Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Substantiation of optimal parameters of rapeseed cake extrusion process

Torebek Baib`atyrov[1], Saule Zhienbayeva[2], Altynai Abuova[3]*, Askhat Umbetbekov[3], Mahamedkali Kenzhekhodzhaev[4], Zhamilya Mazhit[2], Zhazira Mukazhanova[5], Shynar Sanyazova[5]

1. Zhangir Khan West-Kazakhstan Agrarian Technical University, 090009, West-Kazakhstan Region, Uralsk, St. Zhangir Khan 51, Republic of Kazakhstan
2. Department of Technology of Bakery Products and Processing Industries, JSC "Almaty Technological University", 050061, Republic of Kazakhstan
3. Department "Technology of Bread Products and Processing Industries", LLP "International Engineering Technological University", Almaty, Republic of Kazakhstan
4. Department of Food Production and Biotechnology, Taraz Regional University named after M.H. Dulati, 080000, Zhambyl Region, Taraz, St. Tole bi 60, Republic of Kazakhstan
5. Sarsen Amanzholov East Kazakhstan University. 070010, East -Kazakhstan Region, Ust-Kamenogorsk, Republic of Kazakhstan

** Corresponding author's E-mail: a_burkhatovna@mail.ru*

ABSTRACT
The inclusion of rapeseed products in animal and poultry feeds is hindered by the presence of low-nutrient compounds like erucic acid, glucosinolates, tannins, and phytic acid, which can be harmful and reduce overall productivity. This study investigates the variability of glucosinolate content in rapeseed due to growing conditions and evaluates the impact of replacing traditional meals with rapeseed meal in animal feeds. Despite mixed results, the research highlights the potential of double-zero varieties of rapeseed and turnip rape oil in the food and feed industry. The study emphasizes the necessity of removing weed impurities and reducing fiber content to obtain high-quality rapeseed meal. Various processing methods, particularly extrusion, have been explored to enhance digestibility and reduce harmful substances. The findings demonstrate that extrusion effectively decreases glucosinolate and erucic acid content, while maintaining protein levels, making rapeseed meal a promising and cost-effective alternative to soybean and sunflower meals for broiler chicken feed.

Keywords: Rapeseed, Animal feed, Extrusion process, Protein content, Fiber content, Toxicity reduction.
Article type: Research Article.

INTRODUCTION
Insufficient use of rapeseed products in animal and poultry feeds is due to the fact that they contain low-nutrient substances: erucic acid, glucosinolate, tannins, and phytic acid. High concentrations of these substances cause varying degrees of toxicity in animals and reduce productivity. Currently, 90 types of glucosinolates are known, and they are differentiated from each other by amino acid radicals. Glucosinolates are broken down in water by the enzyme "myrosinase." Degrading enzymes and glucosinolates are typically separated from each other in plant tissues. In the presence of water, when this separation is disrupted, the enzyme and substrate interact to form degradation products: aglycones, glucose, and inorganic sulfates (McGregor & Downey 1975; Demyanchuk & Mikitin 1987). The total amount of glucosinolates in rapeseed ranges from 10 to 250 µmol g^{-1}. One of the main reasons for the variation in glucosinolate content in rapeseed is the growing conditions, including weather conditions. It is conventionally considered that high-glucosinolate rapeseed meal contains 3 to 8% glucosinolates, while low-glucosinolate one contains 0.3% to 1% (Tsikunib *et al.* 1991). In studies conducted by Chesnokova (1989), when 5% meal from an old variety of rapeseed containing 48% erucic acid and 2.9% glucosinolate was

Caspian Journal of Environmental Sciences, Vol. 22 No. 3 pp. 715-725 Received: Jan. 12, 2024 Revised: April 19, 2024 Accepted: May 28, 2024
DOI 10.22124/CJES.2024.7917

Publisher: University of Guilan

used in the diet of broiler chickens instead of sunflower meal, the live weight gains were the same as in the control group. However, when 10% rapeseed meal was used instead of sunflower meal, there was a decrease in live weight and an upraise in feed consumption per unit of gain. In Canada, researchers fed broiler chickens from one-day old to 7 weeks with feed containing 20, 40 and 60% Chinese bean meal replaced with Tower rapeseed meal, then 20, 40, 60, 80, and 100% replaced with Chinese pea meal with Candle rapeseed meal. The live weight, average daily gain, and livestock survival rate were the same when 80% of rapeseed meal replaced soybean meal in the feed compared to the control, while poultry productivity decreased when soybean meal was replaced with 100% rapeseed meal (Hulan *et al.* 1982; Smulikowska *et al.* 2006).

Inclusion of up to 10% winter rapeseed in the composition of compound feeds did not have a negative impact on nutrient digestibility. At the end of the experiment, the live weight gain in broilers of the first and second experimental groups was higher than in the control group. In the third and fourth groups, this indicator differed from the control by 10-11 g. The feed costs per kilogram of live weight gain with the inclusion of different amounts of winter rapeseed 'Severyanin' in the diets of broiler chickens were as follows: in the first and second experimental groups, they were lower than in the control group; in the third group, they were at the same level as the control; and in the fourth group, they exceeded the control. The best results in terms of productivity and feed costs were obtained with the inclusion of 4% and 6% winter rapeseed 'Severyanin' in the compound feeds (Kosolapov *et al.* 2017). In the current season, according to the National Bureau of Statistics of the Republic of Kazakhstan, the sown area for oilseeds in Kazakhstan has reached nearly 3 million hectares. The area sown with rapeseed amounted to 127,000 hectares. The key oilseed crops grown and exported from the country are flax, rapeseed, and sunflower seeds (Volovik *et al.* 2013; Abuova *et al.* 2016; Oilseed Market of Kazakhstan 2020). The oil from double-zero varieties of rapeseed and turnip rape is used in the food industry as well as in animal feed production to balance feeds in terms of energy. It is well-balanced in composition, containing low levels of saturated fats and a moderate amount of polyunsaturated essential fatty acids in the form of linoleic (omega-6) and α-linolenic (omega-3) acids, which are not synthesized in the bodies of humans and animals and play an important role in growth and reproduction processes (Shpakov 2018). To obtain rapeseed meal with high feed value, primarily with a high crude protein content, it is necessary to remove weed impurities from the rapeseed as much as possible and reduce the fiber content in the meal. This is typically achieved by completely or partially dehulling and removing the seed coat. In 2005, a new variety of rapeseed "Yubileiny" was released in North Kazakhstan region. Rape variety "Yubileiny" - spring, type 00, is well adapted to the natural conditions of northern Kazakhstan. It differs from other varieties in the size of seeds. Chemical composition of rapeseed and rapeseed cake is shown in Table 1. Table 1 shows that rapeseed and rapeseed cake has an increased energy value: fat, fiber and protein contents in rapeseed and in cake are 42.42%, 3.80%, 22.03%, compared to 10.8%, 19.74%, 38.99% respectively. The fiber content in rapeseed is 3.80%, while in the meal 19.74%, which does not meet the standard requirements, as according to GOST 11048 (1995). The fiber content in rapeseed meal should not exceed 16%. The toxic elements (mg kg^{-1}) are: mercury 0.02, cadmium 0.1, lead 0.5, and the mass fraction of isothiocyanates should not exceed 0.8%, which exceeds the norm by 3.1 times. The fiber content exceeds the norm by 23.3%. To reduce the amount of radionuclides and poorly digestible substances in rapeseed and rapeseed cake, various processing methods were used. The most effective and most suitable method that has a beneficial effect on biochemical parameters of feed components is extrusion, which its process contributes to obtaining a well-digestible, sterile, with improved taste properties of the product. Extrusion in the production of feed and feed additives makes it possible to obtain deep biochemical changes in the nutrients of the feedstock - protein denaturation, inactivation of anti-nutrients, starch dextrinization, destruction of cellulose-lignin formations, which in turn increases the nutritional value of feed (Poverinova *et al.* 2006; Ostrikov, & Vasilenko 2015; Merynyuk & Martynenko 2017). Rapeseed meal is a promising source of protein and fiber, which is formed after oil pressing from rapeseed seeds. Due to its high availability and certain dietary restrictions limiting its inclusion level, rapeseed meal is relatively inexpensive compared to other meals such as soybean or sunflower. Rapeseed meal has been used as an ingredient in blends to study its impact on extruder performance, rheological properties, and physical quality indicators of extruded food products and feeds (Ostrikov *et al.* 2007; Kadyrov & Garzanov 2008; Zhienbayeva & Baybatyrov 2010; Tsuglenok *et al.* 2014).

To obtain rapeseed meal with high feed value, primarily with a high crude protein content, it is necessary to maximize the removal of weed impurities from rapeseed seeds and reduce the fiber level in the meal. This is typically achieved by complete or partial crushing and removal of the seed coat. Usually, rapeseed seeds are processed together with their husks in uncrushed form, as oil extraction plants and oil mills lack the technology and equipment to remove the seed coat. Such rapeseed meal contains a large amount of fiber, which limits its application area, especially in poultry feeding (Ostapchuk 1977; Vygodin *et al.* 1995; Tyapkova *et al.* 2016; Martin *et al.* 2019). This circumstance allows the use of extruded products for the preliminary preparation of some components of animal feed for animals and calves with a painful stomach. Due to the fact that the content of poorly digestible substances and strontium in the composition of rapeseed products did not comply with the ND, its extrusion was envisaged (Kumar *et al.* 2017; Martin *et al.* 2021a,b).

Table 1. Chemical composition of rapeseed and rapeseed cake.

Indicators	**Raw materials**	
	Rapeseed grain	**Rapeseed cake**
Nutritional value (%)		
Proteins	22.03	38.99
Fats	42.42	10.8
Carbohydrates	28.35	14.79
Cellulose	3.80	19.74
Ash	1.6	4.7
Metabolic energy per 100 g (kcal)	447.9	335.5
Vitamin content (mg/100 g)		
E	7.5	7.2
β – carotene	0.028	0.034
B_1	0.12	0.71
B_2	0.26	0.40
PP	10.1	6.62
Content of glucosinolates, mmol/kg	11,9	24,6
Toxic elements (mg kg^{-1}), no more		
Lead	0.7	0.8
Cadmium	-	-
Arsenic	0.148	0.172
Mercury	-	-
Radionuclides, bq/kg, no more	-	-
Cesium-137	60	36.1
Strontium-90	-	172.3

MATERIALS AND METHODS

To substantiate optimal parameters of rapeseed cake extrusion, a statistical method of planning experiments was used. The main indicators that affect the quality of extrudate, the extrusion temperature, T (°C) and product moisture W (%). The studied factors (modes and parameters of rapeseed cake extrusion process) and the deviation value are shown in Table 2.

Table 2. Regulated parameters of extruding rapeseed cake process and amount of deviation.

Adjustable parameters	**Quantity**					**Deviation interval**
Extruding temperature *T* (°C)	110	120	130	140	150	10
Product moisture *W* (%)	14	16	18	20	–	2

Each factor can take one of several values (levels) in the experiment. A fixed set of factor levels determines one of the possible states of rapeseed cake extrusion process.

Evaluation of rapeseed cake extrusion efficiency was carried out using the response functions Y_1 and Y_2, which were taken as the following output (resulting) indicators of the process:

Y_1 – amount of glucosinolate (mmol kg^{-1});

Y_2 – specific power consumption of extruder (kWh/t).

It was required, according to the observed laboratory data (Table 3), to construct an adequate regression equation for each output indicator Y_1 and Y_2, using multiple regression methods. For each indicator, the main statistical characteristics were calculated: *location measures* – arithmetic mean *M*, *m* mean error, median (*med*), mode (*mod*); *scattering measures* – dispersion s^2, standard (root mean square) deviation *s*, minimal (*min* – minimum), maximal (*max* – maximum) values and range *L* of sample data; *shape measures* – standardized indicators of asymmetry *A* and excess *E*, coefficient of variation *V* (Table 4).

Table 3. Experimental data on rapeseed cake extrusion.

Experiment	Options		Response functions		Experiment	Options		Response functions	
	T	W	Y_1	Y_2		T	W	Y_1	Y_2
1	110	14	24.6	10.7	11	130	18	15.7	6.2
2	110	16	20.1	6.6	12	130	20	15.8	7.6
3	110	18	17.8	5.3	13	140	14	20.9	12.0
4	110	20	17.0	6.4	14	140	16	17.5	8.6
5	120	14	23.7	11.3	15	140	18	14.1	7.7
6	120	16	19.3	7.5	16	140	20	14.2	8.5
7	120	18	16.5	6.0	17	150	14	19.7	12.8
8	120	20	15.4	6.9	18	150	16	16.6	9.4
9	130	14	21.3	11.8	19	150	18	12.6	9.1
10	130	16	17.8	8.2	20	150	20	16.3	10.2

Table 4. Statistical characteristics of indicators characterizing the processes of rapeseed cake extrusion.

Statistical characteristics	Conventions	Response function		Adjustable parameters	
		Y_1	**Y_2**	***T***	***W***
Scope of control (experience)	*N*	20	20	20	20
Average	*M*	17.845	8.640	130.000	17.000
Standard error	*m*	0.703	0.494	3.244	0.513
Standard error, % by M	*m*, %	3.941	5.722	2.496	3.018
Median	*med*	17.250	8.350	130.000	17.000
Fashion	*mod*	17.800		110.000	14.000
Standard deviation	*s*	3.146	2.211	14.510	2.294
Dispersion	s^2	9.894	4.889	210.526	5.263
Excess	*E*	-0.037	-0.925	-1.323	-1.401
Asymmetry	*A*	0.587	0.404	0.000	0.000
Range	*L*	12.0	7.5	40	6
Minimum	*min*	12.6	5.3	110	14
Maximum	*max*	24.6	12.8	150	20
Coefficient of variation (%)	*V*	17.6	25.6	11.2	13.5

RESULTS AND DISCUSSION

Statistical indicators of Table 4 characterize all the data obtained on the process of extruding rapeseed cake. Standard error for specific electricity consumption (kWh/t), Y_1 – glucosinolate levels (mmol kg^{-1}) and Y_2-extruder is small and lower by 6% according to the average value. It can be seen that the mean, mode, and median of these indicators are approximately the same. The asymmetry index for the amount of glucosinolate and specific power consumption is equal to zero, which indicates the symmetry of these indicators with respect to the average. At the same time, the excess value in absolute value does not exceed 2, the minimum and maximum values lie to the same extent as the average ones, the coefficient of variation for all indicators does not exceed 33%, which corresponds to the correct distribution law. Histograms and curves for the correct law were built using the "distribution correction" module of the STATISTICA system and statistical graphs, and Kolmogorov-Smirnov D and Shapiro-Wilk SW-W agreement values were calculated, which are shown in Figs. 1 and 2 for the amount of glucosinolate and specific extruder power consumption.

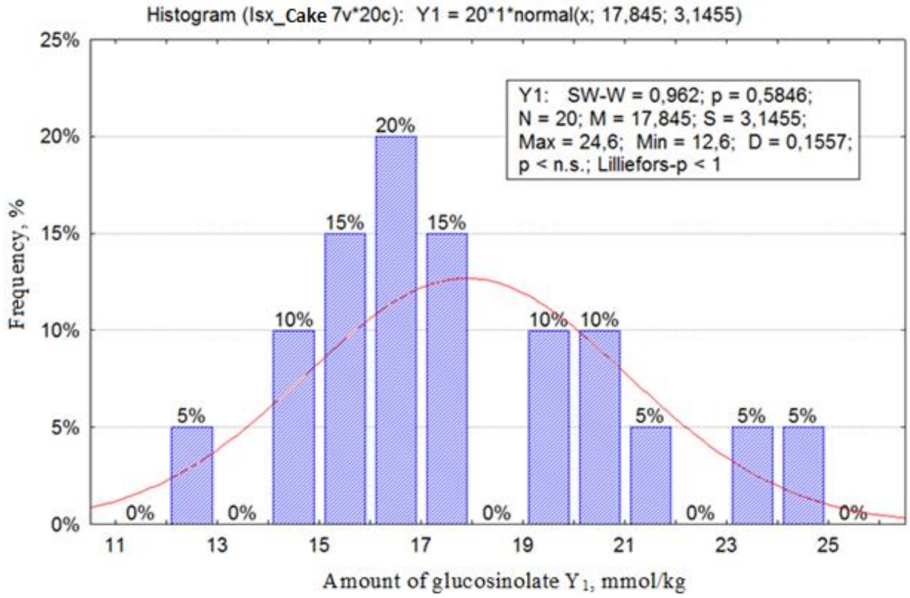
Empirical distributions shown in Figs. 1 and 2 are similar to the normal distribution, which is valid for the level of glucosinolates and the specific power consumption of the extruder due to the obtained values of the criteria *D* and *SW-W*. This is the basic requirement for successful regression modeling of the rapeseed cake extrusion process.

Since the analytical form of the regression dependencies $Y_1 = f_1(T,W)$ and $Y_2 = f_2(T,W)$ is unknown, we use polynomials for their approximation:

$$\begin{cases} Y_1 = a_0 + a_1 T + a_2 W + a_{11} T^2 + a_{22} W^2 + a_{12} TW; \\ Y_2 = b_0 + b_1 T + b_2 W + b_{11} T^2 + b_{22} W^2 + b_{12} TW, \end{cases} \quad (1)$$

where T and W – independent (adjustable) process parameters;
a_i and b_i – regression coefficients to be estimated from experimental data.
The choice of model 1 is justified by the fact that the relationships between indicators Y_1 and Y_2 and the influencing parameters are non-linear, for an adequate description of which in the experimental zone polynomials of the 2nd degree are well suited.
To estimate the coefficients of quadratic regression 1 by the least squares method, laboratory data obtained during the experiments were used.
On the basis of the obtained experimental data, the computer program *Statistica* 7.0 calculated full quadratic regression equations for the studied indicators Y_1 and Y_2, as well as the main statistical criteria for assessing the quality of mathematical description of rapeseed cake extrusion process (Table 5).

a)



b)

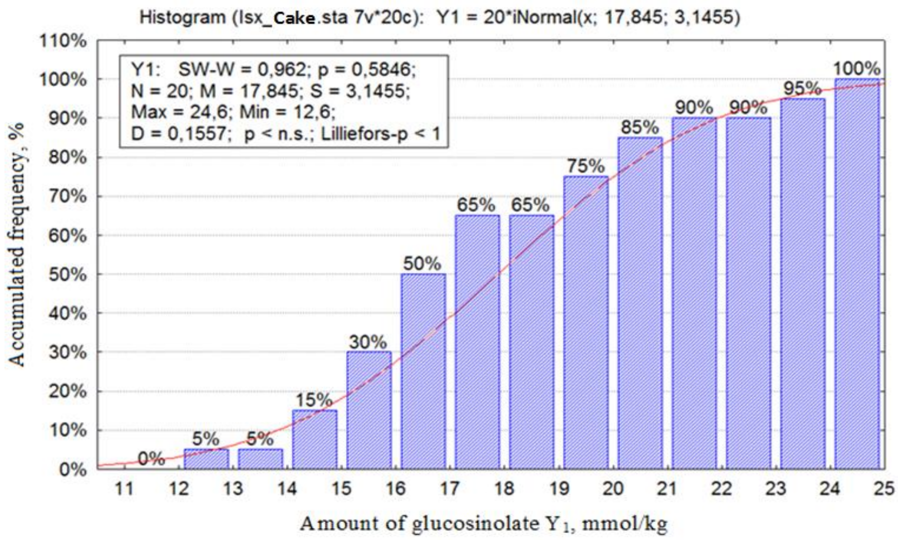


Fig. 1. Differential (a) and integral (b) distribution for Y_1.

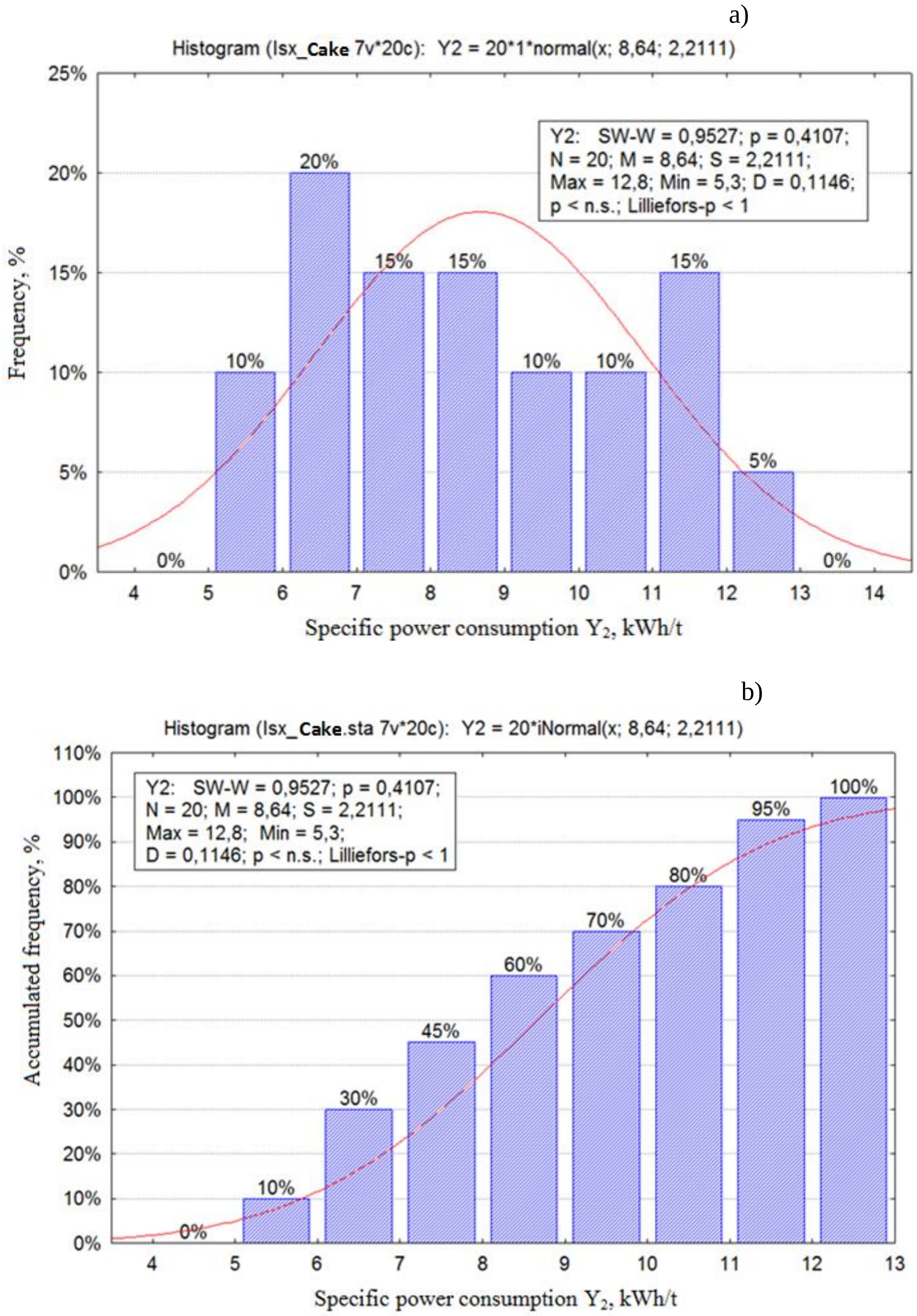


Fig. 2. Differential (a) and integral (b) distribution for Y_2.

Table 5 shows natural-scale regression coefficient estimates for independent variables obtained by the least squares method, their standard errors, and 95% lower and upper confidence limits.

To test the significance of regression components, we calculated Student's *t*-tests and *p*-levels. As follows from Table 4, all regression components at the level of 0.05 have a significant impact on the efficiency of rapeseed cake extrusion. The exception is T_2, since its effect on the level of glucosinolates Y_1 turned out to be insignificant.

Substituting the coefficients from Table 4 into equation 1, we write the equations of quadratic regression of two independent variables - extrusion temperature T (°C) and product moisture W (%) - in the following form:

For glucosinolate levels (mmol kg^{-1}):

$$Y_1 = 170.96 - 0.6194\,T - 11.663\,W + 0.0012\,T^2 + 0.2612\,W^2 + 0.013\,TW; \quad \mathbf{(2)}$$

For specific power consumption of extruder (kWh/t):

$$Y_2 = 125.09 - 0.284\,T - 11.667\,W + 0.0009\,T^2 + 0.295\,W^2 + 0.0077\,TW \quad \mathbf{(3)}$$

Table 5. Results of regression analysis of rapeseed cake extrusion efficiency indicators.

Designation	Regression coefficient	Standard error	Student's t-test	p-significance level	95% confidence limits	
					lower	upper
Level of glucosinolates Y_1 (mmol kg^{-1})						
	170.95914	25.52329	6.69816	0.00001	116.21713	225.70116
T	-0.61943	0.29680	-2.08706	0.05565	-1.25599	0.01713
W	-11.66350	1.70474	-6.84182	0.00001	-15.31979	-8.00721
T^2	0.00118	0.00108	1.09352	0.29263	-0.00113	0.00349
W^2	0.26125	0.04509	5.79438	0.00005	0.16455	0.35795
TW	0.01300	0.00570	2.27947	0.03883	0.00077	0.02523
Specific power consumption of extruder Y_2 (kWh/t)						
	125.08750	8.74760	14.29963	9.6E-10	106.32575	143.84925
T	-0.28400	0.10172	-2.79196	0.01441	-0.50217	-0.06583
W	-11.66750	0.58426	-19.96956	1.1E-11	-12.92062	-10.41438
T^2	0.00088	0.00037	2.36878	0.03277	0.00008	0.00167
W^2	0.29500	0.01545	19.09061	2.0E-11	0.26186	0.32814
TW	0.00775	0.00195	3.96497	0.00141	0.00356	0.01194

Equations 2 and 3 contain the main linear effects a_1, a_2 and b_1, b_2, pair interactions a_{12} and b_{12}, as well as a_{ii} and b_{ii} (i = 1. 2) – squares of independent variables T and W. In this case, the effect of i parameter on the response of Y_1 and Y_2 is estimated by the coefficients of the corresponding polynomial. To assess adequacy of the obtained mathematical description of the process of extruding rapeseed cake, Table 6 of the variance analysis was calculated.

Table 6. The results of dispersion analysis of the regression equations characterizing the process of extruding rapeseed cake.

Source of variability	Number of degrees of freedom (*df*)	Sum of squares (*SS*)	Medium square (*MS*)	Ratio of mean squares (*F*)	Significance *F* (p-level)
Level of glucosinolates Y_1 (mmol kg^{-1})					
Regression (R)	5	178.8825	35.77649	54.99819	1.04E-08
Remainder (E)	14	9.107043	0.650503		
Total amount (T)	19	187.9895			
Specific power consumption of extruder Y_2, (kWh/t)					
Regression (R)	5	91.81825	18.36365	240.32821	4.71E-13
Remainder (E)	14	1.06975	0.07641		
Total amount (T)	19	92.888			

From Table 6 it follows that the value of F is significant at the level of $p<0.05$. This indicates that the experimental data are in good agreement with the obtained regression equations. The quality of regression equation calculated from the experimental data was checked by the multiple correlation coefficient R, determination R^2 and Durbin-Watson test d (Table 7).

Table 7. Criteria for assessing the quality of regression equation obtained for the parameters of rapeseed cake extrusion process

Statistical measure of regression quality	Response value	
	Y_1	Y_2
Multiple correlation (R)	0.975	0.994
Determination coefficient (R^2)	0.952	0.988
Normalized (df-corrected; R^2)	0.934	0.984
Standard error	0.807	0.276
Durbin-Watson criterion d	2.349	1.609

The values of multiple correlation coefficient R and the coefficient of determination R^2 given in Table 7 have values close to unity, which indicates a very close relationship between the indicators Y_1 and Y_2. In addition, the parameters T and W included in the equation. The values of Durbin-Watson d test indicate the absence of serial correlation in the regression residuals. All this shows 95% reliability of the obtained regression equations and their adequacy to the process of rapeseed cake extrusion.

An analysis of the regression equations made it possible to determine in the future the optimal range of adjustable parameters *T* and *W* of rapeseed cake extrusion process. The nature of behavior of the resulting indicators Y_1 and Y_2, which varies from the studied parameters, is illustrated by Figs. 3 and 4, which show the response surfaces and lines of equal levels (isolines) depending on various combinations of factors. Volumetric graphs in Figs. 3 and 4 give a visual representation of how the level of glucosinolates Y_1 and the specific power consumption of extruder Y_2 are related to the extrusion temperature T (°C) and raw material moisture content W (%). The color labels in these Figs. show the value of indicator by means of intensity. From them it is possible to determine the range of values of variables T and W, where Y_1 and Y_2 have the smallest value. Figs. 3 and 4 also show the contour lines of equal levels of the response surfaces, which are built according to equations 2 and 3. The contours of equal levels are horizontal sections of the response surfaces, which, as can be seen in Figs. 3 and 4, have a minimum.

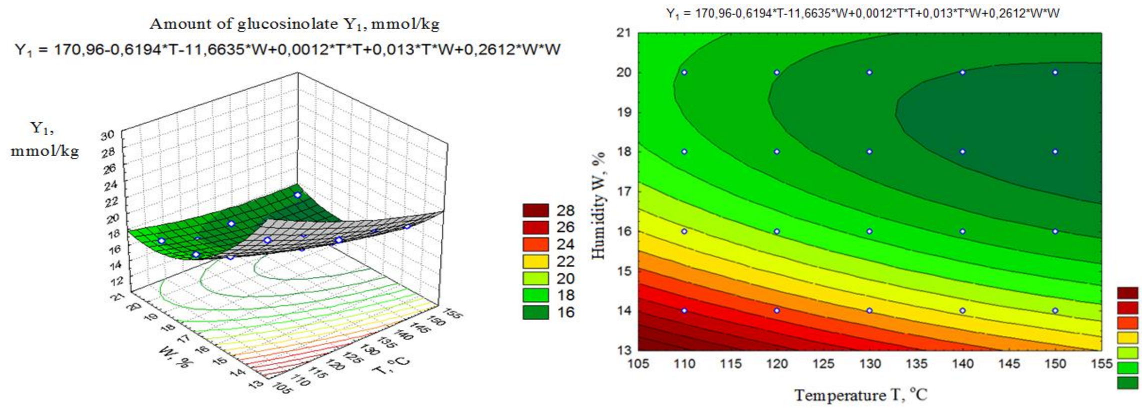


Fig. 3. Y_1 response surface and lines of equal level depending on extrusion temperature *T* (°C) and raw material moisture *W* (%.).

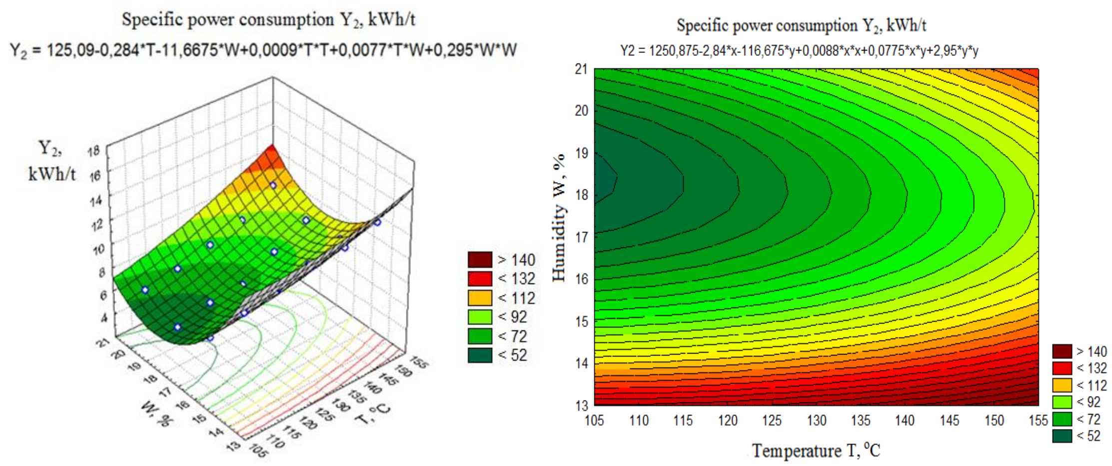


Fig. 4. Y_2 response surface and lines of equal level depending on extrusion temperature *T* (°C) and raw material moisture *W* (%).

To determine optimal values of the level of glucosinolates Y_1 and the specific power consumption of the extruder Y_2, the obtained regression equations 2 and 3 were used as target functions. The following model for optimizing the main parameters of the rapeseed cake extrusion process has been compiled: to find minimum content of glucosinolates Y_1 and the specific power consumption of the extruder Y_2:

$$\begin{cases} Y_1 = f_1(T,W) \Rightarrow \min; \\ Y_2 = f_2(T,W) \Rightarrow \min \end{cases} \quad \textbf{(4)}$$

under the following bilateral restrictions: for extrusion temperature, T (°C).

$$110 \le T \le 150; \quad \textbf{(5)}$$

and raw material moisture *W* (%)

$$14 \le W \le 20. \tag{6}$$

Optimization problem 4 - 6 belongs to the class of non-linear mathematical programming problems. To solve it, the "Search for a Solution" module of the Excel 2003 office program was used. Formulas 2 and 3 were entered into the target cells E2 and F2 of the Excel "Oilcake" sheet to calculate the indicators Y_1 and Y_2. As independent variables [temperature of extrusion T (°C) and raw material moisture content W (%)], two cells H2 and I2 were taken, which vary in the ranges 5 and 6. The task worksheet is shown in Fig. 5.

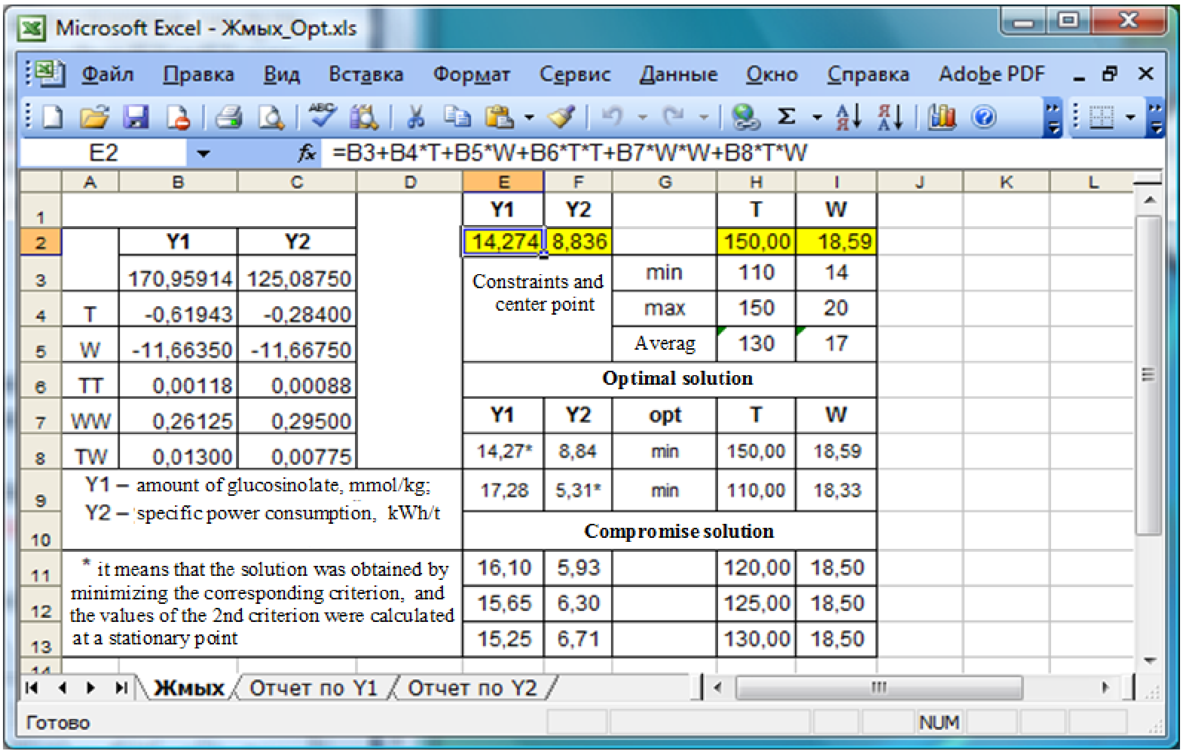


Fig. 5. To substantiate the parameters of rapeseed cake extrusion.

In the range of values \$B\$3:\$C\$8 (Fig. 5) due to the influence of the coefficients on the level of glucosinolates Y_1 and the power consumption of extruder Y_2, Cells \$H\$3:\$I\$3 and \$H\$4:\$I\$4 contain the values of the left and right parts of restrictions system on the parameters *T* and *W*. Using the worksheet, the cells of which contain formulas, the values of the left and right boundaries for the studied parameters T and W, the objective functions Y_1 and Y_2 are calculated. After the appropriate preparation of worksheet, we turn one of the target cells to the minimum in turn and find the values of Y_1 and Y_2 at a stationary point. As shown in Fig. 5, the moisture content of raw materials in the optimal solution of these two problems is almost the same, which allows us to take it equal to 18.5% in a compromise solution. For the second parameter, extrusion temperature *T*, the process of rapeseed cake extrusion was studied in the temperature range from 120 °C to 130 °C. The results of a compromise solution to the problem are shown in Table 8.

Table 8. Optimal parameters for extruding rapeseed cake.

Extrusion option		**Response function**	
T – Temperature (°C)	***W* – Raw material moisture (%)**	**Y_1 – Level of glucosinolates (mmol kg^{-1})**	**Y_2 – Specific electricity consumption (kWh/t)**
120.00	18.50	16.10	5.93
125.00	18.50	15.65	6.30
130.00	18.50	15.25	6.71

In the feed shop of "Ruby Rose Agricole" poultry farm, on the extruder KMZ-2, with the obtained optimal extrusion values: at an extrusion temperature of 125 °C and a moisture content of rapeseed cake of 18.5%, rapeseed cake was extruded. The results of extruding rapeseed cake are shown in Table 9.

Table 9. Results of rapeseed cake extrusion.

Indicators	**Rapeseed cake**	
	non-extruded	**extruded**
Protein (%)	38.99	38.93
Fat (%)	10.80	9.96
Cellulose (%)	19.74	14.75
Ash (%)	4.7	6.27
Content of glucosinolates (mg kg^{-1})	25.0	16.0
Erucic acid (%)	1.02	0.54

The study results showed that during the processing of rapeseed in the extruder, the protein content did not change, and fat content decreased by 7.8%, fiber by 25.28%. The content of harmful substances: when processed in an extruder, the content of glucosinolate decreased by 37.72 -36%, and erucic acid decreased by 1.88 times. The results obtained show the effectiveness of extrusion process when using rapeseed cake in the production of feed for broiler chickens.

REFERENCES

Abuova, AB, Vyurkov VV, Baybatyrov TA, Tulkubayeva SA, Kulzhabayev EM, Zhiengaliev AT 2016, Method of cultivating spring rapeseed for seed oil and green fodder. Innovative Patent No. 31207, MURK, Registered in the State Register of Inventions of the Republic of Kazakhstan on May 19, 2016.

Demyanchuk, GT, Mikitin NS 1987, Glucosinolates of rapeseed and rape seeds: structure, properties and quantitative content. Agricultural Biology, 8:112-118.

Chesnokova, NL 1989, Camelina meal in the diets of broiler chickens. Abstract of the dissertation for BHC Zagorsk, 23 p.

GOST 11048-95, Rapeseed cake. Technical Conditions. Minsk, 8 p.

Hulan, HW, Proudfoot, FG & Zarkadas, CC 1982, Potato Waste meal. The nutritive value and guality for broiler chicken. Canadian Journal of Animal Science, 62: 1161-1180.

Kadyrov, D & Garzanov, A 2008, Extrusion processing of biological waste into feed. Poultry Farming, 7: 51-54.

Kumar, L, Brennan, MA, Mason, SL, Zheng, H & Brennan, CS 2017, Rheological, pasting and microstructural studies of dairy protein-starch interactions and their application in extrusion-based products: A review. Starch-Stärke 69: 1600273.

Kosolapov, VM, Gaganov AP & Araslanova AI 2017, The use of feed containing rapeseed in feeding broiler chickens. Achievement of Science and Technology of Agro-Industrial Complex, 3: 25-27

McGregor, DL, Downey RK 1975, A rapid and simple assey for indentifying low glucosinolate rapesud. Canadian Journal of Plant Science, 5: 191-196.

Martin, A, Osen, R, Greiling, A, Karbstein, HP & Emin, A 2019, Effect of of rapeseed press cake and peel on the extruder response and physical pellet quality in extruded fish feed. Aquaculture, 512.

Martin, A, Osen, R, Karbstein, HP & Emin, MA 2021a, Impact of rapeseed press cake on the rheological properties and expansion dynamics of extruded maize starch. Foods, 10: 616.

Martin, A, Naumann, S, Osen, R, Karbstein, HP & Emin, MA 2021b, Extrusion Processing of Rapeseed Press Cake-Starch Blends: Effect of Starch Type and Treatment Temperature on Protein, Fiber and Starch Solubility Foods 10(6): 1160, https://doi.org/10.3390/foods10061160

Merynyuk, L, Martynenko, Y 2017, Extrusion of barley. Feed industry, 5: 25-26.

Oilseed Market of Kazakhstan 2020, A new round of development, abnormally high prices, logistics disasters and a promising future - Severnoye Zerno Group of Companies. https://www.apk-inform.com/ru/exclusive/opinion/1517755.

Ostapchuk, NV, 1977, Mathematical modeling of technological processes of grain storage and processing. Moscow, pp. 43-93.

Ostrikov, AN & Magomedov, GO, Derkanosova, NM *et al.* 2007, Technology of extrusion products: Textbook, St. Petersburg: Prospekt Nauki, 202 p.

Ostrikov, A, Vasilenko, V 2015, Technology for the production of extruded feed. Mixed Feed, №. 6. 31 p.
Poverinova, EM, Loskomoinikov, IA, Burlakova, LV, Koshelev, SN 2006, The effectiveness of using flax, sunflower, camelina, rapeseed and rapeseed cakes when fattening bulls. Oil Crops. Scientific and Technical Bulletin of VNIIMK, 135: 156-158
Shpakov AS 2018, Feed production system of Central Russia: dairy and meat animal husbandry. Moscow, RAS, 272 p.
Smulikowska, S, Czerwiński, J & Mieczkowska, A 2006, Nutritional value of rapeseed expeller cake for broilers: Effect of dry extrusion. Journal of Animal and Feed Sciences, 15: 445-453.
Tsikunib AD, Beloglazova LK, Shcherbakov VG 1991, Determination of the content of glucosinolates in rapeseed meal by its toxic effect. News of universities. Food Technology. 4: 22-24.
Tyapkova, O, Osen, R, Wagenstaller, M, Baier, B, Specht, F & Zacherl, C 2016, Replacing fishmeal with oilseed cakes in fish feed. A study on the influence of processing parameters on the extrusion behavior and quality properties of the feed pellets. Journal of Food Engineering, 191: 28-36.
Tsuglenok NV, Yanova MA, Danilin VG *et al*. 2014, Technological regulations for the production of extruded grain: Regulations, Krasnoyarsk, Federal State Budgetary Educational Institution of Higher Professional Education Krasnoyarsk State agrarian University, 38 p.
Vygodin VA Kasperovich VL, Zinyukhin GB *et al.* 1995, Extrusion equipment and technology: status, prospects. Food Industry, №. 7, pp. 4-6.
Volovik, VT *et al.* 2013, Rapeseed cultivation in the Non-Chernozem zone and its role in the production of vegetable oil and high-protein concentrated feed. Adaptive Feed Production, 13: 14-20.
Zhienbayeva, ST & Baybatyrov, TA 2010, A method for increasing the feed value of rapeseed cake. Patent, Innovation Patent Number: 23305 Published: 15.12.2010.

Bibliographic information of this paper for citing:
Baib`atyrov, T, Zhienbayeva, S, Abuova, A, Umbetbekov, A, Kenzhekhodzhaev, M, Mazhit, Z, Mukazhanova, Z, Sanyazova, S 2024, Substantiation of optimal parameters of rapeseed cake extrusion process, Caspian Journal of Environmental Sciences, 22: 715-725.