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DETERMINING OPTIMAL PROCESS PARAMETERS FOR SPROUTING BUCKWHEAT AS A BASE FOR A FOOD SEASONING OF IMPROVED QUALITY

Ayana Serikbaeva
Doctoral student*
Bagimkul Tnymbaeva
PhD, Senior Lecturer*
Maryna Mardar
Corresponding author
Doctor of Technical Sciences, Professor
Department of Marketing, Business and Trade**
E-mail: marinamardar2003@gmail.com
Nataliia Tkachenko
Doctor of Technical Sciences, Professor, Head of Department
Department Milk, Oil and Fat Products
and Cosmetics Technology**
Saniya Ibraimova
Doctoral Student*
Raushangul Uazhanova
Doctor of Technical Sciences, Professor*
*Department of Food Safety and Quality
Almaty Technological University
Tole bi str., 100, Almaty, Republic of Kazakhstan, 050012
**Odessa National Academy of Food Technologies
Kanatna str., 112, Odessa, Ukraine, 65039

In order to determine the influence of temperature and time of germination of the Bogatyr variety buckwheat on a change in the content of vitamins E, C, and B group, the germination parameters were optimized when developing a new type of seasoning. To optimize the germination parameters, the response surface methodology was used. The maximum total content of B, E, and C group vitamins in the sprouted buckwheat (4.591 mg/100 g) was observed at a temperature of 21.5 °C and the duration of germination of 3 days.

The Bogatyr variety buckwheat was sprouted for 4 days. Changes in the nutritional and biological value of the sprouted grains were registered after 24 hours. Based on the comparative chemical analysis, it was established that the content of protein, fiber, vitamins, amino acids increases during the germination of buckwheat in comparison with the control sample. The protein content on day 4 increases by 1.38 times compared to control. At the same time, the mass fraction of carbohydrates on day 4 is reduced by 1.57 times; the mass fraction of fat – by 2 times.

It was established that the prototype seasoning that contains 30 % of sprouted buckwheat is characterized by a higher content of protein, vitamins, micro-and macronutrients compared to the control sample (without the addition of sprouted buckwheat). Adding the sprouted buckwheat grain to the seasoning has made it possible to increase by 25 % the antioxidant activity of the finished product compared to the control sample, which is 259.09 and 383.72 mg/100 g, respectively. In terms of safety indicators, the new product fully complies with the requirements for sanitary and hygienic safety.

The results reported here give reasons to recommend the production of a new type of seasonings of enhanced nutritional value based on the sprouted Bogatyr variety buckwheat, which could expand and improve the quality of nutrition

Keywords: quality assessment, optimization, germination, buckwheat grain, seasoning of improved quality, antioxidant activity

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1. Introduction

Proper nutrition is the most important factor that ensures the quality of health and life expectancy of a person. Modern nutrition science testifies to the need to harmonize nutrition, to fully provide the human body with the necessary nutrients and energy [1]. Given this, adding foods of increased nutritional value to the diet is the most effective and internationally recognized way to solve the problem of good nutrition [2].

One of the promising areas in the field of healthy nutrition is the use of sprouted grain in the composition of fortified products. Germination increases the nutritional and biological value of cereals while reducing the level of antinutrient compounds [3]. Sprouted grains are a complex food matrix, where nutrients are more accessible, rich in antioxidant and biologically active compounds, which are healthy foods [3]. The use of sprouted grains for the enrichment of seasonings is one of the promising methods of reducing the deficiency of biologically active substances (BAS) in the human diet.

Seasonings play a key role in human nutrition as a rich source of micro-and macronutrients, phenolic compounds with antioxidant activity; they also possess antimicrobial properties [4, 5].

The use of sprouted grain in the composition of seasonings would create a product with improved organoleptic properties, increased nutritional and biological value. However, a change in the chemical composition induced by germination depends not only on the variety of grain but also on the conditions of its germination. For this reason, germination process optimization is crucial for improving the nutritional and biologically active properties of the selected grain variety [6]. Thus, it is a relevant task to study the influence of temperature and germination time on the content of BAS, namely vitamins, in the Bogatyr variety buckwheat.

2. Literature review and problem statement

One of the effective ways to increase the nutritional and biological value of food seasonings is to devise technologies for enriching them with various natural components.

Scientists from different countries conduct numerous studies in this area. Formulations of seasonings enriched with herbs, spices, and seafood (*Ethmalosa Fimbriata* or *Capriusgariepinus*, garlic or ginger, onions, moringa, shrimp, salt, and basil) have been developed. During the research, it was found that the addition of these components led to an increase in the content of protein, fat, and calcium in the resulting product [7].

It has been proposed to use natural powder from fish to increase the nutritional and biological value of the finished product [8].

A multicomponent food seasoning was patented, based on dry vegetables and fruits, wheat bran, crushed sprouted corn grains, crushed amaranth seeds, dried greens, and herbs. During the research, it was found that the addition of these components leads to an increase in the antioxidant activity of the product [9].

A seasoning based on four sprouted kinds of cereal (corn, chickpeas, soy, lentils) was patented. The seasoning is rich in fiber, enzymes, macro-and microelements, vitamins, amino acids. A distinctive feature of the seasoning is that live lactic acid bacteria were introduced into its composition, ensuring the normal functioning of the gastrointestinal tract [10].

When preparing the enriched seasoning, we used the Bogatyr variety buckwheat. That relates to the fact that a given crop is a symbol of a healthy diet since it contains valuable chemical compounds such as protein, fat, dietary fiber, vitamins, minerals, flavonoids, phytosterols, etc. Proteins contain albumins, globulins, prolamins, and glutelin, while not containing gluten [11].

Scientists are now focusing their efforts on identifying new functional ingredients that could expand opportunities to develop innovative foods with health benefits. Germination is seen as a promising green food engineering strategy to increase the nutritional value of grains, with potential applications in the markets of functional food, pharmaceuticals, and cosmetology. In the food industry, products containing or made on the basis of sprouted seeds are increasingly manufactured. Basically, these are bakery, pasta, and confectionery products. However, at the same time, there is practically no work on the manufacture of flavoring and aromatic additives based on sprouted grain [12].

The target principles of germination are aimed at increasing the nutrients in the grain. This is a consequence of the activation of enzymes and their participation in the synthesis of a wide range of chemical compounds that cause an increase in nutritional qualities. In the process of germination, the amount of such essential amino acids as isoleucine, leucine, lysine, threonine increases. The indicator of biological value in sprouted grain increases by an average of 6 %, which makes it possible to recommend this type of grain raw material as an enriching additive in the production of healthy food [13].

When grain is germinated, the protein substances contained in it are hydrolyzed by proteolytic enzymes to amino acids and peptides, which are used to build new germ tissues and the necessary metabolism. Starch breaks down to soluble carbohydrates, dextrin, and maltose [14]. Lipids are necessary for human nutrition as energy and structural material. In addition, they are involved in the metabolism of other nutrients, for example, contribute to the absorption of vitamins A and D. During germination, the lipid decay products are its components such as glycerin and free fatty acids (linoleic, oleic, and palmitic), which the developing sprout uses [15].

Sprouted grain is a useful, easily digestible product containing vitamins A, C, B_1, B_2, B_6, PP, as well as dietary fiber. During germination, the content of some B group vitamins in the grain increases (for example, vitamins B, B_2, and PP, on average, by 1.5–2 times), as well as E vitamin; vitamin C appears in sprouts, which is absent in ordinary grain. In sprouted grain, phytates are partially destroyed, blocking the absorption of calcium, magnesium, zinc, and other mineral elements. In the process of buckwheat germination, it was found that the amount of polyphenols increases from 50.26 to 298.03 mg/100 g, the amount of rutin increases from 13.66 to 283.43 mg/100 g, in, quercetin – from 4.77 to 223.76 mg/100 g [16]. In addition, sprouted buckwheat is also rich in flavones, flavonoids, phytosterols, D- chiro inositol, and myo-inositol [17].

The maximum value of the grain is at the very beginning of the germination process when the sprout reaches a length of 4 to 5 mm. This occurs when the visible part of the sprout has a length of 2–3 mm, while another 2 mm is hidden inside the grain. If the length of the sprout is greater than the length of the grain itself, then it would no longer have any nutritional value for the synthesis of new cells [18]. As a result, the choice of the optimal germination time is important since the concentration of nutrients weakens along with the further growth of the stem.

Numerous studies are carried out, both on the development of seasonings of increased nutritional value and on the germination of grain crops. However, studies on the use of sprouted buckwheat in the composition of the seasoning are not conducted. In this regard, it is advisable to study the issue of including sprouted buckwheat, which has antioxidant properties and is characterized by a high content of BAS, in the composition of the seasoning. It is important to define the optimal germination process in order to study the influence of temperature and germination time on the nutritious, biologically active, and other qualitative indicators of the Bogatyr variety buckwheat.

3. The aim and objectives of the study

The aim of this research is to optimize the process of germinating the Bogatyr variety buckwheat when devising a new type of seasoning of improved quality.

To accomplish the aim, the following tasks havebeen set:

– to build regression equations characterizing the dependence of the content of vitamins E, C, and group B in the Bogatyr variety buckwheat on the temperature and time of germination, to determine the germination parameters at which buckwheat contains the maximum amount of the examined vitamins;

– to determine the change in the nutritional and biological value of the Bogatyr variety buckwheat during germination;

– to define the quality indicators for a new type of seasoning based on sprouted buckwheat.

4. The study materials and methods

4. 1. Examined materials

The object of our research was the Bogatyr variety buckwheat [19].

Grain selection was carried out according to GOST ISO 24333-2017 Grain and products of its processing [20].

In this work, we applied a modified wheat grain germination technique based on the procedure by Ann Wigmore [21]. For sprouting, we placed buckwheat grains (30 grams) in a container (200 ml), to subsequently wash the contents with running water. Next, the seeds were left for soaking, the grains were poured with clean water in proportion: three parts of water were poured into one part of buckwheat. We then left the seeds to swell at a temperature of 22 °C for no longer than 6 hours and closed the container with gauze. After that, we drained all the water and set the jar upside down at an angle of 45° so that the water could drain freely. The contents were disinfected 2 times a day with a weak solution of potassium permanganate (0.05 %), leaving for 5 minutes in the solution, and washed with water. We set the maximum period of germination by the maximum growth of vitamins: C, E, and B group. We determined the mass fraction of vitamins every 24 hours based on 10 experiments until the vitamin content decreased [21].

To obtain seasoning, we dried the sprouted grains at a temperature of 40 to 45 °C for 8 to 9 hours. After drying, we cooled the dried grains at room temperature. Dried sprouted grains, dried vegetables (pumpkin, carrots, garlic), and herbs (oregano, basil, celery, dill) were crushed; we added crushed spices (turmeric, ginger, curry, paprika, coriander). Further, in accordance with the formulation given in [22], we mixed the prepared components to obtain a food seasoning.

4. 2. Methods to study the quality indicators of sprouted buckwheat

To optimize the sprouting process, the response surface methodology was used [23]. The simulation and treatment of experimental data employed the *Statistica 10* software package (StatSoft, Inc.).

The nutritional value of sprouted buckwheat was assessed according to standard research methods every 24 hours over a month:

– the mass fraction of fat was determined by the Soxhlet method;

– the mass fraction of carbohydrates – by iodometric titration;

– the mass fraction of protein – according to the Kjeldahl method, using an automated combustion furnace and a distillation machine;

– the mass fraction of water-soluble vitamins was determined by the method of capillary zone electrophoresis “Kapel 105 M” [24];

– the mass fraction of vitamin E was determined by high-performance liquid chromatography (HPLC) at the Merck-Hitachi installation (Merck, Darmstadt, Germany) [25];

– the mass fraction of amino acids was determined at the system of capillary electrophoresis “Kapel 105 M” [26];

– the antioxidant activity was determined at the device “TsvetYauza-01-AA” by the amperometric method [27].

The content of heavy metals and minerals was determined at the spectrometer with electrical atomization “KVANT-Z.ETA-T” by atomic absorption spectroscopy (AAS) [28].

We determined the content of pesticides in finished products by the analytical stationary gas chromatograph “Kristallyuks-4000M” (Russia) with an electron capture detector and the software NetChrom (Russia) [29].

When determining microbiological parameters, we used classical methods of microbiological analysis: the methods of sampling and preparation of samples for microbiological analyses [30], the methods of cultivation of microorganisms [31, 32].

5. Results of optimizing a buckwheat sprouting process and determining the quality indicators for a new product

5. 1. Results of studying the influence of temperature and time of buckwheat sprouting on a change in the content of vitamins

At the first stage of research, work was carried out to determine the influence of temperature and time of buckwheat sprouting on a change in the content of vitamins from groups B, E, C, as well as optimize the sprouting parameters for the selected buckwheat variety.

The methodology of response surface [23] is a set of mathematical and statistical techniques aimed at modeling processes and finding combinations of the parameters under study. It is used to optimize the response function $\hat{y}$ (x, b), which is generally described by the following polynomial:

$$\hat{y}(x,b)=b_0+\sum_{l=1}^{n}b_l x_l+\sum_{k=1}^{n}b_k x_k^{\ 2}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}b_{ij}x_i x_j, \qquad (1)$$

where $x \epsilon R^n$ is the vector of variables, b is the vector of parameters.

In the process of sprouting the Bogatyr variety buckwheat, a response function was chosen in the form of a polynomial of the second power:

$$C_{\text{vit.E}}=b_0+b_1\cdot DS+b_{11}\cdot DS^2+ +b_2\cdot ST+b_{22}\cdot ST^2+b_{12}\cdot DS\cdot ST, \qquad (2)$$

$$C_{\text{vit.C}}=b_0+b_1\cdot DS+b_{11}\cdot DS^2+ +b_2\cdot ST+b_{22}\cdot ST^2+b_{12}\cdot DS\cdot ST, \qquad (3)$$

$$C_{\text{vit.gr.B}}=b_0+b_1\cdot DS+b_{11}\cdot DS^2+ +b_2\cdot ST+b_{22}\cdot ST^2+b_{12}\cdot DS\cdot ST, \qquad (4)$$

$$C_{\text{amountvit}} = b_0 + b_1 \cdot DS + b_{11} \cdot DS^2 + \\ + b_2 \cdot ST + b_{22} \cdot ST^2 + b_{12} \cdot DS \cdot ST, \quad (5)$$

where $C_{\text{vit.E}}$, $C_{\text{vit.C}}$, $C_{\text{vit.gr.B}}$, $C_{\text{amount vit}}$ is the content of vitamin E, vitamin C, B group vitamins, and the amount of vitamins studied, respectively, mg/100 g; b_0 is the constant; DS is the duration of buckwheat sprouting, day; ST is the buckwheat sprouting temperature, °C; b_1, b_{11}, b_2, b_{22}, b_{12} are the coefficients for each element of the polynomial.

The matrix of experiment planning, as well as response functions, are given in Table 1.

To verify the significance of the regression coefficients (2) to (5), Pareto diagrams were constructed, shown in Fig. 1 (L – linear effect, K – quadratic effect). The Pareto diagrams show standardized coefficients that are sorted by absolute values.

The analysis of data in Fig. 2, *b* reveals that in terms of the content of vitamin C in the sprouted Bogatyr variety buckwheat, the effect of the interaction among parameters is insignificant. This is because the column for estimating this effect does not cross the vertical line, which is a 95 % confidence probability. Therefore, the effect of the interaction among parameters was eliminated from regression (3). For the E vitamin, the B group vitamins, and the sum of vitamins, all parameters are significant (Fig. 2, *a, c, d*, respectively). The resulting equations for determining the content of the studied vitamins and their sum including the calculated coefficients take the following form:

$$C_{\text{vit.E}} = -7.792 + 1.912 \cdot DS - 0.304 \cdot DS^2 + \\ + 0.582 \cdot ST - 0.014 \cdot ST^2 + 0.006 \cdot DS \cdot ST, \quad (6)$$

$$C_{\text{vit.C}} = -7.386 + 1.374 \cdot DS - 0.203 \cdot DS^2 + \\ + 0.673 \cdot ST - 0.017 \cdot ST^2, \quad (7)$$

$$C_{\text{vit.gr.B}} = -3.402 + 1.255 \cdot DS - 0.320 \cdot DS^2 + \\ + 0.238 \cdot ST - 0.006 \cdot ST^2 + 0.018 \cdot DS \cdot ST, \quad (8)$$

$$C_{\text{amount vit}} = -18.527 + 4.518 \cdot DS - 0.827 \cdot DS^2 + \\ + 1.490 \cdot ST - 0.036 \cdot ST^2 + 0.025 \cdot DS \cdot ST. \quad (9)$$

Adequacy of the devised models (6) to (9) was checked by the analysis of variance.

The determination coefficients for model (6) accept the following values – R^2=0.98693 and for model (7) – R^2=0.99965 and R^2_{adj}=0.99945, for model (8) – R^2=0.98571 and R^2_{adj}=0.97381, for model (9) – R^2=0.99352 and R^2_{adj}=0.98813. No loss of consistency (for all models, the significance level of this indicator p>0.05) indicate that the models adequately describe our experiment.

The combined influence of the duration and temperature of the Bogatyr variety buckwheat sprouting, described by polynomials (6) to (8), on a change in the content of vitamins of groups B, E, and C is visualized in Fig. 2–4.

Our treatment of polynomials (6), (7) has made it possible to establish that the maximum content of vitamins E and C (1.673 and 1.593 mg/100 g, respectively) is observed in buckwheat after 3.3 days at a temperature of 21.8 °C, and after 3.4 days at 20.4 °C (Fig. 2, 3). After 4 days of sprouting at a temperature of 18 °C, the content of vitamins E and C is 1.364 and 1.468 mg/100 g, respectively; at a temperature of 22 °C – 1.548 and 1.440 mg/100 g, respectively (Fig. 2, 3).

Our treatment of polynomial (8) using the Statistica 10 software package (StatSoft, Inc.) (USA) has made it possible to establish the optimal parameters for sprouting the Bogatyr variety buckwheat – a temperature of 22.0 °C, the sprouting duration of 2.6 days, at which the maximum content of B group vitamins (1.059 mg/100 g) in buckwheat is observed.

The values derived do not make it possible to determine the optimal sprouting parameters. Therefore, we optimized the temperature and duration of sprouting the Bogatyr variety buckwheat according to the total content of vitamins E, C, and group B in it.

The combined influence of the duration and temperature of sprouting the Bogatyr variety buckwheat, described by polynomial (9), on a change in the content of the total amount of vitamins E, C, and group B is visualized in Fig. 5.

Table 1

Experiment planning matrix and response functions

No. of experiment	Duration of buckwheat sprouting (*DS*)		Buckwheat sprouting temperature (*ST*)		Vitamin content in sprouted buckwheat, mg/100 g			
	encoded level	day	encoded level	°C	E	C	B group	Vitamins, total
1	–1	1.44	–1	18.6	0.4500	0.9600	0.5000	1.9100
2	–√2	1.00	0	20.0	0.1800	0.6400	0.2800	1.1000
3	–1	1.44	+1	21.4	0.5500	0.9900	0.6100	2.1500
4	0	2.50	+√2	22.0	1.5700	1.5800	1.0300	4.1800
5	+1	3.56	+1	21.4	1.7600	1.7700	0.7000	4.2300
6	+√2	4.00	0	20.0	1.5100	1.7000	0.2814	3.4914
7	+1	3.56	–1	18.6	1.6500	1.7400	0.5800	3.9700
8	0	2.50	–√2	18.0	1.3700	1.5400	0.9300	3.8400
9	0	2.50	0	20.0	1.4900	1.6300	0.9720	4.0920
10	0	2.50	0	20.0	1.4900	1.6200	0.9800	4.0900
11	0	2.50	0	20.0	1.5000	1.6300	0.9720	4.1020
12	0	2.50	0	20.0	1.5000	1.6200	0.9800	4.1000

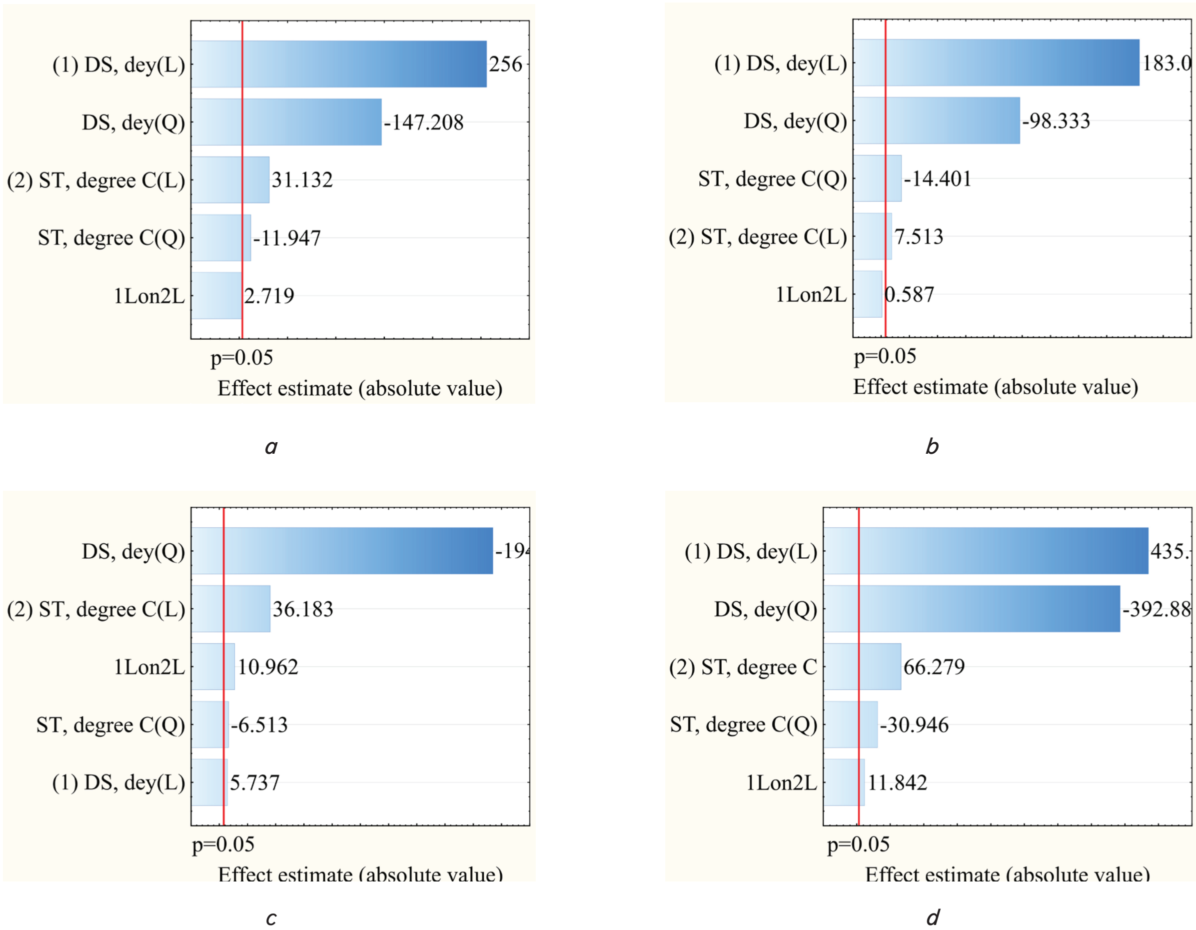


Fig. 1. Pareto diagram to check the significance of coefficients: *a* – regression (2); *b* – regression (3); *c* – regression (4); *d* – regression (5)

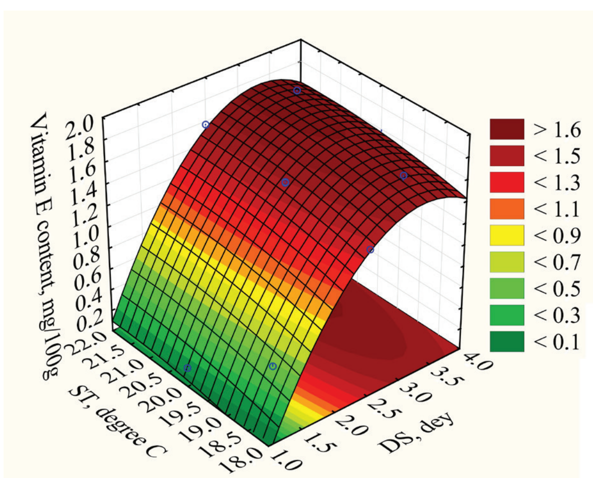


Fig. 2. Influence of the duration (day) and temperature (°C) of the Bogatyr variety buckwheat sprouting on a change in its vitamin E content (mg/100 g)

Our treatment of polynomial (9) using the software package Statistica 10 (StatSoft, Inc.) has made it possible to establish the optimal parameters for sprouting the Bogatyr variety buckwheat – a temperature of 21.5 °C, a sprouting duration of 3.0 days. With optimal sprouting parameters, the total content of vitamins E, C, and group B in buckwheat is maximum – 4.591 mg/100 g (Fig. 5, *a*, *b*).

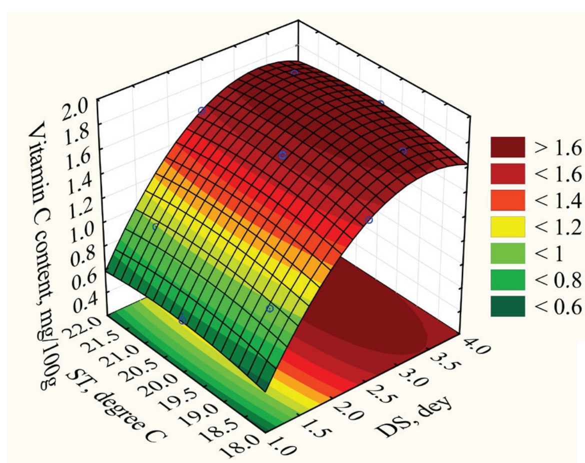


Fig. 3. Influence of the duration (day) and temperature (°C) of the Bogatyr variety buckwheat sprouting on a change in its vitamin C content (mg/100 g)

Consequently, the optimal parameters for sprouting the Bogatyr variety buckwheat are as follows: temperature, 21.5 °C; sprouting duration, 3.0 days.

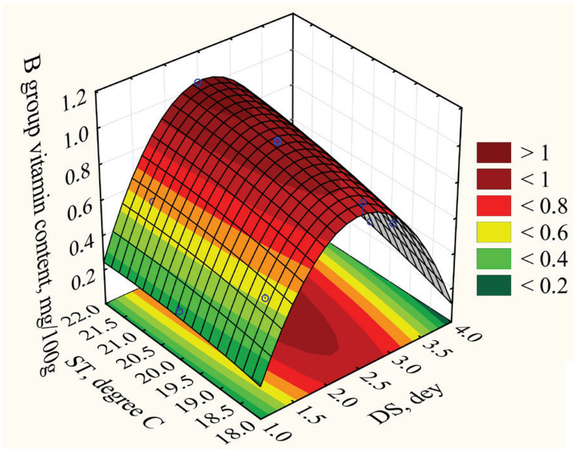


Fig. 4. Influence of the duration (day) and temperature (°C) of the Bogatyr variety buckwheat sprouting on a change in its B group vitamin content (mg / 100 g)

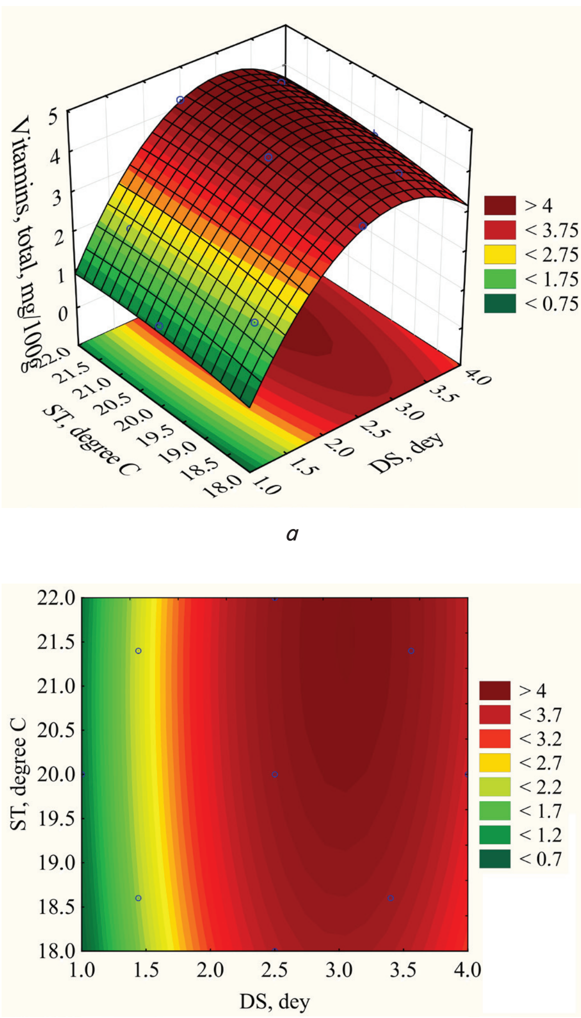


Fig. 5. Influence of the duration (day) and temperature (°C) of sprouting the Bogatyr variety buckwheat on a change in the content of the sum of vitamins E, C, and group B (mg / 100 g): *a* — the response surface; *b* — contour plot

5. 2. The results of studying changes in the nutritionaland biological value of buckwheat during sprouting

The process of grain germination is accompanied by various biochemical changes related to the synthesis of protein, vitamins, enzymes [33]. Buckwheat was sprouted for 4 days. Changes in the nutritional and biological value of the sprouted grains were registered every 1–4 days. The results of changes in the nutritional value of prototypes and control are given in Table 2.

The data given in Table 2 show that in comparison with the control sample, the protein content in buckwheat grain increases during sprouting. Thus, the protein content on day 4 increases by 1.38 times compared to the control. At the same time, the content of carbohydrates and fats in comparison with the control sample is reduced. The mass fraction of carbohydrates on day 4 is reduced by 1.57 times. The obtained results correspond to the literature data [33], namely, when grains germinate, proteins are broken down into amino acids, starch breaks down to soluble carbohydrates, fat – into glycerin and free fatty acids. All these chemical transformations help the sprout develop.

A change in the amino acid composition of the Bogatyr variety buckwheat during sprouting is illustrated in Fig. 6.

Table 2

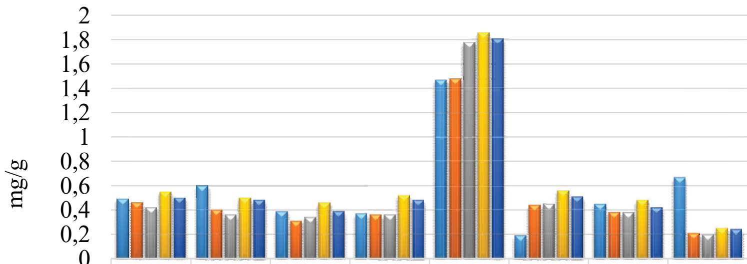
Changes in the nutritional value of buckwheat in the process of sprouting

Indicator	Actual data				
	Control	Day 1	Day 2	Day 3	Day 4
Protein mass share, %	9.67±0.03	5.4±0.04	11.2±0.03	11.9±0.04	13.3±0.03
Fat mass share, %	1.67±0.02	1.88±0.02	1.3±0.02	1.06±0.03	0.82±0.03
Carbohydrate mass share, %	50.6±0.5	45.0±0.4	39.6±0.6	36.26±0.6	32.1±0.5
Moisture mass share, %	9.54±0.05	9.4±0.06	9.46±0.06	9.53±0.06	9.52±0.05
Ash mass share, %	1.70±0.02	1.71±0.03	1.72±0.02	1.72±0.02	1.71±0.02

The results from our amino acid analysis demonstrate that, compared with the control sample, the amino acid content increases on day 3 day of sprouting. For example, the content of arginine, from 1.47 to 1.86 mg/100 g, threonine – from 0.39 to 0.46 mg/100 g, alanine – from 0.37 to 0.52, glycine – 0.19–0.56 mg/100 g, and valine – 0.49–0.55 mg/100 g.

In the process of sprouting, there was a change in the vitamin composition. The data given in Fig. 2, 3 show that the content of vitamins E, C, and group B in the grain of the Bogatyr variety buckwheat increases during sprouting compared to the control sample.

The content of vitamins E and C increases by 2 times (1.673 and 1.593 mg/100 g, respectively) on day 3.3 of sprouting. The content of B group vitamins increases from 0.197 mg/100 g to 1.059 mg/100 g on day 2.6 of sprouting compared to the control.



	Valne	Lysin	Threonine	Alanine	Arginine	Glicerin	Serine	Tyrosine
Control	0,49	0,6	0,39	0,37	1,47	0,19	0,45	0,67
1 day	0,46	0,4	0,31	0,36	1,48	0,44	0,38	0,21
2 day	0,42	0,36	0,34	0,36	1,78	0,45	0,38	0,2
3 day	0,55	0,5	0,46	0,52	1,86	0,56	0,48	0,25
4 day	0,5	0,48	0,39	0,48	1,81	0,51	0,42	0,24

Fig. 6. Change in the amino acid composition of the Bogatyr variety buckwheat in the process of sprouting

5. 3. The results of studying the chemical composition and quality indicators of a new type of food seasoning

A new type of seasoning containing 30 % of the sprouted Bogatyr variety buckwheat was devised in the laboratory at the Research Institute of Food Safety, Almaty Technological University (Kazakhstan). The chemical composition and the main quality indicators of the food seasoning with the addition of 30 % of sprouted buckwheat and a control sample (a seasoning without sprouted buckwheat) are given in Table 3.

Based on our chemical analysis, it was found that the food seasoning with the addition of 30 % of sprouted buckwheat, compared to the control sample, is characterized by a higher content of proteins, vitamins, as well as micro-and macronutrients.

Fig. 7 shows the results of the antioxidant activity of the studied samples.

The results of our study demonstrate that the food seasonings enriched with sprouted buckwheat increase antioxidant activity compared to the control sample. The antioxidant activity of the seasoning with the addition of 30 % of sprouted buckwheat is 25 % higher compared to the control sample, which is 259.09 and 383.72 mg/100 g, respectively. Our results correlate with the literature data [15], which indicate that sprouted buckwheat has high antioxidant activity.

Table 4 gives the results of studying the safety indicators of the test samples. The prototypes of a food seasoning with the addition of sprouted buckwheat meet the safety requirements for all indicators established by TC TP 021/2011. That shows that the tested sample of food seasoning with the addition of 30 % of sprouted buckwheat is safe for human consumption.

Table 3

Chemical composition and nutritional value of the samples under study, *g* (mg) per 100 g of bread $P \geq 0.95$, $n=3$

Indicator	Control	Food seasoning containing 30 % of sprouted buckwheat
Proteins, g	5.0±0.08	5.37±0.1
Carbohydrates, g	43.18±0.559	44.62±0.49
Food fiber, g	10.89±0.22	15.58±0.17
Fat, g	1.57±0.03	2.53±0.2
Ash, g	5.45±0.06	5.04±0.06
Moisture mass share, %	9.38±0.11	8.93±0.06
Vitamins, mg:		
Ascorbic acid (C)	242.93±82.60	319.5±56.23
Thiamine (B_1)	0.280±0.056	0.506±0.101
Riboflavin (B_2)	0.513±0.216	0.649±0.273
Niacin (B_3)	6.16±1.23	7.643±1.52
Pantothenic acid (B_5)	1.49±0.27	1.460±0.263
Pyridoxine (B_6)	0.943±0.189	1.212±0.242
Folic acid (B_9)	0.108±0.022	0.124±0.025
Retinol (A)	0.0613±0.08	0.93±0.12
Tocopherol (E)	4.77±0.05	5.2±0.10
Minerals, mg:		
Iron (Fe)	24.04±0.26	23.22±0.46
Magnesium (Mg)	600.9±11.03	712.9±10.69
Potassium (K)	1,731±21.7	1,868.45±28.03
Phosphorus (P)	289.85±3.67	329.75±4.95
Calcium (Ca)	401.52±5.94	403.55±6.05
Silicon (Si)	1.4±0.03	1.5±0.05
Energy value, kcal	191.85±0.909	206.62±3.86

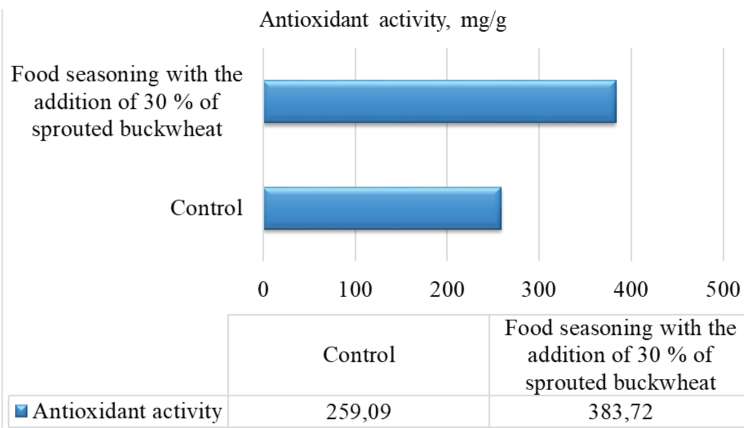


Fig. 7. Antioxidant activity of the studied samples

The results of the chemical composition and biological value indicate the feasibility of producing a new type of food seasoning with the addition of sprouted buckwheat as a product of increased nutritional value. That could expand the range of products and diversify the nutrition of consumers who want to improve their quality of life.

6. Discussion of results of optimizing the process of sprouting the Bogatyr variety buckwheat and the quality indicators for the new product

As evidenced by the data given in Fig. 2, the content of the studied vitamins in buckwheat is significantly influenced by the duration of sprouting. The sprouting temperature has much less effect on the change in the content of water- and fat-soluble vitamins in buckwheat grains. With an increase in the duration of sprouting from 1.0 to 2.6 days, the content of all the vitamins studied in the Bogatyr variety buckwheat increases (Fig. 2–4). In particular, the content of B group vitamins increases from 0.197–0.261 mg/100 g to 0.880–1.059 mg/100 g (Fig. 4). After this period of sprouting the buckwheat grains, the content of B group vitamins is significantly reduced and, on day 4 of sprouting, almost corresponds to the value after 1 day of sprouting and is 0.134–0.414 mg/100 g (Fig. 4). This can be explained by the fact that after 4 days the grain that gave the shoot becomes unfit for consumption because it gives all the nutrients and energy to the young plant [33].

The content of antioxidant vitamins – vitamin E and vitamin C – increases from the first day of sprouting the Bogatyr variety buckwheat to days 3.3 and 3.4 days of its sprouting, respectively. This is because most seeds have a low level or no vitamin C before germination. In addition, L-galactan-gamma-lactone dehydrogenase is the main enzyme in the biosynthesis of ascorbic acid. The activity of these enzymes increases during sprouting with an increase in the content of ascorbic acid. As is known [34], in terms of the mechanism of action, vitamin E (tocopherol) is a biological antioxidant. It inhibits free radical reactions in cells and thus prevents the development of chain reactions of peroxidation of unsaturated fatty acids in the lipids of biological membranes and other molecules. It is proved [34] that germination affects the content of isomers of vitamin E. As can be seen (Fig. 2, 3), after 3.3 and 3.4 days of sprouting, there is a slight decrease in the content of antioxidant vitamins in sprouted buckwheat.

Table 4

Results of studying the safety indicators of the test samples $P \geq 0.95$, $n=3$

Indicator	Allowable level according to TC TP 021/2011	Food seasoning control sample	Food seasoning with the addition of 30 % of sprouted buckwheat
Toxic elements, mg/kg:			
Lead	Not exceeding 0.35	0.001	Not detected
Arsenic	Not exceeding 0.15	Not detected	Not detected
Cadmium	Not exceeding 0.07	0.0008	Not detected
Mercury	Not exceeding 0.015	Not detected	Not detected
Pesticides, mg/kg:			
β-isomerhexachlorocyclohexane	Not exceeding 0.5	0.2	0.2
γ-isomerhexachlorocyclohexane	Not exceeding 0.5	0.1	0.1
DDT and its metabolites	Not exceeding 0.02	0.001	0.001
2,4-D acid, its salts and esters	Not allowed	Not detected	Not detected
hexachlorobenzene	Not exceeding 0.01	0.003	0.003
Mycotoxins, mg/kg:			
aflatoxin B_1	Not exceeding 0.005	0.001	0.001
deoxynivalenol	Not exceeding 0.7	0.2	0.2
T-2 toxin	Not exceeding 0.1	0.01	0.01
zearalenone	Not exceeding 0.2	0.1	0.1
QMAFAnM, CFU/g	Not exceeding 1×10^4	1.3×10^2	1×10^2
BGKP (coliforms), per 0.01 g of product	Not exceeding 0,01	Not detected	Not detected
Sulfite-reducing clostridia, (d)	Not exceeding 1.0	Not detected	Not detected
Molds, CFU/g	Not exceeding 100	Not detected	Not detected
B.cereus, CFU/g	Not exceeding 100	Not detected	Not detected

The total content of the studied vitamins is more significantly affected by the duration of their sprouting. With an increase in the duration of germination from 1 to 3 days, the total content of vitamins E, C, and group B increases from 0.770–1.070 mg/100 g to 4.090–4.590 mg/100 g (Fig. 5, *a, b*). A further increase in the duration of sprouting up to 4 days leads to a decrease in the total content of vitamins to 3.269–3.869 mg/100 g, which is mostly due to a decrease in the vitamins of group B. This is confirmed by studies of scientists in the field of plant biochemistry, the synthesis of vitamins during grain germination [33]. The sprouting temperature has a less significant effect on the total content of vitamins in buckwheat in comparison with the duration of germination. The maximum content of the sum of vitamins is noted at a higher sprouting temperature in the studied range – 21.5–22.0 °C.

The results of our studies on changes in the nutritional and biological value of the Bogatyr variety buckwheat during sprouting have shown that, compared with the control sample, the protein content in buckwheat grain increases during sprouting. Thus, the protein content on day 4 increases by 1.38 times compared to the control. At the same time, the content of carbohydrates and fats, in comparison with the control sample, is reduced. The mass fraction of carbohydrates on day 4 is reduced by 1.57 times. These data correspond to the literature data [33], namely the process of grain germination leads to the breakdown of proteins and the breakdown of starch and fat. All these chemical transformations help the sprout develop.

The results of our studies of the amino acid composition indicate that, in comparison with the control sample, the amino acid content increases on day 3 of sprouting. For example, arginine 1.47–1.86 mg/100 g, threonine 0.39–0.46 mg/100 g, alanine 0.37–0.52, glycine 0.19–0.56 mg/100 g, and valine 0.49–0.55 mg/100 g. Thus, the protein in the sprouted grain transforms into an easily digestible state – the amino acid content increases.

Due to the addition of sprouted buckwheat to the food seasoning, the nutritional value and antioxidant activity of the finished product increases. This is confirmed by the comparative analysis of the developed product with a control sample (Table 3). Given the content of vitamins, flavonoids, the sprouted buckwheat has a high antioxidant activity, which is manifested in the finished product (Fig. 7). Moreover, the addition of 30 % of sprouted buckwheat leads to an improvement in the vitamin-mineral composition of the finished product. This indicates the prospects for the development and introduction to the consumer market of a new type of food seasoning with increased nutritional value.

The results of our research can be recommended for devising multicomponent food products based on sprouted grain, namely the Bogatyr variety buckwheat. This would expand the range of products and diversify the nutrition of consumers.

The prospects for further research are the preparation of a risk analysis plan and critical control points (HACCP) for an enterprise producing new types of seasonings based on sprouted buckwheat seeds; the study of the storage process, and the establishment of guaranteed shelf life for new types of food seasonings.

7. Conclusions

1. We have built regression equations describing the dependence of the content of vitamins E, C, and group B in the Bogatyr variety buckwheat on the temperature and time of sprouting. A significant factor affecting the total content of the vitamins under study is the sprouting time. When sprouting from 1 to 3 days, the total content of vitamins E, C, and group B increases from 0.770–1.070 mg/100 g to 4.090–4.590 mg/100 g. A further increase in the duration of sprouting up to 4 days leads to a decrease in the total content of vitamins to 3.269–3.869 mg/100 g, which is mostly due to a decrease in the vitamins of group B. To maximize the content of vitamins, it is advisable to sprout the buckwheat of the Bogatyr variety for 3 days at a temperature of 21.5 °C.

2. A change in the protein, carbohydrate, and fat content of the Bogatyr variety buckwheat during sprouting has been determined. As a result, the protein content on day 4 increases by 1.38 times compared to the control. At the same time, the mass fraction of carbohydrates on day 4 is reduced by 1.57 times, and the mass fraction of fat – by 2 times. An increase in the content of amino acids was established. Thus, on the 3rd day of sprouting, the content of arginine increases, compared with the control sample, by 1.86–1.47 mg/100 g, threonine – 0.46–0.39 mg/100 g, alanine – 0.52–0.37, glycine – 0.56–0.19 mg/100 g, and valine – 0.55–0.49 mg/100 g, respectively.

3. Based on the chemical analysis, it was found that buckwheat sprouting for 3 days at a temperature of 21.5 °C leads to that the prototype food seasoning is characterized by a higher content of protein, vitamins, micro-and macronutrients. The antioxidant activity value for a food seasoning with the addition of 30 % of sprouted buckwheat is 25 % higher compared to the control sample, which is 259.09 and 383.72 mg/100 g, respectively. According to safety indicators, the developed food seasoning meets the requirements for sanitary and hygienic safety.

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