Research on power consumption of screw press for pressing of oil from rape seed

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Abstract. The work highlights the analysis of the influence of technological and structural parameters of the screw press, namely the step of the turns of the screw shaft of its speed and the area of openings for the removal of cake on the energy parameters of the process of oil expression.

Based on the results of the multifactorial experiment, regression dependence allows us to estimate the influence of the parameters and operating modes of the screw press on the power consumption of the screw press and can be used in the process of synthesis and modeling of machines intended for pressing of vegetable oils from oil-containing raw materials. The surfaces of the response of the dependence of the power consumption of the screw press from the area of the openings for the removal of the cake as well as the step of the turns and the speed of the screw shaft have been constructed.

Providing the following parameters of the pressing process: turn pitch of the auger shaft $X_{10} = 21.8$ mm; area of openings for oil cake withdrawal $X_{20} = 107.99$ mm^2; rotation frequency of the auger shaft $X_{30} = 5.12$ min $^{-1}$, the power consumption of the screw press will be 170 W, ensuring the maximum yield of oil $q = 36\%$.

1 Analysis of recent research works and publications

The process of oil expression from seed of oil-bearing crops by pressing is difficult and energy-consuming. The results of the research of this process indicate that energy costs consist of three main components: the capacity to consolidate the oilseed material, the power to overcome the friction forces between the raw material, the screw shaft and the extracting box, as well as the power required to squeeze oil [1, 5, 12, 13, 16, 21]. It is possible to improve the energy indexes of a screw press by optimizing its technological and constructive parameters. The first ones include the speed of the screw shaft and the area of the openings for the removal of cake, and to the other - the length of the screw shaft, its inner and outer diameters, the step and shape of the screw channel. In addition, the energy indicators are influenced by the physical and mechanical properties of oil-bearing raw materials - the geometric dimensions of the seeds, the coefficient of friction slip, etc.

The results of research on the influence of technological parameters of the screw oil press have shown that with increasing the rotational speed of the shaft, the power of oil extraction is linearly increased, and along with this, the energy parameters of the process deteriorate [9]. In addition, they also depend on the geometric features of the screw channel [21] and the length of the extracting box [1], and, correspondingly, the screw shaft. In works [5, 16] it is noted that it is expedient to increase the length of the shaft, since in this case more pressure is developed in the pressure chamber [3, 6] and there is an increase in the time of the latter's action on the pressed material, which leads to deeper oil expression. The disadvantage of long shafts is that they are quickly overloaded. This causes loss of strength that is why it is necessary to use high-quality steels, which work well for complex deformation. In addition, the size of the press increases, and operation and maintenance are complicated.

In this connection, it is necessary to study in more detail the influence of the step of the turns of the screw shaft of its rotational speed and the area of the openings for the removal of cake on the energy parameters of the pressing process.

2 Setting objectives

The aim of the work was to increase the efficiency of the process of pressing the seeds of oil-bearing crops in the screw oil press by reducing energy costs by substantiating the steps of the spindle shaft of its rotational speed and the area of openings for the removal of cake.

3 The main material

The achievement of research has been conducted by multifactor experiment as for the determination of the influence of some parameters of pressing process - turn pitch of auger shaft (*h*), area of openings for oil cake

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withdrawal (*s*) and rotation frequency of auger shaft (*n*) on the completeness of power consumption (*p*). Experiments have been conducted using the improved construction of auger press Auger Oil Press-1, the constructive form of which is given in Fig. 1.

Fig. 1. General view of the measuring equipment for determining the pressure in the pressing chamber of the oil extraction press:

1 - bed; 2 - pressure sensors from the firm Keller PA-6T; 3 - screw press; 4 - cylindrical gearbox; 5 - frequency converter ATX-3.0; 6 - strain gauge amplifier; 7 - measuring station (KI - 505); 8 - PC with built-in board L-154.

It is known that the generalized result of multifactor experiment is equation of regression and when we research it as for the extremum one can optimize the meaning of researched parameters. In our case for developing an equation and determination of its coefficients, one can use the three-layered plan of the second range of Box-Benkin [8]. According to it one should determine zero levels of researched parameters. Taking into account the methodology of experimental data [2, 8] and the construction of the improved sample of experimental press, it is determined: turn pitch of auger shaft $X_{10} = 22$ mm; area of openings for oil cake withdrawal $X_{20} = 109$ mm^2; rotation frequency of auger shaft $X_{30} = 45$ min^{-1}. For every parameter the intervals for varying have been determined. They have been determining the pressing regimes or in other words the conditions of experiment conducting (Table 1).

Table 1. Results of coding of investigated factors.

Factors and units of measurement	The usual sign	The encoded sign	Interval of varying	Levels of varying					
				usual			encoded		
				Uppers(+1)	Zero (0)	Lower (-1)	upper (+1)	Zero (0)	Lower (-1)
Turn pitch of auger shaft(*h*), mm	X_1	x_1	2	24	22	20	+1	0	-1
Area of openings for oil cake withdrawal (*s*), mm^2	X_2	x_2	20	129	109	89	+1	0	-1
Rotation frequency of auger press, (*n*), min.$^{-1}$	X_3	x_3	30	75	45	15	+1	0	-1

Experiments have been conducted using seeds of winter rape of Danhal sort with the moisture 7%. Single auger shafts (Fig. 2) with the changing turn pitch have been set up on press. The form of their riffle has been

done in the form of circle segment. Rotation frequency of auger shaft has been changed with the help of frequency converter of current power of electric engine.

Fig. 2. Constructions of auger shafts: 1, 2, 3 – turn pitch of shafts, according to 20 mm, 22 mm, 24 mm.

Table 2. Matrix plan and results of multi-factor experiment.

№	Value of coded factors			Power of the press drive, W			Average value	S_u^2
	x_1	x_2	x_3	Sample 1	Sample 2	Sample 3		
1	-1	-1	0	594.0	594.0	594.1	594.03	0.003
2	1	-1	0	375.2	375.3	375.1	375.20	0.010
3	-1	1	0	318.2	318.4	317.9	318.17	0.063
4	1	1	0	169.3	169.2	168.8	169.10	0.070
5	-1	0	-1	293.2	293.1	293.0	293.10	0.010
6	1	0	-1	90.9	90.0	91.2	90.70	0.390
7	-1	0	1	733.5	734,2	733.6	733.77	0.143
8	1	0	1	568.2	568.7	568,9	568.60	0.130
9	0	-1	-1	395.3	395.8	396.5	395.87	0.363
10	0	1	-1	70.1	75.4	78.5	74.3	0.163
11	0	-1	1	716.2	716,5	717.9	716.87	0.823
12	0	1	1	612.3	612.5	612.9	612.57	0.093
13	0	0	0	389.0	389.5	390.1	389.53	0.303
14	0	0	0	389.0	389.5	390.1	389.53	0.303
15	0	0	0	389.0	389.5	390.1	389.53	0.303

As a result of processing of the obtained data Table 2 of the multivariate experiment and the use of software Statistica 8.0, the regression equation for power consumption is:

$$y_e = 390 - 92x_1 - 120.3x_2 + 229.2x_3 + 17.5x_1x_2 + 9.5x_1x_3 - 68.5x_2x_3 - 19.5x_1^2 - 6.15x_2^2 + 51.19x_3^2. \quad (1)$$

As a result of calculations according to Table 2, the calculated Cochran criterion made up – $G_{calc} = \dfrac{0.823}{3.170} = 0.260$. The table value of the Cochran criterion at $n = 15$ and $f = 3-1 = 2$ is 0.335. Therefore, the process is considered reproducible, since $G_{calc} = 0.260 < G_{table} = 0.335$.

The hypothesis about the adequacy of the description of the equation (1) of the experimental results can be considered correct with a 95% probability, since Fisher's calculation criterion is less tabular:

$$F_{calc} = 1.90 < F_{table} = 2.12.$$

Let's represent the regression equation (1) in the following way:

$$y_e = 1052.7 + 1136x_1 - 17.42x_2 - 13.4x_3 + 0.43x_1x_2 + 0.15x_1x_3 + 0.01142x_2x_3 - 4.87x_1^2 - 0.0154x_2^2 + 0.0569x_3^2. \quad (2)$$

On the basis of equation (1), the surface of the response of the power consumption of the screw press from the area of the openings for the removal of the cake, the step of the turns and the speed of the screw shaft is constructed. During the construction of the surface of the response varied only two factors, and the third remained equal to zero. For this we used the software Statistica 8.0.
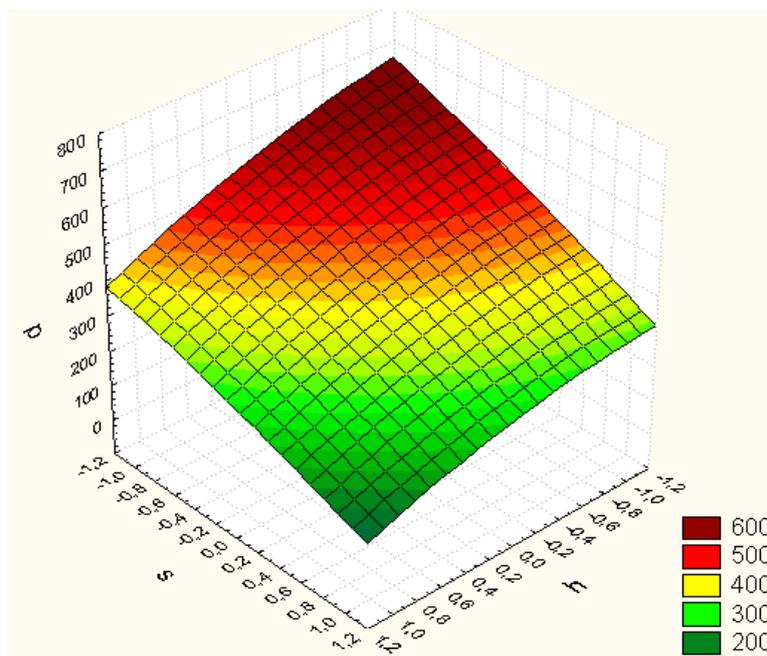
Fig.3. The equilibrium surface $p = f(h, s)$.

When analyzing the response surface, it should be noted that the minimum power, less than 200 W, is provided for maximal opening of openings and maximum step of turns.

Dependence $p = f(h, s)$ (Fig. 3) shows that at the turn pitch of the auger shaft $X_{10} = 22$ mm; area of openings for oil cake withdrawal $X_{20} = 129$ mm^2; rotation frequency of the auger shaft $X_{30} = 45$ min^{-1}, the lowest power consumption is achieved. For such structural parameters, the power of the screw press is 169.10 Watts.
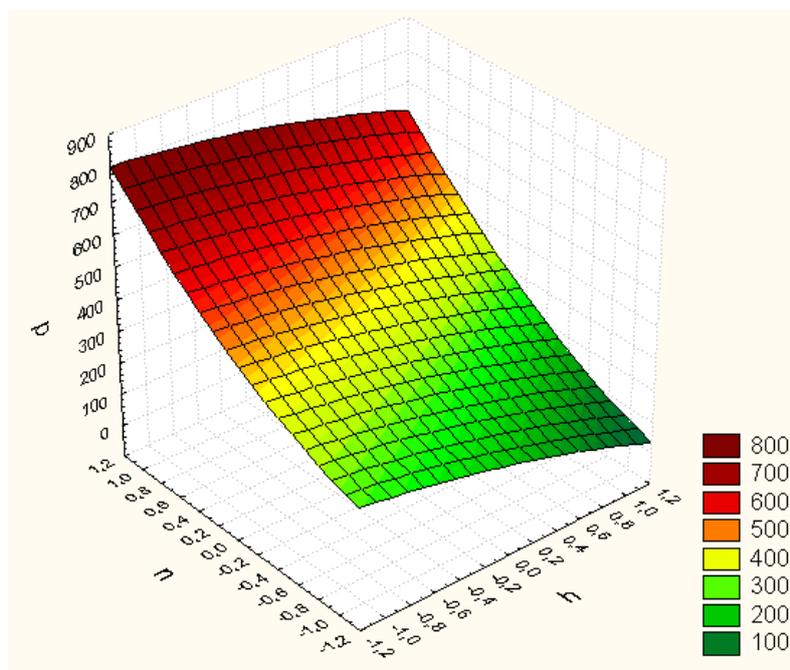

Fig.4. The equilibrium surface $p = f(n, h)$.

Dependence $p = f(n, h)$ (Fig. 4) shows that at the turn pitch of the auger shaft $X_{10} = 20$ mm; area of openings for oil cake withdrawal $X_{20} = 129$ mm^2; rotation frequency of the auger shaft $X_{30} = 15$ min^{-1}, the lowest power consumption is achieved. With such design parameters, the power of the screw press is 90.1 Watts.
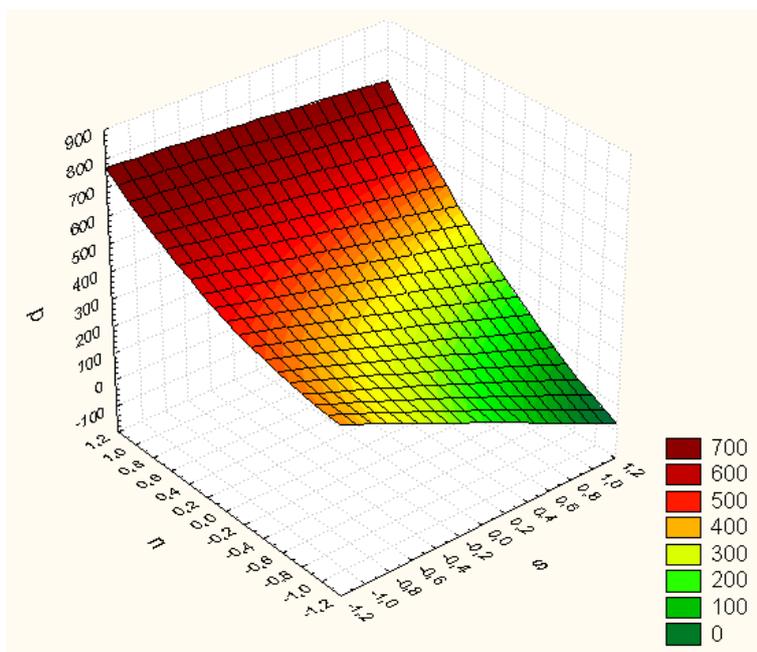
Fig.5. The equilibrium surface $p = f(n, s)$.

Dependence $p = f(n, s)$ (Fig. 5) shows, that at turn pitch of auger shaft $X_{10} = 22$ mm; area of openings for oil cake withdrawal $X_{20} = 109$ mm^2; rotation frequency of auger shaft $X_{30} = 15$ min^{-1} the lowest power consumption is achieved. With such design parameters, the power of the screw press is 170 Watts.

It is possible to optimize the parameters of the power consumption by comparing the obtained results with the results of the influence of the structural and technological parameters of this press on the output of oil. Since the maximum oil extraction q = 36% [14] is ensured at the turn pitch of auger shaft $X_{10} = 21.8$ mm; area of openings for oil cake withdrawal $X_{20} = 107.99$ mm^2; rotation frequency of auger shaft $X_{30} = 5.12$ min^{-1} then the power consumption of the screw press at such parameters will be 170 W.

4 Conclusions

1. Use of the proposed design of oil auger press in the process of pressing seeds of oil-bearing crops with reasonable technological parameters allows for obtaining high-quality at low energy costs, with maximum output of oil.
2. The results of investigations of the influence of technological parameters of the screw oil press have shown that with an increase in the rotational speed of the shaft, the power of the oil press is linearly increased, and at the same time, the energy parameters of the process deteriorate.
3. Providing the following parameters of the pressing process as turn pitch of auger shaft $X_{10} = 21.8$ mm; area of openings for oil cake withdrawal $X_{20} = 107.99$ mm^2; rotation frequency of auger shaft $X_{30} = 5.12$ min^{-1} the consumed power of the screw press will be 170 W, providing the maximum yield of oil q = 36%.

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