DEVELOPMENT OF THE METHOD OF OBTAINING GRAIN FLAKES USING UV-IRRADIATION

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Abstract. *The method of obtaining flakes of increased biological value from grain crops has been developed. This method includes preparation of grain for processing, which involves cleaning grain from impurities, sorting, airing, separation of ferromagnetic impurities, washing and disinfection, peeling, hydrothermal treatment at a temperature of 12 - 16° C. Hydrothermal treatment takes place in three cycles, each of which involves intensive moistening of the grain for 4 hours followed by dehydration for 4-6 hours with a total duration of 26 - 30 hours. After the first cycle, the grain is treated with ultraviolet radiation with constant stirring. The thickness of the grain layer is 15 - 20 cm. The wavelength of ultraviolet radiation 250 - 300 nm; radiation intensity is 200 - 260 W/m^2. The distance from the grain placement plane to the radiation source is 25 - 30 cm, process duration 55 - 60 sec. The next stage is flattening of raw materials, drying of the flakes at a temperature of 45 - 65° C to a moisture of 12 - 14%, airing, packing.*

The main physico-chemical and organoleptic indicators of quality of wheat flakes of increased biological value are investigated. The nutritional value of the product is determined. It was investigated that the microbiological seedability of wheat flakes does not exceed the permissible values. Storage for 6 months does not significantly impair quality.

The developed method of processing cereals for producing flakes allows to obtain a product with high biological value, namely, an increased content of water-soluble and fat-soluble vitamins, in particular, the content of vitamin E is 8.5 mg%, B_1 - 1.12 mg%, B_2 - 1.15 mg%; content of food fibers, which are natural food sorbents - 2.5%.

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Introduction. One of the leading branches of the agro-industrial complex of Ukraine is the grain processing industry, the urgent issue of which is the improvement of existing and the development of new methods for the preparation of grain materials for the production of food products, in particular, increased biological value.

Currently, there are a large number of ways for processing cereals, which are characterized by certain advantages and disadvantages. It is worth noting that methods that would contribute to the maximum preservation and accumulation of biologically active grain compounds are quite small.

One of the promising ways of improving the quality of raw materials is the use of physical methods of exposure, in particular UV-irradiation. Ultraviolet radiation treatment is used in pre-sowing treatment of grain and seeds of agricultural crops in order to reduce the influence of phytopathogenic microflora, stimulate the processes of seed life, create environmental prerequisites for plant protection during the growing season.

In the process of processing with ultraviolet radiation, the absorption of photons by matter occurs. Energy conversion in biological objects occurs in stages: absorption of a photon by a molecule and transfer of energy to another molecule. One form of conversion of absorbed energy of optical

radiation is photobiological action - change of biological state of structures of living organism. Thus, when treated with ultraviolet radiation, intracellular metabolic processes are activated both in the grain and in the seedling. Short-term treatment with wave ultraviolet radiation increases the indicators of the physiological fullness of grain, such as energy and the ability to germinate, germ viability by 10 - 15%, which leads to activation of synthesis of biologically active compounds - vitamins, vitamin-like substances, etc. In addition, ultraviolet radiation treatment contributes to a significant decrease in the level of external and internal phytopathogenic microflora, provides disinfection of grain, increases consumer qualities and shelf life of cereal processing products.

UV-irradiation of grain for 5 - 6 hours using a wavelength of 254 nm can serve as an ecological friendly and safe method of sterilization, relative to the microbiological purity of raw materials (Hidaka et al., 2006).

A number of authors who investigated the effect of UV-irradiation of wheat grain on its sowing qualities using mercury-quartz lamps or other emitters note the activation of the antioxidant system of grain under the action of physical influence, as well as an increase in the ability to germinate (Araújo, et al., 2016; Wang et al., 2012).

Scientists have studied that UV-irradiation with doses of 120 J/м^2 of rapeseed seeds increases the germination energy by 15%, compared to control samples; increased hydration of raw materials was also noted (Semenov, et al., 2021). It is noted that treatment with ultraviolet radiation for 5-60 minutes of seeds of peanuts and mung beans contributes to the improvement of growth parameters (Siddiqui A. et al., 2011).

UV radiation treatment is proposed by scientists as an ecological technology for changing the characteristics of wheat flour. It is noted that irradiation of wheat flour with UV-C radiation (254 nm) of different radiation power and exposure time affects the change in physical and chemical properties (water-binding capacity, content of amylose, reducing sugar, sulfhydryl (SH), disulfide (SS) groups (Kumar A. et al., 2020).

It has been investigated that UV treatment of raw materials causes the accumulation of phytochemicals, including ascorbic acid, carotenoids, glucosinolates and phenolic compounds (Darré M. et al., 2020). Among UV-C ranges, light at 253.7 nm is recognized as an effective and safe technology for food disinfection (Monteiro M.L.G. et al., 2022) it is the most effective against microorganisms, since at this wavelength the highest absorption of light by microbial nucleic acids occurs (Koutchma T., 2019). In the literature there is no data on the possibility of producing flakes based on biologically activated wheat grain using UV-irradiation of grain.

Materials and Methods. The purpose of our work was the scientific and practical substantiation of the method of producing flakes of increased nutritional value based on grain crops, which involves the use of UV-irradiation of grain in the process of its biological activation.

To achieve the goal, it was set to solve the following tasks:

- to develop and scientifically substantiate a method for producing flakes of increased biological value;
- to investigate the influence of the processing mode on the content of vitamins in the grain;
- research the main quality indicators of wheat flakes;
- to investigate indicators of microbiological stability of flakes;
- determine the nutritional value of wheat flakes.

During experimental studies, wheat grains, varieties Odeska 267, harvests 2021 were used; produced samples of flakes. The moisture of the test samples was determined by drying to a constant mass at a temperature of 105°C. Protein content was determined by Bradford, starch by polarimetric method. Fat was determined by exhaustive extraction with chemically pure hexane. Vitamin E is determined colorimetrically; B_1, B_2 – fluorometrically; fiber – by acid hydrolysis. Vitamin C was determined by titrometric method. The method is based on the extraction of vitamin C from the test sample with a solution of acid (hydrochloric, metaphosphoric or a mixture of acetic and metaphosphoric), followed by titration visually or potentiometrically with a solution of 2,6-dichlorophenolindophenolate sodium.

The wavelength of ultraviolet radiation characterizes the active factor. Three regions can be distinguished from the biological activity of ultraviolet radiation: UV-A (380 - 315 nm) - it has relatively little biological activity; UV-B (315-280 nm) - has a stronger effect on biological objects; UV-C (280 - 100 nm) - harmful effect on humans and plants (Bjorn L.O., 2015). Therefore, the ultraviolet wavelength 320 - 290 nm is selected for processing the grain mass in the proposed method, such an effect provides the desired effect.

Treatment with ultraviolet radiation of native dry grain with a moisture of 10 - 14%, in which biological processes are not active, is not advisable to increase its biological value, in particular, the content of vitamins and vitamin-like substances. In the grain, which is hydrothermal treatment at low temperature conditions, enzymatic processes are activated, which stimulate the synthesis of biologically active substances, ultraviolet radiation treatment significantly intensifies these processes. Therefore, for the efficiency of ultraviolet radiation treatment, the grain is pre-intensively moistened to the moisture of the 18 - 24%.

Microbiological indicators of the mixture of flakes were determined in finished samples, the moisture of which was 11 - 12%. To this end, the test samples were seeded superficially on agarized nutrient media: meat-peptone agar (detection of mesophilic aerobic and facultative anaerobic microorganisms - MAFAnM), wort-agar (yeast and fungi). Plates with crops were incubated for 2 - 3 days at a temperature of 37°C to set the total amount of m/o (MAFAnM). Cultures on plates with wort-agar medium for detection of fungi and yeast were incubated at a temperature of 28°C for 5 - 7 days.

Object and subject of research. The object of research is a method of obtaining flakes of health-improving purpose from wheat grain. The subject of the study is the content of vitamins in wheat grain prepared according to the proposed method; nutritional value and microbiological indicators of flakes.

Results and Discussion. We have proposed a method of obtaining flakes of increased biological value from wheat grain. The initial stage includes grain preparation for processing, which involves cleaning the grain from impurities, sorting, airing, separation of ferromagnetic impurities, washing and disinfection. Next, the grain husking process is carried out. The next stage is hydrothermal treatment of the prepared raw materials at a temperature of 12 - 16ºC in three cycles, each of which involves intensive moistening of the grain for 4 hours with subsequent dehydration for 4 - 6 hours followed by dehumidification with a total duration of 18 - 30 hours. Due to the activation of the enzyme complex, biological changes occur in the grain structure, it begins to germinate, is in the so-called "awakened state", the grain is biologically activated.

After the first cycle, the grain is treated with ultraviolet radiation with constant stirring, grain layer thickness 15 - 20 cm, ultraviolet radiation wavelength 250 - 300 nm; radiation intensity 200 -

260 W/м^2, distance from grain placement plane to the radiation source 25 - 30 cm, process duration 55 - 60 sec.; flattening, drying flakes at a temperature of 40 - 45° C to a moisture of 12 - 14%, airing, packing.

The intended process of grain peeling provides for the use of this method for film crops - oats, barley, rye, millet, buckwheat, etc.

The effect of biological activation, which is combined with UV irradiation, on the content of vitamins in wheat grain, was investigated, Table 1.

Table 1.

Effect of treatment regimen on vitamin content in wheat grain

№	Grain moisture, after hydrothermal treatment, %	Distance from grain to irradiation source, cm	Vitamin content in wheat grain, (mg%) after hydrothermal treatment and ultraviolet radiation treatment				Conclusions
			C	B_1	B_2	E	
1	12.2±0.4 Control (native grain)	20	2.52± 0.14	0.22± 0.01	0.12± 0.02	0.32± 0.03	A small increase in vitamins, compared to the initial amount.
2	18.3±0.1	25	4.25± 0.03	0.70± 0.01	0.65± 0.01	9.85± 0.01	The content of vitamins in the grain after processing increased 1.5 - 3 times, vitamin E - 30 times compared to the initial amount.
3	20.5±0.3	28	6.20± 0.04	0.93± 0.01	1.01± 0.02	11.5± 0.04	The content of water-soluble vitamins in the grain after hydrothermal treatment increased by 2 - 4 times, vitamin E - 35 times compared to the initial amount.
4	24.3±0.2	30	6.00± 0.03	1.12± 0.01	1.15± 0.01	12.30 ±0.02	The content of water-soluble vitamins in the grain after hydrothermal treatment increased by 2 - 4 times, vitamin E - by 38 times compared to the initial amount.
5	30.6±0.5	35	4.00± 0.06	0.80± 0.03	0.85± 0.01	10.20 ±0.06	Decrease in vitamin content

Thus, the proposed method of processing cereal crops on a flake allows to increase the biological value of the grain, in particular the content of vitamins, and, accordingly, the consumer qualities of flakes from it.

It has been experimentally established that ultraviolet irradiation of grain, which underwent preliminary intensive moistening for 4 hours and dehydration for 4 - 6 hours, stimulates physiological indicators, in particular energy and germination ability, viability of the embryo, intensifies the processes of synthesis of vitamins and vitamin-like substances in the grain. It has been found that irradiation of the grain for longer than 60 seconds is undesirable due to excessive overheating of the grain, which negatively affects the biological activation process. Thus, with ultraviolet irradiation 70 - 80 seconds indicators of physiological value of grain are reduced by 15 -20%, with the effect of ultraviolet irradiation 80 - 100 seconds - by 25 - 30%. It has been investigated that the optimal duration of the ultraviolet radiation treatment process is 55 - 60 seconds.

The optimal distance from the grain placement plane to the infrared radiation source is 25-30 cm, (Table 1). At the same time, the wavelength of ultraviolet radiation is 250-300 nm; radiation intensity – 200 - 260 W/m^2. Under such influence, the desired effect of increasing the physiological fullness of the grain is achieved, as well as intensification of the synthesis of vitamins and vitamin-like compounds; that is, higher power is impractical, energy consumption increases.

Experimentally, it was found that for uniform treatment with ultraviolet irradiation with constant mixing of the entire grain mass, the thickness of the grain layer should not exceed 15 - 20 cm.

Under laboratory conditions, an experimental batch of flakes of increased biological value from wheat grain was produced according to the developed method.

The main physical and technological indicators of wheat flakes quality are determined (Table 2).

Table 2

Physical and technological quality indicators of wheat flakes

№	Indicator	Wheat flakes
1	Moisture, %	11.5±0.3
2	Volumetric mass, g/cm^3	441.5±0.3
3	Average particle size, mm	6.3±0.1
4	Angle of natural inclination, deg	65.5±0.2
5	Sliding angle on metal, deg	18.5±0.3
6	Actual density, g/cm^3	462.3±0.2
7	Cohesiveness	1.4±0.1

Wheat flakes have a permissible moisture value. The average particle size of the flakes depends on the grain size and is within the range acceptable for grain-based foods. Values of volumetric mass and actual density indicate the high quality of this grain product. Optimal values of cohesiveness of wheat flakes characterize their ability to move freely during unloading from containers and during transportation.

The organoleptic indicators of the quality of wheat flakes of increased biological value were investigated, Table 3.

Table 3

Organoleptic indicators of wheat flakes

Indicator	Received data
Appearance of flakes	Oval-shaped flattened grains up to 1.2 mm thick
Color	Creamy white
Taste and smell	Inherent in wheat cereals without an extraneous taste and smell and signs of musty and mold
Consistency after cooking	The grains are completely swollen, well boiled, and stick together a little
Taste and smell after cooking	Inherent in wheat grain processing products without an extraneous taste and smell

It has been experimentally established that cereal flakes of increased biological value have acceptable organoleptic indicators, which makes it possible to predict consumers' demand for these products.

The nutritional value of wheat flakes obtained according to the developed method was studied (Table 4).

Table 4.

Characteristics of the nutritional value of wheat flakes

Product sample	Energetic substances,%			Dietary fiber,%	Vitamin content, mg%			Energy value, kcal
	Proteins	Fat	Carbo-hydrates		E	B_1	B_2	
Wheat flakes	12.8 ±0.3	1.5 ±0.1	68,5 ±0.3	2.52 ±0.06	8.54 ±0.02	1.12 ±0.01	1.15 ± 0.03	338

The developed method of processing cereals for production of flakes allows to obtain a product with high biological value, namely, increased content of water-soluble and fat-soluble vitamins and vitamin-like compounds, minerals, dietary fibers, in terms of the content of the main energy-generating substances, wheat flakes are not inferior to traditional grain products.

We investigated the microbiological resistance indicators of wheat grain flakes prepared according to the developed method. Fresh dried flakes were used for determination, as well as those stored for 6 months, Table 5.

Table 5.

Microbiological indicators of wheat flakes produced according to the developed method

Microbiological indicators	Cereal flakes, normative value	Wheat flakes after drying	Wheat flakes after storage for 6 months
MAFAnM, KFU/g, no more	$5 \cdot 10^4$	$1 \cdot 10^2$	$5 \cdot 10^2$
Molds fungi, KFU/g, not more	$1 \cdot 10^3$	Not found	Not found
Pathogenic microorganisms, including bacteria of the genus *Salmonella*, in 25 g	Not allowed	Not found	Not found
Bacteria of the group of *E. coli (coliforms*), in 0.1 g	Not allowed	Not found	Not found
Sulfite-reducing clostridia, in 0.01 g	Not allowed	Not found	Not found

As a result of the conducted studies, it was found that the microbiological seedability of flakes made on the basis of biologically activated wheat grain does not exceed the permissible values. Storage for 6 months does not significantly impair the quality, such grain products are safe from the point of view of microbiological purity.

Conclusions. Wheat flakes produced on the basis of grain prepared by the developed method are a product of health-improving purpose. Biologically activated cereals and, in particular, wheat, are valuable raw materials for the production of innovative food products for functional, health and therapeutic and preventive purposes. The developed method of processing cereals for producing flakes allows to obtain a product with high biological value, namely, an increased content of water-soluble and fat-soluble vitamins, in particular, the content of vitamin E is 8.5 mg%, B_1 - 1.12 mg%, B_2 - 1.15 mg%; content of food fibers, which are natural food sorbents - 2.5%. In terms of the content of basic energogenic substances, wheat flakes are not inferior to traditional grain products.

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