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THE RESEARCH OF TECHNOLOGICAL PROCESS OF GRAIN EXTRUSION WITH VEGETABLE COMPONENTS

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According to scientists, most vegetable plants for their economic purpose provide valuable products that should be used as a food and feed. Many vegetable plants have a large amount of nutrients and vitamins, preserving, antiseptic and bactericidal properties, which is extremely important for improving the quality of feed [1–7].

The purpose of the experiment. To develop optimal indicators of technological process of grain extrusion with vegetable components on the basis of multivariate experiment.

Research methodology. The experimental part was performed at the Department of Grain Storage and Processing Technology and at the Scientific Laboratory of Mass Analysis (attestation № AO6-203 of 25.10.16) of Uman NUS. The research were conducted in accordance with conventional methods. The technological process of grain extrusion with beet was adopted as the object of research. The data obtained was processed using Microsoft Excel applications and STATISTICA for Windows software.

The planning of the experiment was carried out by the method of steep ascent, or the Box-Wilson method, with the subsequent construction of a mathematical model of the process. Based on the chosen plan, we built a model that corresponds to the review under consideration, and used known methods of finding the extremum to find the values of the factors for which the selected objective function defined in the model will be extreme. If the

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found values of the factors corresponding to the extreme point lie on the boundary of the applied plan, the planning area either shifts or expands and a new model is built, after which the search for the extremum is repeated.

We used the following components: grain content (x_2), beet content (x_1) in planning, conducting and processing the results of a multifactorial experiment to formulate and solve an optimization problem. The experiment plan is shown in Table 1. Two experiments were implemented at each point of the plan. The variables x_i ($i= 1, 2, \dots, q$) of such systems are the proportions (relative content) of the i -components of the mixture and correspond to the condition $\sum x_i = 1$ ($x_i \geq 0$).

Table 1

Experiment planning matrix and parameter definition

№	Beet content (x_1)	Grain content (x_2)	Dependent variable
1.	2,5	97,5	y_1
2.	5,0	95,0	y_1
3.	10,0	90,0	y_1
4.	15,0	85,0	y_1
5.	20,0	80,0	y_1
6.	22,5	77,5	y_1

Research results. A multifactorial experiment was conducted to develop and introduce into the production process of grain extrusion with vegetable components. During the examination of each object of the study distinguished input actions affecting the system and the corresponding reactions of the system. The parameters of influence on the system are called factors, the response of the system to the external influence is called the response, parameter or criterion of optimization. There are certain requirements for response function and optimization factors.

As the optimization criterion, which best characterizes the object of study, the specific energy intensity of the extrusion process, taking into account the degree of grinding and the quality of the crushed particles, is selected:

$$E = \frac{N_c \cdot K_k}{Q \cdot \lambda} \rightarrow \min, \text{ kJ/kg}, \quad (1)$$

where N_c – the total power, kW; K_k – dimensionless quality factor; Q – productivity, kg/h; λ – the degree of grinding.

The proposed assessment (1) allows us to objectively determine the specific energy intensity of the feed extrusion process at different degrees of grinding and

quality of crushed particles and more accurately characterize the degree of perfection of the work process. The multifactor experiment was carried out in order to obtain a mathematical model of the technological process of extrusion and to determine the optimal parameters that ensure the minimum energy intensity of the process according to the specified quality indicators of feed.

For the multivariate experiment, the significant factors that most strongly influence the initial parameters of the grinding process were selected (Table 2).

Table 2

The list of variable factors

Factors	Marking	Area of the experiment	Explanation
Beet content, %	x_1	5...15	The limits of factor change are chosen without the minimum (2,5) and maximum (22,5) possible values
Grain content, %	x_2	85...95	The lower and upper levels of the factor are selected for technological reasons and correspond to the limit of change during the use of the extruder
Productivity, kg/h	x_3	10–25	The limits of factor change are determined by previous experiments

The coding factors and the choice of intervals for their variation are shown in table 3. To obtain a mathematical model of the process described by the second-order polynomial, a three-factor rotatable three-level plan of the Box-Wilson for three factors, which is more economical in number of experiments and has their properties, compared to orthogonal and rotatable ones.

Table 3

Encoding of factors and choice of intervals of their variation

Designation of factors	x_1	x_2	x_3
Name of factors	Beet content, %	Grain content, %	Productivity, kg/h
Basic level	8	85	15
Variation interval	5	5	5
Upper level factor	15	95	25
Lower level factor	5	80	10
Response function	y – energy consumption of the extrusion process		

The hallmark of the plan is that some factors are at zero levels. The design parameters of the extruder were in accordance with the design of the experiment.

Using STATISTICA for Windows, regression coefficients were obtained and mathematical model of energy intensity of feed extruding process y as a function of beet content x_1 , grain quantity x_2 and extruder productivity x_3 , which can be written as a second-order polynomial:

$$y = 4,700165 - 0,703805 x_1 - 0,297750 x_2 - 0,038090 x_3 + 0,001279 x_1 x_3 + 0,021375 x_1 x_2 + 0,001000 x_2 x_3 + 0,035609 x_1^2 + 0,018750 x_2^2 + 0,000247 x_3^2. \quad (2)$$

Finalloss: R=0.99545 Varianceexplained: 99.092%.

The correlation coefficient of the results of the calculations of the polynomial model (2) is equal to $R = 0,99545$, which indicates a sufficiently accurate description of the obtained model of the real process of feed extrusion. The mathematical model obtained also determines the significance of the influence on the dependent variable of both the factors of the experiment and their products. Thus, the energy intensity of the extrusion process is significantly influenced by factor x_1 than factors x_2 and x_3 .

The graphical representation of the model obtained as a function of the factors $x_1 - x_2$, $x_1 - x_3$, $x_2 - x_3$ can be obtained as a square surface of the energy response of the feed extrusion process (Figure. 1–2).

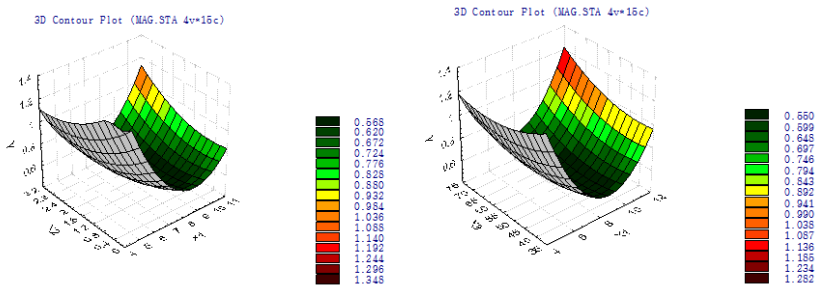


Figure 1. Polynomial energy response surface feed extrusion process as a function of factors $x_1 - x_2$, $x_1 - x_3$

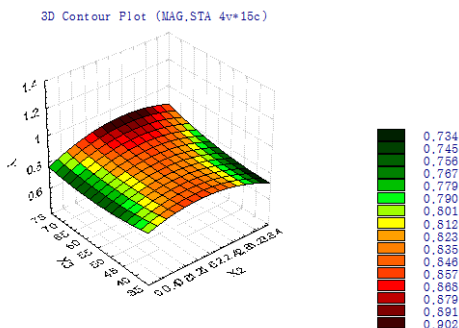


Figure 2. The polynomial surface of the energy response of the feed extrusion process as a function of the factors x_2 – x_3

Graphical analysis of the model showed that the optimal value of the parameters corresponding to the minimum energy consumption of the feed extrusion process is $y = 0,480 \dots 0,568$ kJ/kg, are within: beet content $x_1 = 8\%$, grain amount $x_2 = 92\%$, productivity, kg/h. $x_3 = 48 \dots 52$ kg/h.

Conclusion. It is proved that vegetables are a valuable raw material for the production of compound feed and analysis of the model showed that the optimal value of the parameters corresponding to the minimum energy consumption of the feed extrusion process is $y = 0,480 \dots 0,568$ kJ/kg, are within: beet content $x_1 = 8\%$, grain amount $x_2 = 92\%$, productivity, kg/h. $x_3 = 48 \dots 52$ kg/h.

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