The modes to produce flattened spelt groats using an electromagnetic field of ultrahigh frequency have been scientifically substantiated. The influence of the duration of irradiation by the field of ultrahigh frequency and water heat treatment on the temperature, yield, and duration of flattened spelt groats cooking was investigated.

When irradiated with a field of ultrahigh frequency from 20 to 180 s, the minimum temperature of the product is 27–128 °C, and the maximum temperature is 43–159 °C. Treatment with a field of ultrahigh frequency from 20 to 100 s does not significantly affect the total yield of groats from spelt. The total yield, in this case, is 94–97 %. At the irradiation with a field of ultrahigh frequency from 120 to 180 s, the total yield of groats is significantly reduced to 83–90 %. Treating with a field of ultrahigh frequency for 100–180 s significantly reduces the duration of flattened groats cooking. The duration of cooking groats, in this case, is 14.0–15.8 minutes. It should be noted that water-heat treatment reliably reduces the duration of cooking flattened groats compared to the option without moistening.

The peculiarity of the technology to produce flattened groats from spelt wheat using the field of ultrahigh frequency is that whole groats must be irradiated for 60–80 s with moistening by 1.0–1.5 %. Under this mode, the total yield of groats is 94–97 %, and the duration of cooking groats is 14.3–15.9 minutes. Subject to the production of flattened groats of the highest grade, it is necessary to irradiate with a field of ultrahigh frequency for 80 s without water-heat treatment. Under such a mode, the yield of flattened groats of the highest grade is 80 %, and that of the first grade is 13 %. The duration of cooking such groats is 16.8 minutes.

The recommendations from this study could be used by small-scale grain processing enterprises in order to produce flattened groats

Keywords: electromagnetic field, groats, wheat spelt, culinary quality, water-heat treatment

UDC 641.53.092:683.958:664.71-11
DOI: 10.15587/1729-4061.2022.262102

IMPROVING ELECTROMAGNETIC FIELD EXPOSURE REGIMES IN THE PRODUCTION OF FLATTENED SPELT GROATS

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Received date 01.06.2022
Accepted date 05.08.2022
Published date 30.08.2022

***How to Cite**: Liubych, V., Mostoviak, I., Novikov, V., Leshchenko, I., Belinska, S., Kirian, V., Tryhub, O., Pykalo, S., Petrenko, V., Tverdokhlib, O. (2022). Improving electromagnetic field exposure regimes in the production of flattened spelt groats. Eastern-European Journal of Enterprise Technologies, 4 (11 (118)), 15–22. doi: https://doi.org/10.15587/1729-4061.2022.262102*

1. Introduction

The objective prerequisite for creating a competitive environment in the modern food market is an increase in the number of potential consumers. A sufficient level of their solvency, and modernization of technological equipment, which can significantly reduce the cost of the finished product [1]. Human nutrition is an important issue because it involves a significant number of factors. These include the type of raw materials and techniques for changing their physicochemical properties during processing [2].

The most common raw material in the food industry is a cereal grain, in particular, soft wheat [3]. It is recognized [4] that soft wheat is the dominant crop in temperate countries. It serves as the main raw material for a wide range of foods. Soft wheat grain is used to produce bakery, confectionery, pasta, groats, etc. Consumption of soft wheat grain processing products allows the body to provide biologically active substances, dietary fiber, and essential amino acids. In addition, soft wheat processing products have high culinary quality, which is a significant advantage.

Given the high level of consumption of soft wheat products in the world, special attention is paid to their anti-nutritional properties. It is proven that wheat grain processing products can be a prerequisite for the development of autoimmune diseases [5]. Safer for consumption are those products that are made from other sparsely distributed types of wheat, in particular spelt [6].

The range of cereal products and food concentrates is wide. Groats products differ in shape and physical properties. Modern consumers give greater preference to cereal products with high culinary characteristics and a minimum cooking time. These products include crushed groats and flattened groats [7]. Potentially attractive to the consumer are flattened groats, due to a combination of high culinary quality and minimal cooking time. However, the production technology of flattened groats is characterized by increased material consumption due to the use of grain steaming and its flattening. The steaming process requires the additional involvement of heat carriers, the installation of steam generators, and the arrangement of steam supply lines to the production premises. For small-scale enterprises, these production requirements are associated with critical risks of investment [8]. The solution to this problem is the use of alternative sources of thermal energy, in particular the electromagnetic field of ultra-high frequency currents. There are other technological advancements regarding the use of alternative methods of thermal or chemical treatment, which are being introduced into production today [9].

Scientific research related to studying alternative types of energy and ways to expand the range of cereal products from wheat grain is important for producers and small farms. The results of such studies are needed in practice since they provide an opportunity to modernize existing cereal workshops. The use of alternative energy sources will make it possible to intensify the industrial production of flattened groats. The use of rare types of raw materials will make it possible to significantly expand the range of finished products. Thus, the establishment of links between the technical indicators of cereal production when using alternative types of thermal energy, as well as the studies into the culinary quality of the resulting products, are relevant tasks.

2. Literature review and problem statement

Spelt grains are used to produce high-quality products [10]. Thus, bread made from spelt flour is used all over the world but most of all in Switzerland. In Italy, they are used to produce pasta and as a substitute for rice [11]. It is proved that grain products from spelt have sensory properties at the level of the best varieties of soft wheat or even higher [12]. However, the research did not examine the issue of the influence of technological parameters on the yield and quality of finished products.

Work [13] reports the results of studying the use of spelt flour to produce high-quality bread, confectionery, and pasta. However, the cited study was aimed at developing methods for identifying the genes of spelt to detect counterfeit.

Study [14] shows the effect of irradiation of wheat grain with a field of ultrahigh frequency. It was shown that irradiation with small doses had a positive effect on the germination and germination energy of soft wheat grain. At the same time, the germination rate increased to 100 %. However, the recommended modes cannot be used to produce groats because the technological properties of objects are different.

Other results indicate that electromagnetic field treatment of ultrahigh frequency (600 W, 30 s) may contribute to an increase in the content of total flavonoids, reduced sugars, and soluble protein [15]. It was found [16] that the treatment with an electromagnetic field of ultrahigh frequency stimulates the activity of enzymes to promote the germination and accumulation of active substances in the seeds of groats. Study [17] has shown that an ultra-high frequency electromagnetic field can enhance the activity of antioxidant enzymes, including peroxidase, ascorbate peroxidase, and glutathione peroxidase. It has also been demonstrated that electromagnetic field treatment of ultrahigh frequency is effective in promoting an increase in the activity of α-amylase [18]. It was found that the treatment of oat seeds (*Avena sativa* L.) with an electromagnetic field of ultrahigh frequency contributes to the activity of nitrate reductase and glutamine transferase and inhibits the activity of proteolytic enzymes and ribonuclease [19]. It was also found that irradiation with an electromagnetic field of ultrahigh frequency for 5–25 s can increase the activity of α-amylase [20]. It is evident that such changes will take place in products that are exposed to the electromagnetic field.

The advantage of using an ultra-high frequency electromagnetic field is a decrease in the number of microorganisms in products. It is believed that the mechanism of inhibition of microorganisms is based on the effects of internal heating, which leads to the denaturation of proteins, enzymes, and nucleic acids [21]. Under optimized conditions, the growth of microbes on the grain can be completely suppressed without compromising its quality [22]. A study showed that the processing of crops can effectively inhibit the germination of spores of aflatoxin-producing fungi (*Aspergillus spp.*) [23]. Consequently, the use of an ultra-high frequency electromagnetic field during the production of groats will contribute to obtaining a product that is clean from microbes.

The influence of processing modes of groats and legumes in the electromagnetic field of ultrahigh frequency currents was investigated in [24]. Reasonable are the recommendations for the introduction of the stage of grain processing in the electromagnetic field of ultrahigh frequency currents as an analog of classical fumigation methods. This type of processing significantly reduces the disinsection time and has a continuous effect, which is beneficial for use for automating primary processing processes and increasing their efficiency.

The effectiveness of grain processing in microwave radiation for the destruction of pests is considered in [25]. The links between the power of electromagnetic radiation and the mortality of pests have been established, and recommendations for the introduction of the processing stage in the electromagnetic field of grain have been provided.

The modes of application of the electromagnetic field of currents reported in works [24, 25] cannot be used to produce flattened groats since they are designed for the disinfection of grain. The technological regime of irradiation with an electromagnetic field of ultrahigh frequency for flattening is different.

Various genotypes of ancient wheat in the formation of bread quality is investigated and analyzed in [26]. The results indicate variability of final characteristics of bread made from ancient wheat while the attributes of bread produced from modern wheat varieties had signs of homogeneity. However, the results of research on the formation of the quality of grain products from spelt are not enough. In addition, the results of the influence of technological parameters on the yield and quality of products are not highlighted. Such conclusions do not apply to cereal products.

Consequently, spelt grain is in demand for the production of high-quality foods. The use of ultra-high frequency electromagnetic field irradiation has advantages in food technologies. At the same time, the influence of its regimes on the yield and quality of flattened spelt groats has not been studied in detail. Therefore, it is expedient to devise modes for the use of an electromagnetic field of ultrahigh frequency in the production of groats from spelt.

3. The aim and objectives of the study

The aim of this study is the scientific substantiation of the modes of production of flattened spelt groats using an electromagnetic field of ultrahigh frequency. The results could provide an opportunity for the practical application of an electromagnetic field of ultrahigh frequency in the production of flattened spelt groats. The expected practical results from the implementation of the recommendations are the expansion of the range of cereal products and minimization of fixed asset costs during the moderation of existing production or when launching a new one.

To accomplish the aim, the following tasks have been set:

– to investigate the effect of water-heat treatment on the temperature of the intermediate product;

– to determine the effect of water-heat treatment on the yield of groats and related products;

– to determine the influence of modes of water-heat processing of groats on the duration of preparation of the finished product;

– to substantiate the rational parameters in the production of groats from spelt.

4. The study materials and methods

4. 1. The study's object and hypothesis

The chosen object of this study is cereal production technology. Our hypothesis assumed a probable influence of the duration of the processing of flattened spelt groats in the electromagnetic field of ultra-high frequency currents and their preliminary moistening on the yield of groats. The electromagnetic field of ultrahigh frequency currents has the greatest effect on water molecules. Therefore, it was expedient to identify possible changes in the culinary quality of groats under different modes of water-heat processing. To simplify the research, the average values of the duration of moistening of groats (30 min) and the power of the electromagnetic field were selected.

4. 2. Raw materials to produce flattened spelt groats

To produce groats, the Golikivska variety spelt, grown under the controlled conditions of the left-bank forest-steppe of Ukraine, was used. The samples were obtained in 2021. The main part of our research took place in Q4'2021. Post-harvest processing of grain involved its cleaning from impurities that differed in geometric and aerodynamic indicators. Next, the finished grain was stored under controlled conditions. Moisture content of grain during storage, 12.0±0.2 %; protein content, 14,3±0,3 %; vitrescence, 95±2 %.

4. 3. Program, methodology, equipment

Flattened groats were obtained by processing groats No. 1, obtained in the laboratory. To produce groats No. 1, spelt grain was peeled for 80 s in the shock-washing machine USHZ-1, Ukraine. The resulting peeling products were separated at the laboratory screen RLU-1, Ukraine. The resulting groats No. 1 were moistened by micro-droplet technique, dampened for 30 minutes, processed in an electromagnetic field of ultra-high frequency currents (Rainford RMW-301 microwave oven, China), and flattened with a machine tool (VPK-200, Ukraine). The products of flattening were cooled to room temperature and separated in size. The groats obtained by passing the sieve of 6.5 mm and the sieve yield of 3.2 mm were attributed to the highest grade. The fine groats were received by passing a sieve of 2.0 mm and the No. 067 sieve yield. The particles that were interconnected were removed by using a sieve of 6.5 mm.

The mass of products was determined on laboratory scales. The temperature of the product after heat treatment – with the TROTEC BP5F pyrometer (Germany).

The culinary assessment was carried out by a tasting group formed of specialists with a sufficient level of competence. The statements of experts were agreed upon, which is confirmed by statistical analysis.

4. 4. Statistical treatment of experimental data

Studies were performed four times, randomized over time. The results were treated using the software Microsoft Excel 2016 (Microsoft Corporation, USA) and Statistica 12 (StatSoftStatistica Ultimate Academic, Ukraine) in accordance with the guidelines given in [27, 28].

5. Results of studying the indicators of flattened groats production

5. 1. The influence of water-heat treatment modes on the temperature of the resulting intermediate product

The temperature of the product was distributed unevenly over the plane of the groats layer, which was processed in the electromagnetic field of ultrahigh frequency currents. The increase in the duration of processing groats in the electromagnetic field of ultrahigh frequency currents led to an increase in the temperature of the product. The trends in temperature changes were similar in the samples that were premoistened and those that were not moistened before heat treatment (Fig. 1).

The more uneven temperature distribution was observed in the samples that were processed for a long time (140–180 °C) and were not pre-moistened (Fig. 1, *a*).

The relationship between the duration of thermal treatment of groats, the mode of preliminary moistening, and its temperature is reliable (Fig. 2). The greatest impact on temperature was predetermined by the duration of heat treatment (Partial eta-squared=0.89). A smaller impact on the temperature is due to the use of different modes of moistening of groats (Partial eta-squared=0.10).

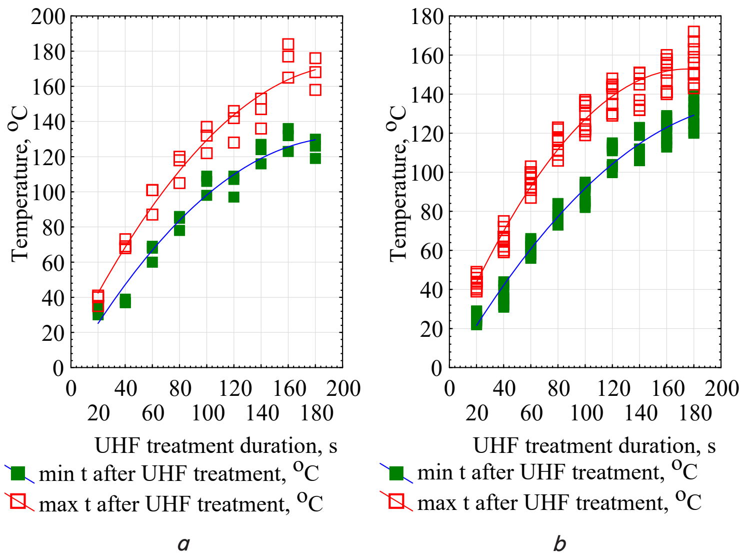

Fig. 1. Groats temperature after processing in the ultrahigh frequency current electromagnetic field: *a* – without the use of preliminary moistening; *b* – after applying the preliminary moistening

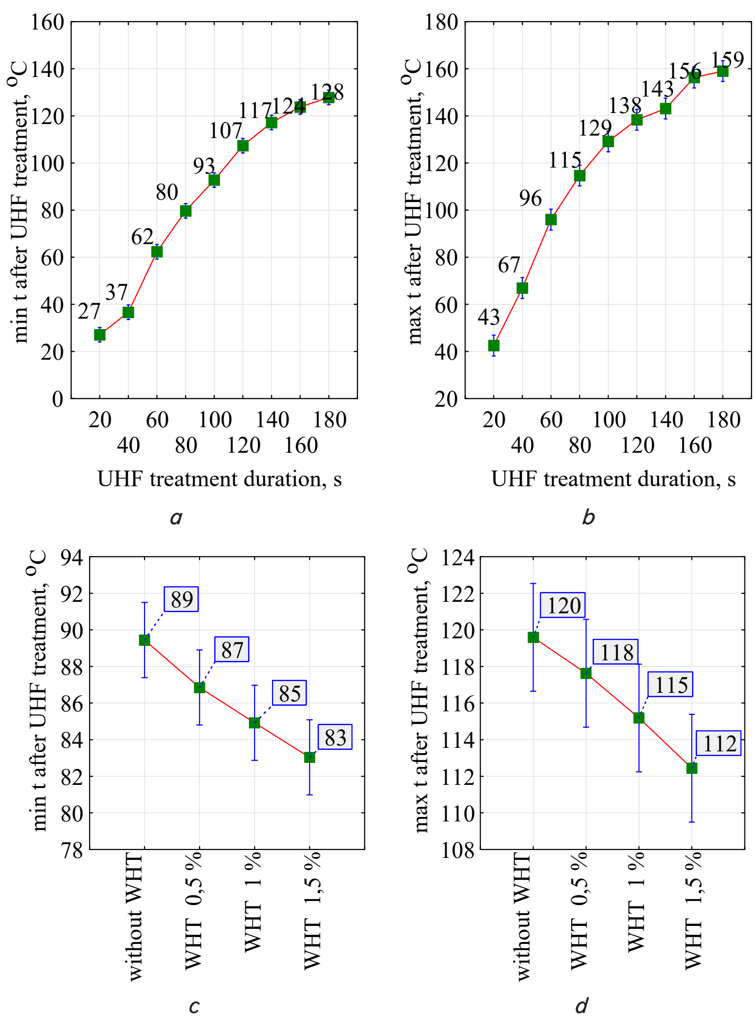

Fig. 2. Influence of the duration of heat treatment and humidification modes on the temperature of the groats before flattening: *a* – the minimum temperature of the groats depending on the duration of heat treatment; *b* – the maximum temperature of groats depending on the duration of heat treatment; *c* – the minimum temperature of the groats depending on the mode of moistening; *d* – the maximum temperature of groats depending on the mode of moistening

A rapid increase in temperature was recorded in the first 80 s of groats processing (Fig. 2, *a*, *b*). The subsequent increase in the temperature depending on the duration of the heat treatment was less intense.

The use of grain moistening makes it possible to achieve a lower heating temperature of the groats compared to samples that have not been moistened (Fig. 2, *c*, *d*).

5. 2. The influence of water-heat treatment modes on the yield of groats and related products

Modes of water heat treatment are important during the formation of the yield of groats products since they significantly affect the level of starch gelling. A high yield of flattened groats can be obtained as a result of a high level of starch gelatinization. It was established that the use of moistening before heat treatment did not significantly affect the yield of groats of the highest and first grades (Fig. 3, *a*). Without moistening, a 1–3 % lower yield of flattened groats was obtained compared to samples moistened before heat treatment.

The use of different durations of processing samples in the electromagnetic field of ultrahigh frequency currents predetermined significant changes in the yields of groats of the highest and first grades (Fig. 3, *b*). The minimum yield of groats of the highest grade was recorded with a minimum duration of processing (20 s). The increase in the duration of processing to 80 s contributed to an increase in the yield of top-grade groats. A further increase in the duration of heat treatment produced a negative effect on the yield of high-grade groats. With a maximum duration of processing (180 °C), the yield of groats of the highest grade was recorded at 40 %, which is 50 % less compared to the maximum yield of these groats obtained for processing at 80 °C. An increase in the yield of top-grade groats led to a decrease in the yield of first-grade groats. A significant decrease in the yield of first-grade groats was registered at an increase in the duration of processing from 20 s to 80 s (Fig. 3, *b*). A further increase in the duration of processing led to an increase in the yield of second-grade groats.

In general, the yield of groats products decreased by 2–3 % due to the preliminary moistening of grain before processing by ultrahigh frequency current electromagnetic field (Fig. 4, *a*). Similarly, the yield of the pinch decreased. The yield of flour increased with the use of preliminary moistening by an average of 1–2 %.

The yield of groats increased by 1–2 % when processing during 80–100 s. A further increase in the duration of heat treatment significantly reduced the total yield of groats (Fig. 4, *b*). The decrease in the total yield was due to an increase in the yield of related products (flour and fine groats).

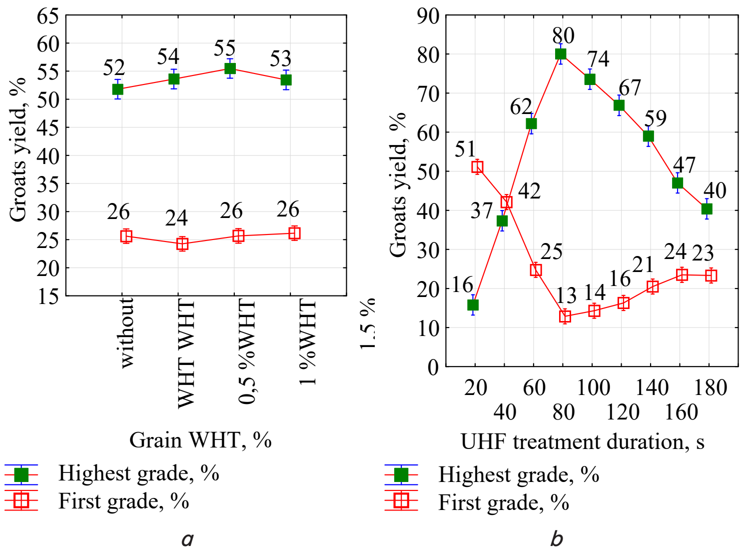

Fig. 3. The yield of groats depending on the mode of water-heat treatment: *a* – depending on humidification; *b* – depending on the duration of heat treatment

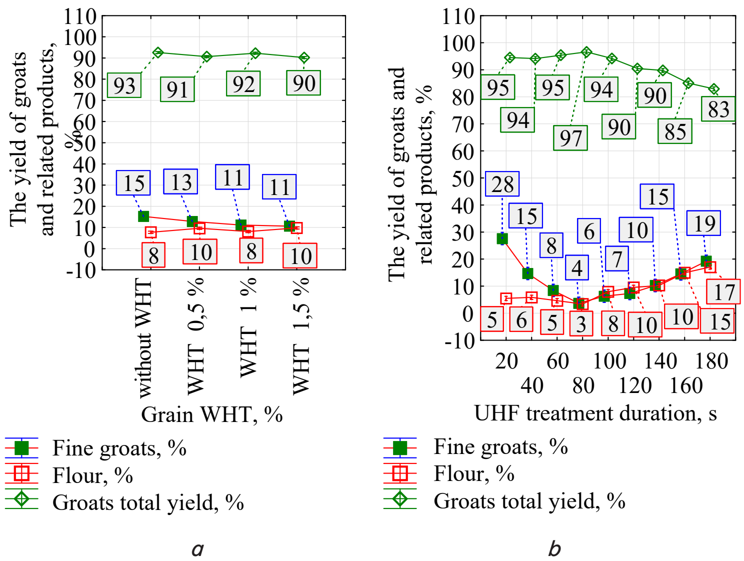

Fig. 4. The yield of groats and related products depending on the modes of water-heat treatment: *a* – depending on humidification; *b* – depending on the duration of heat treatment

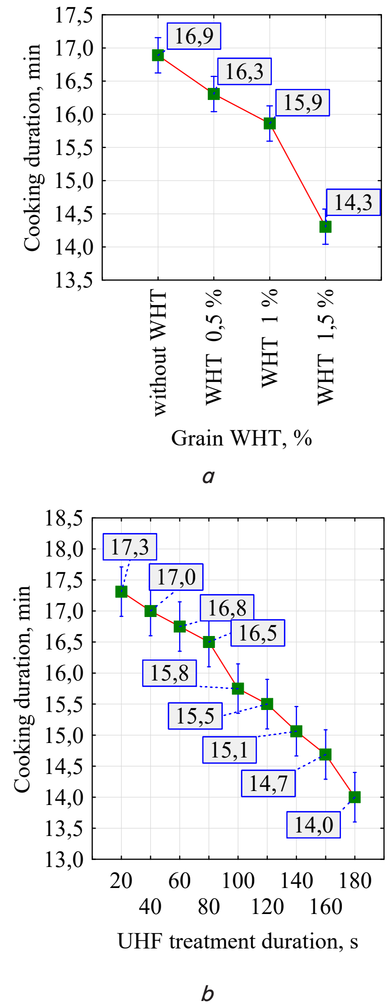

Fig. 5. The duration of cooking porridge from flattened groats depending on the modes of water-heat treatment: *a* – depending on moistening; *b* – depending on the duration of heat treatment

5. 3. The influence of the water-heat treatment modes of flattened groats on the duration of preparation of the finished product

The culinary quality of the resulting products was high (the overall culinary score was 8.2–8.6 points out of 9). There were no significant changes in the indicators of smell, taste, color, or consistency.

The duration of porridge preparation was related to the modes of hydrothermal treatment (Fig. 5).

Moistening the groats by 1.5 % before heat treatment led to a decrease in the duration of cooking porridge by an average of 2.6 minutes (Fig. 5, *a*). A more significant decrease in the duration of cooking occurred as a result of long-term processing by ultrahigh frequency current electromagnetic field (Fig. 5, *b*). The use of the maximum duration of treatment predetermined a decrease in the cooking time of porridge by 3.3 minutes compared to the sample processed for 20 s.

5. 4. Justifying the rational modes to produce flattened groats from spelt

To compile recommendations regarding the production modes involving water-heat treatment using alternative thermal energy, a generalized desirability function was constructed, which is graphically shown in Fig. 6.

The basic requirements for the desirability function were the maximum total yield of groats; the maximum culinary quality of groats products; the minimum cooking time. The maximum values of the desirability function (0.6 – good on the Harington scale) were obtained with a UHF treatment duration of 80 s. A further increase in the duration of treatment negatively affected the value of the generalized desirability function. A significant deterioration in the values of the function was recorded at the duration of the processing of 140 s or more. The use of moistening groats before processing by UHF had a positive effect on the value of the desirability function. The maximum desirability function value was recorded when moistening groats by 1.5 % before UHF treatment.

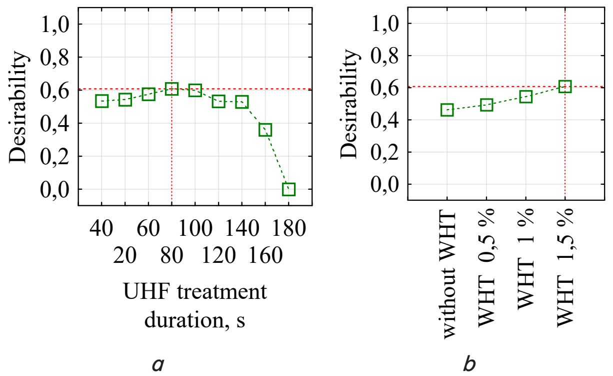

Fig. 6. Generalized desirability function: *a* — depending on the duration of heat treatment; *b* — depending on moistening

6. Discussion of results of studying of flattened spelt groats production

The culinary properties of the finished product are the main prerequisite for the modern consumer when choosing food. The culinary quality of groats products significantly depends on the amount of fiber in them [29, 30]. The fiber content in groats products is associated with the applied peeling index (the number of shells removed). High culinary performance can be obtained when removing 10–15 % of shells. During the production of flattened groats, groats No. 1 was used, which was characterized by a peeling index of 10 %. The applied modes of heat treatment did not cause reliable changes in the structure of fiber, which led to a decrease in the estimate of the parameters of the consistency of porridge during chewing and in terms of color. However, other parameters of culinary quality, in particular smell, taste, texture, color were at a high level. Thus, the overall culinary quality of the obtained products was high and did not change depending on the applied modes of water-heat treatment.

The increase in the duration of processing in the electromagnetic field of ultrahigh frequency currents significantly increased the temperature of the processed product (Fig. 2, *a, b*). This correlates with the specificity of processing the product when using the specified technique. Our results are similar to those reported in works by other researchers [25, 26].

After moistening the groats, a significant decrease in the minimum and maximum temperature after treatment was observed (Fig. 2, *c*, *d*). In previous studies, the mechanisms of influence of additional moistening on the physicochemical changes in groats produced from spelt grain were not defined. Therefore, it can be assumed that a decrease in the temperature of the premoistened groats may be due to a change in the heat capacity and thermal conductivity of the resulting mixture. However, this assumption requires additional research.

The use of moistening groats before heat treatment had a positive effect on the yield of groats of the highest and first grades (Fig. 3, *a*). For flattened groats, an important indicator is the degree of starch gelatinization, which depends on the parameters of water-heat treatment and the tuning parameters of the flattening machine (diameter of the rollers, gap between the rollers). High-quality flakes are obtained as a result of starch gelling. The process of gelling occurs during hydrothermal treatment and subsequent flattening of the grain. Samples with low humidity that are subjected to flattening are not able to form flakes and, at the stage of sorting flattening products, do not belong to the first or second grades of groats. Therefore, the additional humidification applied before treatment with electromagnetic radiation probably affected both the humidity of the resulting product and the degree of gelatinization. The rheological properties of intermediate products of groats production, which were exposed to the action of the electromagnetic field of ultrahigh frequency currents, require a deeper further study.

The increase in the duration of processing in the electromagnetic field of ultrahigh frequency currents from 20 to 80 s had a positive effect on the yield of groats of the highest grade (Fig. 3, *b*). This feature is associated with an increase in the degree of gelling of starch by increasing the temperature of the product before flattening. Simultaneously with the increase in the yield of the highest grade, a decrease in the yield of the first grade was observed at the specified duration of thermal processing of groats before flattening. With a processing time of more than 80 s, the yield of top-grade groats was significantly reduced and the yield of first-grade groats increased. Such changes may be associated with a significant loss of humidity as a result of exposure to high temperatures and the duration of groats processing. Therefore, the products of flattening had high fragility and were not able to form fractions, which can be attributed to the highest grade. It is obvious that a more detailed study of the effect of processing duration on moisture and starch gelling indicators is needed in further research.

Significant changes in the total yield of the finished product, depending on the previous moistening, were not recorded. Nevertheless, a decrease in the number of fine groats is reliable (Fig. 4, *a*). A significant impact on the indicator of total yield was predetermined by the duration of heat treatment (Fig. 4, *b*). A significant decrease in the total yield at the duration of heat treatment of 80 s or more is associated with a significant increase in related products (flour and fine groats). With long-term processing, the finished product is characterized by high brittleness with the formation of fractions, which, according to the granulometric composition, are referred to as flour and fine groats.

The increase in the duration of cooking porridge was significantly reduced by increasing the moisture content of the product before treatment and the duration of such processing (Fig. 5). This feature can be explained by high processing temperatures (up to 159 °C) at which irreversible physicochemical changes took place in the groats.

Based on the set of indicators, it can be argued about the expediency of introducing ultra-high frequency currents into production as an effective analog of traditional water-heat treatment.

The peculiarity of the proposed method is the exclusion of the damping stage and a significant reduction in the duration of thermal treatment of groats compared to typical and generally accepted techniques of water-heat treatment. In contrast to the known techniques of using electromagnetic radiation [25, 26], our proposed method can significantly expand the scope of use of targeted energy delivery. The special feature of the method is to change the physicochemical properties of raw materials at the stage of water-heat treatment in the technology of processing spelt grains into flattened groats. The use of the proposed modes will make it possible to effectively introduce the production of groats using exclusively electrical energy.

The revealed patterns complement the knowledge of the electromagnetic field of ultra-high frequency currents, which were partially investigated in works [18, 20, 24]. The difference between the obtained results is the expansion of information about the links between the technical indicators of production and the modes of water-heat treatment using electromagnetic radiation.

The limitation of this study is the lack of an industrial version of the technological equipment for processing by ultrahigh frequency current electromagnetic field at the stage of groats production before flattening. However, industrial variants of such machines are known, used for disinfecting grain masses. Modernizing such equipment is possible and can be carried out in a short time.

The main disadvantage of our study is the specific features of the raw materials, which were used during experiments. The results of [26] indicate a high variability of indicators during the processing of various varieties of ancient wheat, including spelt. Therefore, technical indicators during the processing of other varieties of spelt may differ.

Further development of the current study implies studying the varietal properties of spelt grain and indicators of its processing into various foods. It is expedient to establish links between the modes of treatment by the electromagnetic field of currents of ultrahigh frequency of raw materials with different indicators of thermal conductivity.

7. Conclusions

1. The influence of the duration of irradiation by the field of ultrahigh frequency and water-heat treatment on the temperature of the intermediate product has been determined. It was established that irradiation with a field of ultrahigh frequency reliably affects the temperature of groats from spelt No. 1. When irradiated with a field of ultrahigh frequency from 20 to 180 s, the minimum temperature of the product is 27–128 °C, and the maximum temperature is 43–159 °C. The water-heat treatment of groats from spelt No. 1 before irradiation affects the temperature of the product in different ways. Thus, moistening groats No. 1 by 1.5 % significantly reduces the temperature compared to the option without water-heat treatment. The minimum temperature, in this case, is 83 °C, and the maximum temperature is 112 °C. It should be noted that there is no reliable difference between the options for moistening groats by 0.5, 1.0, and 1.5 %.

2. Treatment with a field of ultrahigh frequency from 20 to 100 s does not reliably affect the overall yield of groats from spelt. The total yield is 94–97 %. At the irradiation with a field of ultrahigh frequency from 120 to 180 s, the total yield of groats is significantly reduced to 83–90 %. The irradiation by the field of ultrahigh frequency of groats from spelt No. 1 for 20–80 s reliably increases the yield of flattened groats of the highest grade. Under this regime, the yield of flattened groats of the highest grade increases from 16 to 80 %, and the first grade is significantly reduced from 51 to 13 %. At the irradiation with fields of ultrahigh frequency for 100–180 s, the yield of flattened groats of the highest grade is significantly reduced from 74 to 40 % and the first-grade increases from 14 to 23 %. Conducting water-heat treatment does not affect the yield of flattened groats from spelt.

3. Pre-treatment of groats with an ultra-high frequency field for 100–180 seconds reliably reduces the duration of preparation of the finished product. The duration of cooking groats, in this case, is 14.0–15.8 minutes. At the irradiation with a field of ultrahigh frequency from 20 to 80 s, the cooking time is 16.5–17.3 minutes. It should be noted that water-heat treatment reliably reduces the duration of cooking flattened groats compared to the option without moistening. The water-heat treatment of groats by 1.5 % reduces the cooking time reliably compared to 0.5–1.0 % moistening up to 14.3 minutes.

4. In the technology of production of flattened groats from spelt using the field of ultrahigh frequency, it is necessary to irradiate groats for 60–80 s with moistening by 1.0–1.5 %. Under this mode, the total yield of groats is 94–97 %, and the duration of cooking groats is 14.3–15.9 minutes. When producing flattened groats of the highest grade, it is necessary to irradiate with a field of ultrahigh frequency for 80 s without water-heat treatment. Under this mode, the yield of flattened groats of the highest grade is 80 %, and that of the first grade is 13 %. The duration of cooking such groats is 16.8 minutes.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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