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MODELING AND OPTIMIZATION OF THE TECHNOLOGICAL PROCESS OF EXTRUDING BUCKWHEAT TEMPERATURE PARAMETERS

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Abstract.

This article discusses the possibility of mathematical modeling and optimization of parameters of the process of buckwheat. As a result of the research, a regression equation was obtained, which allows to predict the optimal extrusion parameters of buckwheat and reduce the number of experiments. Extrusion processing is one of the most attractive methods of processing grain crops to obtain semi-finished products. The efficiency and effectiveness of the use of this equation is proved in laboratory conditions. The influence of all factors was studied during the extrusion of buckwheat grain, pressure, temperature, processing time and humidity of the feedstock on the yield of blasted cereal, the content of water-soluble substances, the swelling and density of the extruded raw material. A mathematical model of the process of extrusion of buckwheat grain made it possible to find rational process parameters allowing to obtain extrudates with high consumer properties.

Keywords: extrusion, good nutrition, extrudates, buckwheat, mathematical model, regression, planning matrix, extrusion parameters, experience.

Introduction.

Recently, rational human nutrition for the majority of the world's population has become a problem. An important task to solve this problem is the production of high-grade food. Recent studies show the need and importance of good nutrition, depending on health, age, the nature of the activity performed, weather and geographical circumstances. Since the economy of Kazakhstan is unstable, a constant imbalance in the food allowance of the population is a serious problem that worsens the health of the population. The ability to consume natural foods decreases over time. Grocery stores mainly provide us with industrial food, in which the composition, properties and functions of the product are changed during the manufacturing process.

The selection of the latest types of food raw materials and methods for its processing is considered one of the directions in the formation of the grain processing area [1].

Buckwheat is one of the most valuable cereal crops. According to some sources, East Asia, in particular, the northern regions of India, is considered to be the birthplace of buckwheat [2]. According to another assumption, the plant comes from China and was exported from there to Europe via Central or Southeast Asia. [3]. Buckwheat grain in Germany is called "Tatar grain" or "Turkish fruit", which allows us to draw further conclusions about the origin of buckwheat.

A characteristic feature of today's formation of the food industry is the production of high-quality latest food products with increased nutritional value, contributing to the improvement of human well-being due to the stabilizing and normalizing effects on the human body, taking into account its physiological condition and age [4].

Extrusion is an ideal process for enriching products with proteins, fibers, vitamins and other additives. The production of a variety of extruded products with a high content of proteins, vitamins and minerals plays an important role in the prevention of many human diseases [5, 6].

The mathematical-statistical method was used as a mathematical instrument and a system of regression equations was obtained that models the relationships of the most preferred optimality criterion with the rest [7.8].

Materials and research methods.

Object of study: buckwheat groats produced in Kazakhstan. Buckwheat groats meet the requirements of regulatory documentation in accordance with GOST R 56105-2014 “Buckwheat. Technical conditions".

Objects of study: Optimization of the extrusion process.

Methods of modeling and optimization of the extrusion process.

The technique includes:

- A mathematical model of the process of extruding buckwheat is formed, which allows to determine the objective function.

- The main factors and the area of factor space are determined

- An experiment planning matrix is compiled to build a regression model

- Parallel experiments are performed. During the experiment, it is obvious that recalculation of the output parameter with the same set of input will not lead to its change. We propose to organize conditionally parallel experiments. They vary the input parameters of the model, the values of which are in a certain range, and the researcher cannot influence their change, but has the ability to fix the values they accept in different conditions.

- At each of the points of the planning matrix, the mathematical expectation of the objective function is defined, which calculated according to the provided experiments.

- Regression model building.

- The following is a statistical analysis of the models. Plan points were discovered in which the response distribution obeys the normal law, as well as points that do not obey the normal laws. The significance of all the coefficients of the regression models was evaluated by the Student's criterion.

- The adequacy assessment was carried out using the Fisher test. The Fisher criterion is used only in the case where, the points of the matrix are not violated by the normal law of response distribution.

In accordance with the chosen methodology of the computational experiment, it was decided to use its value when evaluating the reproducibility dispersion at the indicated points.

As criteria for optimality affecting the process of extrusion of buckwheat grain were taken specific factors that determine specific production conditions. In this regard, it is advisable to adjust the system of regression equations in accordance with the factors taken.

Results and their discussion.

The regression equation of the mathematical model of buckwheat extrusion will have the form:

$$y=b_0+b_1x_1+b_2x_2+b_3x_3+b_{12}x_1x_2+b_{13}x_3+b_{23}x_2x_3+b_{11}x_1^2+b_{22}x_2^2+b_{33}x_3^2 \quad (1)$$

where b(i = *0, 1, ..*,33) represent the regression coefficients of the model.

To determine the optimal temperature parameters, the intervals and levels of variation of parameters were coded as shown in Table 1. Literature data were taken as zero temperatures.

Table 1 - Coding of intervals and levels of variation of input factors

Factors		Levels of variation					Intervals of variation
Natural	coding	-1,68	-1	0	+1	+1,68	
$T_в$, ^0C	x_1	120	125	130	135	140	5
T, ^0C	x_2	145	150	155	160	165	5
$T_{вых}$, ^0C	x_3	175	180	185	190	195	5

Literature data were taken for zero temperatures.

The following factors were established for experimental studies of buckwheat extrusion: inlet temperature ($T_в$, ^0C), temperature inside the extruder (T,$_0$C) and outlet temperature ($T_{вых}$,^0C) that influence optimization criteria - expansion coefficient (K).

The expansion coefficient is defined as the ratio of the diameter of the extrudate to the diameter of the outlet of the extruder die[9].

A mathematical model and optimization of the buckwheat extrusion process. Extrusion experiments were carried out with modes. The planning matrix and experimental results are shown in table 2.

The coefficient of the regression equation is significant if its absolute value is greater than the confidence interval. Otherwise, it is considered insignificant and can be excluded from further consideration by the mathematical model [10].

Table 2 - The results of experimental studies of the extrusion process of buckwheat

№	Coded values			Natural values			Experimental values
	x_1	x_2	x_3	$T_в$, ^0C	T, ^0C	$T_{вых}$, ^0C	K
1	2	3	4	5	6	7	8
1	-	-	-	125	150	180	7,9
2	-	-	+	125	150	190	8,1
3	-	+	-	125	160	180	7,9
4	-	+	+	125	160	190	8,5
5	+	-	-	135	150	180	8,1
6	+	-	+	135	150	190	8,2
7	+	+	-	135	160	180	8,1
8	+	+	+	135	160	190	8,5
9	-1,68	0	0	120	155	185	7,9
10	+1,68	0	0	140	155	185	8,2
11	0	-1,68	0	130	145	185	8
12	0	+1,68	0	130	165	185	8,6
13	0	0	-1,68	130	155	175	8,1
14	0	0	+1,68	130	155	195	8,2
15	0	0	0	130	155	185	8,1
16	0	0	0	130	155	185	8,0
17	0	0	0	130	155	185	8,1
18	0	0	0	130	155	185	8,2
19	0	0	0	130	155	185	8,1
20	0	0	0	130	155	185	8,3

Based on the obtained experimental results, we obtain coefficients for constructing the regression equation. The coefficients of the regression equations are presented in table 3.

Table - The coefficients of the equations of regression of the output parameters for y(K)

Optimization criterion	Coefficients	Humidity
1	2	3
	With coded factor values	
	b_0	8,07499632
	b_1	0,080813
	b_2	0,117706
	b_3	0,114778
	b_{12}	-2,2212

Expansion coefficients	b_{13}	-0,05
	b_{23}	0,1
	b_{11}	-0,01675
	b_{22}	0,071453
	b_{33}	0,018533
	With natural factors	
	B_0	167,3901
	B_1	0,528002
	B_2	-1,64956
	B_3	-0,65725
	B_{12}	-8,8818
	B_{13}	-0,002
	B_{23}	0,00400
	B_{11}	-0,00067
	B_{22}	0,002858
	B_{33}	0,000741

We obtain the regression equation of the extrusion process by substituting the coded values of the factors in formula 1, we obtain:

$$y1=8,07499632+ 0,080813x_1 + 0,117706x_2 + 0,114778x_3-2,2212x_1x_2-0,005x_3 + 0,1x_2x_3 -0,01675x_1^2 + 0,071453x_2^2+ 0,018533x^2_3$$

Having decoded the independent variables in the equation, we obtain the regression equation for the natural values of the factors:

$$B= 167,3901+ 0,528002T_в-1,64956T- 0,65725T_{вых}– 8,8818T_вT-0,002T_{вых} + 0,00400TT_{вых} -0,00067T_в^2+ 0,002858T^2+0,000741T_{вых}^2$$

Figure 1 - Three-dimensional model in space, characterizing the dependence of $y_n=f(Tв,T)$ at the inlet temperature ($Tв,^0C$) and the temperature inside the extruder ($T,^0C$) on the expansion coefficient (K)

At the stage of optimization of the extrusion parameters of buckwheat grain, of particular interest is the temperature of the extruder at the outlet, as a characteristic that determines one of the main extrusion parameters affecting the humidity of the finished product. Dependences (Fig. 1-3) of the influence of the main parameters ((inlet temperature ($T_в$, ^0C), inside temperature of the extruder ($T,_0C$) and outlet temperature ($T_{вых}$, ^0C)) of extrusion were obtained. Figure 2 shows that the initial moisture state of the finished product decreases with increasing temperatures at the inlet and inside the extruder, in the temperature range inside the extruder from 155 до 165^{0}C the greatest decrease in humidity of the finished product is observed. The highest humidity peak of the finished product falls on the site where the lowest temperature, inlet temperature is 130^{0}C and the temperature inside the extruder is 160^{0}C, the maximum expansion coefficient is 8,5 %.

Figure 2 - Three-dimensional model in space, characterizing the dependence of y_n=f(Тв,Твых) inlet temperature (Тв,^{0}C) and outlet temperature (Твых,^{0}C) on the expansion coefficient(К)

From this model of Figure 2 it follows that at the lowest temperature at the outlet of 185^{0}C the extrudates are the wettest. Regarding the temperature axis inside the extruder, it can be seen that from 155 to 160 % the largest coefficient of expansion is observed. Crossing the line at 160%, the expansion coefficient is gradually declining.

Figure 3 - Three-dimensional model in space, characterizing the dependence of y_n=f(Тв,Твых) of the temperature inside the extruder (Т,^{0}C) and outlet temperature (Твых,^{0}C) on the expansion coefficient (К)

Since the value of the expansion coefficient equal to 8.6 is the most optimal, it follows from Figure 3 that the temperature inside the extruder is 160^{0}C. Thus, based on the mathematical model, we can choose the optimal parameters for extrusion: inlet temperature 130^{0}C, temperature inside the extruder 160^{0}C and outlet temperature 185 ^{0}C.

Thus, on the basis of the studies, the optimal extrusion parameters of buckwheat were determined.

Conclusion

Based on mathematical modeling and optimization of the buckwheat extrusion process, universal regression equations have been obtained that make it possible to predict the yield of products depending on the process parameters.

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ҚАРАҚҰМЫҚТЫ ҚЫЗДЫРУДЫҢ ТЕХНОЛОГИЯЛЫҚ ПРОЦЕССТЕРІНІҢ ТЕМПЕРАТУРАЛЫҚ ПАРАДЕРЛЕРІН МОДЕЛЬДЕУ ЖӘНЕ ОҢТАЙЛАНДЫРУ

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Түйін. Үш факторлы эксперимент жүргізу арқылы алынған математикалық процестің сипаттамасы жасалды, бұл жылдам таңғы ас алу үшін экструдердің барлық үш аймағының оңтайлы температура параметрлерін анықтауға мүмкіндік берді. Қазақстандық шикізаттан жедел таңғы ас алу үшін оңтайлы температура шарттары алынды. Сонымен қатар эксперименттік және теориялық нәтижелер бір-бірімен сәйкес екендігі анықталды.Зерттеу нәтижесінде қарақұмықтың оңтайлы экструзия параметрлерін болжауға және тәжірибелер санын азайтуға мүмкіндік беретін регрессия теңдеуі алынды. Экструзионды өңдеу жартылай фабрикаттарды алу үшін дәнді дақылдарды өңдеудің ең тартымды әдістерінің бірі болып табылады. Бұл теңдеуді қолданудың тиімділігі мен тиімділігі зертханалық жағдайда дәлелденген.

Кілттік сөздер: экструзия, жақсы тамақтану, экструдаттар, қарақұмық, математикалық модель, регрессия, матрицаны жоспарлау, экструзия параметрлері, тәжірибе.

MODELING AND OPTIMIZATION OF TEMPERATURE PARAMETERS OF THE TECHNOLOGICAL PROCESS OF EXTRUDING BUCKWHEAT

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Abstract: A description of the mathematical process obtained by implementing a three-factor experiment is carried out, which made it possible to establish the optimal temperature parameters of all three zones of the extruder to obtain a quick breakfast. The optimum temperature conditions for obtaining instant breakfast from Kazakhstani raw materials are obtained. It was also established that the experimental and theoretical results are in good agreement. As a result of the research, a regression equation was obtained that allows us to predict the optimal extrusion parameters of buckwheat and reduce the number of experiments. Extrusion processing is one of the most attractive methods of processing grain crops to obtain semi-finished products. The efficiency and effectiveness of the use of this equation is proved in laboratory conditions.

Key words: extrusion, good nutrition, extrudates, buckwheat, mathematical model, regression, planning matrix, extrusion parameters, experience.