		$S_{ад}^2$	
				2,04		0,000029437		0,00594582	
Fisher's criterion			F	F(0,05;8;30)		Result.			
			201,984	2,16		The model is adequate			

The analysis of the equation shows that the performance of the vibrating feeder has a slight negative effect on the distribution coefficient, since the coefficient at q is negative. This indicates that with an increase in the material feed, the uniformity of its distribution may deteriorate, due to flow overload or uneven flow of particles into the separation zone. The airflow velocity Va has a significant effect on the distribution coefficient. The linear term has a positive sign, which means that as the velocity Va increases, the separation factor improves, i.e. the efficiency of particle separation increases. The quadratic term, however, is negative, indicating that there is an optimum value for the airflow velocity. If the velocity exceeds a certain level, the separation efficiency begins to decrease, possibly due to turbulent effects or excessive particle removal. The content of kernels and seeds in the initial mixture ψk has a positive effect on the distribution coefficient, which is logical, since an increase in the number of kernels in the initial material contributes to their more uniform distribution in the flow.

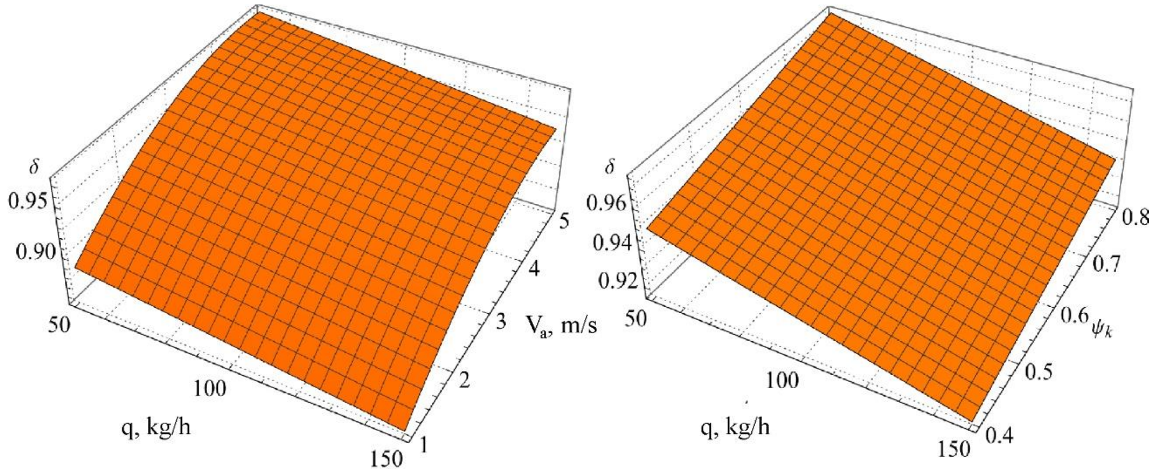

Fig. 3. Dependence of the distribution coefficient δ on the performance of the vibratory feeder q, air flow rate V_a and the content of sunflower kernels and seeds in the mixture ψ_k

Thus, to achieve the optimal separation factor, it is necessary to control the performance of the vibrating feeder, avoiding excessive increase of q, and to set the air flow rate in the optimal range to ensure effective separation of particles without losses. Under the condition of maximising δ = 0.975, we obtain the values of the factors q = 50 kg/h, V_a = 4.59 m/s, ψ_k = 0.8.

Using the Wolfram Cloud software package, we obtained a second-order regression equation in coded form, which characterises the dependence of power consumption P on the studied factors:

$$P = 559{,}711 + 63{,}6417\,x_9 - 6{,}02222\,x_9^2 + 255{,}875\,x_3 - 10{,}0667\,x_9x_3 - \\ - 10{,}6722\,x_3^2 - 2{,}05833\,x_8 - 8{,}48333\,x_9x_8 - 2{,}8\,x_3x_8 + 9{,}59444\,x_8^2, \quad (6)$$

where P – the power consumption of the aerodynamic separator, W.

The statistical indicators obtained as a result of the calculations are shown in Table 4. The regression coefficients for which the calculated Student's coefficient was less than the table value are highlighted in grey. Since these coefficients are statistically insignificant, they are not taken into account in further analysis. The Cochran test confirmed the homogeneity of the variances. The value of the Fisher's criterion exceeds the table value, which allows us to reject the null hypothesis and confirm the significant impact of the model on the dependent criterion.

Table 4.

Statistical indicators of the regression equation (6)

b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
559,711	63,642	255,875	-2,058	-10,067	-8,483	-2,800	-6,022	-10,672	9,594
Δb_0	Δb_9	Δb_3	Δb_8	Δb_{93}	Δb_{98}	Δb_{38}	Δb_{99}	Δb_{33}	Δb_{88}
32,426	19,857	19,857	19,857	28,082	28,082	28,082	29,229	29,229	29,229
b_0	b_9	b_3	b_8	b_{93}	b_{98}	b_{38}	b_{99}	b_{33}	b_{88}
559,711	63,642	255,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Cochrane criterion			G	G(0,05;2;15)		Result.			
			0,27957	0,3346		The variances are homogeneous			
Student's criterion				t(0,05;30)		$S_{вос}^2$		$S_{ад}^2$	
				2,04		154,45		22719,49	
Fisher's criterion			F	F(0,05;8;30)		Result.			
			147,094	2,09		The model is adequate			

After decoding and excluding statistically insignificant regression coefficients, an updated equation was obtained (Fig. 7):

$$P = 48{,}6153 + 1{,}27283\ q + 127{,}938\ V_a. \quad (7)$$

The analysis of the equation shows that the power consumption is linearly dependent on both the performance of the vibratory feeder and the air flow rate. The coefficient at q is equal to 1.27283, which indicates a direct positive effect of the vibrating feeder performance on power consumption. This means that with the increase in the performance of the vibrating feeder, the power consumption increases proportionally. The coefficient at Va is 127.938, which indicates a significant effect of airflow rate on power consumption. This means that increasing the airflow rate significantly increases the power consumption, probably due to the need to overcome additional air resistance or increase energy to provide the higher airflow rate. In general, the equation confirms that both the performance of the vibratory feeder and the airflow rate must be optimized to effectively manage power consumption. An increase in either of these parameters leads to a proportional increase in power consumption, so it is important to balance these two factors correctly to achieve energy efficiency. With the condition of minimizing P = 240.2 W, we obtain the values of the factors q = 50 kg/h, V_a = 1 m/s.

As the preliminary analysis has shown, the optimal values of the research factors for the selected criteria do not coincide, so a compromise problem needs to be solved. Namely, the effective operation of the developed aerodynamic column-type separator is possible provided that the content of sunflower kernels and seeds in the kernel intake area ηk-k, the performance of the vibrating feeder q, and the minimization of its power consumption P are maximized:

$$\begin{cases} \eta_{k-k} \to \max, \\ q \to \max, \\ P \to \min. \end{cases} \quad (8)$$

After ranking the criteria and reducing them to a single generalising criterion, we will transform system (8) to the following form:

$$K_5 = \frac{\eta_{k-k} - \min(\eta_{k-k})}{\max(\eta_{k-k}) - \min(\eta_{k-k})} \frac{q - \min(q)}{\max(q) - \min(q)} \frac{\max(P) - P}{\max(P) - \min(P)} \to \max. \quad (9)$$

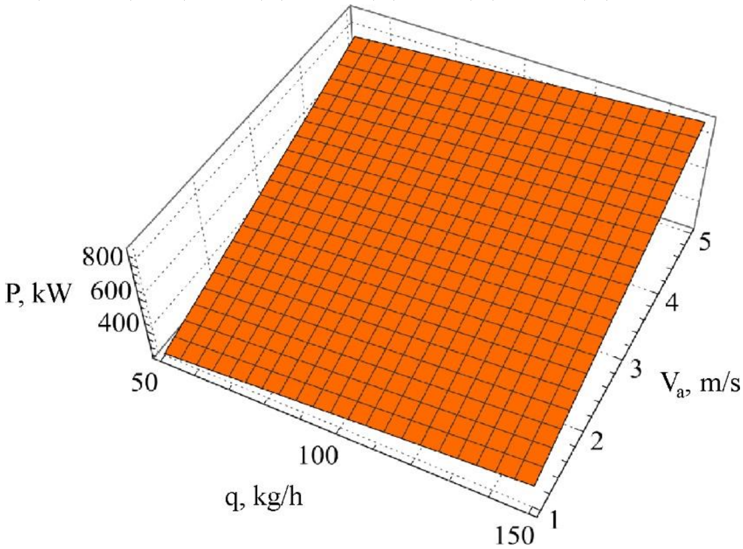

Fig. 4. Dependence of power consumption P on the performance of the vibratory feeder q and air flow rate V_a

By solving equation (9) in Wolfram Cloud together with (3) and (7), we obtain two equations that indicate the relationship between the performance of the vibratory feeder q and the air flow rate Va on the content of sunflower kernels and seeds in the mixture ψk (Fig. 5):

$$q = 38{,}352\ \psi_k + 108{,}89, \quad (10)$$
$$V_a = -2{,}5013\ \psi_k + 4{,}378. \quad (11)$$

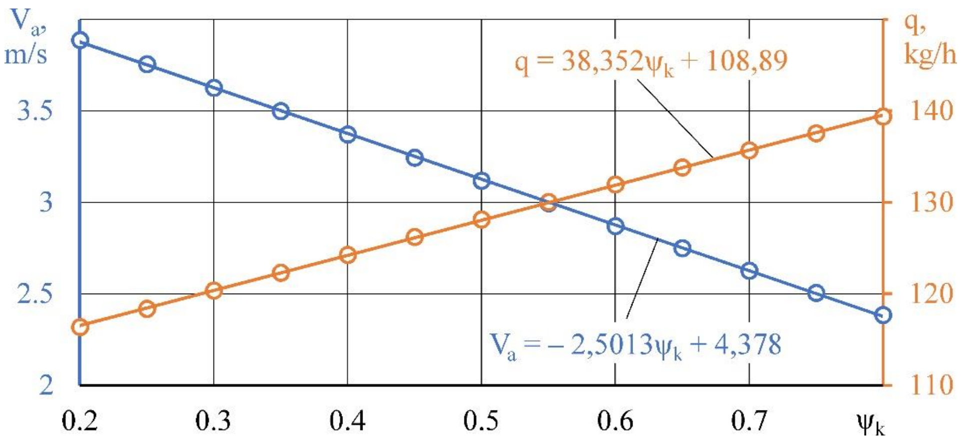

Fig. 5. Dependence of the vibrating feeder performance q and air flow rate Va on the content of sunflower kernels and seeds in the mixture ψk

The analysis of the obtained dependences of the vibrating feeder performance q and the air flow velocity Va on the content of sunflower kernels and seeds in the mixture ψk allows us to draw several important conclusions. Equation (10) shows that the productivity of the vibrating feeder increases linearly with the increase in the content of sunflower kernels and seeds in the mixture. This means that an increase in the content of kernels and seeds in the mixture has a positive effect on productivity, because with a higher content of material in the mixture, the vibrating feeder needs more power to process this volume. The coefficient of 38.352 indicates a relatively high sensitivity of performance to changes in kernel and seed content, which highlights the importance of properly adjusting the vibrating feeder parameters to achieve optimal performance. Equation (11) indicates an inverse relationship between air flow rate and sunflower kernel and seed content. As the kernel and seed content of the mixture increases, the airflow rate decreases. This may be due to the fact that a larger number of particles in the mixture creates more resistance to the air, which reduces the speed of its movement through the separator. This may also indicate the need to adjust the ventilation system parameters to achieve optimal airflow for different material composition.

Both dependencies are important for optimising the operation of an aerodynamic separator, as a high kernel and seed content increases productivity but reduces airflow. From the equations obtained, it can be concluded that optimising the separator's operation involves controlling the content of kernels and seeds in the mixture, which will maintain high productivity and at the same time maintain an efficient air flow for the subsequent separation process. The dependencies in Figure 5 are used to adjust the operating parameters and achieve maximum efficiency of the column-type aerodynamic separator.

5. Conclusion

The results of experimental studies of a column-type aerodynamic separator have shown that the model describing the dependence of the content of kernels and sunflower seeds in the area of the kernel intake ηk-k (3) is significant and adequate. This model includes nonlinear dependencies between all research factors: vibratory feeder performance q, air flow rate Va, and kernel content in the initial mixture ψk. Additionally, equations describing the dependence of the distribution coefficient δ (5) and power consumption P (7) on the research factors were obtained.

To achieve the efficiency of the column-type aerodynamic separator, it is necessary to achieve the condition of maximising the content of sunflower kernels and seeds in the kernel intake area ηk-k, the performance of the vibrating feeder q, and minimising its power consumption P. The solution to the stated trade-off problem is two equations that indicate the relationship between the performance of the vibrating feeder q (10) and the air flow rate Va (11) and the content of sunflower kernels and seeds in the mixture ψk. The obtained dependencies were used to adjust the operating parameters of the column-type aerodynamic separator and achieve maximum efficiency of its operation.

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РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ АЕРОДИНАМІЧНОГО СЕПАРАТОРА КОЛОННОГО ТИПУ

Розробка та запровадження у виробництво технологічних ліній очищення зерна та відходів насіннєвої суміші соняшнику з використанням аеродинамічних сепараторів, зокрема і сепараторів колонного типу, відіграють важливу роль у організації сучасних рішень щодо первинної обробки зерна, забезпечуючи ефективне очищення та сортування зерна за допомогою потоків повітря.

Актуальність їх застосування зумовлена низьким споживанням енергії порівняно з традиційними механічними методами сепарування, вони мають високу продуктивність, що дозволяє швидко сортувати великі обсяги зерна та насіння, мають високу ефективність видалення легких домішок, пилу, сміттєвих та зернових домішок, характеризуються відсутністю механічного контакту з оброблюваним матеріалом, що знижує ризик пошкодження зерна під час обробки. Також їх можна віднести до універсальних машин, бо підходять для роботи з різними культурами (пшениця, кукурудза, соняшник тощо).

Сучасні підприємства з первинної обробки зерна та насіння все частіше впроваджують аеродинамічні сепаратори для підвищення ефективності зернового виробництва та відповідності вимогам міжнародних стандартів.

Наведені в статті результати експериментальних досліджень аеродинамічного сепаратора колонного типу показали, що модель, яка описує залежність вмісту ядер і насіння соняшнику в області забірника ядер, є значущою та адекватною. Додатково були отримані рівняння, які описують залежності коефіцієнта розподілу і споживної потужності від факторів досліджень.

Для досягнення ефективності роботи аеродинамічного сепаратора колонного типу необхідним є досягнення умови максимізації вмісту ядер і насіння соняшнику в області забірника ядер, продуктивності віброживильника та мінімізації його споживної потужності. Отримані залежності використані для налаштування операційних параметрів аеродинамічного сепаратора колонного типу і досягнення максимальної ефективності його роботи.
Ключові слова: *відходи насіння соняшнику, сепарування, очищення, повітряний потік, ефективність очищення, моделювання, оптимізація.*
Ф. 11. Рис. 5. Табл. 4. Літ. 13.

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