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Review

Quality and safety indicators of multigrain bread with freshly prepared rye malt using phytoantioxydants

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Abstract: The quality and safety indicators of a new type of multigrain bread using freshly obtained rye malt were studied. Hydrogen peroxide as a safe prooxidation activator and aqueous phytoextracts as natural antioxidants were used for the bioactivation of grain. The choice of phytoextract was made by comparing the antioxidant properties of thyme and oregano obtained with warm (60 ℃) or hot (80 ℃) extraction. The rate of accumulation of organic acids and reducing substances was maximum during malting under the influence of thyme extract (80 ℃). Oregano extracts were used to make rye-textured flour. The paper describes a new method for producing emulsified malt, known as “rye cream”. Unlike other methods, it is proposed to use not dried malt, but freshly obtained rye malt extract. This made it possible to form the adaptogenic properties of the food system, which was evident from the results of the antioxidant activity assessment. This assessment was carried out at different stages of the bread production process. It was shown that at the stage of rye cream production, the oxidation-reduction balance of the food system was shifted towards prooxidants, so the use of phytoextracts with antioxidant properties was necessary. At the dough production stage, the balance changed in the opposite direction, and antioxidants began to dominate the food system as functional nutritional components. Multigrain bread had antioxidant activity twice as high as the standard (Borodinsky bread) and had better characteristics compared to two analogues. Under the influence of multigrain bread, the production of free radicals was inhibited more gently than under the influence of rye bread “BIO”. Another analogue, Fitness bread, had the properties of a strong prooxidant, not an antioxidant. According to the results of an objective assessment in independent laboratories, multigrain bread with rye cream met regulatory requirements for quality and safety, which was confirmed by the results of physicochemical and microbiological analysis.

Keywords: rye multigrain bread; rye cream; bioactivation; thyme; oregano; antioxidants

1. Introduction

For many centuries, rye bread has been a staple food for people of different social, professional and age groups [1]. Currently, the share of rye bread and rye flour products is less than 10%, that is, less than 100 g per day [2]. This is one of the reasons why today’s diets have become deficient in many functional nutrients. This is one of the reasons why today’s diets have become deficient in many functional nutrients [3]. At the same time, the current range of rye products sold is significantly poorer than their wheat counterparts [4], although alimentary-related nutritional status disorders are rapidly expanding. This determines the relevance of developing new technologies for the production of rye bakery products for everyday consumption in order to meet the basic physiological needs of a person. A promising direction is the production of multigrain bread, in which the content of adaptogenic nutrients is guaranteed to be increased. The most suitable regulation for the production of multigrain bread at present is GOST 32677-2014 [5], which sets out the following basic requirements for multigrain bread. The first requirement is that the recipe contains at least three types of grain and their processed products (except rye and wheat flour). The second requirement is humidity above 19%.

The product's food system allows for supplementation and diverse combinations of nutrients. This paper presents a description of the main points of the technology and recipe for multigrain bread containing processed grain products of buckwheat, oats, and rye. The last component is presented as a product of processing malted grain, called by the term "rye cream". Rye malt as a component of bread is a source of many functional components [6]. Malt is a product of the bioactivation of grain. Bioactivation (germination, hatching) begins with grain hydration, when, under the influence of heat and aeration, reactions are triggered to transform organic polymers into oligomers and monomers that can more easily be included in metabolic reactions. Bioactivated grain is an environmentally friendly raw material with an increased content of biologically active substances. Many authors have used fermented rye malt to improve the flavor and quality of food products, including bread [7]. However, freshly prepared raw malt is practically not used in the production of bread products. One of the reasons is the long duration of the malting stage. Data on the duration of this stage vary from 24 h [8] to 72 h [9]. However, this stage can be significantly accelerated by using free radical mechanisms at the stage of grain bioactivation.

The biochemical processes during grain malting, which occur with the participation of free radicals, have not been sufficiently studied. Therefore, they are not often used in practical work. In particular, there is no data on the optimal composition of the reaction medium to accelerate the germination of rye grain. When malting, clean drinking or filtered water is usually used. In this case, the grain is kept under conditions of constant mechanical mixing to improve aeration. This is a really long process that takes at least two days and also requires the use of special mechanical devices and energy expenditure. The process can be accelerated in another way. In particular, the laws of oxidation-reduction processes occurring with the participation of free radicals can be applied to this. One of the safe sources of radicals in living systems is hydrogen peroxide. The compound decomposes to form oxygen and water. It is well known that hydrogen peroxide is used in pre-sowing seed treatment to protect against harmful microflora [10]. However, this does not take into account that hydrogen peroxide is a product of the interaction of superoxide anion radicals with hydrogen ions and can also serve as a source of free radicals in the presence of triggers, such as divalent iron ions [11]. Free radicals provide microbicidal protection to the system by destroying cell membranes. Therefore, this mechanism can be used to accelerate grain germination. It has previously been shown that the use of hydrogen peroxide reduces the germination time of rye grain to 12–14 h [12]. Since free radical reactions have a chain mechanism, the system must be supplemented with substances that break these chains. The use of phytoextracts of spicy plants at various stages of the process allows supplementing the food system with antioxidants that have a synergistic bactericidal and adaptogenic effect [13]. It is important that antioxidants are preserved throughout the entire bread production chain and that their content in the final product is high.

The aim of the work was to evaluate the functional properties of multigrain rye bread using fresh malt extract (rye cream) obtained during stimulated malting under the influence of hydrogen peroxide and phytoextracts with antioxidant properties.

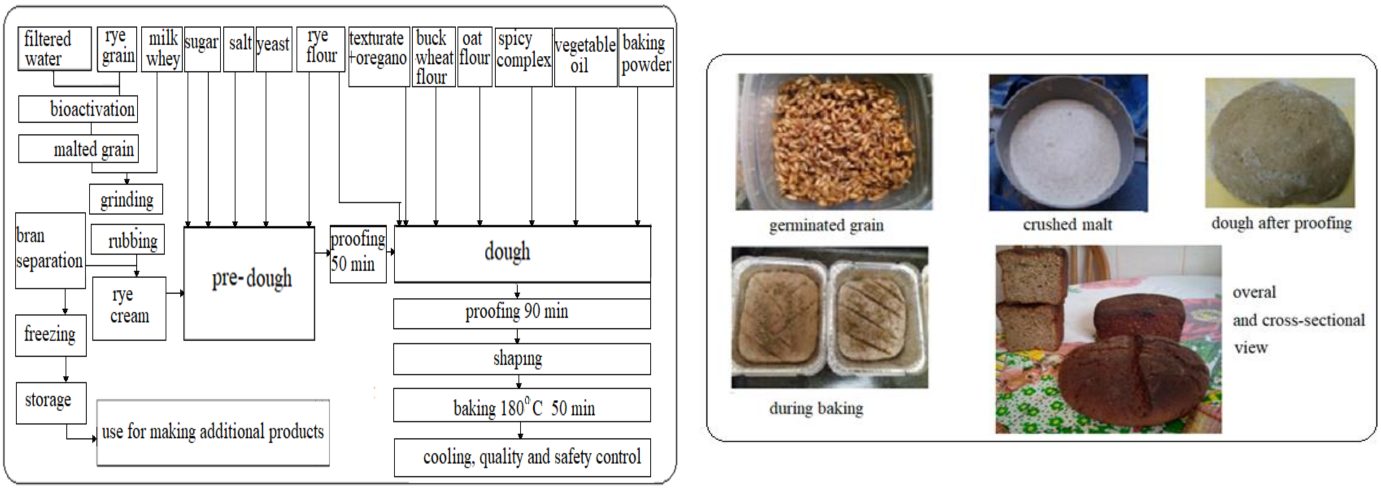
The objectives of the work were: 1) selection of a phytoextract with the best antioxidant activity, taking into account the infusion holding temperature; 2) study of the dynamics of functional components (reducing compounds and organic acids) in germinating grain under the influence of phytoextracts; 3) assessment of the antioxidant activity of multigrain rye bread with malt obtained under the influence of spicy phytoextracts, in comparison with the standard and analogues.

2. Materials and methods

The malting technology included cleaning the grain from impurities, washing, and germination in a mixture of phytoextract with the addition of hydrogen peroxide and iron sulfate. Hydrogen peroxide and iron salt were components of the redox system. These components, when used together, initiate the production of secondary active oxygen species, which are formed during the chain free-radical decomposition of hydrogen peroxide. The presence of free radicals in the grain-water system was necessary to accelerate the bioactivation of grain and reduce the time it takes for malt to form. Other authors have described the use of hydrogen peroxide as a microbicidal agent in the bioactivation of feed grain [14]. Under these conditions, hydrogen peroxide slowly decomposes into oxygen and water. Oxygen prevents the growth of anaerobic microflora. In the present work, hydrogen peroxide was used as a safe source of reactive oxygen species to soften grain hulls and perforate membranes. This is necessary to facilitate grain hydration and requires the use of a minimal amount of hydrogen peroxide. To regulate the free radical process, a plant extract from the Labiatae (or Lamiaceae) family (thyme or oregano) was added to the system. The choice of plants is due to the fact that they are Siberian wild plants and belong to the same family of Lamiaceae, which are characterized by a high content of spicy components with potential redox activity [15]. To prepare phytoextracts, dry leaves and flowers of thyme or oregano were used. The phytomass was collected and processed in August-September 2022 in the Yemelyanovsky district of the Krasnoyarsk Territory. The phytomass was dried in compliance with established pharmacopoeial requirements [16]. A sample of phytomass (m = 10 g) was poured with boiled water (200 mL) at different temperatures (60 ℃, "warm" or 80 ℃, "hot") and kept under adiabatic conditions for 60 min. Different water temperatures were used because previous studies have shown that the biological activity of phytoextracts depends on the physical conditions of exposure to water [17]. The optimal extraction duration was previously determined to be 60 min. The relationship between the results and temperature was volatile, so in this work two temperature values were used, conventionally designated as 60 ℃ ("warm") and 80 ℃ ("hot"). The resulting herbal infusion was filtered, cooled to room temperature, and the volume was brought to 200 mL with distilled water. A solution of hydrogen peroxide (3%, 8 mL) was added to 192 mL of distilled water and combined with the phytoextract. The total filling volume was 400 µL, excluding iron salt $FeSO_4$ (20 µL, 0.01%), which was added to the solution immediately before adding to the rye grain.

The grain was prepared for malting as follows. The grain (500 g) was washed in running water, spread in a thin layer (no more than 0.5 cm thick) in an enamel tray (area 25 cm × 40 cm), and poured with a mixture of thyme phytoextract and hydrogen peroxide solution. The final concentration of hydrogen peroxide (0.02 M) was 5 times less than the lethal concentration of the preparation for microbicidal treatment of grain (0.1%) and 1.5 times less than the minimum concentration of the preparation when treating grain for disinfection at elevated temperatures (0.03%) [18]. The consumption of hydrogen peroxide was four times less than when treating grain with fruit acids [19]. At the same time, the efficiency of the process increased dramatically, since the malt was obtained several times faster. This approach is the authors' know-how. Preliminary studies have shown that this ratio of reagents is optimal for complete absorption of moisture and stimulation of germination of 100% of the grain mass [20]. Rye grain in enamel advised you to sovereign with a soft dump slot and left for 12 h at room temperature until sprouts no longer than 1 mm appeared. Rye grain in emamel advice you sovereign with a soft dump slot and left for 12 hat room temperature until octopus but longer than 1 mm appeared. The resulting dispersion was separated by rubbing through a sieve, separating the homogeneous emulsion from the bran (grain husks). The bran was separated and stored in the refrigerator for further use in the production of additional food products.

The main stages of the entire process (a) and the appearance of intermediate and final products (b) are shown in **Figure 1**.



(a) **(b)**

Figure 1. Steps in the process of making multigrain bread. **(a)** process flow chart; **(b)** intermediate and final products.

The technology used in the work included a number of non-standard elements. Thus, unlike traditional technology, the basis of rye bread was rye cream, not dried fermented malt. It was a finely dispersed emulsion obtained by dispersing malted grain. The peculiarity of this component is the presence of all enzyme systems and complexes of biologically active substances formed in bioactivated grain. This biosystem was not preserved by drying. On the contrary, all water-soluble extractive substances were immediately directed to the production of dough and the subsequent production of bread with increased biological value. A significant difference from the traditional recipe was the replacement of part of the rye flour with three types of whole grain products: buckwheat flour, oat flour, and textured flour enriched with oregano extract. The textured product was rye grain soaked in oregano infusion to a moisture content of 14.8% [21], mechanically crushed in an EK-100 screw extruder with a die diameter of 8 mm; the moisture content of the resulting extrudate was 6.5%. After obtaining the extruded mass, it was cooled to room temperature, dried to an air-dry state, and ground in a mill. The result was a texture enriched with oregano phytoextract. The texturate was used to prepare dough. Another feature of the recipe was the replacement of water during the grinding of malt with whey. This component is a by-product of cheese making. In the described technology, it was used as a secondary raw material. The whey was purchased from the scientific research and production laboratory of cheese (SRL) “LacCor,” which is a structural subdivision of the Krasnoyarsk State Agrarian University. The flow chart above shows that the rye grain was processed with, in fact, no waste. The coarsely dispersed bran that remained after dispersion and separation of the emulsion was sent for storage in the freezer for subsequent use in other products, such as rye cookies, crispbreads, biscuits, snacks, etc. The dough was prepared according to the current regulations for rye bread. The standard used was Borodinsky bread, made according to the GOST 2077-2023 [22]. The bread «Borodinsky» was bought in the retail network of Krasnoyarsk. In order to compare the functional properties of the final product with analogues, two more samples were purchased: “BIO” bread (OOO Yarkhleb, Krasnoyarsk) and “Fitness” bread (OOO Komandor-Holding, Lenta FRESH trademark). There is no state standard for multigrain bread. Test baking was carried out in a laboratory oven with a fan SNO-4.6.5/4 I1. The baking time was 60 min at 180 °C, the recommendations [23] were taken into account when choosing the conditions. Physicochemical analysis was carried out taking into account the requirements of the Technical Regulations of the Customs Union 021/2011 and the current GOST 2077-84 [24]. Custom studies were carried out at the Research and Testing Center of the Krasnoyarsk State Agrarian University, test protocol No. 70/23 dated 12/21/2023. Custom microbiological studies of food safety were conducted at the BioKhimAnalit Testing Laboratory LLC, Krasnoyarsk, Russia, test protocol No. 2566-24 dated 03/24/2024.3. Total acidity and the content of reducing sugars were determined in the food expertise laboratory of the Institute of Food Production of the Krasnoyarsk State Agrarian University. The level of reducing sugars was determined according to GOST 12575-2001 [25]. The method of iodometric titration of copper ions reduced under the influence of reducing sugars in solution was used. At the sample preparation stage, a 1 g sample was prepared with the addition of 100 mL of water. The results were recalculated taking into account the molar mass of glucose in mass fractions of reducing sugars per 100 g of product (g%). The total acidity of the samples was determined by acidimetric titration according to GOST 13496.12–98 [26]. The results were expressed in Neumann degrees (°N, deg.). Antioxidant activity was measured by a luminol-dependent chemiluminescent method [27]. The measurements were carried out using a PC-controlled complex “Biochemiluminometer-3606” (SKTB “Nauka”, Krasnoyarsk, Russia). When conducting chemiluminescent analysis, a sample for analysis was taken from the middle of the bread crumb. The sample weight was 5 g, the sample was suspended in 100 mL of distilled water. The recording time of the chemiluminescent curve was 5 min at a temperature in the recording chamber of +25 °C. The reaction mixture of the registration cuvette included the following components. The test sample was added to the reaction mixture in the amount of 50 μL, the control was distilled water. Luminol (200 μL, 2.2×10^{-4} M, Sigma) was used as a chemiluminescent probe and enhancer. Luminol has a high sensitivity to secondary oxygen radicals (OH·, HClO·, lipid peroxides), so it was used to assess the integral activity of antioxidant components of various natures in the test sample [28]. The luminol solution was preliminarily alkalized with sodium hydrogen carbonate to bring the pH to 7.8. As a source of free radicals, the reaction mixture was supplemented with hydrogen peroxide (100 μL, 3%) with the addition of iron salt $FeSO_4$ (10 μL, 50 mM) as a trigger for free radical decomposition. Iron salt was added last and measurements were started immediately. The amount of free radicals was estimated by the light sum of quanta (S, impulses) generated during the observation period. The parameters were recorded and automatically written to the database. Statistical processing was performed using the parametric Student t-test at a significance level of $p < 0.05$.

3. Results and discussion

3.1. Evaluation of antioxidant activity of phytoextracts of thyme and oregano depending on the infusion temperature

A comparative assessment of the antioxidant activity of phytoextracts of thyme and oregano depending on temperature is presented in **Figure 2**. Both types of extracts had reliable antioxidant activity, which increased in the same direction with an increase in water temperature during the preparation of the extract. At the same time, the antioxidant activity of thyme was higher, since under its influence the production of free radicals decreased by 80% against a decrease of 55% under the influence of oregano extract.

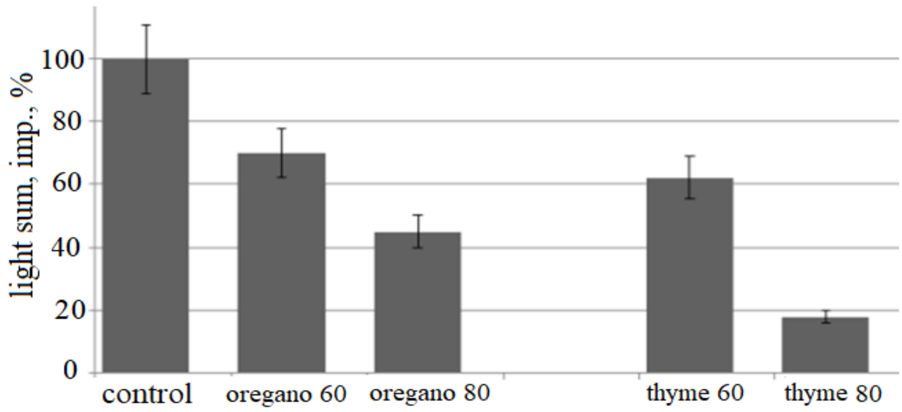


Figure 2. Dependence of antioxidant activity of phytoextracts of thyme and oregano on water temperature.

It is known that when the temperature of the solution increases, the most labile hydrophilic antioxidants are destroyed, such as ascorbic acid and most enzymes. On the other hand, such antioxidants as hydrophobic vitamins (tocopherols, carotenoids, phylloquinones), coenzyme Q, flavonoids, terpenoids, and a number of antioxidant enzymes—glutathione reductase [29], some forms of peroxidase [30], and others—are relatively heat-resistant objects. Based on the available data, the antioxidant activity of oregano and similar spices is formed by heat-stable hydrophobic antioxidants, such as carotene and essential oil components (linalool, pinene, cineole, limonene). Their high content in plants of the Lamiaceae family was established in previous studies [31]. At the same time, the antioxidant activity of the extracts varied significantly. According to other authors, there is a mechanism of functional inversion, when the same object exhibits antioxidant or prooxidant activity depending on its chemical affinity to the environment [11,28]. It can be assumed that the reduced AO activity of oregano may be due to the inversion of antioxidant activity into prooxidant activity, which is confirmed by other authors [32]. In the conditions of this study, two facts were important: 1) Both plant sources contain a rich set of antioxidants; 2) The "hot" thyme extract has the highest and most stable AO activity of all the options considered. Under its influence, the production of free radicals was reduced 1.5 times more effectively than under the influence of the "hot" oregano extract. Then it was necessary to answer the question of which extract is preferable for use in the process of bioactivation of rye grain. The indicator was the level of compounds most actively involved in the oxygen metabolism of germinating grain and detected using express methods. Such compounds are reducing sugars and organic acids. Reducing sugars participate in the exchange of antioxidants, and organic acids ensure acid-base balance and the work of the Krebs cycle. The impact of strong and weak antioxidants on the dynamics of malting was assessed at the next stage.

3.2. Dynamics of antioxidant components (reducing sugars and organic acids) under the influence of spicy phytoextracts

Figure 3 shows the results of changes in the level of reducing sugars and total acidity during the malting process of rye grain under the influence of «hot» phytoextracts of thyme and oregano.

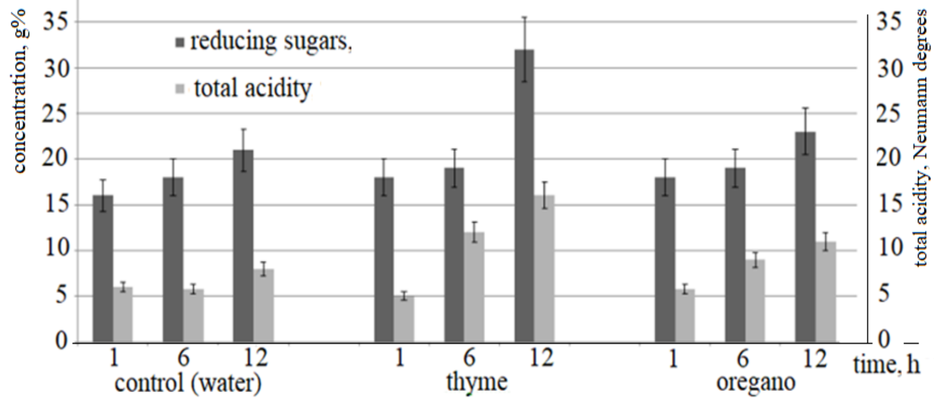


Figure 3. Dynamics of reducing sugars and total acidity during malting of rye grain under the influence of «hot» phytoextracts of thyme and oregano.

The figure shows that the greatest increase in reducing sugars and organic acids occurred under the influence of phytoextract of thyme. By the 12th hour of malting, the content of reducing sugars in grain under the influence of thyme was 39% higher than under the influence of oregano and 52% higher than in the control. The total content of organic acids was characterized by even higher dynamics. By the 6th hour of malting, the level of organic acids in grain under the influence of thyme was 33% higher than under the influence of oregano and 2 times higher than in the control. By the 12th hour of malting, the leading values of the indicator were 45% and 100%, respectively. During bioactivation of rye grain, disintegration of high-molecular compounds (proteins, polysaccharides, lipids) occurs and their transition into easily accessible chemical forms. At the initial stages of autofermentation, the natural base is enriched with biologically active metabolites, which is an oxygen-dependent process and occurs with the formation of active forms of oxygen by a chain free-radical mechanism [33]. Extremely high levels of reactive oxygen species (ROS) can lead to negative autolytic processes. Therefore, elimination of excess ROS is a necessary regulatory factor. The results confirm that under the influence of thyme, the accumulation of endogenous antioxidants in bioactivated grain was more effective in comparison with oregano extract. This means that the thyme preparation is the most preferable for use at the stage of endo-fermentation during malt germination. In turn, oregano extract will be more useful at the stage of dough preparation, since exogenous antioxidants will be supplemented by endogenous ones.

3.3. Evaluation of antioxidant activity of rye bread with malt obtained using phytoextracts

During the experimental baking, samples were obtained. Antioxidant activity was analyzed at various stages of obtaining the samples: production of the base ingredient (rye cream), dough after proofing, the target product (multigrain bread) in comparison with the closest analogue presented on sale (rye bread "Borodinsky"). The dynamics of antioxidant activity of the samples is shown in **Figure 4**.

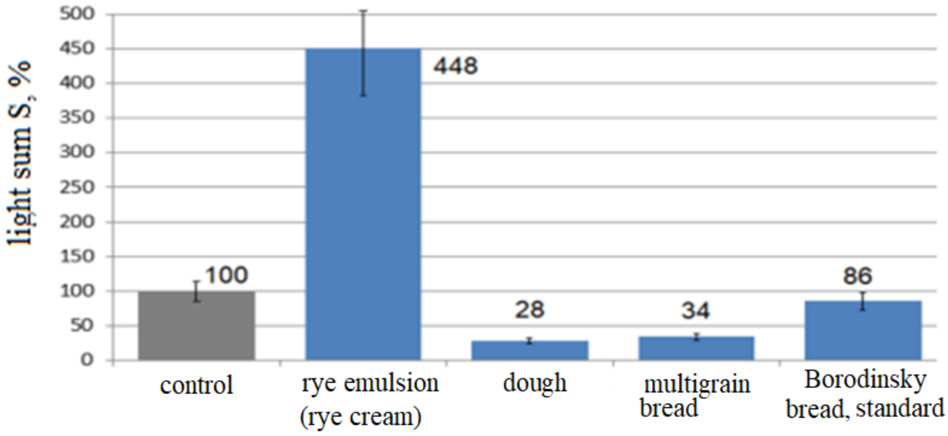


Figure 4. Antioxidant activity of multigrain bread compared to standard.

The figure shows that fresh rye emulsion has no antioxidant but strong prooxidant properties. This fact was quite expected and easily explained. Indeed, in the process of bioactivation, stimulated by chemical and biological oxidation activators, the resulting emulsion is a biochemical reactor where chain free-radical processes develop with the participation of autolytic enzymes released from lysosomes. At the same time, the AO activity of the dough increases significantly during proofing. This is indicated by the following results. The light sum under the influence of the sample is 28% of the control level. This is due to the fact that the design of the food matrix included the introduction of components with high antioxidant potential (oat and buckwheat flour, whey, and spice mixture). The final AO activity of the target product exceeded the corresponding indicator of the analogue (Borodinsky bread) by more than two times, since under the influence of multigrain bread, the production of free radicals decreased to 34% of the control, and under the influence of Borodinsky, it was only 86%. Apparently, the result is due to the higher diversity of the composition of multigrain bread compared to "Borodinsky," which does not contain grain components. The results of the physicochemical control are given in **Table 1**.

Table 1. Physicochemical properties of bread with rye malt obtained using phytoextracts.

Parameter	**Result**	**Regulations**	**Standart range**
Protein, mass fraction, %	11.2 ± 0.7	GOST 25832-89	not regulated
Humidity, %	44.72 ± 1.5	GOST 31807-2018	19 … 55
Soluble dry matter, a.d.m.	55.0 ± 1.5	GOST 21094-75	not regulated
Fat, mass fraction, %	1.1 ± 0.7	GOST 5668-68	not regulated
Chlorides, %	1.1 ± 0.7	GOST 5698-51	not regulated
Total acidity, Terner degrees	3.67 ± 0.4	GOST 2077-84	below 10%

From the results presented in **Table 1**, it can be concluded that the experimental multigrain bread fully complies with current regulations on humidity and total acidity parameters. It is known [34] that the average protein content in traditional bread varieties is 4.5 ... 8%. Consumption of such a product can satisfy up to 25% of the daily protein requirement. A higher protein level (8.3 … 10.8%) is typical for sourdough bread [35]. Multigrain bread contains 11.2 ± 0.7% protein, i.e. the nutritional value of such a product is increased. It is known that the moisture content of the product depends on the type of product. The moisture range for wheat bread is 35 … 45%, for rye bread 46 … 52%. The moisture level of multigrain bread was intermediate (44.72 ± 1.5). This is lower than for standard types of rye bread. Therefore, multigrain bread will go stale more slowly than regular rye bread. Increased protein content will also slow down the staling process, as proteins retain moisture. Increased acidity also helps to extend the period when bread remains fresh. It is known that rye products prepared with sourdough have a higher acidity (up to 12 degrees) than wheat products prepared with yeast, and their acidity does not exceed 4 degrees [35]. This indicator for multigrain bread is 3.67 degrees and is explained by the presence of carbonic and organic acids. An accelerated increase in their content occurs at the stage of grain malting under the influence of phytoextracts, the dynamics of the process were described above (p. 3.2).

Consequently, multigrain bread contains a complex of biologically active compounds (organic acids, proteins, reducing sugars), which, under conditions of optimal product moisture, ensure its high antioxidant activity. At the same time, the product safety indicators also comply with regulations (**Table 2**).

Table 2. Safety indicators of bread with rye malt obtained using phytoextracts.

Parameter	Result	Regulations	Standart range
Total bacterial count, CFU/g	below 1×10^3	Sanitary Rules and Norms 2.3.2.1078-01	1×10^3
Bacteria of the coli group	not detected	GOST 31747	not allowed in a 1 g sample
Staphylococcus aureus	not detected	GOST 31746	not allowed in a 1 g sample
Molds, CFU/g	below 50	GOST 10444.12	50 CFU/g
Proteus	not detected	GOST 2560	-
Pathogens of potato disease of bread	not detected	GOST 27669-88	-

The data in the table show that multigrain bread is safe against the most common pathogen of potato disease, as well as proteus, mold, coliform bacteria, and staphylococci. The total bacterial count is below 1×10^3. Judging by the results obtained, the food system of multigrain bread has an optimal balance between oxidants that inhibit the development of pathogens and antioxidants as essential nutrients. Such a balance does not form spontaneously and can be significantly disrupted. This follows from the results of a comparative assessment of the antioxidant activity of two other non-traditional types of bread (**Figure 5**).

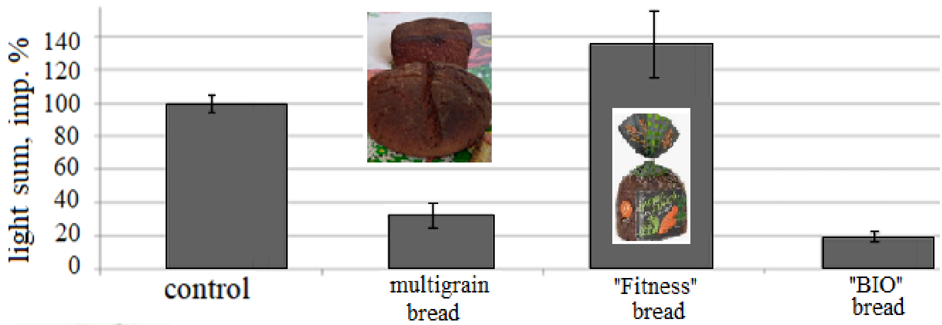


Figure 5. Antioxidant activity of the tested bread in comparison with the standard and analogue.

The figure compares the results of the redox activity assessment of multigrain bread and two varieties of rye bread presented on the consumer market of Krasnoyarsk: “BIO” rye bread (LLC “Yarkhleb”, Krasnoyarsk) and “Fitness” bread (LLC Komandor Holding). Both varieties of bread are made from a mixture of rye and wheat flour in various proportions with the addition of various seeds and rye flakes. From the figure, it is clear that multigrain bread with malt occupies an intermediate position between the other two samples. Under the influence of the “BIO” bread sample, the production of free radicals in vitro decreased by 80%

relative to the control, i.e., the total antioxidant activity of the sample was sharply expressed. On the contrary, under the influence of the "Fitness" bread sample, the production of free radicals increased by 38%, i.e., the object exhibited not antioxidant, but prooxidant properties. Under the influence of the multigrain bread sample with malt, the production of free radicals decreased by an average of 64%. This result is more consistent with the physiological effect on active oxygen forms than in the case of BIO bread. Oxidative homeostasis of the human body is formed as a balance between antioxidants and prooxidants with an asymmetry towards antioxidants. However, a sharp inhibition of oxidant production in the body is the same violation of homeostasis as oxidative stress. The functioning of non-specific immunity as a consequence of the production of active forms of oxygen by blood phagocytes is the first line of defense against exogenous and endogenous stress factors. Therefore, among everyday food products, preference should be given to those that will gently regulate oxidative homeostasis. Judging by the results obtained, such products include multigrain bread with malt.

4. Conclusion

1) According to the results of chemiluminescent analysis, it was revealed that the antioxidant activity of thyme and oregano extracts directly depends on the extraction temperature. The extracts prepared at 80 ℃ showed the greatest antiradical activity. At the same time, the antioxidant activity of thyme extracts is 1.5 times higher than that of oregano. Therefore, to limit the production of free radicals during malting, thyme extract is preferable to oregano extract. It is advisable to introduce oregano extracts into the food system at the stage of dough preparation as part of rye-textured product.

2) During the malting process, the most active increase in reducing sugars and organic acids occurred under the influence of thyme phytoextract. After 12 h from the start of bioactivation, the content of reducing sugars in the grain was 39% higher than under the influence of oregano and 52% higher than in the control; the level of total acidity was 45% and 100% higher, respectively. The results of this stage are fully consistent with the results of the previous one.

3) Malt emulsion (rye cream) and malt cake had prooxidant, not antioxidant properties. This is explained by the formation of a large number of autolytic components and the activation of many enzyme complexes during stimulated malting of grain. Restoration of the redox balance with the participation of antioxidants occurs inertially. Therefore, at the stage of kneading the dough, subsequent proofing and baking, the prooxidant activity of rye cream is naturally inverted into antioxidant.

4) According to the results of an independent assessment carried out in certified laboratories, multigrain bread with rye cream meets quality and safety requirements for physicochemical and microbiological indicators and also has functional properties. The product is characterized by twice the antioxidant activity of the standard Borodinsky bread. Multigrain bread with rye cream has a higher adaptogenic potential compared to analogues, since it has a softer antioxidant effect

than BIO bread, while Fitness bread, on the contrary, is characterized by prooxidant activity.

Conflict of interest: The authors declare no conflict of interest.

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