Investigation of germinated crops elemental composition

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Abstract. The introduction of the crops germination stage allows increasing their nutritional value by increasing the amount of minerals, vitamins and amino acids, which are easily digested and have a beneficial effect on a human body. At the same time, heavy metals located on the surface of grains pose a danger to human health. When the grains swell, the water treated in various ways (magnetic, ultrasonic, etc.) is used. However, there is not enough information about changes in minerals and the toxic elements content during germination of flax seeds and buckwheat grains processed with physical methods. Therefore, in the work, we investigated the change in mineral substances and toxic elements during germination of flax seeds with the application of magnetized water and buckwheat grains - with ultrasonic treatment of tap water using mass spectrometry and atomic emission spectrometry with inductively coupled plasma. It was found out that the germinated flax seeds and buckwheat grains were characterized by different mineral contents and fewer toxic elements. The content of calcium, potassium, magnesium, phosphorus, selenium, copper, zinc increased in crops in the process of germination.

1. Introduction

According to the “Fundamentals of the state policy of the Russian Federation in the field of healthy nutrition for the period up to 2020” there is a lack of consumption of macro- and microelements, vitamins and proteins in the population diet [1]. The tasks to create conditions for a new generation foods production with predetermined quality characteristics, namely functional, enriched, specialized and organic were given in the government documents “The Concept of Ensuring Sanitary and Epidemiological Well-Being of the Population by Developing Functional and Specialized Bakery of the Russian Federation until 2020 (Bread is Health)”, “Strategy for Improving the Quality of Food Products in the Russian Federation until 2030”. Therefore, the problem of providing the population with foods based on the traditional food products modification, ensuring an increase in the content of useful substances through the use of non-traditional types of raw materials, including flax seeds and buckwheat grains, is relevant nowadays [2, 3, 4, 5, 6].

Flax seeds and their processed products have a unique biochemical composition, a wide range of properties and a set of biochemically active substances. They are promising raw materials for the production of functional foods. Flax seeds contain macro- and microelements, proteins, polyunsaturated fatty acids (omega-3, omega-6), digestible carbohydrates, dietary fiber, B vitamins (B1, B2, B5, PP), vitamin C, tocopherols, minerals (phosphorus, potassium, magnesium, iron, manganese, zinc, calcium,
sodium) [7, 8]. The germination process allows one to obtain products with a high content of vitamins, enzymes, minerals [9]. The seedlings contain sulforaphane, isothiocyanates, glucosinolates, enzymes, antioxidants, vitamins, which are effective in the prevention of oncology or in cancer therapy. In addition, the seedlings have an antigenotoxic effect, protecting DNA from damage, and are easily digestible [10].

Buckwheat is rich in flavonoids, iron, magnesium, calcium, phosphorus, iodine, copper, vitamins B1, B2, E, folic acid, dietary fiber, and antioxidants [11]. The benefits of buckwheat increase considerably after germination: the amount of essential amino acids and minerals increases. Germinated buckwheat grain contains a complex of balanced vitamins and minerals, being in easily digestible form. This allows them to have a beneficial effect on the human body - to improve intestinal motility, to tighten the blood vessels walls, to regulate cholesterol, to remove toxins from the body [12].

Environmental deterioration results in the food raw materials contamination with heavy metals to the greatest extent. The main source of contaminates supply to the grain is soil, which, unlike other environmental components (air and water), is a powerful heavy metals accumulator that is a great danger to human health. Their content decreases in the crops soaking process. There are many methods for tap water treating in the food industry such as electromagnetic, electrochemical, magnetic, ultrasonic. They allow changing water properties [13].

Physical methods of grain crops preparing, allowing to reduce the duration of flax seeds (linseed) germination process by 2 hours (with the application of magnetized water), buckwheat grains - by 4.5 hours (due to the use of water treated with ultrasound) were developed at the Department of Technology for Confectionery, Pasta and Grain Processing productions of Voronezh State University of Engineering Technologies. However, there is not enough information about the change in mineral substances during flax seeds and buckwheat grains germination and the effect of physically treated water on the degree of toxic elements migration from the seeds and grain surface.

2. Aims and objectives of research
The aim of the work was to study the elemental composition of flax seeds (linseed) and buckwheat grains, previously prepared in different ways. The objects of research were four samples: 1 - native seeds of oil flax (Commodity Specification 9729-004-25646217-2006), 2 - flax seeds germinated with the use of magnetized water (Commodity Specification 9729-527-02068108-2020), 3 - native buckwheat grains (Commodity Specification 9294-003-99621687-10), 4 - buckwheat grains germinated with the use of ultrasound treated water (Commodity Specification 9715-498-02068108-2018).

3. Materials and methods

3.1 Germination of grain crops
Germination of flax seeds was carried out as follows: first, the seeds were washed with water, simultaneously discarding the floated and damaged ones, then they were added into water and left to swell at a temperature of (25 ± 2) °C. Then, the excess water was removed and the seeds were sent for germination until seedlings of no more than 1.5 mm long appeared [14]. Magnetized water was used in the germination process. It was obtained by tap water passing through a magnetic track filter of the MTPF type (Commodity Specification 3697-001-73201199-2014).

Germination of buckwheat grains was carried out as follows: buckwheat grains were washed, popped up and damaged ones were removed. The remaining grains were poured with water that underwent ultrasonic treatment for 20 min at the ultrasonic control machine (UCM) - 4.003 and the grains were kept at a temperature of (20 ± 2) °C for 2 hours. Then the excess water was removed and germination was continued until seedlings of 2 mm long appeared [15].

3.2 Elemental Composition Research
The elemental composition (macro- and microelements and heavy metals content) of the samples studied was determined on the Nexion 300 D quadrupole mass spectrometer and on the Optima 2000 DV atomic emission spectrometer (PerkinElmer, USA) by inductively coupled plasma mass
spectrometry (MS-ICP) and inductively coupled plasma atomic emission spectrometry (AES-ICP) at the autonomous non-profit organization "Center for Biotic Medicine" after Dr. A. V. Skalny (Moscow).

4. Results discussion

A comparative assessment of macro- and microelements content in the studied crops showed a difference in the elemental composition in flax seeds (linseed) and buckwheat grains before and after their germination (Table 1).

It was found out that in the germinated flax seeds (sample No. 2) the content of macronutrients such as calcium and phosphorus increased by 739 μg / g and 1128 μg / g respectively. The content of potassium and sodium decreased by 1767 μg / g and 279 μg / g respectively compared to sample No. 1 (native flax seeds). As to trace elements, an increase in iron (by 8.45 μg / g), silicon (by 7.22 μg / g), strontium (by 8.8 μg / g), zinc (by 10.12 μg / g), copper (by 1.97 μg / g) took place. The content of the following elements increased slightly: aluminum (by 0.6 μg / g), arsenic (by 0.01 μg / g), cadmium (by 0.01 μg / g), chromium (by 0.66 μg / g), manganese (by 0.42 μg / g), nickel (by 0.61 μg / g), palladium (by 0.612 μg / g), selenium (by 0.08 μg / g), tin (by 0.005 μg / g). A decrease in boron (by 4.03 μg / g), cobalt (by 0.01 μg / g), iodine (by 0.26 μg / g), lithium (by 0.01 μg / g) was noted. The amount of vanadium in the flax seed (linseed) germination process did not change.

Germinated buckwheat grains (sample No. 4) had more macroelements compared to native ones: calcium - by 4.2 times, potassium - by 1.1 times, sodium - by 33.3 times, phosphorus - by 1.2 times, magnesium - by 1.2 times, selenium - by 1.5 times. The trace elements content increased slightly (boron, iron, iodine, lithium, manganese, tin, strontium, zinc). The amount of aluminum, cobalt, chromium, nickel, silicon decreased.

Table 1. The elemental composition of germinated crops

| Element      | The content of elements in the samples, μg / g |
|--------------|-----------------------------------------------|
|              | native flax seeds | flax seeds germinated in magnetized water | native buckwheat grains | buckwheat grains germinated in ultrasonic treated water |
| Aluminum (Al) | 3.36±0.34         | 3.96±0.4                              | 2.09±0.21               | 2.08±0.25                                      |
| Boron (B)     | 17.73±1.77        | 13.7±1.37                              | 7.74±0.77               | 7.96±0.96                                      |
| Calcium (Ca)  | 1634±163          | 2373±237                               | 127±13                  | 534±64                                        |
| Cobalt (Co)   | 0.16±0.02         | 0.15±0.018                             | 0.008±0.012             | 0.05±0.011                                     |
| Chromium (Cr) | 1.24±0.12         | 1.9±0.19                               | 1.72±0.17               | 1.59±0.19                                     |
| Copper (Cu)   | 9.61±0.96         | 11.58±1.16                             | 4.67±0.47               | 5.46±0.66                                     |
| Iron (Fe)     | 75.53±7.55        | 83.98±8.4                              | 31.86±3.19              | 32.15±3.86                                    |
| Iodine (I)    | 1.08±0.11         | 0.82±0.099                             | 0.21±0.025              | 0.28±0.041                                    |
| Phosphorus (P)| 6643±664          | 4876±488                               | 3792±379                | 4005±481                                      |
| Lithium (Li)  | 0.06±0.009        | 0.05±0.007                             | 0.01±0.002              | 0.03±0.005                                    |
| Magnesium (Mg)| 3163±316          | 3366±337                               | 1983±198                | 2355±283                                      |
| Manganese (Mn)| 21.48±2.15        | 21.9±2.19                              | 15.07±1.51              | 16.95±2.03                                    |
| Sodium (Na)   | 506±51            | 227±23                                 | 4.26±0.43               | 142±17                                        |
| Nickel (Ni)   | 1.11±0.11         | 1.72±0.17                              | 1.75±0.18               | 1.6±0.19                                      |
| Phosphorus (P)| 4938±494          | 6066±607                               | 3937±394                | 4765±572                                      |
| Selenium (Se) | 0.07±0.011        | 0.15±0.018                             | 0.005±0.001             | 0.09±0.013                                    |
| Silicon (Si)  | 23.52±2.35        | 30.74±3.07                             | 8.86±0.89               | 6.56±0.98                                     |
| Tin (Sn)      | 0.005±0.001       | 0.01±0.002                             | 0.001±0.0003            | 0.003±0.0008                                  |
| Strontium (Sr)| 4.25±0.42         | 13.05±1.3                              | 0.38±0.046              | 2.09±0.31                                     |
| Vanadium (V)  | 0.04±0.006        | 0.04±0.007                             | 0.02±0.002              | 0.02±0.005                                    |
| Zinc (Zn)     | 43.65±4.37        | 53.77±5.38                             | 19.98±2                 | 23.33±0.5                                     |
The revealed differences in the content of macro- and microelements in the studied samples are due to the fact that during germination under the influence of their own enzymes of grain and seeds, hydrolysis of high molecular weight compounds occurs intensively, contributing to a change in the elemental composition [16].

The content of toxic elements in the process of germination decreased and was within the limits established by Technical Regulations of the Customs Union (TR CU) 021/2011 (Table 2). This is caused by their migration from the grain surface during washing with water treated with physical methods.

### Table 2. The content of crops toxic elements

| Toxic elements | Requirements of TR CU 021/2011, mg / kg, not more than | The content of toxic elements in the samples, μg / g |
|----------------|------------------------------------------------------|---------------------------------------------------|
|                | native flax seeds                                   | flax seeds germinated in magnetized water          | native buckwheat grains | buckwheat grains germinated in ultrasonic treated water |
| Arsenic (As)   | 0.2                                                 | 0.02±0.003                                         | 0.01±0.002             | 0.002±0.0004                                           | 0.001±0.0002 |
| Cadmium (Cd)   | 0.1                                                 | 0.09±0.013                                         | 0.09±0.012             | 0.02±0.002                                             | 0.02±0.004 |
| Mercury (Hg)   | 0.03                                                | <0.0036                                            | <0.0036                | <0.0036                                                | <0.0036    |
| Lead (Pb)      | 0.5                                                 | 0.008±0.0016                                       | 0.006±0.0014           | 0.007±0.0013                                           | 0.005±0.0013 |

### 5. Conclusion

Thus, the analysis of the results of studying the elemental composition of flax seeds (linseed) and buckwheat grains by inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry showed that the content of macro- and microelements, the physiological role of most of which in the human body is very significant, different in native and germinated grain crops.

Germinated seeds and grains have enormous energy potential, contain all the components necessary for life, possess a system that promotes their full digestion. All this proves their powerful healing effect on the human body. Therefore, the results obtained allow us to recommend the use of flax seeds (linseed) and buckwheat grains germinated with water treated in various ways in the manufacture of bakery products to prevent various diseases and improve the population life quality.

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