The possibility of using mogar grain for the production of food concentrates based on the traditional national dish "Talkan" is considered. "Talkan" is a national food concentrate for Republic of Kazakhstan, which has been used as a staple food in long-distance trekking by various cultures for centuries. Traditionally, talkan is prepared from various cereals, particularly millet, wheat and barley. When boiling water and oil are added, it turns into a hearty porridge, and when oil and sugar are added, it becomes a delicious dessert.

The difficulty lies in the careful handling and preparation of the mogar grain. During intensive cooking, the grain can easily overcook, resulting in all the valuable nutrients being leached into the broth. In addition, improperly prepared mogar can burn during further roasting. To determine the optimal parameters of mogar hydrothermal treatment and to create a high-quality food concentrate based on the national dish "Talkan", a complex experiment was conducted using modern methods of experiment planning.

A number of variables were tested during the experiment, including temperature limits and duration of cooking, as well as temperature, duration and intensity of stirring during drying and roasting of mogar. The study showed that the most favourable conditions for mogar grain involve cooking at an initial temperature of between 15–20 °C for about 60 minutes, gradually reaching 100 °C. The drying and roasting processes are best carried out for 25 minutes, with a layer thickness of 25 mm and a surface temperature of 250 °C.

The determined of hydrothermal treatment serve as a basis for the design of specialised equipment for preparation of mogar grain for the purpose of making Talkan

Keywords: hydrothermal treatment, grain quality, roasting, drying, mogar, Talkan

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OPTIMIZATION OF THE METHOD OF HYDROTHERMAL TREATMENT OF MOGAR GRAIN FOR PRODUCTION OF FOOD CONCENTRATE "TALKAN"

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1. Introduction

The growing demand for plant-based protein over animal protein has sparked interest in exploring currently underutilized plant protein sources within the food industry. The emerging trend is centered around the production of protein concentrates, which has garnered significant attention in scientific research. Among the various protein concentrates, Talkan emerges as a viable means of producing an affordable and palatable food concentrate. Talkan, derived from coarse flour made from roasted barley or wheat, offers numerous health benefits as it is rich in essential microelements, low in calories, and has the capacity to dissolve cholesterol and salt deposits in blood vessels, joints, spine, liver, and kidneys. Additionally, it serves as an effective enterosorbent. The key to enhancing the quality of raw materials obtained from mogar grain, used in the production of cereal food concentrates and confectionery products, lies in the hydrothermal treatment of the grain, which involves regulating the cooking and drying processes. The GTO (Grain Treatment Optimization) process aims to strengthen the endosperm while reducing the strength of the floral membranes. The more pronounced these changes become, the greater the efficiency achieved in processing grain into cereals and oatmeal (flour).

Therefore, studies investigating the effect of different processing methods on the quality of end products are of great scientific relevance. In today's world, where the pursuit of healthier and more efficient food production methods is of paramount importance, studying the effects of different processing methods on products such as Talkan is of considerable scientific interest. Such research contributes to expanding our understanding of food processing and its impact on both traditional and modern dietary practices.

2. Literature review and problem statement

Sorghum and millet are cereal crops that can grow in semi-arid climates with nutritional and bioactive properties superior to those of major cereals such as rice, wheat and maize. However, these properties vary widely, depending on genetic factors, growing conditions and location. Millets contain a significant amount of starch, ranging from 51 % to 79 %, which is similar to other cereal grains. Different types of millets, like finger millets and pearl millet, have varying starch content, with finger millets having a higher starch content [1]. Millets are a nutritionally rich group of grains containing 60–70 % carbohydrates, 1.5–5 % fat, 6–19 %

protein, 12–20 % dietary fiber, and 2–4 % minerals. They are also abundant in vitamins, lipids, dietary fiber, polyphenols, and minerals, with variations depending on the specific millet type. The popularity of millets is attributed to their gluten-free nature and their high content of fiber, protein, and antioxidants [2–4]. Millets are suitable for individuals with celiac disease due to their gluten-free nature. They are known to regulate blood glucose levels, making them effective for diabetes management. Epidemiological studies show a lower incidence of diabetes among millet consumers [5–7]. Millets have 3–5 times the nutritional value of wheat or rice. Finger millet, for example, contains three times the calcium content of milk and ten times that of wheat, brown rice, and maize [8, 9]. While numerous studies have delved into aspects of grain processing, it is clear that critical knowledge gaps and unresolved issues still exist. These gaps necessitate further research.

The paper [10] presents the results of research the processing of parboiled rice involves three main steps: dipping, gelling, and drying. These three stages are different from those for polished and whole rice [11]. Initially, the husked rice is immersed in water in a cylindrical vessel with a cone-shaped bottom at a temperature below the starch gelatinization threshold. Hydration positively correlates with immersion water temperature [12]. Thus, the main factor controlling rice hydration is temperature [13]. After draining, the husked rice is heated to gelatinize the starch with hot steam (100 to 120 °C) for 5 to 30 minutes. min, resulting in a grain water content of approximately 35 % [14]. However, despite the recognized importance of these cereals, the key to unlocking their potential lies in optimizing their processing methods. This requires identifying ideal processing conditions that will produce the desired grain characteristics without compromising grain integrity, nutrition and practicality. While previous studies have investigated factors such as immersion temperature and steaming duration, they have yet to provide a definitive understanding of exactly what conditions are required to achieve optimal results for specific products. Also, the effects of traditional cooking methods on grain quality and nutrient content have not been comprehensively investigated. The potential benefits of roasting as a modifier to increase the content of bioactive compounds and nutritional value of grains have also not been sufficiently explored.

Studying the effect of steaming conditions, immersion temperature (65 °C, 70 °C and 75 °C), steaming at 112 °C and immersion time (10, 15 and 20 minutes) on rice quality, [15] found that the maximum yield of brown rice is achieved at an immersion temperature of 75 °C. Higher immersion temperatures can accelerate the rate of hydration as well as reduce swelling cracks and rearrangement of starch granules, increasing grain resistance to breakage. Deformed grains are observed with an increase in the duration of steaming, which is associated with a possible annealing process.

Boiling can be considered a way of preparing simple traditional staple foods at a household level. This simple processing method is associated with changes in the nutrient content of millet [16].

Mogar cooking time in the next study was 5 minutes and 36 minutes, with two methods of cooking, in a microwave oven and in a frying pan. After preparation, the samples were dried overnight at 50 °C in a hot air oven, ground, and then subjected to further analysis. The results showed that pan and microwave cooking of millet increased the carbohydrate content from 78.51 to 78.91 and 81.69 g/100 g while reducing fat from from 3.24 to 2.3 and 3.05 g/100 g, respectively [17]. Although some studies have investigated factors such as immersion temperature and steaming duration in grain processing, it has not yet been possible to accurately determine the optimum processing conditions under which the desired grain properties can be achieved without compromising grain integrity. This knowledge gap poses a challenge to achieve consistently high-quality grain processing.

Moreover, millet and small millet cooking can cause a 28 % reduction in in-vitro starch digestibility [18]. In another study, the effect of a cooking method called "parboiling" (partial or semi-boiling of food) on the in vitro digestibility of two traditional millet products – porridge and steaming. Kashi and steamed couscous made with millet have been researched [19]. Existing research has shown that traditional cooking methods can affect grain quality and nutrient content. However, there is a lack of full understanding of the full range of effects, including changes in nutrient content, digestibility and overall nutritional value. A more in-depth study of the effects of traditional methods on grain quality is needed.

Millet contains many antioxidants, which can reduce free radicals induced by oxidative stress and prevent cancer. Roasting millet can affect these bioactive compounds in different ways. Roasting millet millet for 10 minutes at 110 °C significantly increased the total phenol content of phenols from 295 to 670 mg/100 g (ferulic acid equivalent). It was explained that roasting can promote the hydrolysis of C-glycosylflavones and cause the release of subsequent phenolic compounds. It was also found that the total antioxidant capacity of treated millet depended on the quadratic effect of roasting time and temperature. Increasing the roasting temperature increased the values of the antioxidant capacity of millet [20].

Roasting can significantly increase protein digestibility from 22.3 % to 60.1 % [21]. This increase may be due to improved nitrogen digestion when heated, making the protein more vulnerable to hydrolysis [22]. It is concluded that roasting should be taken into account to improve the efficiency of millet utilization. Roasting has shown promise in enhancing the bioactive compound content and nutritional value of grain. However, the specific roasting conditions required to achieve optimal results and their influence on protein digestibility remain largely unexplored. This gap in knowledge offers great potential for improving the nutritional value of roasted grains.

An analysis of general trends and directions for solving the problem of grain processing showed the possibility of not only improving the technological properties of grain, but also made it possible to identify the most effective modes of its processing, which contribute to the economical use of electricity, do not require the use of complex equipment, and accelerate the technological process.

But there were unresolved issues related to the question of determining rational processing modes during cooking, drying and roasting mogar remained unexplored. It was necessary to find such modes under which the grain would be ready for use, but would not be boiled and would not be crumbly. At the end of processing, the grain must retain its shape. However, several critical knowledge gaps and unresolved issues have emerged from this examination.

Optimal Processing Conditions: While previous studies have examined factors like immersion temperature and steaming duration in grain processing, we have not yet determined the precise, optimal processing conditions that consistently yield the desired grain characteristics without compromising integrity.

Effects of Traditional Cooking Methods: Our review revealed that traditional cooking methods can influence grain quality and nutrient content. Yet, there is a lack of comprehensive understanding regarding the complete range of implications, including changes in nutrient content, digestibility, and overall nutritional value.

Roasting as a Potential Modifier: Roasting has been identified as a promising technique for enhancing the bioactive compounds and nutritional value of grains. However, the specific roasting conditions necessary for optimal results and their effects on protein digestibility remain largely unexplored.

Given the knowledge gaps and unresolved issues, it is evident that further research is warranted. Therefore, the research goal is to address these gaps by determining the most effective processing modes for mogar, ensuring both quality and practicality in its utilization.

The rationale for this research goal is rooted in the need to optimize grain processing techniques. These optimizations can lead to more efficient and economical grain utilization, enhancing both the quality of the final product and its nutritional value. Consequently, the research will focus on establishing the ideal processing conditions for mogar, considering factors like immersion temperature, steaming duration, and roasting parameters.

In conclusion, the research goal is to contribute to the resolution of the identified knowledge gaps and challenges in grain processing, with a particular emphasis on enhancing the quality and nutritional value of mogar.

3. The aim and objectives of the study

The aim of the study is to determine the rational modes of hydrothermal treatment of mogar in order to obtain high-quality national food concentrate Talkan. Determination of rational modes of cooking and drying processes was carried out by the method of mathematical planning of the experiment.

To achieve the objective, the following objectives were set:

– to determine the rational mode of the process of cooking mogar by the method of mathematical planning and visualize by the method of Surface Responses;

– to determine the rational mode of the drying process of hydrothermally treated mogar, to visualize the result by the method of surface responses.

4. Materials and methods

The object of the study is the process of hydrothermal treatment of mogar grain. This means that the whole process of processing and preparation of mogar grain for further processing in "Talkan" is considered as the object of research.

The subject of the study is mogar grain which is subjected to hydrothermal treatment and further processing into food concentrate "Talkan". That is, the study is focused on the properties and parameters of mogar grain in the context of its processing and use in the production of "Talkan".

The hypothesis of the study may be the assumption that the optimum parameters of hydrothermal treatment of mogar grain can be determined using the method of mathematical planning of experiment, and it will allow obtaining high quality national food concentrate "Talkan".

The material in this study was grains of mogar Setaria italic.

According to the technology of preparation of the national food concentrate Talkan, mogars are boiled, then dried, fried, crushed, and sugar, butter and national crushed red cheese are added to the crushed raw materials. Requirements for mogar during cooking – should not boil soft. The grains must be whole.

The experiment was carried out by the method of mathematical planning, the matrix of the experiment was compiled [23]. As factors influencing the course of the cooking process, the following were taken: X_1 – the duration of the process (min); X_2 – water temperature (°C); X_3 – grain mixing frequency, rpm; X_4 – the ratio of water and grain. The number of boiled grains (%) was taken as an optimization criterion (Y). The duration of the cooking process X_1 varied from 30 to 60 minutes, the water temperature X_2 from 20 to 100 °C, the grain mixing frequency X_3 from 1 to 3 revolutions per minute, the ratio of water and grain X_4 from 1:1 to 5:1.

As factors influencing the course of the drying-roasting process, the following were taken: X_1 – surface temperature (°C); X_2 – duration of the process (min); X_3 – grain layer thickness, mm; X_4 – air temperature (°C). The moisture content of the final product (%) was taken as an optimization criterion (Y).

The surface temperature X_1 varied from 150 to 250 °C, the duration of the drying-roasting process X_2 from 15 to 25 minutes, the grain layer thickness X_3 from 5 to 25 mm, the air temperature X_4 from 60 to 100 °C.

Experiment design matrices are presented in Tables 1, 2. In these matrices, the factors are denoted by X with the corresponding index, the upper level is marked with a (+) sign and the lower level is marked with a (–) sign.

Table 1

Matrix for planning the experiment of the cooking process of Mogar grain

No. i. e.	X_1 Continue the process τ, min	X_2 Water temperature t, °C	X_3 Mixing frequency grain, rpm	X_4 Ratio water and grain
1	+(60)	+(100)	+(3)	+(5:1)
2	–(30)	+(100)	+(3)	+(5:1)
3	+(60)	–(20)	+(3)	+(5:1)
4	–(30)	–(20)	+(3)	+(5:1)
5	+(60)	+(100)	–(1)	+(5:1)
6	–(30)	+(100)	–(1)	+(5:1)
7	+(60)	–(20)	–(1)	+(5:1)
8	–(30)	–(20)	–(1)	+(5:1)
9	+(60)	+(100)	+(3)	–(1:1)
10	–(30)	+(100)	+(3)	–(1:1)
11	+(60)	–(20)	+(3)	–(1:1)
12	–(30)	–(20)	+(3)	–(1:1)
13	+(60)	+(100)	–(1)	–(1:1)
14	–(30)	+(100)	–(1)	–(1:1)
15	+(60)	–(20)	–(1)	–(1:1)
16	–(30)	–(20)	–(1)	–(1:1)

Table 2

Matrix of planning the experiment of the process of drying-roasting of mogar grain

No. i. e.	X_1 Surface temperature t, °C	X_2 Process length τ, min	X_3 Thickness layer, mm	X_4 Air temperature t, °C
1	–(150)	–(15)	–(5)	–(60)
2	+(250)	–(15)	–(5)	–(60)
3	–(150)	+(25)	–(5)	–(60)
4	+(250)	+(25)	–(5)	–(60)
5	–(150)	–(15)	+(25)	–(60)
6	+(250)	–(15)	+(25)	–(60)
7	–(150)	+(25)	+(25)	–(60)
8	+(250)	+(25)	+(25)	–(60)
9	–(150)	–(15)	–(5)	+(100)
10	+(250)	–(15)	–(5)	+(100)
11	–(150)	+(25)	–(5)	+(100)
12	+(250)	+(25)	–(5)	+(100)
13	–(150)	–(15)	+(25)	+(100)
14	+(250)	–(15)	+(25)	+(100)
15	–(150)	+(25)	+(25)	+(100)
16	+(250)	+(25)	+(25)	+(100)

To clarify the model of the cooking process, the data were processed in the Statistica 12.0 program and also calculated manually [24].

Calculation of optimization of the process of deep hydrothermal treatment.

The mathematical model of the process is represented by the equation:

$$Y = b_0 + b_1x_1 + b_2x_2 + \ \dots\ + b_nx_n, \quad (1)$$

where Y – process optimization parameter;

x_1, x_2, x_n – levels of factors influencing the process;

b_1, b_2, b_n – regression coefficients showing the degree of influence of factors on the output of the process;

b_0 – the residual term in the regression equation, characterizing the average output of the process.

It is necessary to check whether the linear approximation equation is adequate.It is possible to calculate the output values Ŷ for each option:

$$\hat{Y} = b_0 + b_1x_1 + b_2x_2. \quad (2)$$

Process dispersion is calculated by the formula:

$$\sigma^2 = \Sigma\Sigma\left(Y - \hat{Y}\right)^2 : (\gamma - 1)\times N = $$
$$= 2\ \Sigma\left(Y - \hat{Y}\right)^2 : (\gamma - 1)\times N. \quad (3)$$

Number of degrees of freedom:

$$f = N(\gamma - 1), \quad (4)$$

where N – the number of experiment options;

γ – the number of repetitions.

Next, using the formula, let's calculate the confidence interval:

$$E = t\sqrt{\frac{\sigma}{N\gamma}}. \quad (5)$$

The dispersion of adequacy is calculated by the formula:

$$\sigma_a^2 = \Sigma\left(\breve{Y} - \hat{Y}\right)^2 : N - n - 1. \quad (6)$$

The resulting models were tested for statistical validity using regression analysis and analysis of variance (ANOVA). The adequacy of the models was determined using model analysis, a non-conformity test, and $R2$ (determination factor) analysis.

The optimal values of the processing variables are obtained using the numerical optimization method Statistica 12.0 software to find a solution that satisfies the imposed constraints, the goals are combined into a common compound function $D(x)$, called the desirability function [24], which is defined as:

$$D(x) = (d1\times d2\times \ldots \times dn)1/n. \quad (7)$$

A desirability function is a way of assessing how desirable a combination of input variables is, given several objectives at the same time. It helps to balance competing objectives and constraints when optimizing a process.

The information presented describes the methodology and techniques used in our experiment and is related to the optimization and quality control of mogar preparation for processing in Talkan.

5. Research results on determination of optimal modes by RSM method

5. 1. Determination of rational mode of mogar cooking process by mathematical planning method

Result, the calculated regression equation for the cooking process will have the final form:

$$Y = 7.55 + 0.85x_1 - 1.06x_2 + 0.39x_3 - 0.3x_4,$$

$$R^2 = 0.982 \quad (8)$$

The calculated regression equation for the cooking process is:

$$Y = 7{,}55 + 0{,}85x_1 - 1{,}06x_2 + 0{,}39x_3 - 0{,}3x_4 -$$
$$-1{,}29x_1x_2 - 0{,}35x_2x_3 - 0{,}25x_1x_3 + 0{,}34x_1x_2 +$$
$$+0{,}31x_2x_4 - 0{,}39x_3x_4 + 0{,}36x_1x_2x_3 - 0{,}3x_1x_2x_4 +$$
$$+0{,}3x_1x_3x_4 + 0{,}36x_2x_3x_4 + 0{,}51x_1x_2x_3x_4. \quad (9)$$

Fig. 1 shows the Pareto chart for the brewing process.

The Pareto chart (Fig. 1) shows the absolute values of the standardized effects from the largest effect to the smallest effect. The graph also includes a control line, indicating that the effect of boil time is statistically significant. At the same time, the coefficient of determination was 0.86, which indicates the significance of the coefficients obtained.

Fig. 2 shows the response surface for the brewing process with the most significant factors

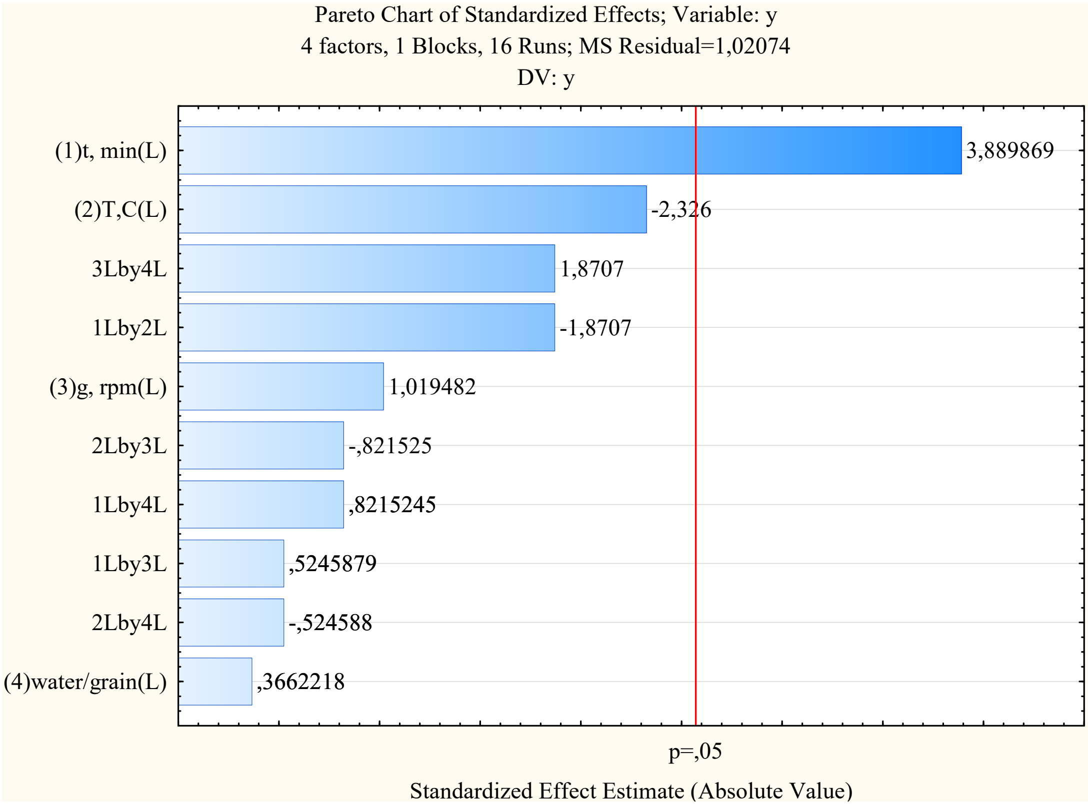

Fig. 1. Pareto chart for the brewing process

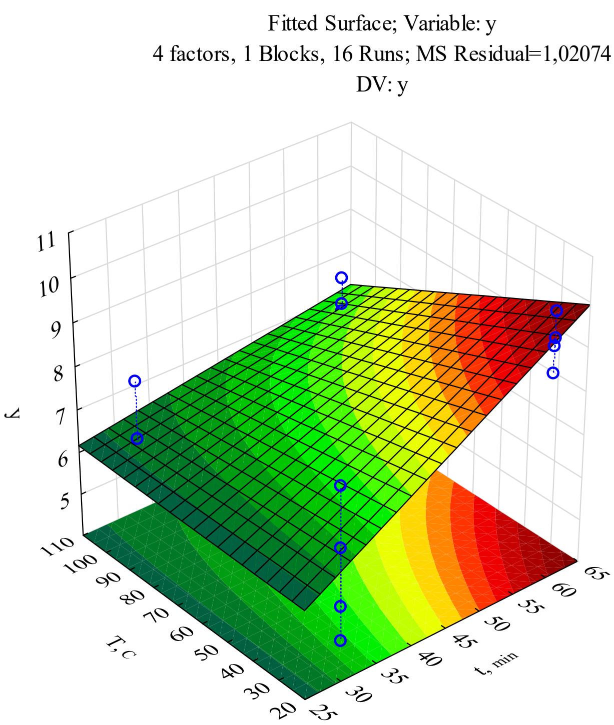

Fig. 2. Response surface of the dependence of the cooking process on temperature and duration of cooking

Where it is possible to see that the largest number of boiled grains will be at minimum temperatures and maximum temperatures, the minimum value of boiled grains, respectively, let's get if to observe the time mode of 40–45 minutes and a temperature of 60 °C.

Fig. 3 show profiles of predicted values and desirability at optimum and desirability surfaces/contours.

In Fig. 3, it can be seen that the minimum values of boiled grains occur at a temperature of 20–50 °C, time from 50–60 minutes at a speed of 2.8–3.2 rpm, and at a water/grain ratio of 0.2. Also, from the above results, it can be seen that the more grains in the water, the more often it is necessary to interfere with cooking and the less time is required to boil the grains.

To determine the difference between the variation of the fitted model (full model) and the un-fitted model (residual) let's use SS Whole Model vs. SS Residual test and the results are shown in the Table 3.

This Table 3 provides statistical information that is commonly used in regression analysis to assess the performance and significance of a predictive model.

From the data presented, there is a model with three predictors and it is possible to evaluate its significance and suitability for predicting the dependent variable related to cooking. An F-statistic of 7.114764 suggests that there is a significant relationship between the predictors and the dependent variable because the corresponding p-value (0.044170) is less than the usual alpha level (e. g., 0.05).

Table 3

For cooking

Dependent Variable	Test of SS Whole Model vs. SS Residual (Spreadsheet2)									
	Multiple R	Multiple R^2	Adjusted R^2	SS Model	df Model	MS Model	SS Residual	df Residual	MS Residual	F	p
y	0.917700	0.842174	0.723804	19.73920	3	6.579733	3.699200	4	0.924800	7.114764	0.044170

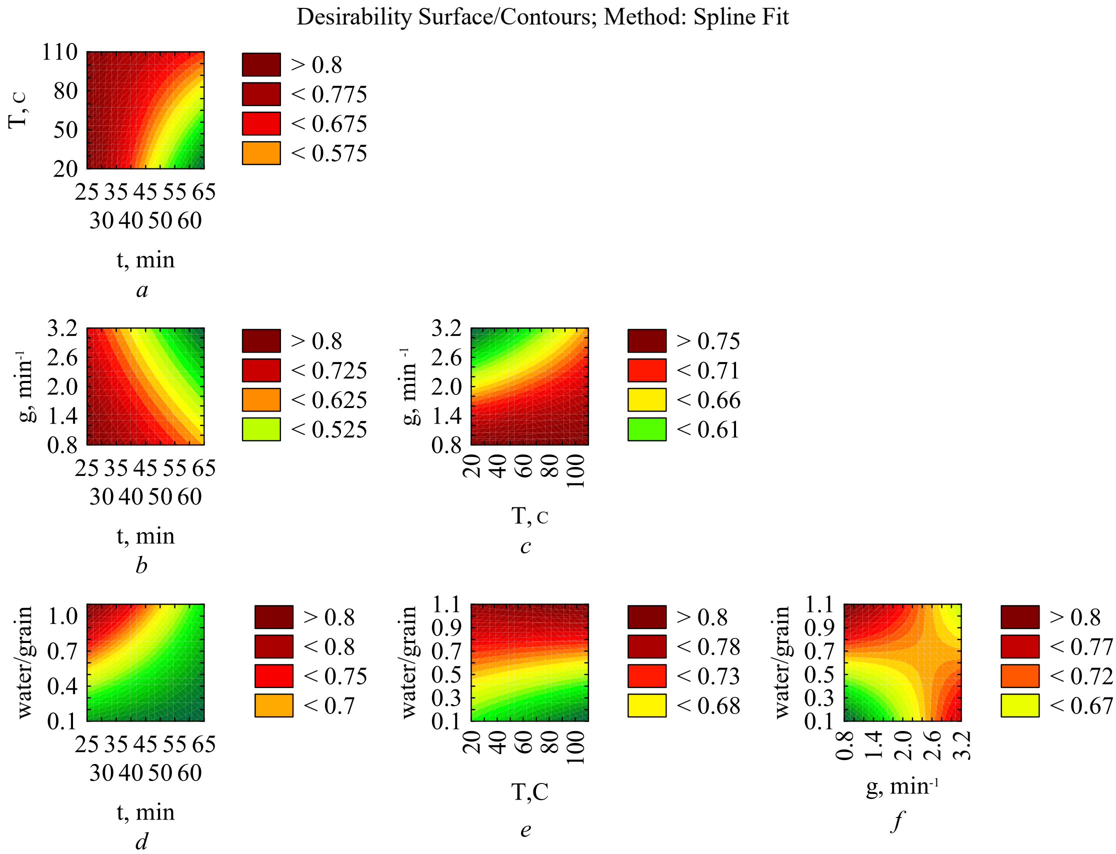

Fig. 3. Desirability surfaces/contour: *a* – desirability function as a function of temperature and process duration; *b* – desirability function depending on process duration and mixing intensity; *c* – desirability function depending on mixing intensity and temperature; *d* – desirability function depending on water/grain ratio and process duration; *e* – desirability function depending on water/grain ratio and temperature; *f* – desirability function depending on water/grain ratio and mixing intensity

5. 2. Determination of rational mode of drying process of hydrothermally treated mogar

The calculated regression equation for the drying-roasting process has the form for the drying-roasting process:

$$Y=12.71-1.48x_1-2.06x_2+1.76x_3-0.61x_4,\ R^2=0.976, \quad (11)$$

$$Y=12.71-1.48x_1-2.06x_2+1.76x_3-0.61x_4+0.18x_1x_2+0.53x_2x_3+0.11x_1x_3+0.08x_1x_4-0.38x_2x_4-0.06x_3x_4-0.06x_1x_2x_3-0.23x_1x_2x_4+0.18x_1x_3x_4-0.28x_2x_3x_4+0.01x_1x_2x_3x_4. \quad (12)$$

Fig. 4 shows the Pareto chart for the drying and roasting process.

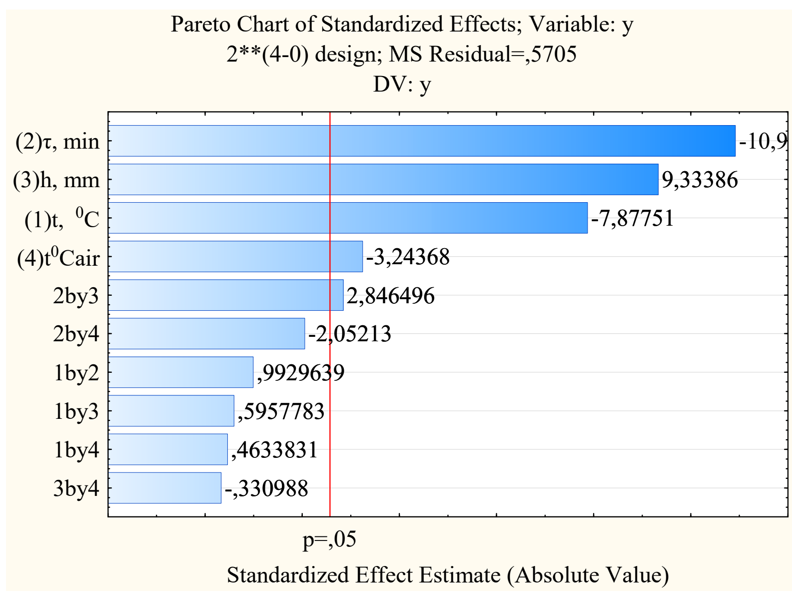

Fig. 4. Pareto chart for the drying and roasting process

The Pareto diagram of the drying and roasting process shows that with a significance of 0.5, the significant factors for the drying and roasting process are air temperature, layer height, and process duration. The coefficient of determination is 0.94, the analysis was carried out according to the plan of Blanket Berman.

Fig. 5 shows the response surface.

Fig. 5 shows that for a lower moisture content of the grains, it is necessary to provide a high air temperature with a process duration of 20–26 minutes

The temperature of the heating surface and the duration of the process (Fig. 6).

To determine the difference between the variation of the fitted model (full model) and the un-fitted model (residual) let's use SS Whole Model vs. SS Residual test and the results are shown in the Table 4.

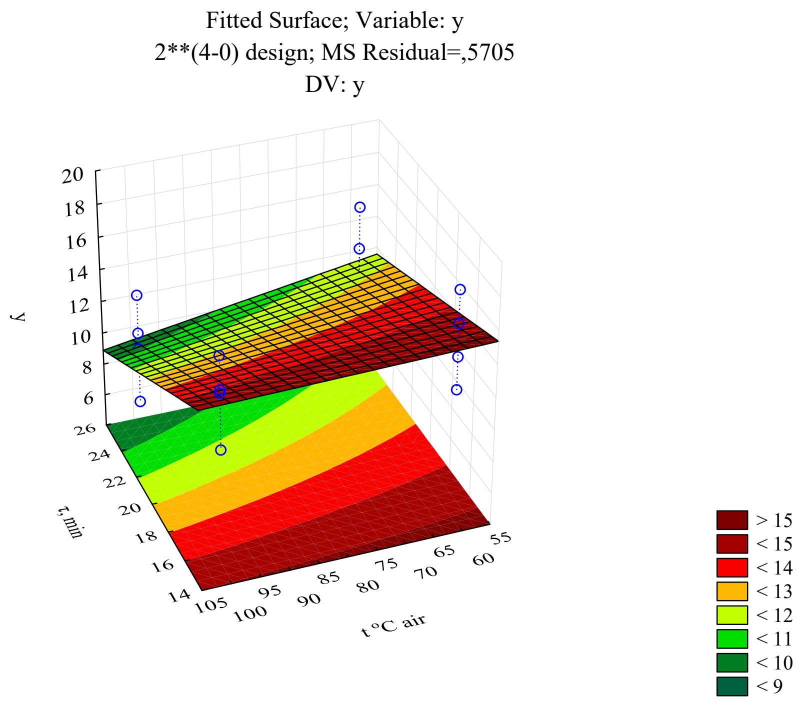

Fig. 5. The response surface of the drying and roasting process depending on the air temperature and the duration of the process

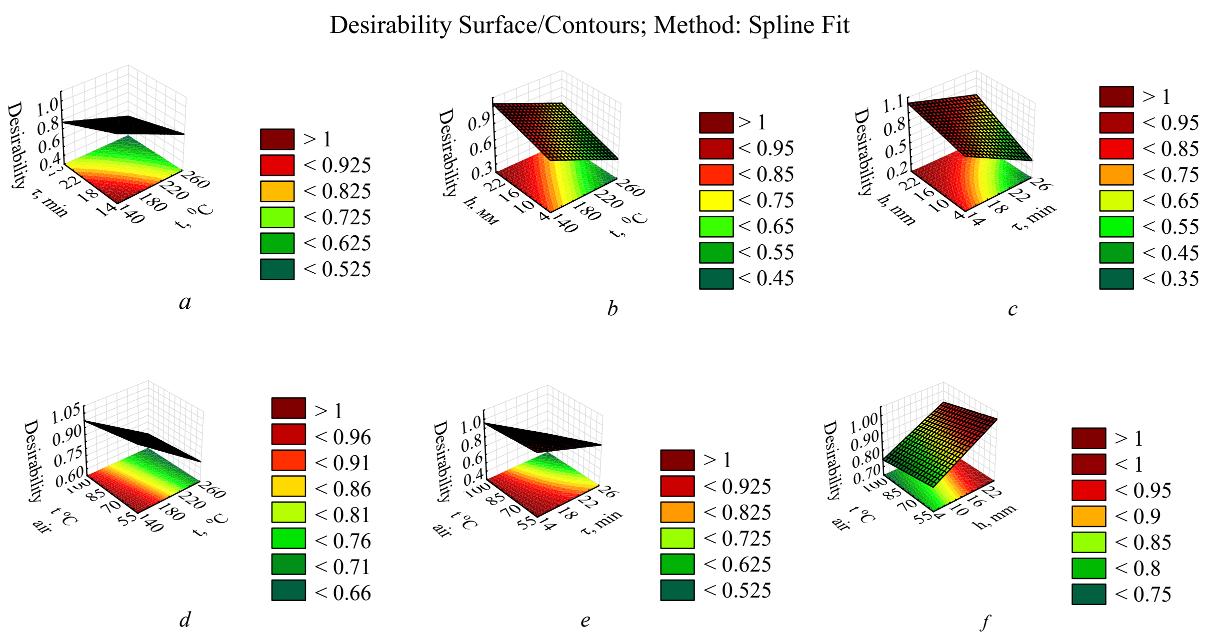

Fig. 6. Desirability surfaces for the drying and frying process: *a* – the desirability surface of the treatment duration and temperature; *b* – desirability surface from layer height and temperature; *c* – desirability surface from the layer height and duration of treatment; *d* – desirability surface from heating temperature and duration of treatment; *e* – desirability surface from heating temperature and duration of treatment; *f* – desirability surface from air temperature and layer height

In this case, it is 0.967630, indicating a strong positive correlation.

An R^2 equal to 0.936308 means that approximately 93.63 % of the variance of the dependent variable (y) is explained by the independent variables in our model.

An adjusted R^2 of 0.913147 indicates that even after adjusting for the number of predictors, our model still explains a significant amount of variance in the dependent variable.

The F-statistic is used to test whether there is a significant difference between the variation explained by the model and the unexplained variation. In this case, the F-statistic is 159.1700.

The p-value associated with the F-statistic. A very low p-value (e. g., 0.000002) suggests that the model is statistically significant, indicating that the variation explained by the model is not due to random chance.

Table 4

For the frying process

Dependent Variable	Test of SS Whole Model vs. SS Residual (Spreadsheet6жарка)										
	Multiple R	Multiple R^2	Adjusted R^2	SS Model	df Model	MS Model	SS Residual	df Residual	MS Residual	F	p
y	0.967630	0.936308	0.913147	159.1700	4	39.79250	10.82750	11	0.984318	40.42646	0.000002

In summary, the statistical results indicate that the model for the frying process is highly significant, with a strong multiple R, high R-squared values, and a very low p-value, suggesting that the independent variables in the model are good predictors of the dependent variable.

As practice shows, the most important result given in this table is the statistical significance of the regression model p value should be less than 0.05, R2 significance indicator in our case 0.91–0.97.

The adequacy of the model was checked by the Fisher criterion.

For the cooking process.

The value of Fisher's criterion (F) for the cooking process is 4.48. This value indicates the statistical significance of the influence of the considered factors on the cooking results. The interpretation of this result can be as follows: changes in cooking conditions such as temperature and time have a significant effect on the quality and characteristics of the finished product.

For drying and frying process.

The value of Fisher's criterion (F) for the drying and roasting process is 2.69. This value indicates the degree of influence of the considered parameters on the drying and roasting results. The interpretation of this result could be: the drying and roasting regimes have a less significant statistical effect on the quality of the final product compared to the cooking process.

6. Discussion of the results of the experiment to determine the optimal modes of mogar processing

The results of the cooking process analysis show that water temperature and cooking time are significant factors affecting the final product. Tables 2, 3 summarise the adequacy of the models, while Tables 1, 2 show the scheduling matrix for mogar and frying respectively. In particular, the graph (Fig. 2) shows.

The study found that water temperature and cooking time are the main factors affecting the cooking process. The results showed that lower temperatures and short cooking time lead to undercooked grains, while higher temperatures and longer cooking time lead to overcooked grains.

The study identified specific conditions for cooking mogar grain to achieve the desired result. These conditions involve an initial temperature of 15–20 °C, which is maintained for approximately 60 minutes, gradually reaching 100 °C. This configuration ensures that the grains are thoroughly roasted while maintaining their structural integrity.

Layer thickness, temperature and duration: Analyses of the drying and roasting process showed that layer thickness, heating surface temperature and process duration are of great importance (Fig. 5). Smaller layer thickness and higher heating surface temperature contribute to more efficient drying and roasting. The significance of these factors is confirmed by the calculated values.

The study determined the optimum parameters for the drying and roasting process. These include surface temperature of 250 °C, duration of 25 minutes and layer thickness of 25 mm. Such parameters ensure that whole dried mogar grains are obtained, which is the most important step in the creation of Talkan.

The objectives of the study were to establish effective mogar processing regimes to ensure quality and practicality of mogar. By setting parameters such as an initial cooking temperature of 15–20 °C for 60 minutes, it is proposed a practical solution to obtain perfectly cooked grains. In addition, defining the drying and roasting parameters ensures that whole dried mogar grains are obtained, making it easier to create a Talkan.

This process results in whole dried mogar grains and, thereby providing an opportunity to increase the nutritional value of the national product, Talkan, by preserving the nutrients within the grains.

The effectiveness of grain drying and roasting is in agreement with the results of other studies that reported improved digestibility and flavour characteristics of millets as a result of heat treatment.

Compared to existing studies, this work is different in that it comprehensively addressed the main parameters of mogar grain processing. The works [25, 26] referred to the ratio of water and rice grains to improve the flavour and cooking process. Similar results were obtained in previous studies, which increases the validity of the results obtained [27]. Analysis of the drying-roasting process also revealed key factors such as layer thickness, heating surface temperature and process duration. In [28], rice texture variation was observed during cooking and roasting process.

Consideration of the effect of temperature and time on grain quality provides a practical basis for efficient and economical utilisation of grain. Careful optimisation of these parameters enhances the quality and nutritional value of grain-based products.

Despite the successful identification of key factors (Fig. 1, 4) affecting grain processing, it is necessary to recognise the limitations of this study. In addition, the inability to track textural changes during the manufacturing process requires further investigation.

Future research should go beyond these specific conditions by looking at different grain types and preparation conditions. Studying the interaction of factors under more complex conditions will provide a more complete understanding of grain processing. In addition, a promising direction for future research is to investigate the possibility of tracking textural changes during processing.

7. Conclusions

1. It was found that the minimum number of boiled grains occurred at a temperature range of 10–50 °C, a cooking time of 50–60 minutes, a grain mixing speed of

2.8–3.2 rpm, and a water-to-grain ratio of 0.2. This provides valuable insights for achieving consistent and high-quality cooked mogar. The results of the linear approximation adequacy analysis showed that the value of Fisher's criterion was 4.48 for the cooking process, indicating that the process is near the optimum region under the conditions considered.

2. The research identified the optimal parameters for drying and roasting mogar grains, including surface temperature, duration, and layer thickness. These optimized conditions result in whole dried mogar grains and play a crucial role in the production of the national food concentrate, Talkan.

Optimum parameters were determined for the drying and roasting process of mogar grains, including a surface temperature of 250 degrees Celsius for 25 minutes with a layer thickness of 25 mm.

These hydrothermal regimes ensure that whole dried mogar grains are obtained. Once the grains are cleaned, they are finely ground and finally the national product, Talkan, is produced.

Conflict of interest

The authors declare that there is no conflict of interest.

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Data availability

Data will be made available on reasonable request.

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