Micronutrient value and antioxidant activity of malt wheat sprouts

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Abstract. Currently, one of the main directions of development of the food and processing industry is to expand the range of fortified food products using secondary raw materials of grain crops. Secondary raw materials of grain crops include by-products of malt production - malt wheat sprouts, which can be used as a food fortifier. The article presents the results of the research on the micronutrient composition of malt wheat sprouts (12 batches) obtained during the germination of wheat grains of the sort “Moskovskaya-56” for malt. The obtained data on the micronutrient composition and antioxidant activity of malt wheat sprouts make it possible to position them as a functional food ingredient. The presented experimental data can be used in the development of fortified and functional food products with the addition of malt wheat sprouts.

1. Introduction

Currently, the main directions of development of the food and processing industry include increasing the raw material base and expanding the range of products. Thus, the Draft Strategy of the food and processing industry of the Russian Federation for the period up to 2030 notes that one of the problems at the present stage is the limited production of certain types of agricultural raw materials with certain quality characteristics. The main challenges facing the food and processing industry in the next decade include expanding the raw material base and increasing the production of enriched and specialized products.

Today, according to Federal state statistics service, in Russia annually 42 - 44 thousand tons of fortified food products for medical and preventive purposes, with the market demand of 1 - 1.5 million tons per year are produced.

When processing agricultural products, a significant amount of secondary raw materials is formed. The degree of their involvement in the further processing is minimal.

One of the main objectives of the state policy in the field of healthy eating is to increase the production of food products with high nutritional value, including products enriched with vitamins and minerals. The modern ration of an adult is insufficiently enriched with vitamins and mineral elements. It is noted that vitamin deficiency is all-season and often has the character of polyhypovitaminosis, a lack of three vitamins or more is found in 30-70% of the population in the Russian Federation [1]. Mineral deficiency is primarily associated with a lack of the macronutrients calcium and potassium and the trace elements iodine, zinc and iron [2]. It was found that the diet of Russian people is deficient in
most vitamins of group B, C, A, β-carotene, calcium, magnesium, and iron [3]. One of the ways to solve this problem is to involve by-products of grain processing in food production as fortifiers.

By-products of wheat malt production—sprouts—are promising raw materials for food fortification, on the one hand, due to the high content of micronutrients, on the other, due to availability and economic acceptability [4, 5].

Positioning malt wheat sprouts as a functional food ingredient requires comprehensive information, including its chemistry, nutritional value, and antioxidant properties. In this regard, the researches in this direction are actual and have the scientific and practical interest.

The purpose of this work was to study the micronutrient composition and determine the antioxidant activity of malt wheat sprouts.

2. Material and methods

As objects of the research, malt sprouts formed in the process of germinating of wheat grain for malt were used, provided by LLC «Orel Malt Production Plant». After germination, malt wheat sprouts are separated on sprouting machines and dried to a moisture content of no more than 15%. 12 batches of sprouts obtained as a result of germination of wheat for malt of the variety "Moskovskaya-56" were studied.

The content of B vitamins was determined according to State Standard (GOST) 32042-2012 and GOST EN 14663-2014 by HPLC on a Millichrom-5-UF E device («Granat», Russia) equipped with a Multichrom computer data processing system. Sample preparation for the determination of vitamins B1 (thiamine) and B2 (riboflavin) was carried out according to clause 7.4.1 of GOST 32042-2012, sample preparation for the determination of vitamin B5 (nicotinic acid) - according to clause 10.2.3.1 of GOST 32042-2012.

Vitamin B6 was defined as the sum of pyridoxine, pyridoxal, and pyridoxamine, including their phosphorylated derivatives, as well as β-glycosylated forms, in terms of pyridoxine. Sample preparation of vitamin B6 was carried out in accordance with clause 6.2.1.2 of GOST EN 14663-2014. The chromatographic column was filled with the sorbent Duacorb C16T (5 microns); As an eluent, a mixture of acetonitrile - 0.03 M KH2PO4 - 0.02 M C2H5NH2 in a ratio of 9:9:1:0.5 (by volume) was used, the wavelength of the spectrophotometric detector was 254 nm. The experiments were repeated twice.

The chemical composition of the main ash components (P, K, Mn, Fe, Mg, Ca, Si, Zn, Cu, Mo) was determined by energy dispersive spectrometry (ESD) using an analytical scanning electron microscope JSM 6090 LA (JEOL, Japan).

The microscope resolution is 4 nm at an accelerating voltage of 20 kV (secondary electron image), scaling from 10 to 10000. For elemental analysis the working distance (WD) is 10 mm. The energy dispersive spectrometer allows to perform quantitative X-ray microanalysis with the desired area of analysis: in a point or in a plane and obtaining maps of the distribution of elements. X-ray microanalysis data are presented in the form of standard protocols that contain a picture of the microstructure of the sample under study, a table of data on weight and atomic correlation, spectra and histograms. Taking into account the intensity of the spectrum lines, it is possible to determine the concentration of the desired element. The fractional accuracy of chemical analysis is distributed as follows: when the concentration of elements is from 1 to 5% the accuracy is less than 10%; 5 to 10% accuracy is less than 5%; with an element concentration of more than 10%, the accuracy is less than 2%. 100 ash zones of each sample were examined. Local analysis - 3 mm, scanning area - not less than 12 microns [6, 7].

The total antioxidant activity of water and alcohol extracts (ethanol at a concentration of 70%) of malt wheat sprouts was determined using a Helios gamma spectrophotometer (Thermo Electron Corporation, USA) using the DPPG method [8]. The method is based on the interaction of antioxidant substances with the stable Chromogen radical 2,2-diphenyl-1–picrylhydrazyl, which has a blue-violet color on the Helios Y spectrophotometer in the visible region of the spectrum (λ = 517 nm). A 0.0025% DPPH solution was used as the background solution.
The antioxidant activity was calculated as a relative value and was determined by the ratio of extinction at a certain reaction time (10 minutes). The % inhibition of the DPPH-radical by alcohol and water solutions was calculated using the formula 1:

\[ AA = \frac{A_0 - A_{10}}{A_0} \times 100 \]  

(1)

A0 – the optical density of the radical solution,

A10 – the optical density of the radical solution with the sample after 10 minutes.

The experiments were repeated three times.

The total content of phenolic substances was determined by the colorimetric method using the Folin-Ciocalteu reagent. The method is based on the oxidation of the phenolic groups of the alcoholic extract of the test sample (2 g of the test sample is extracted with 50% ethanol at 36 °C for 2 hours) with the Folin-Ciocalteu reagent in saturated sodium carbonate. The reaction took place at 20 °C for 30 minutes, after which the transmittance was measured at 725 nm on a Helios gamma UV spectrophotometer (Thermo Electron Corporation, USA). Gallic acid was used as a standard, an aqueous solution of gallic acid (200 mg in 1 L) was diluted with distilled water to obtain the appropriate concentration for the calibration curve. The total content of phenolic substances was expressed in mg of gallic acid per 100 g of dry weight of the feedstock. The experiments were repeated three times.

The experimental data were processed by the methods of mathematical statistics.

Processing of experimental data was performed by methods of mathematical statistics.

3. Results and discussion

The study of the vitamin composition of malt wheat sprouts revealed a significant content of B vitamins (table 1).

According to GOST R 52349-2005, functional food ingredient is a substance or a complex of substances of animal, plant, microbiological, mineral origin or identical to natural ones, which are part of a functional food product in an amount of at least 15% of the daily physiological need, per serving products with the ability to provide a scientifically substantiated and confirmed effect on one or more physiological functions, metabolic processes in the human body with the systematic use of a functional food product containing them [9].

In this regard, the calculation was made of the size of the portion of malt wheat sprouts recommended for use in the diet in order to meet the need for vitamins in the amount of 15% of the daily norm.

Table 1. Vitamin content in malt wheat sprouts.

| Vitamin        | Recommended intake (RDA), mg / day | Content, mg / 100 g | Portion of the product required to meet the body's need for vitamins by 15% of the daily norm, g |
|----------------|------------------------------------|---------------------|------------------------------------------------------------------------------------------------|
| Thiamine       | 1.5                                | 0.56±0.12           | 40                                                                                              |
| Riboflavin     | 1.8                                | 0.36±0.08           | 75                                                                                              |
| Pantothenic acid| 5.0                                | 1.86±0.05           | 40                                                                                              |
| Pyridoxine     | 2.0                                | 0.54±0.06           | 54                                                                                              |
| Nicotinic acid | 20.0                               | 9.70±0.18           | 32                                                                                              |

As can be seen from the data obtained in table 1, to ensure that the need for the studied vitamins is satisfied in the amount of 15% of the daily norm, the recommended portion of malt wheat sprouts is 32-75 g per day.

Previously, we conducted research of the vitamin content in malted barley sprouts. Comparison of the vitamin content of malt sprouts barley and wheat sprouts indicates that wheat sprouts are higher in the content of most B vitamins than barley sprouts: thiamine - by 8%, riboflavin - by 6%, and nicotinic acid - by 75%, in addition, wheat sprouts contain pantothenic acid, which was not found in barley sprouts [9].
The results of studying the mineral composition of malt wheat sprouts and calculating the portion of the product required to meet the body's need for minerals by 15% of the daily norm are presented in Table 2.

### Table 2. Content of mineral elements in malt wheat sprouts.

| Mineral element     | Recommended intake (RDA), mg / day | Content, mg / 100 g | Portion of the product required to meet the body's need for vitamins by 15% of the daily norm, g |
|---------------------|-----------------------------------|---------------------|-----------------------------------------------|
| **Macroelements**   |                                    |                     |                                               |
| Potassium, mg       | 2500                              | 818.96±2.94         | 47                                            |
| Calcium, mg         | 1000                              | 88.64±4.62          | 187                                           |
| Magnesium, mg       | 400                               | 156.16±10.78        | 32                                            |
| Phosphorus, mg      | 800                               | 418.30±8.17         | 29                                            |
| **Microelements**   |                                    |                     |                                               |
| Iron, mg (male)/18(female) | 10 | 7.16±0.18               | 20/34                                          |
| Manganese, mg       | 2.0                               | 4.08±0.13           | 8                                             |
| Copper, mcg         | 1.0                               | 0.12±0.01           | 125                                           |
| Zinc, mg            | 12.0                              | 5.20±0.06           | 34                                            |
| Molybdenum, mcg     | 70                                | 196.08±10.16        | 6                                             |
| Silicon, mg         | 30                                | 28.80±0.25          | 16                                            |

The analysis of the obtained data showed that the satisfaction of the need for macro- and microelements by 15% of the daily norm is provided when 6 g of malt wheat sprouts are included in the diet. The optimal portion of malt wheat sprouts, covering the daily requirement of 15% or more in such mineral elements as molybdenum, manganese, silicon, iron, phosphorus, magnesium, zinc and potassium is 47 g. To meet the daily requirement for calcium, it is necessary to consume 187 g malted wheat sprouts, in copper - 125 g, the consumption of such a large amount of sprouts in food is rather difficult, so these mineral elements of malt wheat sprouts cannot be positioned as functional ingredients.

Comparative analysis of the content of mineral elements in wheat sprouts and barley sprouts showed that in terms of the content of macroelements, wheat sprouts are significantly inferior to barley sprouts. Thus, the content of potassium in barley sprouts is higher by 66%, calcium - by 280%, magnesium - by 24%, and phosphorus - by 44%. At the same time, in terms of the content of microelements, wheat sprouts surpass barley sprouts in some indicators. Thus, the content of manganese in wheat sprouts is 155% higher, and the content of molybdenum is 85% higher. In terms of iron and copper content, wheat sprouts are inferior to barley sprouts: by 44% and 50%, respectively. A particularly significant difference between malt sprouts is observed in the content of zinc: in wheat sprouts this microelement is 13 times higher than in barley sprouts [9].

Thus, the totality of the studies carried out on the content of vitamins and minerals in malt wheat sprouts shows that their consumption as part of the daily diet in an amount of 47 g or more satisfies the body's needs for individual nutrients in an amount of 15% of the daily norm.

At the next stage, the antioxidant properties of water and alcoholic extracts of wheat sprouts were studied, and the content of phenolic compounds (PCs) in wheat sprouts was determined.

The results of studies of the antioxidant activity of malt wheat sprouts and the content of phenolic compounds in them are presented in Table 3.

### Table 3. Antioxidant activity and phenolic compounds of malt wheat sprouts.

| Name of indicators | Value of the indicator |
|--------------------|------------------------|
| Antioxidant activity, %: Water extract | 15.17±0.32 |
Alcohol extract  43.00±1.02  
Sum of phenolic compounds, mg / 100 g dry weight  255.11±3.56

It is known that natural substances exhibiting antioxidant activity include a number of organic substances: phenolic compounds, carotenoids, vitamins, catalyst proteins and some other substances. In addition, according to their solubility, antioxidants are divided into water-soluble and fat-soluble. Water-soluble antioxidants include ascorbic acid, some B vitamins, flavonoids, catechins, polyphenols, aromatic amines. Fat-soluble antioxidants are represented by vitamins E and A, carotenoids, ubiquinone, phospholipids. It is likely that the water extract of wheat sprouts shows antioxidant activity mainly due to the presence of phenolic compounds. The high content of phenolic compounds causes a high antioxidant activity of water extracts and extracts, which is shown in the work of Makarova N. V. and Zyuzina A.V. on the example of fruit and berry raw materials [10].

For an adequate comparison of the antioxidant activity of wheat sprouts, the results of the study of this indicator in the products of grain processing should be considered. In the work Of Sizova T. I. the antioxidant activity of water extracts of barley malt (20.68%), malt barley sprouts (19.89%) and malt sprout pomace (20.11%) was studied, the results of the antioxidant activity of water extract of wheat sprouts are consistent with these data, and there is no significant difference in this indicator. In the works of foreign scientists, the results of studying the antioxidant activity of wheat sprouts differ from the results obtained by us: the antioxidant activity of the water extract was 80.6 ± 11.2% and that of the alcohol extract was 9.7 ± 1.8% [11, 12].

The difference in the obtained values can be connected with various factors influencing the antioxidant activity, which include the nature of the initial products (variety, growing area, soil composition, climatic conditions, etc.), production technology (conditions and modes of wheat germination), additional processing (beating of sprouts, drying, etc.), conditions and modes of extraction (temperature, strength of the extractant, duration of extraction, concentration of the substrate, etc.). In the future, these issues require experimental study to identify and optimize the parameters of factors affecting antioxidant activity. Since the antioxidant activity of the alcohol-soluble fraction was quite high (43.0%), it can be assumed that wheat sprouts contain vitamins E and A, carotenoids, ubiquinone and some other compounds in wheat sprouts.

4. Conclusion

Thus, the totality of the data obtained on the content of vitamins and mineral elements in wheat sprouts, as well as their antioxidant activity, makes it possible to position them as functional food ingredients. The combination of malt sprouts of wheat and barley will make it possible to create a complex food ingredient with a more pronounced functional focus, which can be further used to enrich a wide range of food products. The presented experimental data can be used in the designing of fortified and functional food products using malting by-products.

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