Development of technology for hydrothermal processing of oat grain

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Abstract. The paper presents technical solutions aimed at increasing efficiency of technological process for obtaining food concentrates using oat flour made from grain that has undergone hydrothermal treatment. The technology for oat flour production with a high content of biologically active substances provides for the stage-by-stage (complex) processing of oat grain, including cleaning, hydrothermal treatment of grain, further hulling and grinding. The paper describes the author's resource-saving technology and new developed equipment, which provide for hydrothermal treatment of grain crops with removal of stagnant zones in the working volume of the chamber due to continuous mixing of grain using a screw winding, which is repeating an oval shape in the body cross-section, and equal distribution of the steam mixture due to the steam distributing jacket of the body and steam manifolds mounted on the auger shaft. The authors carried out comparison of the developed resource-saving technology with the existing technology of grain preparation for peeling, which has found wide application at grain processing enterprises. Based on the studies carried out, the main solutions have been identified, the introduction of which increases the efficiency of using hydrothermal treatment to 100%, increases the yield of whole grain in the peeling process by 90-96%, and reduces the amount of waste in the form of crushed grain by 4-6%. The developed technology and equipment are intended to be introduced into production schemes for processing grain seeds for mini-shops on the territory of the Krasnoyarsk Territory. It was found that the use of the developed resource-saving technology and new equipment reduces the cost of hydrothermal treatment of oat seeds, in comparison with existing technologies, up to 8-10%.

1. Introduction
In natural and climatic conditions of the Krasnoyarsk Territory, oat is one of the main grain crops, it is unpretentious to weather conditions, and begins to germinate even at temperature of -5 degrees Celsius, which gives certain advantages when sowing this crop in Eastern Siberia. In 2020, 4132.0 thousand tons of oat were collected from the fields of the Krasnoyarsk Territory [1].

Oat grains are widely used in food products such as whole oats, rolled whole groats, and a wide variety of oat flakes and instant food concentrates.

Modern food production technologies provide for the widespread use of berry raw materials to expand the production range of functional food products. Earlier, the authors found [2] that the Arctic zone territory and the northern areas of the Krasnoyarsk Territory has huge reserves of wild berries, which must be rationally used in the technological processes of food production, including the use of grain crops as raw materials.

According to existing technologies, oat processing begins with preliminary grain cleaning in a grain cleaning shop to remove weed and grain impurities, then the refined grain enters the hulling shop, where
fractional hulling takes place and its further separation into hulling products in a sifter, in an air separator and on a paddy machine with subsequent grinding. The control over production of finished non-crushed oatmeal is carried out in sifting, air and magnetic separators [3]. This technology, which is used by most of the cereal and flour-grinding industries in Russia, requires the use of a large number of energy-intensive machines to perform working operations, which leads to duration of the technological process and an increase in production cost.

In the process of modern development of grain processing enterprises, we reveal tendencies towards further improvement of grain processing technological processes. The actual problem at the present time for oat processing remains development of resource-saving and energy-saving technologies using small-sized and combined equipment, combining performance of several working operations in one machine. Such a combination of working operations in one technological complex is in demand by farms and small producers of cereals with small volumes of oats processing. It is very important to take into account the fact that the quality must comply with All Union State standard 3034-75 [4].

Decker, E.A., Rose, D.J., Hu X., Xing X., and others, have addressed the nutritional issues of oat grain in their work, as it contains an excellent lipid composition and a large amount of soluble fiber, however, oat kernel in is largely indigestible and, therefore, should be used steamed and grind ed [6]. Grinding consists of many steps, the most important of which are peeling to improve the digestible properties of the cereal, heat treatment to inactivate the enzymes that cause rancidity, and cutting, rolling or grinding. Oat can also be processed into functional products to obtain fractions with a high fiber content [7].

Previous research by scientists in the technology of oat grain processing recommended using grain steaming as a hydrothermal treatment to achieve the best technological effect. The use of steaming can increase the yield of whole grains, as well as increase its nutritional value and lengthen the shelf life of finished food products [8].

However, this technological process is energy-intensive due to the use of additional equipment for obtaining saturated steam, which entails an increase in financial costs and production costs. In addition, long-term hydrothermal treatment of oats with saturated steam does not have the best effect on biochemical changes in the grain composition, changing the ratio of biologically active substances downward. To achieve high biochemical parameters, it is necessary to change the modes of hydrothermal treatment, which can be achieved by changing the technological process and using new equipment: new developed design of a combined peeler that eliminates the identified shortcomings of commercially available equipment.

2. Problem statement
Development of technologies and new hydrothermal equipment for the stage-by-stage (complex) processing of oat grain using wild berry raw materials from the northern territories of the Krasnoyarsk Territory and the Arctic zone in production of functional food products.

3. Research questions
The technologies for hydrothermal processing of oat grain can be applied at grain processing enterprises of various production capacity, and development of small enterprises in the Krasnoyarsk Territory for the functional food production using oat flour required the implementation of scientific and technical work related to the study of hydrothermal processing of grain and grain mixtures with the addition of berries from northern and Arctic zones of the Krasnoyarsk Territory, and studying the technical possibilities of using the existing serially produced equipment. It has been established that one of the ways to solve the problem of further development of the Arctic zone and the northern territories of the
Krasnoyarsk Territory is to involve large reserves of wild-growing raw materials in economic circulation with developed technologies using patented specialized equipment for obtaining functional food products.

4. Purpose of the study
The purpose of the study is to develop technologies and new specialized equipment for the production of food products of increased nutritional value based on oat grain using wild plant raw materials from the Arctic zone and the northern territories of the Krasnoyarsk Territory.

5. Research methods
During the research, the authors used methods of comparative analysis, experimental research, mathematical modeling and patent research on international and Russian information bases, the content and procedure of which is determined by All Union State Standard R 15.011-96 “System for the development and launch of products into production” [9].

To determine possible influence of hydrothermal treatment parameters on change in the physicochemical parameters of the grain in the samples under study, the qualitative parameters of the grain, such as moisture content, the content of proteins and starch, were determined.

As a result of the research, the technology of oat grain processing into cereals was modernized, the technology of grain peeling was studied, patent studies were carried out, as a result of which prototypes and analogues were selected, which are used in the development of technical solutions for machines for calibration, hydrothermal treatment and peeling of grain, also experimental laboratory studies of application of the brush-vortex mechanism of grain hulling was carried out, mathematical processing to substantiate the technological parameters of oat grain hulling was performed.

6. Findings
The new developed technology for hydrothermal treatment of oat grain, based on equipment, the novelty of which is confirmed by patents of the Russian Federation, provides at the first stage for cleaning and calibrating oat grain in the “Device for calibrating seeds of plant origin” (the patent of the Russian Federation No. 2695870). In the process of calibration, grain enters the inside of the housing, where there is an equal distribution of grain over the entire inner surface of the drums, when the drums rotate, the grain mixture is evenly distributed into fractions from coarse grain to fine grain and grain heap, and the grain heap with the remnants of trash is removed into the pallet located under the device for calibrating seeds of plant origin [10].

Oat grain, calibrated by fractions, goes for hydrothermal treatment in the “Device for steaming grain”, the novelty of which is confirmed by the patent of the Russian Federation No. 2699190 [9]. The kinematic diagram of which is shown in Figure 1.

![Figure 1. Kinematic diagram of the device for steaming grain](image-url)
The developed technology of oat grain hydrothermal treatment is carried out by loading oat grain into a receiving housing 5, which has a feed auger 6 mounted on a drive shaft 4 connected through a coupling 3 with a shaft 2 and an electric motor 1. The oat grain is moved by means of a screw 6 inside the housing 8 made in the shape of an oval in cross-section and having a steam distribution jacket 7. The grain entering the inside of the housing 8 is moved and mixed with the help of the screw 11 repeating the shape of the housing 8 to remove stagnant zones during hydrothermal treatment, while the oat grain is continuously processed with steam supplied from the steam generator 14 through the steam pipeline 13 and through the holes 10 made in the hollow shaft 9 and the holes in the steam distribution jacket 15 inside the housing 8. The grain that has undergone hydrothermal treatment by a screw 12 is unloaded from the device along a discharge pipe 16 to the next technological operation [11].

Previous studies by the scientists Anisimova L.V., Abramov S.Yu. [12] recommended the use of oats hydrothermal treatment of in steaming grain in a continuous screw steamer with a processing time of 8 to 15 minutes, with an increase in swelling by 1.5 times.

According to the results of laboratory experimental studies, it was found that all 100% of oat grains undergo hydrothermal treatment, due to multidirectional steam flows on the grain and the absence of “stagnant zones” in comparison with commercially available equipment, while the efficiency of hydrothermal treatment increases to 100%, the yield of crushed grain decreases to 4-6% and the yield of whole grains increases to 90-96%.

The laboratory analysis of the chemical composition of hydrothermal treated oat grain is presented in Table 1.

| No. | Temperature of hydrothermal processing, °C | Humidity, % | Proteins, % | Polysaccharides, % | Lipids, % | Duration of hydrothermal processing, min |
|-----|------------------------------------------|-------------|-------------|--------------------|-----------|----------------------------------------|
| 1   | 0                                        | 10.82       | 14.73       | 33.71              | 3.44      | 0                                      |
| 2   | 70                                       | 12.44       | 13.72       | 46.42              | 3.05      | 5-15                                   |
| 3   | 70                                       | 14.54       | 12.10       | 48.25              | 2.84      | 20                                     |
| 4   | 70                                       | 15.62       | 11.63       | 52.39              | 2.80      | 25                                     |
| 5   | 70                                       | 15.87       | 10.69       | 58.11              | 2.62      | 30                                     |

As a result of laboratory studies, and analysis of the results obtained in Table 1, it can be concluded that with an increase in the time of hydrothermal treatment, the moisture content increases by 5.05% within 30 minutes, the percentage of proteins and lipids in oat grain decreases by 4.04% and 0.82%, respectively, which is associated with the processes of protein denaturation and lipid esterification, which significantly affect the nutritional value of the final product from oat grain. The amount of polysaccharides, on the contrary, increases due to the duration of the hydrothermal treatment process, since the process of gelatinization occurs, followed by swelling, which ensures the rapid assimilation of the formed sugars.

7. Conclusion
The results of the studies carried out on the hydrothermal processing of oat grain showed that the developed technology and new technological equipment make it possible to carry out a full-fledged 100% processing of all incoming grain and at the same time full disclosure of the outer fruit shells occurs, which ensures the peeling efficiency up to 90-96% and reduces the yield of crushed grain from 4 to 6%. Hydrothermal treatment of oat grain affects not only the chemical composition, but also the nutritional value, which must be taken into account when formulating functional products.
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