Elubaev Sagyntay Zekenovich – Academician of the National Academy of Sciences of the Republic of Kazakhstan, Doctor of Agricultural Sciences, Professor, Professor Department of "Ecology, life safety and environmental protection" Abay Myrzakhmetov Kokshetau University, 020000, 189 A Auezova St., Kokshetau, Kazakhstan; kuam_nauka@mail.ru; +7 705 120 0110; https://orcid.org/0000-0002-3929-2341.

Kazybayev Beibit Orynbaevich – Senior Lecturer Department of "Ecology, life safety and environmental protection" Abay Myrzakhmetov Kokshetau University, 020000, 189 A Auezova St., Kokshetau, Kazakhstan; biko1987@mail.ru; +7 777 205 6587; https://orcid.org/0000-0001-8763-568X.

Abildakhanova Saltanat Rakhmatullaevna – Senior Lecturer Department of "Ecology, life safety and environmental protection" Abay Myrzakhmetov Kokshetau University, 020000, 189 A Auezova St., Kokshetau, Kazakhstan; abildahanova_s@mail.ru; +7 778 800 1106; https://orcid.org/0000-0002-7951-8085.

Салихов Талғат Құмарұлы – ауыл шаруашылығы ғылымдарының кандидаты, профессор, Абай Мырзахметов атындағы Көкшетау университетінің «Экология, тіршілік қауіпсіздігі және қоршаған ортаны қорғау» кафедрасының профессоры, 020000, Қазақстан, Көкшетау қ., Әуезов 189А көшесі; tuatai_76@mail.ru; +7 777 573 3316; https://orcid.org/0000-0002-8720-0931.*

Елюбаев Сағынтай Зекенұлы – Қазақстан Республикасы Ұлттық ғылым академиясының академигі, ауыл шаруашылығы ғылымдарының докторы, профессор, Абай Мырзахметов атындағы Көкшетау университетінің «Экология, тіршілік қауіпсіздігі және қоршаған ортаны қорғау» кафедрасының профессоры, 0020000, Қазақстан, Көкшетау қ., Әуезов 189А көшесі; kuam_nauka@mail.ru; +7 705 120 0110; https://orcid.org/0000-0002-3929-2341.

Қазыбаев Бейбіт Орынбаевич – Абай Мырзахметов атындағы Көкшетау университетінің «Экология, тіршілік қауіпсіздігі және қоршаған ортаны қорғау» кафедрасының аға оқытушысы, 020000, Қазақстан, Көкшетау қ., Әуезов 189А көшесі; biko1987@mail.ru; +7 777 205 6587; https://orcid.org/0000-0001-8763-568X.

Әбілдаханов Салтанат Рахматуллақызы – Абай Мырзахметов атындағы Көкшетау университетінің «Экология, тіршілік қауіпсіздігі және қоршаған ортаны қорғау» кафедрасының аға оқытушысы, 020000, Қазақстан, Көкшетау қ., Әуезов 189А көшесі; abildahanova_s@mail.ru; +7 778 800 1106; https://orcid.org/0000-0002-7951-8085.

*Салихов Талгат Кумарови*ч – кандидат сельскохозяйственных наук, профессор, профессор кафедры «Экология, безопасность жизнедеятельности и защита окружающей среды» Кокшетауского университета имени Абая Мырзахметова, 020000, Казахстан, г.Кокшетау, ул. Ауэзова 189А; tuatai_76@mail.ru; +7 777 573 3316; https://orcid.org/0000-0002-8720-0931.*

Елюбаев Сагинтай Зекенович – академик Национальной академии наук Республики Казахстан, доктор сельскохозяйственных наук, профессор, профессор кафедры «Экология, безопасность жизнедеятельности и защита окружающей среды» Кокшетауского университета имени Абая Мырзахметова, 020000, Казахстан, г.Кокшетау, ул. Ауэзова 189А; kuam_nauka@mail.ru; +7 705 120 0110; https://orcid.org/0000-0002-3929-2341.

Казыбаев Бейбит Орынбаевич – старший преподаватель кафедры «Экология, безопасность жизнедеятельности и защита окружающей среды» Кокшетауского университета имени Абая Мырзахметова, 020000, Казахстан, г.Кокшетау, ул. Ауэзова 189А; biko1987@mail.ru; +7 777 205 6587; https://orcid.org/0000-0001-8763-568X.

Абилдаханова Салтанат Рахматуллаевна – старший преподаватель кафедры «Экология, безопасность жизнедеятельности и защита окружающей среды» Кокшетауского университета имени Абая Мырзахметова, 020000, Казахстан, г.Кокшетау, ул. Ауэзова 189А; abildahanova_s@mail.ru; +7 778 800 1106; https://orcid.org/0000-0002-7951-8085.

IRSTI: 68.85.39
UDC: 621.926
DOI: 10.52269/22266070_2023_1_185

THE RESULTS OF THE ANALYSIS OF STUDIES OF STRUCTURAL AND OPERATIONAL PARAMETERS OF IMPACT CRUSHERS FOR THE PRODUCTION OF FARM ANIMAL FEED

Sapa V.Yu. – Candidate of Technical Sciences, Acting Associate Professor, Kostanay Regional University named after A. Baitursynov.

The article discusses the issues of improving the design and operating parameters of impact crushers for the production of farm animal feed. Based on the analysis of the grinding process, the calculation of the speed and geometric parameters of the crusher was made. As a result of experiments with an impact crusher, the basic regression equation was obtained, which is necessary to analyze the influence of the factors under consideration on the specific productivity of the crusher. The significance of the coefficients of *the model is estimated according to the Student's criterion. The resulting model was tested for adequacy according to Fisher's theory. The model is adequate. To analyze the influence of factors on the specific characteristics of the crusher, response surfaces were constructed. When processing the results of the study using the MathCAD computer program, the maximum value of the specific productivity from the influence of all the factors under consideration was obtained, as well as their optimal values in this regression equation.*

Key words: crushing; particle; feed; productivity; research; speed; analysis.

РЕЗУЛЬТАТЫ АНАЛИЗА ИССЛЕДОВАНИЙ КОНСТРУКТИВНО-РЕЖИМНЫХ ПАРАМЕТРОВ ДРОБИЛОК УДАРНОГО ДЕЙСТВИЯ ДЛЯ ПРОИЗВОДСТВА КОРМОВ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ЖИВОТНЫХ

Сапа В.Ю. – к.т.н., и.о. ассоциированного профессора, Костанайский региональный университет имени А. Байтурсынова.

В статье рассмотрены вопросы совершенствования конструктивно-режимных параметров дробилок ударного действия для производства кормов сельскохозяйственных животных. На основании анализа технологического процесса измельчения был произведен расчет скоростных и геометрических параметров дробилки. В результате проведения опытов с дробилкой ударного действия было получено основное уравнение регрессии, необходимое для анализа влияния рассматриваемых факторов на удельную производительность дробилки. Значимость коэффициентов модели оценена согласно критерия Стьюдента. Полученная модель была проверена на адекватность по теории Фишера. Модель адекватна. Для анализа влияния факторов на конкретные характеристики дробилки были построены поверхности отклика. При обработке результатов исследования с помощью компьютерной программы MathCAD, было получено максимальное значение удельной производительности от влияния всех рассматриваемых факторов, а также их оптимальные значения в данном уравнении регрессии.

Ключевые слова: дробление; частица; корм; производительность; исследование; скорость; анализ.

АУЫЛ ШАРУАШЫЛЫҒЫ ЖАНУАРЛАРЫНЫҢ ЖЕМШӨПТЕРІН ӨНДІРУГЕ ӘСЕР ЕТЕТІН ҰСАТҚЫШТАРДЫҢ КОНСТРУКТИВТІК-РЕЖИМДІК ПАРАМЕТРЛЕРІН ЗЕРТТЕУДІ ТАЛДАУ НӘТИЖЕЛЕРІ

Сапа В.Ю. – т. ғ. к., қауымдастырылған профессордың міндетін атқарушы, А. Байтұрсынов атындағы Қостанай Өңірлік университеті.

Мақалада ауыл шаруашылығы жануарларына жем-шөп өндіруге әсер ететін ұсатқыштардың конструктивті-режимдік параметрлерін жетілдіру мәселелері қарастырылған. Ұнтақтаудың технологиялық процесін талдау негізінде ұсатқыштың жылдамдығы мен геометриялық параметрлері есептелді. Соққы әрекетін ұсатқышпен тәжірибе жүргізу нәтижесінде қарастырылып отырған факторлардың ұсатқыштың меншікті өнімділігіне әсерін талдау үшін қажетті негізгі регрессия теңдеуі алынды. Модель коэффициенттерінің маңыздылығы студент критерийіне сәйкес бағаланады. Алынған модель Фишер теориясының сәйкестігіне тексерілді. Модель барабар. Факторлардың ұнтақтағыштың нақты сипаттамаларына әсерін талдау үшін жауап беттері салынды. Зерттеу нәтижелерін MathCAD компьютерлік бағдарламасымен өңдеу кезінде барлық қарастырылған факторлардың әсерінен нақты өнімділіктің максималды мәні, сондай-ақ берілген регрессия теңдеуіндегі олардың оңтайлы мәндері алынды.

Түйінді *сөздер: ұсақтау; бөлшек; жем; өнімділік; зерттеу; жылдамдық; талдау.*

Introduction. Creating a solid food base is one of the most difficult tasks in providing an animal with the necessary amount of protein. A special place in the diet of animals is occupied by cereals, which are characterized by a high content of protein and minerals. Wheat grains are most effectively used as animal feed, contains a large amount of protein and amino acids, and the digestibility of organic matter by animals is high. The inclusion of wheat in the diets of dairy cows leads to an increase in milk yields and an improvement in the composition of milk, and the diets of fattening pigs improve the quality of meat and the formation of dense granular adipose tissue. Wheat is included in the mixed diets of calves, reducing the norms of drinking whole milk. Cereals have a great potential for expanding the feed base of livestock. Wheat is a very valuable feed, but the machines for its preparation are characterized by high energy intensity, most of which is spent on shredders.

Improving the design of the working parameters of wheat grain crushers is a complex, but important and urgent task, the solution of which is facilitated by the study of the influence of various factors that increase the efficiency of the crushing process [1, pp. 58-62, 2, pp. 13-20, 3, pp. 11-18, 4, pp. 39-38, 5, pp. 61-67, 6, pp. 75-83, 7, pp. 66-75, 8, pp. 83-91].

Materials and methods of research. The analysis of the studies of V.P. Goryachkin, V.A. Eliseev, A.I. Zavrazhnov, S.V. Melnikov, K.G. Murzagaliev, F.G. Plokhova, A. Reiners, G. Ebergardt and others gave valuable recommendations for improving machines and their workflow when grinding feed. As a result of the analysis of studies, the most significant disadvantages of existing shredders have been identified – high energy consumption and over-grinding of finished raw materials.

Based on the analysis of the grinding process, the calculation of the speed and geometric parameters of the crusher was made. The higher the speed of the rotor, the higher the circumferential speed of the knives, which leads to more energy transferred to the material upon impact, but at the same time increases power losses and reduces the efficiency of the machine. A non-central blow, whose vertical velocity is less than the circumferential velocity of the knife, the blow falls on the edge of the material, significantly reducing the impact, since the material fails to fully enter the knife strike zone. The amount of energy transferred to the material upon impact, and if the material simply bounces off the working element without breaking, negatively affects performance.

The linear speed of the knife required for the destruction of the material can be determined by the formula:

$$V_p = 7.7 \cdot \sqrt[3]{\left(\frac{\sigma_p}{\gamma_0 \cdot d_k}\right)^2}, \text{ m/s}, \quad (1)$$

where V_p – the linear speed of the knife at which the destruction of the material occurs;

σ_p – the ultimate strength of the material, Pa;

γ_0 – density, kg/m^3;

d_k – the diameter of the destroyed part of the material, m.

The diameter of the machine body is determined by the formula:

$$d = \frac{60 \cdot V_p}{\pi \cdot n \cdot (1 + K_1)}, \text{ m}, \quad (2)$$

where n – rotor speed, min $^{-1}$;

K_1 – coefficient depending on the type of material being processed.

Calculation of feed crusher productivity. When constructing the mathematical model, the following assumptions were made: the materials in the working chamber are arranged in the form of hollow cylinders with the same density; all particles of the material move at the same speed and in the same direction; aerodynamic processes are not taken into account.

$$Q = 13500 \cdot \frac{\pi \cdot d^3 \cdot K_p}{n \cdot Z \cdot Y}, \text{ t/h}, \quad (3)$$

where K_p – strength factor;

n – rotor speed, min $^{-1}$;

Z – number of knives per tier, pcs;

Y – number of tiers with knives, pcs.

A study of the operation of the impact crusher showed that the productivity of the crusher depends on how the material is fed into the crusher. As more material is fed into the crusher, the amount of material held on the surface formed by the moving rotor blades increases, which ultimately leads to the accumulation of material with a density close to the bulk, the bulk of which is deposited on the surface of the rotor and formed from above. This material under the influence of gravity penetrates into the area of action of the knife to a certain depth, is destroyed and crushed by the knife.

The power that is spent on grinding the material is determined by the formula:

$$N_2 = \frac{d^2}{4}(1 - K_1) \cdot (1 - K_2) \cdot h \cdot K_p Z \cdot Y \cdot \omega. \quad (4)$$

where d – the diameter of the machine body, m;

K_p – material cutting resistance coefficient;

h – working body width;

$\omega = \pi n/30$ – angular rotation speed, s^{-1};

K_2 – coefficient that takes into account the ratio of the values of the angular frequency of rotation of the rotor and the angular frequency of rotation of the material.

Figure 1 shows a scheme of the crusher. 1 – loading hopper; 2 – bilo; 3 – grate; 4 – hatch; 5 – bearings; 6 – unloading funnel; 7 – housing.

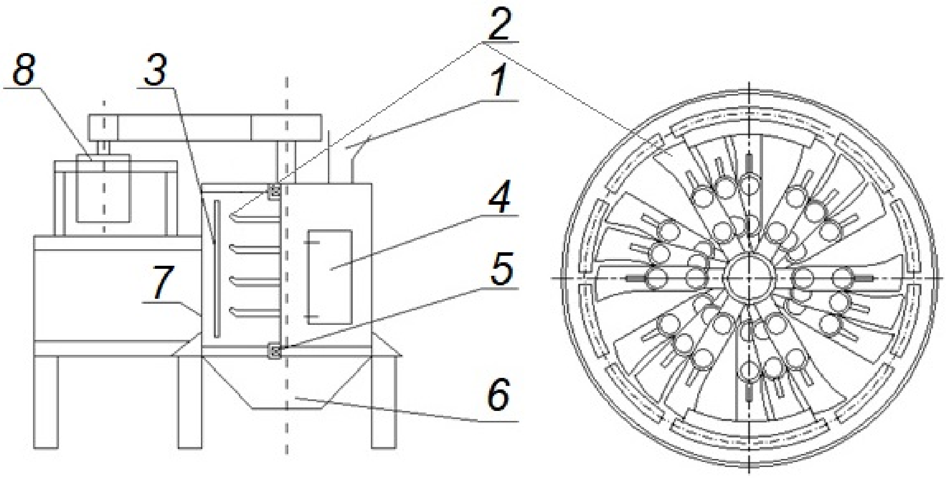

Figure 1 – The scheme of the crusher.

Research results and analysis. When conducting experiments with an impact crusher, the basic regression equation was obtained:

$$y\ (x_1,x_2,x_3) = 2.9 - 0.25 \cdot x_1 - 1.875 \cdot x_2 - 1.1 \cdot x_3 + 0.2 \cdot x_1 \cdot x_2 + 0.65 \cdot x_2 \cdot x_3 + 0.375 \cdot x_2^2 + 0.275 \cdot x_3^2 \qquad (5)$$

When checking the adequacy of the model (5), it was taken into account that one experiment in the scheme was repeated three times. The sum of squares is not equal to $S^2_{неад.}$, because there was only one experiment, it was calculated using equation (2.98) [9, p. 127] For this model, $S^2_{неад.}$ = 0.04.

The adequacy of the model (5) was checked by the F-criterion of Fischer's theory. The calculated value of the criterion F was determined by equation (2.95) [9, p. 126]. For this model $F^{расч}$ = 1.3. The reliability of the model was checked by equation (2.98) depending on the selected significance level α (Appendix IV). 1.3 < 3.63 (tabular value) [9, p. 127]. The condition is met, the model is adequate.

The experimental results obtained were processed using the MathCAD computer program. The measure of the experimental reaction is the specific crushing capacity.

To analyze the influence of factors on the specific characteristics of the crusher, the response surfaces shown in Figures 2-4 were constructed. In the resulting regression equation, two factors alternately fit into the optimum (zero level), and the remaining two factors varied from minimum to maximum. The MathCAD program was used to find the maximum value of the function for each response surface.

Analyzing the response surface shown in Figure 2, the maximum value of specific productivity (Y_{max} = 5.6 kg / kW s) was obtained with a diameter of the destructible part of the material 0.035 m and a drum rotation speed of 8.3 s^{-1}.

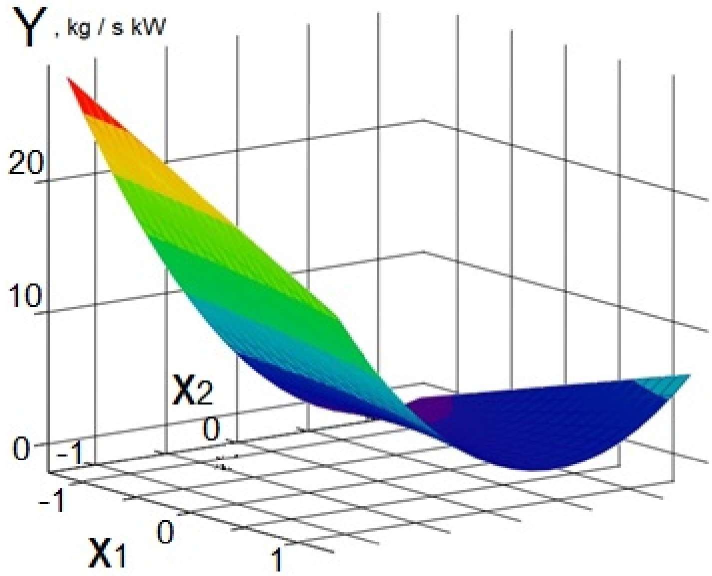

Figure 2 – The dependence of the specific productivity Y on the diameter

of the destroyed part of the material x_1 and the speed of the drum x_2.

Analysis of the dependence of specific productivity on the diameter of the destroyed part of the material and the number of knives on the rotor tier (see Figure 3) allows us to conclude that the maximum value of specific productivity (Y_{max} = 4.5 kg / kW s) is achieved when the diameter of the destroyed part of the material is 0.035 m and the number of knives on the rotor tier is 5.

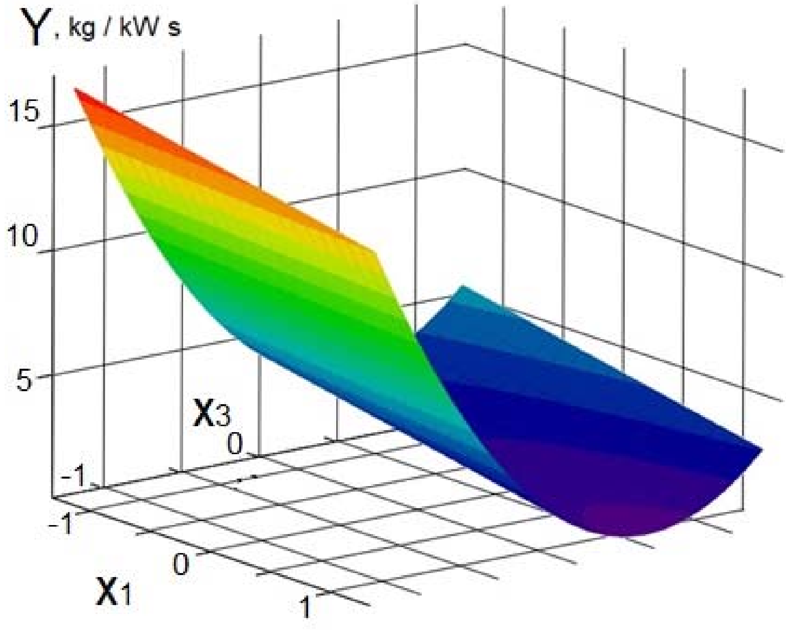

Figure 3 – The dependence of the specific productivity Y on the diameter of the destroyed part of the material x_1 and the number of knives on the rotor tier x_3.

On the response surface (see Figure 4), it can be seen that the optimal value of specific productivity (Y_{max} = 1.2 kg / kW s) is achieved at a drum speed of 8.3 s^{-1} and the number of knives on the rotor tier is 5.

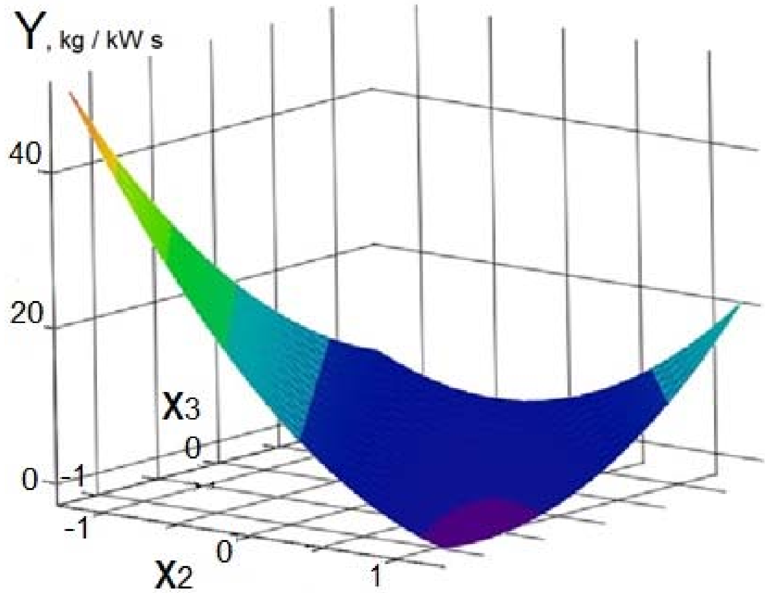

Figure 4 – The dependence of the specific productivity Y on the speed of the drum x_2 and the number of knives on the rotor tier x_3.

Conclusions. When processing the results of the study using the MathCAD computer program, the maximum value of the specific productivity from the influence of all factors was obtained when substituting the values of factors in the encoded version.

$$\text{Maximize} \quad (y, x_1, x_2, x_3) = \begin{pmatrix} -1 \\ -1 \\ -1 \end{pmatrix}$$

$$y \quad (x_1, x_2, x_3) = 2.9 - 0.25 \cdot x_1 - 1.875 \cdot x_2 - 1.1 \cdot x_3 + 0.2 \cdot x_1 \cdot x_2 + 0.65 \cdot x_2 \cdot x_3 + 0.375 \cdot x_2^2 + 0{,}275 \cdot x_3^2$$

$$y \quad (x_1, x_2, x_3) \to 7.625 \text{ kg / kW·s}$$

The maximum value of specific productivity (Y_{max} = 7.6 kg / kW s) was achieved with a diameter of the destructible part of the material of 0.035 m, a drum speed of 8.3 s^{-1} and the number of knives on the rotor tier equal to 5.

REFERENCE:

1. **Kerdyashov, N. N. Kormlenie zhivotnyh s osnovami kormoproizvodstva** [Tekst]: uchebnoe posobie / N. N. Kerdyashov – Penza: PGAU, 2020. – 303 s.

2. **Borshchev, V.Y_A. Oborudovanie dlya izmel'cheniya materialov: drobilki i mel'nicy** [Tekst]: uchebnoe posobie / V.Y_A. Borshchev – Tambov: izdatel'stvo Tambovskogo Gosudarstvennogo Tekhnicheskogo Universiteta, 2004. – 75 s.

3. **Belyaev, P.S. Proektirovanie i raschet oborudovaniya dlya prigotovleniya vysokovyazkih kleevyh kompozicij s ispol'zovaniem perspektivnyh tekhnologij** [Tekst] / P.S. Belyaev, P.S. Belyaev, A.S. Klinkov, S.N. Habarov // Tambov: Tamb. gos. tekhn. un-ta, 1999. – 72s.

4. **Kalimov, N.E. Problemy razvitiya kormovoj bazy zhivotnovodstva Kostanajskoj oblasti** [Tekst] / N.E. Kalimov, ZH.B. ZHarlygasov, ZH. Sagandykova // «3i: intellect, idea, innovation – intellekt, ideya, innovaciya». – Қostanaj: Kostanajskij gosudarstvennyj universitet im. A. Bajtursynova, 2013. – № 3. –39-48 s.

5. **Sapa*, V.Y_U. Analiz rezul'tatov issledovaniya rezhimov raboty eksperimental'nogo vintovogo pressa (ekspandera) dlya proizvodstva vysokoeffektivnyh kormov dlya sel'skohozyajstvennyh zhivotnyh** [Tekst] / V.Y_U. Sapa // «3i: intellect, idea, innovation – intellekt, ideya, innovaciya». – Қostanaj: Kostanajskij regional'nyj universitet im. A. Bajtursynova, 2020. – № 3. –61-67 s.

6. **Makoto, M. Effects of conservation method and crushing method of rice grain on rumen fermentation and nutrient digestibility in steers** [Tekst] / M. Makoto, I. Hidehiko, K. Tetsuo, T. Masanori, K Yuko, N. Kazuhisa// Animal Feed Science and Technology. – 2017. Vol. 227. – pp. 75-83.

7. **Kholif, A.E. Crushed flaxseed versus flaxseed oil in the diets of Nubian goats: Effect on feed intake, digestion, ruminal fermentation, blood chemistry, milk production, milk composition and milk fatty acid profile** [Tekst] / A.E. Kholif, T.A. Morsy, M.M. Abdo // Animal Feed Science and Technology. – 2018. – Vol.244. – pp. 66-75.

8. **Thanha, B.V.Le Amino acid and energy digestibility of Brassica napus canola meal from different crushing plants fed to ileal-cannulated grower pigs** [Tekst] / B.V.Le Thanha, E. Beltranena a b, X. Zhou a, L.F. Wang a, R.T. Zijlstra // Animal Feed Science and Technology. – 2019. – Vol.252. – pp. 83-91.

9. **Novik, F.S. Optimizaciya processov tekhnologii metallov metodami planirovaniya eksperimentov.** [Tekst] / F.S. Novik, Y_A.B. Arsov – M.; Mashinostroenie, 1980. – 237s.

Information about the author:

Sapa Vladimir Yurievich – Candidate of Technical Sciences, Acting associate professor of the Department of Electric Power Engineering, A.Aitmukhambetov Institute of Engineering and Technology, Warriors-Internationalists str., 2a, 110000, Kostanay, phone (WhatsApp): +7 (778)3486986, e-mail: engineering_01@mail.ru.

Сапа Владимир Юрьевич – кандидат технических наук, и.о. ассоциированного профессора кафедры электроэнергетики, инженерно-технический институт им. А.Айтмухамбетова, 110000, г. Костанай, ул. Воинов-Интернационалистов, 2а, телефон (WhatsApp): +7(778)3486986, e-mail: engineering_01@mail.ru.

Сапа Владимир Юрьевич – техника ғылымдарының кандидаты, электр энергетика кафедрасының қауымдастырылған профессордың міндетін атқарушы, инженерлік-техникалық институты. Айтмұхамбетова А., 110000, Қостанай қ., Воинов-интернационалистов көшесі, 2а, телефон (WhatsApp): +7 (778)3486986, e-mail: engineering_01@mail.ru.