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RESEARCH ARTICLE

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Regulation of Fat Content in Triticale Based on Optimization of Technological Processing Modes

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Abstract:

Introduction: The aim of the study was to regulate the fat content based on the optimization of technological processing modes. A promising method of preparing grain for animal feeding is its preliminary germination. Sprouted grain is a dietary food product, as it increases the content of proteins, essential amino acids, and macro- and microelements in comparison with non-sprouted grain.

Methods: The purpose of this study was to regulate the fat content based on the optimization of technological processing modes. Regression equations describing the dependences of the quality indicators of the triticale grain germination modes on the factors t_w, τ, w and t_g affecting them were investigated and obtained. During the study of triticale grains, it was found that the most significant parameter affecting the germination process is the fat content. The optimization of the germination modes of triticale Leather grain was carried out by the method of nonlinear programming.

Results: During the study, it was found that the maximum fat content during germination of triticale grain was observed with the following technological parameters of germination: grain temperature = 30°C; germination time = 24 h; grain moisture = 13%; and grain temperature = 26°C. When controlling the fat content in triticale based on the optimization of technological modes, the target function was 2.83%.

Conclusion: The presented results and conclusion will allow to regulate the fat content in triticale grain during germination.

Keywords: Triticale, Germination, Temperature, Time, Grain, Compound feed, Nutritional value, Fat.

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1. INTRODUCTION

In accordance with modern crop production technologies, cultivated varieties make the most complete and effective use of natural components of agroeco-systems that are resistant to abiotic and biotic environmental factors that negatively affect the volume and quality of the crop, ensure resource and energy efficiency, environmental plasticity, environmental protection, and profitability of the agricultural industry. The created varieties that meet these requirements are considered one of the main directions of crop production. Grain culture, which fully meets these requirements, has high adaptability. In addition, given the combination of valuable biological and economic characteristics and properties, it is gaining increasing popularity among farmers [1, 2].

Triticale, the first synthetic grain, is a product of crossing wheat and rye and is of both practical and theoretical interest. This crossing is an attempt to combine in one variety the high yield and baking qualities of wheat, winter hardiness, high content of lysine and protein, drought resistance and resistance to rye diseases. On all soils that are currently unsatisfactory for wheat but acceptable for rye, it would be desirable to be able to grow cereals that are equal to wheat in yield capacity, both in nutritional value and in the quality of bread baking [3].

The main grain crops, which include rapeseed, corn, barley, rye, oats, wheat and triticale, make up the majority of crop production [4]. Worldwide production of barley, wheat, oats and triticale is about 713 million tons, 144.7, 23.8, and 14.6 million tons [5].

The chemical composition of triticale is similar to wheat than rye. The content of most nutrients in triticale is more predominant than in wheat. A distinctive feature of triticale is its protein content. The protein content of triticale grain is affected, among other things, by the application of fertilizers [6]. Early triticale varieties had poor feed characteristics compared to wheat. It was found that genetic improvements in triticale increased the juiciness of the grain and reduced the protein include. As for the content of crude protein, triticale grain is richer in lysine than wheat, but the content of threonine and sulfurous amino acids is the same as wheat but poorer in tryptophan content than wheat. Triticale contained more lysine, arginine, aspartic acid, and alanine than wheat [7]. Most of the triticale grain grown around the world is used as animal feed. Triticale contains a larger amount of protein than other cereals and is also balanced in amino acid composition, which is useful for pig and poultry farming. It is also used as silage and hay for ruminants.

There are significant differences in fat content between triticale varieties. In the grain of the triticale culture, fat accumulation occurs with unequal intensity. The accumulation of fat in triticale grain in different varieties also occurs in different ways.

Unsaturated fatty acids predominate in the fat of cereals, which are necessary in animals for the normal course of metabolic processes. Fatty acids, which are part of lipids, perform the functions of the main structural components of the cell membranes of a living cell, while the structure-forming units are not passive building blocks but act as active participants and regulators of various biological processes, forming lipid-protein microdomains, organizing the orientation and interaction of proteins [8].

The fat content in triticale grain was not given as much attention as the content of protein and protein substances. Currently, the issues of identifying and creating adaptive forms characterized by stability of the main characteristics of yield and quality of triticale grain, including fat content, have become particularly important.

Fats in cereals are mainly deposited in the embryo. The embryo occupies an insignificant part of the seed compared to the endosperm, so the total fat content in them is small.

In the long run, it is extremely important to reduce the consumption of wheat, which is the main export crop, replacing it with other types of grain. In this regard, it is of great importance to study the effectiveness of using such a non-traditional grain crop as triticale for animal husbandry [9].

Triticale is widely used in agriculture [10]. This is a valuable feed, food, and industrial crop obtained by combining the chromosome complexes of wheat (Triticum aestivum) and rye (Secale cereale) - an artificially bred wheat-rye amphidiploid with a large multi-flowered ear, pronounced immunity to fungal diseases, increased protein and lysine content and higher winter hardiness compared to wheat. Higher content of complete protein, sugars, vitamins, and macro - and microelements, *i.e.*, a high biological value, make triticale grain promising for wider use in animal feeding [11].

However, the availability and absorption of nutrients in grain feed by the animal's body remain low, only 40-60%, and the known methods of preparing grain for feeding (grinding, germination, *etc.*) partially solve this problem. Consequently, in this direction, new ways of preparing grain for feeding or improving the known ones are needed in order to increase the digestibility and assimilation of its nutrients by animals [12].

Solving the problems of this area of research, we have developed a fundamentally new method of preparing triticale grain for feeding. The essence of this method is that two well-known and effective methods for preparing triticale grain (germination and extrusion) are carried out sequentially; first, the triticale grain is germinated and then extruded. The two methods combine well and complement each other, making it possible to improve the quality of sprouted triticale grain and its storage capacity and manufacturability. Ready-made extruded feed can be used as part of mixed feeds for dairy cows.

Compound feed extrusion [13], in studies, improved the chemical composition of feed compared to non-extrusion feed. The process was enhanced when one of the components of the feed mixture was pre-sprouted.

We investigated the technological modes of germination of «Asiada» triticale grain and obtained the following optimal technological modes of grain processing: temperature of water t_b = 15°C; time germination t=72 h; humidity of grain w=13%; temperature of grain t_h=10°C. Under these optimal modes of germination of triticale grain, the objective function was 19.11% [14, 15].

Therefore, research on the regulation of fat content in triticale based on the optimization of technological processing modes is relevant.

2. LITERATURE REVIEW AND PROBLEM STATEMENT

The main goal of this study is to determine the effect of magnetic treatment of 125 mm and 250 MT on the germination and initial growth of triticale seeds. Germination tests were performed under laboratory conditions, exposing triticale seeds to a magnetic field for different periods of time. The effect was studied by exposure to seeds before sowing. The most significant differences were obtained at exposure times of 1 and 24 hours, and the maximum reduction was 12%. In addition, seedlings from seeds treated with a magnetic field grew higher than in the control. The highest average total length was obtained in seedlings exposed to 125 and 250 MT for 24 hours. It is assumed that an external magnetic field increases the viability of seeds, affecting biochemical processes and stimulating the activity of proteins and enzymes.

In this work, the germination and emergence of triticale seedlings (×Triticosecale (VNS)) were determined, and an experiment was conducted on germination of triticale lasting 20 days in growing chambers installed at optimal germination temperatures of 29/18°C, 17/7°C and 17/7. 2°C day/night, respectively, with a 12-hour photoperiod [16]. We calculated % germination and % seed appearance, average germination and emergence time, germination and emergence index, and Timson index and modified Timson index. The results showed that triticale had the highest percentage of germination (80.5% as the main effect of the soil and 87.84% as the main species effect regardless of salinity) and % germination (91.25% in the control experiment and BGW, 87.19% in RO). The average germination and emergence time was the shortest for triticale grain. This clearly demonstrates triticale as a promising salt-resistant forage species that can be grown on dry and degraded pasture lands [17].

A scientific article describes [18] that whole grain is considered sprouted if it has a sprout that does not exceed the length of the grain.

Choosing the optimal amount of water used for germination is also an important criterion for controlled germination of wheat grain since excessive moisture leads to moldy grain, and its lack significantly increases the duration of this process.

Researchers have established that to start the germination of wheat grain, its humidity should be in the range of 35-45%, and the temperature should be 4-22°C [19]. Other authors [20] have established that the beginning of wheat grain germination requires a grain humidity of 30-32% and a temperature of 20-23°C.

In particular, Simbian *et al*. [21] showed that germination improves the properties of both wheat and triticale.

The authors have established the influence of climate change on the fatty acid composition of agricultural crops. Therefore, the study of the influence of precipitation and sunny days on the characteristics of the growth of agricultural crops is an urgent problem [22].

A previous study [23] found that triticale surpasses corn in protein, threonine, phosphorus, lysine, calcium, glycine, and arginine but is inferior in fat and fiber content, cysteine, histidine, valine, phenylalanine, leucine and is equal in isoleucine. The authors investigated the fact that triticale can be added to mixtures for growing pigs, completely replacing corn with its participation in the diet by 50%.

In work [24], the grains used in the feed for calves of the third group were first germinated, and then it was extruded. This technology leads to an increase in the content of digestibility of nutrients in the third experimental group. This technology contributed to the partial splitting of crude fiber into dextrins and simple sugars and proteins into amino acids, which was revealed in preliminary experiments.

Another factor is pre-germination. Thus, according to the results of scientific research, L.I. Butenko and L.V. Ligai found that germination of grain seeds increases the amount of essential amino acids, trace elements, vitamins E and group B, and also increases the edibility of feed and the digestibility of its nutrients [25]. The germination of grain leads to the activation of enzymes contained in it, which break down complex nutrients into pure compounds that are easily absorbed by the animal's body.

Numerous studies show that triticale can successfully replace corn, wheat and barley in feed mixtures for pigs without adversely affecting their productivity [26-30].

Due to the most variable chemical composition of all cereals and high fluctuations in the content of anti-nutritional components, triticale is not a popular component of compound feeds for poultry. It is most often used when feeding broiler chickens and laying hens [31-33].

Previous works [34] have shown that it is possible to include triticale up to 60% in pig mixtures without adversely affecting growth.

It was found in a study [35] that the inclusion of triticale in compound feed led to a lower accumulation of heavy metals in the muscle tissue of fattening pigs.

In different studies [36], the protein content in the dry matter of the analyzed triticale samples was in the range of 13.0-17.8%. In previous studies [37], it was emphasized that different varieties of triticale contain from 11 to 20% crude protein.

Feeding whole grains reduces the cost of preparing feed, facilitates the use of cheaper farm feed [37], and also ensures better development and functioning of the digestive canal.

We have conducted research on the optimization of the extrusion process in the production of compound feeds for dairy cows [38]. The optimal technological modes of extrusion of triticale grain of the leather variety are determined: the content of sprouted triticale grain is 15%, and the extrusion temperature is 140°C. Optimization of technological modes of extrusion of triticale grain of the Kozha variety in the range of 5% to 15% of sprouted triticale grain at an extrusion temperature of 110 to 140°C was carried out, and optimal extrusion modes were established in a given range.

3. THE AIM AND OBJECTIVES OF THE STUDY

The purpose of this study is to regulate the fat content in triticale on the basis of optimization of technological processing modes. The presented results and conclusions will allow regulating the fat content in triticale grain during germination.

To achieve this goal, the following tasks were set:

- Analysis of the regime factors affecting the fat content based on the optimization of technological processing modes.

-Analysis of Skin-triticale grain germination parameters affecting fat content;

-Optimization of the modes of germination of grain Leather-triticale.

4. MATERIALS AND METHODS

The selected object of the study was the triticale Kozha variety, grown in 2022 in the Almaty region.

The research was conducted in the laboratory of LLP Kazakh Research Institute of Processing and Food Industry and in the certified laboratory of the Scientific Research Institute of Food Safety of Almaty Technological University (Republic of Kazakhstan).

Generally accepted studies were used to determine the physicochemical and feed nutritional values:

To determine the optimal modes of germination of triticale grain, a multi-factor experiment was performed.

Statistical data processing and all necessary calculations were performed using the sequential regression analysis program PLAN, developed at the Odessa National Academy of Food Technologies [38].

The paper proposes a way of enriching the composition of mixed fodder by combining two promising technologies with known effects: the inclusion of germinated grain in the composition and extrusion. Crude and digestible protein, fiber, fat, and mineral elements Ca, K, Na, and P were studied. The inclusion of sprouted grain into mixed fodder and subsequent extrusion contribute to improvements in taste qualities, increased edibility, and assimilation of mixed fodder, as well as nutritive value [38].

This program allows you to calculate the regression coefficients for each indicator under study, check the significance of the regression coefficients, and, after removing all insignificant coefficients, determine the necessary statistical characteristics of the obtained regression equations, including checking their adequacy to experimental data. The program's algorithm allows you to obtain regression equations in both natural and encoded variables using various plans — PFE-2^k, B-k type Box, rotatable ones, *etc*.

Regression coefficients were calculated using a matrix in the natural dimension, and accordingly, the regression equations themselves were also obtained in the natural dimension. The general formula of the obtained regression equations for 4 factors is as follows:

$$y = b_0 + b_1\tau + b_2C + b_3P + b_4T + b_{12}\tau\cdot C + b_{13}\tau\cdot P + b_{14}\tau\cdot T + b_{23}C\cdot P + b_{24}C\cdot T + b_{34}P\cdot T. \quad (1)$$

The variable designations in these equations are assumed to be as follows:

y – the studied indicator of the quality of processed grain;

t_w – water temperature,°C.;

τ – germination time, h.

w– grain moisture,%.

t_g – grain temperature,°C.

In the studied grain samples, the following indicators were determined:

y_1- nature, kg/^{m3}.

y_2- weight of 1000 grains, g.

y_3- starch content,%.

y_4- ash content,%.

y_5- fat content,%.

y_6- protein content,%.

y_7- fiber content,%.

y_8- nitrogen-free extractives (NFE),%;

u_9-feed units of fu.

The adequacy of the equations to the experimental data was checked for a significance level of 0.05.

Grain germination was carried out on an Easy Green micro-farm with automatic air humidity control manufactured in the USA (Fig. **1**).

Triticale grains were washed with warm running water and sprouted until sprouts up to 10 mm (1 cm) long appeared from 15 to 72 hours. Inside the equipment, the grain was blown with cool air (16-18°C) and evenly sprayed with water. The sprouted grains were dried at a temperature of 42-45°C.

All studies were performed in triple repetitions. The reliability of experimental data was evaluated by mathematical statistics using Microsoft Excel for Windows 2010. The data obtained are given with a significant probability of 0.91.

Fig. (1). Sprouted grain in the easygre easy green micro-farm.

In order to obtain a reliable assessment of the influence of individual factors of grain processing on the studied quality indicators, methods of multi-factor planning of experiments were applied. Data processing and all necessary calculations were performed using the algorithm and program plan of sequential regression analysis [38].

5. RESULTS

In this series of experiments, we investigated the dependence of quality indicators of Kozha triticale grain on the processing modes — water temperature t_w, grain germination time t, humidity w, and grain temperature t_g. To decrease the number of experiments and get reliable results, methods of planning multi-factor experiments were applied.

To decrease the influence of uncontrolled parameters on the experimental results, the experiments were carried out using tables of random numbers. The experimental modes and the data obtained for determining the quality indicators of processed triticale grain are shown in Table 1.

Table 1. Experimental conditions and quality indicators of processed triticale grain.

No.	Factors				Indicators								
					Physical		Chemical		Nutritional Value				
	t_{in}, °C	τ, h	w, %	t_h, °C	In-kind, kg/m^3	Weight 1000 grains, g	Starch, %	Ash, %	Fat, %	Protein, %	Fiber, %	NFE,	fu.
					y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9
1	15	24	19	26	710	39,98	20.58	1,75	1,022	15.96	2,5	678,08	1,26
2	30	24	19	26	715	46,8	18,70	1.71	1,101	16,28	2.85	670,99	1,26
3	15	72	19	26	720	46,54	16.83	1,67	1.18	16,6	3,2	663,9	1,26
4	30	72	19	26	710	47.09	16,28	0,76	2.34	18,78	2.56	646,0	1,26
5	15	24	13	26	726	38.89	19.01	1,58	1,50	15,75	2,2	680,1	1.27
6	30	24	13	26	667	46,90	15.67	1.18	2.83	17,67	2,8	645,6	1,26
7	15	72	13	26	680	47.37	20,22	1,12	1,23	16.89	2.76	670,4	1,26
8	30	72	13	26	708	42,10	21,61	1,78	1,24	15,98	2.81	672,3	1,26
9	15	24	19	10	712	43,58	18,38	1.45	1.78	16.09	2,97	667,5	1,26
10	30	24	19	10	698	45,20	20,51	0.87	2.25	15,0	2,34	685.8	1,27
11	15	72	19	10	702	41,39	15,16	1,89	1,02	17.89	2.36	658,8	1,27
12	30	72	19	10	684	41.26	18,75	1,78	1,12	16,6	2.18	673,6	1,27
13	15	24	13	10	716	43,15	17,30	1,89	1,87	15.47	2.43	673,8	1,26
14	30	24	13	10	690	42,88	16,97	1,45	1,52	18,12	3,81	641,4	1.25
15	15	72	13	10	706	38,23	16,22	1,39	1.81	17,09	2.05	667,0	1,27
16	30	72	13	10	710	40,28	20,45	1,65	2.43	16,60	2.71	656,5	1,26

Based on the results of the conducted studies, regression equations were obtained that adequately (according to the Fischer criterion) describe the dependences of the above-mentioned indicators of the quality of processed Kozha triticale grain on the factors t_w, τ, w and t_g.

To determine the errors (reproducibility) of the studies, 3 parallel experiments were conducted in the experiment center.

Regression coefficients are calculated using matrices in the natural dimension, and accordingly, the equations themselves are also obtained in the natural dimension.

The general form of regression equations for 2 factors is as follows:

$$y_i = b_0 + b_1 t_b + b_2\tau + b_3 w + b_4 t_h + b_{12} t_b\tau + b_{13} t_b w + b_{14} t_b t_h + b_{23}\tau w + b_{24}\tau t_h + b_{34} w t_h, \quad (2)$$

where y_i – i-th quality indicators of processed triticale grain;

t_w – water temperature,°C.

τ – duration of germination, h;

w– grain moisture,%.

t_g – grain temperature,°C.

The summary data on the obtained regression equation in natural variables are given in the Table 2. The same table shows the root-mean-square errors of the experiments S_e and the inadequacies of $S_{bp.}$, as well as the calculated F_p and critical F_{kr} values of the Fisher criterion, indicating that both equations adequately describe the experimental data with a confidence probability *of* p=0.05.

The developed regression equations are mathematical models that allow predicting the quality indicators of the processed triticale grain depending on the values of technological processing modes, *i.e*., factors t_w, τ, w and t_g (Table 3).

Table 2. Regression data of equations in natural variables and statistical characteristics of the dependence of quality indicators of triticale of the Kozha variety on the conditions of its processing.

Regression Equations in Natural variables	Mean Square Deviation		Fisher's Criterion	
	Experimental	Inadequacy	Calculated	Critical
Kozha				
y1=758.7-2.383t_b-0.8021t–0.03403$t_b\tau$	5.00	14.87	8.84	19,41
$_{y2}$=36.85+0.3134t_b–0.00421t_bb-0.004470.00447t_h	1.64	2.30	1.98	19.41
y_3=0.3741τ+1.144w-0.02345 τw	0.91	1.67	3.37	19.42
y_4=1.769-0.*00076* $t_{in}w$	0.085	0.344	16.35	19.42
y_5=2.819-0.00332τ–0.04265w- –0.06931t_h+0.00274$t_{in}t_h$	0.071	0.24	11.78	19.40
y_6=20.70-0.08122τ-*0.2990* w+0.00607τw	0.33	0.93	7.99	19.41
y_7=0.1326,1326t_{in}+0.1501w-0.00757$t_{in}w$	0.18	0.38	4.51	19.42
y_8=665.7	4.90	12.93	6.97	19.43
y_9=1.262	0.011	0.0058	3.63	3.68

Table 3. Regression equations in natural variables and statistical characteristics of the dependences of the quality indicators of triticale grain of the "Kozha" variety on the conditions of its processing.

No.	Regression Equations in Natural Variables	Mean Square Deviation		Fisher's Criterion	
		Experimental	Inadequacy	Calculated	Critical
1	y1=758.7-2.383t_b-0.8021t–0.03403$t_b\tau$	5.00	14.87	8.84	19,41
2	$_{y2}$=36.85+0.3134t_b–0.00421t_bb-0.004470.00447t_h	1.64	2.30	1.98	19.41
3	y_3=0.3741τ+1.144w-0.02345 τw	0.91	1.67	3.37	19.42
4	y_4=1.769-0.*00076* $t_{in}w$	0.085	0.344	16.35	19.42
5	y_5=2.819-0.00332τ–0.04265w- –0.06931t_h+0.00274$t_{in}t_h$	0.071	0.24	11.78	19.40
6	y_6=20.70-0.08122τ-*0.2990* w+0.00607τw	0.33	0.93	7.99	19.41
7	y_7=0.1326,1326t_{in}+0.1501w-0.00757$t_{in}w$	0.18	0.38	4.51	19.42
8	y_8=665.7	4.90	12.93	6.97	19.43
9	y_9=1.262	0.011	0.0058	3.63	3.68

6. DISCUSSION

To optimize the technological modes of germination of triticale grain of the Kozha variety, the fat content was chosen as the target function:

$$y_5 = 2{,}8186 – 0{,}00332\tau – 0{,}04265w – 0{,}06931t_з + 0{,}00274t_вt_з \rightarrow \max \quad \textbf{(3)}$$

Analysis of equation y_5 shows that the objective function (fat content) is significantly influenced linearly by all the studied factors t_w, τ, w, t_g. An example of a clear linear influence on the fat content of some factors is shown in the figures below (the values of factors not considered in parentheses are taken at optimal levels) (Fig. **2**).

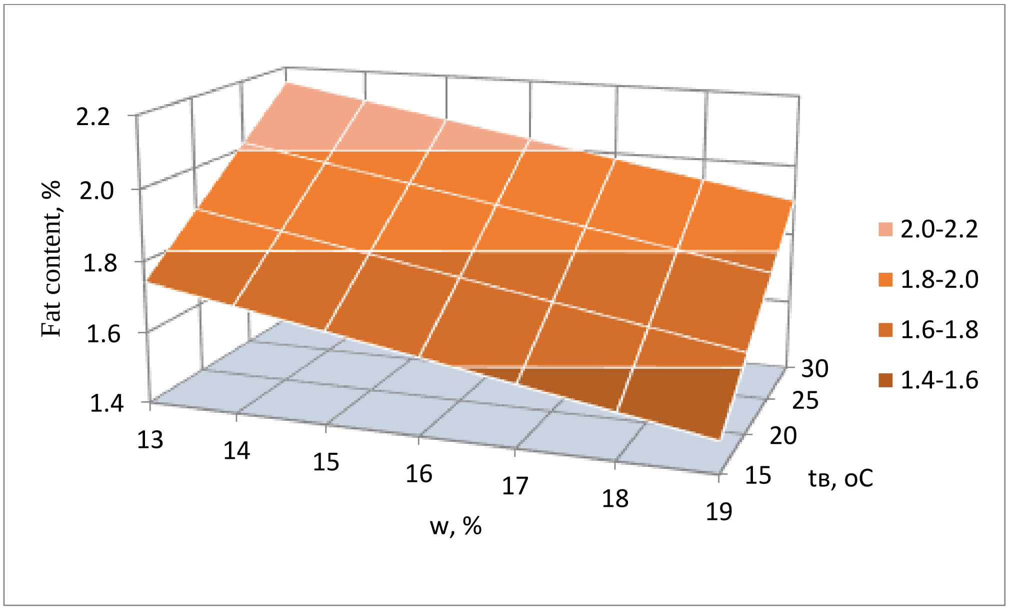

Fig. (2). Influence of factors τ and t_h on the fat content after processing of Kozha triticale grain (at w=72% and t_w=10°C).

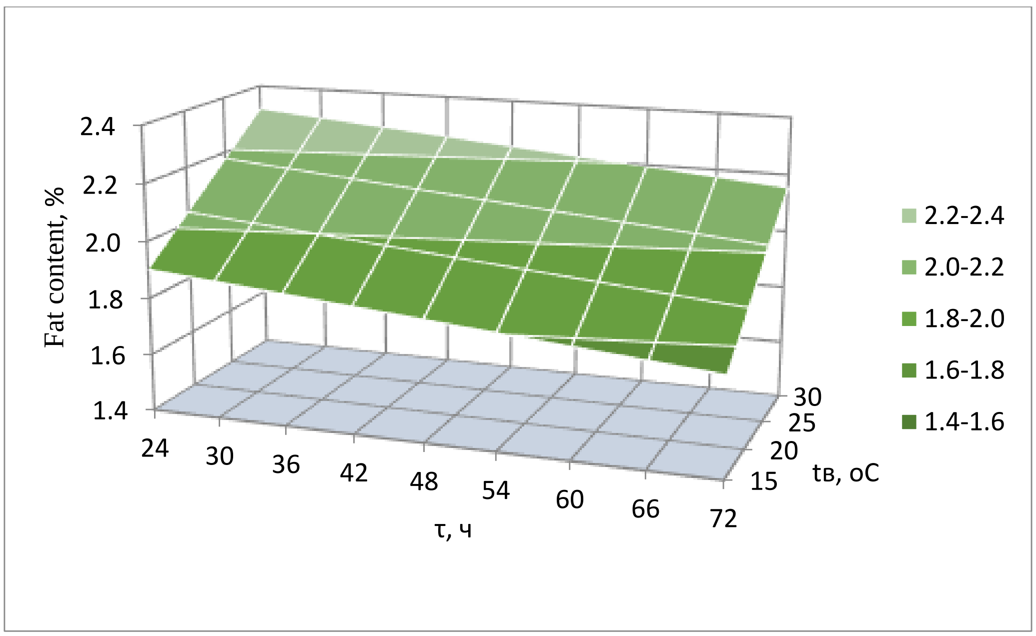

Fig. (3). Influence of factors t_w and τ on fat content after processing of Kozha triticale grain (at w=13% and t_w =10°C).

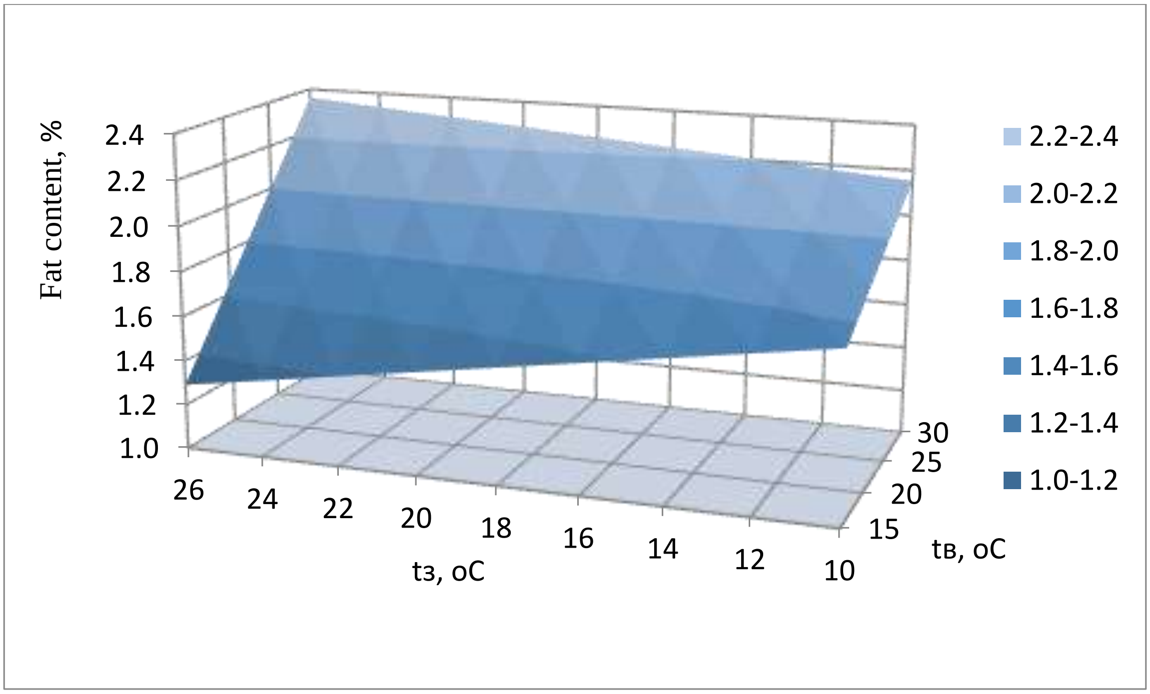

Fig. (4). Influence of factors t_g and t_w on fat content after processing of Kozha triticale grain (at t=72 h, *w*=13%).

In Fig. (**3**), in addition, there is a statistically significant effect on the fat content of the paired interaction of factors t_b and t_h (coefficient b_{14}), which is clearly seen in the figure below:

It can be seen from Fig. (**4**) that the influence of factor *tb on the*$_в$ fat content is unambiguous — with t_{an} increase in tb, the fat content in processed grains of the Kozha variety increases. The effect *of* t_h on the fat content due to pair interaction is ambiguous — it depends on the value *of* t_b — at a low water temperature $t_{b,\ an}$ increase in the grain temperature t_h leads to an increase in the fat content in the processed grain. At a grain temperature of about 30°C, on the contrary, an increase in the grain temperature t_h leads to a certain decrease in fat content.

Optimization was carried out in compliance with the following data limitations of functions in terms of the quality of processed triticale grain:

Restrictions on certain quality indicators of processed grain of the Kozha variety

Referee 3/problem 2

$680 \le y_1=758.7\text{-}2.383t_b\text{–}0.8021\ \tau\text{–}0.03403t_b\tau \le 720$

$38 \le y_2=36.85+0.3134t_b\text{-}0.00421t_b\tau+0.00447\ \tau t_h \le 50$

$15 \le y_3=0.3741\ \tau+1.144w\text{–}0.02345\ \tau w \le 25$

$1 \le y_4=1.769\text{-}0.00076t_{in}w \le 2$

$1 \le y_5=2.81857\text{–}0.00332\ \tau\text{–}0.04265w\text{–}0.06931t_h+0.00274t_{in}t_h \le 3$

$14 \le y_6=20.70\text{–}0.08122\ \tau\text{-}0.2990w+0.00607\ \tau w \le 20$

$1 \le y_7=0.1326t_b+0.1501w\text{-}0.00757t_bw \le 3$

$3{,}660 \le y_8=665.7 \le 700$

$1 \le y_9=1{,}262 \le 2$

The crude protein content was maximal in the range of changes *t* in the regime factors t_w, τ, *w*, and t_g, given in the experimental planning matrix (Table **4**).

Optimization of processing modes of Kozha triticale grain was carried out by the method of nonlinear programming. The following optimal technological modes of grain overwork are obtained:

– water temperature t_w = 30°C;

– germination time τ=24 hours;

– grain moisture *w*=13%;

– grain temperature t_g=26°C.

Under these optimal processing grain modes, the target function was 2.83%. The values of other indicators of quality under optimal grain processing modes are shown in Table **5A**, **B**.

Thus, optimization of technological modes of processing grain of the Kozha variety will make it possible to obtain modes of germination of triticale grain with the maximum content of crude fat.

Table 4. Restrictions on certain indicators of the quality of processed grain of the kozha variety.

No.	-	Indicators	Regression Equations in Natural Variables	Indicators	Values
1	680	≤	y_1=758.7-2.383t_b–0.8021 τ–0.03403t_bτ	≤	720
2	38	≤	y_2=36.85+0.3134t_b-0.00421t_bτ+0.00447 τt_h	≤	50
3	15	≤	y_3=0.3741 τ+1.144w–0.02345 τw	≤	25
4	1	≤	y_4=1.769-0.00076$t_{in}w$	≤	2
5	1	≤	y_5=2.81857–0.00332 τ–0.04265w–0.06931t_h+0.00274$t_{in}t_h$	≤	3
6	14	≤	y_6=20.70–0.08122 τ-0.2990w+0.00607 τw	≤	20
7	1	≤	y_7=0.1326t_b+0.1501w-0.00757$t_b w$	≤	3
8	3,66	≤	y_8=665.7	≤	700
9	1	≤	y_9=1,262	≤	2

Table 5A. Values of quality indicators of Kozha triticale grain processed under optimal conditions.

Quality Indicators	Min.	-	Opt.	-	Max.
1. Nature y_1, kg / m^3	680	≤	643.46	≤	720
2. Weight of 1000 grains y_{y2}, g	38	≤	46.01	≤	50
3. Starch content y_3, %	15	≤	16,53	≤	25
4. Ash content y_4, %	1	≤	1,47	≤	2
5. Fat content *of* y_5, %	1	≤	2,520	≤	3
6. Protein Content y_6, %	14	≤	18,65	≤	20
7. Fiber content $y_{in\ 7}$, %	1	≤	2,98	≤	3
8. Nitrogen-free extractives NFE Y_8, %	660	≤	665,70	≤	700
9. Feed units ke, y_9	1	≤	1.26	≤	2

Table 5B. The values of other indicators of quality under optimal grain processing modes.

No.	Quality Indicators	Unit of Measurement	Min.	Indicators	Opt.	Indicators	Max.
1	Nature y1,	kg / m3	680	≤	643,46	≤	720
2	Weight of 1000 grains y_{y2},	g	38	≤	46,01	≤	50
3	Starch content y_3,	%	15	≤	16,53	≤	25
4	Ash content y_4,	%	1	≤	1,47	≤	2
5	Fat content of y_5,	%	1	≤	2,52	≤	3
6	Protein Content y_6,	%	14	≤	18,65	≤	20
7	Fiber content y_{in7},	%	1	≤	2,98	≤	3
8	Nitrogen-free extractives NFE Y_8,	%	660	≤	665,70	≤	700
9	Feed units ke, y_9	-	1	≤	1,26	≤	2

CONCLUSION

Optimal germination modes of Kozha triticale grain were determined with water temperature t_w = 30°C; germination time t=24 h; grain humidity w=13%; grain temperature t_g=26°C.

Optimization of the germination modes of Kozha triticale grain was carried out in the range from 24 hours to 72 hours at a water temperature of 15 to 30°C, and optimal germination modes were established in a given range. In addition, optimal parameters of germination of Leather-triticale grain were established with germination range from 24 hours to 72 hours at water temperature from 15 to 30°C. The optimal germination modes were established in a given range: water temperature tw = 30°C; germination time t= 24 h; grain moisture w=13%; and grain temperature tg=26°C.

Despite the data obtained, the issues of the influence of climatic situations (precipitation and sunny days) on the germination of triticale grain and its physico-chemical parameters remain unresolved.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

All the data and supporting information are provided within the article.

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CONFLICT OF INTEREST

The authors declared no conflict of interest, financial or otherwise.

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