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# THE EFFECT OF THE ELECTROMAGNETIC FIELD OF EXTREMELY LOW FREQUENCIES ON THE QUALITY OF WHEAT GRAIN

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**Abstract.** The paper presents the results of studies of how the electromagnetic field (EMF) of extremely low frequencies (ELF), magnetic induction of the EMF, and the duration of processing and storage affect the quality characteristics of wheat grain of the cultivar Shestopalivka harvested in the Odesa Region in 2018, 2019, and 2020. Treatment of grain with the EMF of the frequencies 20 and 30 Hz and with magnetic induction of 5 and 10 mT for 2–20 min reduces the germination capacity of wheat, as compared with the control, by 1–12%. As an exception, in several experiments, the germination capacity increased. The biggest increase (by 14%) was observed when the duration of treatment was 12 minutes, the frequency 30 Hz, and the magnetic induction 5 mT. Treatment of grain for 6 min with the EMF at the frequencies 10–28 Hz and with magnetic induction showed that at 10, 18–24 Hz, the germination capacity increased by 1–5%, but after 15 days, at the frequency 12–26 Hz, the germination power increased by 1–9%. A month later, with the frequency 18, 20, and 28 Hz, the germination power exceeded the control by only 2–7%, and after 10 months of storage, only the experiment with the frequency of treatment 24 Hz was at the control level. With all other frequencies, there was a significant decrease in grain germination. It has been established that treating grain 15 days prior to sowing at 14–22 Hz increases the germination capacity by 7–9%, and it reaches the values 92–94%. In the grain treated with the EMF at 10–30 Hz and stored for 14 months at the controlled air temperature 9–23°C and the relative humidity 33–82.5%, the protein content on a dry basis did not change compared with the control (16.5%). Storage of grain treated for 6 minutes with an EMF at 10–30 Hz, the magnetic induction being 10 mT, allows increasing the gluten content by 1.07–1.21 times, as compared with the control. The biggest increase in the amount of gluten is achieved at the frequency 16 Hz. Even under unfavourable conditions, at the temperature 23°C and relative air humidity 82.5%, the gluten quality goes up by 27.65 conditional units of the device VDK (1.49 times) and becomes as high as the gluten quality of grain that was preserved under far better conditions, at 9°C and the humidity 33 %. When grain is EMF-treated for 6 min at 10–30 Hz, with the magnetic induction being 10 mT, under different storage conditions, this most often affects the content of stearic and gondoic acids. The biggest changes in them were noted during storage at 9°C and the relative air humidity 82%: gondoic acid increased by 12.5–18.7%, and stearic acid decreased by 15.5–25.0%. Under any other conditions of EMF treatment and storage of wheat grain, changes in fatty acids are within the allowable error.

**Keywords:** wheat grain, electromagnetic field, extremely low frequencies, magnetic induction, grain treatment, grain storage, grain quality characteristics.

## Introduction. Formulation of the problem

The properties of the electromagnetic field (EMF) have long been used in various technologies and economic activity. Almost as early as the first EMF generators appeared, the study of its effect on biological objects began. It is known that such characteristics as the frequency (or a related parameter, the wavelength), dose, and duration of irradiation determine how effectively the EMF acts on living organisms, in particular, on cereal crops. By now, it has been studied quite fully how they are affected by the EMF of significant intensity that causes certain thermal effects in biosystems [1,2].

In recent decades, a significantly increased interest has been aroused by the problem of how to use the EMF for agricultural purposes, in particular, for the processing of grain and seeds of various crops. The high sensitivity of seeds of agricultural crops and plants to changes in the geomagnetic field and the impact of the artificial EMF on them is indisputable, since it is confirmed by many studies [3,4].

Scientists from China, Iran, India, Morocco, and Brazil made a large and in-depth review of articles published in 1976–2020 and devoted to the use of the EMF. This review shows that in recent decades, more and more attention has been paid to studying and applying the EMF in agriculture, in particular, in presowing treatment of grain, with different types of magnetic fields (MF) used. The authors concluded that a better understanding of the correlation between the MF and a plant's response can revolutionise crop production by making it possible to increase resistance to diseases and stress conditions. Also, a good knowledge of the benefits of using nutrients and water will lead to an increase in crop yields [5].

However, information on treating grain with an electromagnetic field (EMF) is rather contradictory. Various authors suggest quite a range of parameters of electric and magnetic fields to be used for this treatment. So far, it has not been studied enough how crops are affected by weak, low-intensity fields (of a non-thermal nature). This motivated us to carry out our experimental studies.

## Analysis of recent research and publications

Most publications devoted to using the EMF in agriculture focus on how to improve the seeding properties of grain of different crops, thus increasing yields and raising the efficiency of using the seed stock. The studies also consider the effect of the EMF on biochemical processes during grain germination and on activation of the germinating ability of seeds of different crops [6]. In the last decade, interest has increased in works related to treating agricultural raw materials with low-frequency EMF, in particular, in the extremely low frequency range (ELF) – from 3 to 30 Hz, the effect of which is so far understudied [7].

The use of low-frequency electromagnetic fields in presowing preparation of seeds is an effective technique to increase the germination capacity and productivity of plants. It was established that a low-frequency EMF used on seeds increased the germination energy and laboratory germination of treated seeds of peas, barley, and spring wheat by 2–4%. The field germination capacity of treated pea seeds exceeded the control by 6%, that of barley by 5%, and that of spring wheat by 4%. The increase in the yield of peas, compared with the control, was 0.22 t/ha (8.5%), in that of barley 0.27 t/ha (9.7%), in that of spring wheat 0.25 t/ha (8.4%) [6].

The paper by Indian scientists describes the results of experiments to study the effect of low-power microwave radiation on the germination and growth rate of various seeds, including wheat. The bioeffects of low-power microwaves (of non-thermal intensity) modulated by a square wave with the frequency 1 kHz were studied. During the irradiation of the seed samples, such microwave parameters as frequency, power, energy flux density, and exposure time were varied to study their effect on germination. It was found that the effects of various treatments stimulated the germination and growth of plant seedlings, especially with intensive and prolonged treatment, while increasing the frequency and energy flux density reduced seed germination and seedling vigour. The effect also depended on the nature of the seeds [8].

Studies of the influence of the magnetic field on the seeds and yield of barley, wheat, and oats, carried out in the south of Alberta (Canada), showed that it did not affect the yield of oats, but increased the yield of barley in most experiments with winter and spring wheat. The treatment time, strength of the magnetic field, and type of the equipment used had no significant impact on the plant growth and grain yields of the studied crops [9].

The Pakistani scientists studied how magnetising seeds and water stimulated the germination of wheat seeds with low moisture content and growth vigour (45%). It was concluded that wheat seeds with low vigour could be stimulated with magnetised water [10].

The researchers [11] show that treating seeds of cultivated plants with a low-frequency EMF leads to a 15–40% increase in their yield. The authors developed a technological construction for processing seeds in a combine harvester. Laboratory analysis of the quality of grain processed in the combine and 3 months after threshing showed that the suggested technology increased the germination capacity of seeds by 6–20%. The optimal parameters for EMF processing were the frequency 16 Hz and the magnetic induction 6 mT.

The publications describe different modes of EMF processing of grain. Thus, the Iranian researchers studied the effect of pulsed treatment of wet and dry seeds of canola and maize with a low-frequency EMF (15 min treatment, 15 min pause). The magnetic induction of the EMF ranged 1 to 7 mT, in increments of 2 mT, and the maximum intensity was 10 mT for 1 to 4 hours, in increments of 1 hour. All results showed that the wet and dry seeds treated responded differently to the EMF as biotic stress. Applying an EMF with the intensity 10 mT to treat wet seeds caused a decrease in the growth and weight of both fresh and dry canola biomass, while the same treatment of maize caused an increase in the weight of fresh and dry biomass [12].

There are a number of hypotheses that can explain the mechanism of EMF action on physicochemical and biological systems, as well as changes in their properties and individual quality indicators. However, the scientific literature most often discusses hypotheses based on resonance phenomena of different nature [13].

An example is a review article by scientists from Serbia and Romania, which provides literature data on the classification of EMF and the results of experiments indicating an increase in the yield and protein content. Based on the RIES method (resonant impulse electromagnetic stimulation) developed at the Faculty of Agriculture of the University of Novi Sad, the researchers came to conclusions about how an ELF EMF affected different types of crops [14].

According to the studies conducted at the Joint Institute for Nuclear Research (Dubna), the biological effects of a magnetic field are determined not by the absolute value of its strength, but by the change in the latter in space and time [15].

The mechanism of action and the reasons for the change in the quality of MF-treated wheat grain were investigated by the scientists [16] in their two-year study of wheat seeds of the variety Zorya. In the experiments, the grain was treated with an alternating magnetic field, with the frequency 30–33 Hz, the strength 30 mT, and a shape close to sinusoidal. It was shown that short-term treatment with a low-frequency magnetic field led to an increase in the germination capacity and germination rate of seeds. As established by the researchers, the high sensitivity of wheat seeds to a low-frequency magnetic field is due to a change in the pH and the release of proteins that more quickly bring seeds out of dormancy, stimulate the development of recovery processes in them, and restore the barrier function of membranes, thus increasing the germination capacity of old seeds.

Protein changes are discussed in the paper by a group of Chinese scientists [17]. They considered the effect of electric fields and EMF on the protein structure and concluded that these factors could cause conformational changes in protein and thus affect the functional properties of proteins for the food industry. In the researchers' opinion, active research in this direction should be continued.

Another publication, too, is focused on the change in the chemical composition that results from treating wheat grain. The results obtained by Polish scientists in studying the effect of EMF on seeds and seedlings showed that it was still impossible to draw unambiguous conclusions about its effect. Seeds are an extremely complex system, and biological processes in them run in parallel and can react differently not only to the EMF, but also to environmental parameters. The researchers showed not only an increased effect of the EMF on the yield of wheat, but also changes in its chemical composition (a higher content of gluten and starch) [18].

An increase in minerals and protein is described in the article by Indian scientists. The researchers studied five cultivars of the mung bean after three different treatments with the sinusoidal magnetic field (SMF) of extremely low EMF frequency. Portions of fresh mung bean seeds were exposed to the EMF for 5 hours a day during 15 days. Untreated seeds served as controls. In the experiments, the mineral substances and protein content were determined. The seedlings showed an 8.3% increase in protein when treated at 10 Hz and a 7.2% increase at 50 Hz, compared with the corresponding controls [19].

A method and modes of presowing treatment of grain of different crops were suggested, allowing not only increasing its germination power and the productivity of the production line, but also extending the storability of grain. To this end, before sowing, seeds were treated for 40–60 min with a constant magnetic field and simultaneously with an EMF, with phase-modulated ELF waves, the field strength being 120–1400 A/m. besides, a method was suggested for prolonging the storage period of agricultural raw materials, including grain seeds, under the influence of a low-frequency electromagnetic field (LF EMF) [20].

Domestic scientists, too, study the effect of the EMF on grain quality. A group of Ukrainian scientists [21] studied how water-thermal treatment and the duration of electromagnetic irradiation affected the yield and quality of rolled wholegrain groats from emmer wheat. A significant effect of electromagnetic radiation on the grain yield was established. The use of optimal grain treatment parameters (moistening by 1.0%, EMF irradiation for 80–100 seconds) results in as high a yield of high-quality rolled wholegrain groats as 91.7–92.3%, with the culinary score 7.3 points.

Thus, a review of the literature has shown that EMF treatment is widely used in the presowing treatment of grain of different crops and allows heightening the germination capacity of the grain treated and, accordingly, increasing grain production. There are data on possible changes in certain technological parameters of the quality of treated grain (protein, gluten, nutritional value of grain processing products, storability).

Of all the existing methods and modes of EMF grain treatment, in recent years, the focus has mainly been on the use of its extremely low frequency range, which has a number of advantages: it is close to that of the geomagnetic field of the Earth, and is thus safer, it consumes less power, grain treated in this frequency range is not heated, etc.

Along with this, it has been shown that there are a number of unresolved problematic issues. They are related to clarifying the mechanisms of the action of the EMF on grain, improving its quality and storability, and determining the possibilities for further application of modern electrophysical methods of grain processing. All this confirms that research on the effect of the EMF on the quality of wheat grain is important for the country's grain industry and so should be continued.

The **purpose of the work** is to find out the regular patterns in the effects that the EMF of extremely low frequency has on the main qualities of wheat grain intended for sowing and food purposes, which will improve its quality and the efficiency of its storage and use.

**Research objectives.** To achieve the purpose of the work, the following research objectives were set:

1) to determine how frequency, magnetic induction, and duration of treating grain with the EMF of an extremely low frequency range affect the main characteristics of wheat grain quality (germination capacity, protein content, quantity and quality of gluten, fatty acid composition);

2) to investigate changes in the main parameters of wheat grain quality in the course of EMF treatment and storage.

## Research materials and methods

The experimental studies were carried out on wheat grain of the cultivar Shestopalivka grown in the Odesa Region and harvested in 2018, 2019, and 2020.

Wheat grain samples were treated with the EMF of an extremely low frequency range, with different magnetic induction and duration of processing and storage, to determine a number of its quality parameters: germination capacity, content and quality of protein and gluten, fatty acid composition.

*EMF treatment of grain at ELF.* The wheat grain was treated on a test installation. It consisted of a cylindrical polymer tube (grain container), a solenoid coil, an GZ-112/1, and a low-frequency power amplifier. The output signal of the oscillator was set in the form of a sinusoid and controlled with an oscilloscope S1-78.

The studies were carried out in the range of extremely low frequencies of the EMF varied within the limits $\nu$=10–30 Hz, the values of which were set with the electromagnetic oscillator GZ-112/1.

The magnetic induction (B) of the EMF during grain treatment was constant and equal to 5 mT and 10 mT. The current intensity in the test installation required to provide this magnetic induction was 0.5 A or 1 A respectively. To this end, before each experiment on grain treatment, the required current intensity was adjusted by means of the low-frequency amplifier and then controlled with a universal (combined) digital voltmeter B7-38.

The duration of EMF treatment of grain in the experiments varied within $\tau$=2–20 min. The quality parameters of treated and untreated (control) grain were determined immediately after EMF treatment, and then after storage under different conditions for up to 15 months.

*Storage of grain under controlled conditions.* To store grain under controlled conditions, a given temperature and relative air humidity were maintained in desiccators, simulating the conditions of grain storage at different times of the year. The required temperature was set in a thermostat and a refrigerator and controlled with thermometers TU 25-1102.043-83 TC-4 Mk 0-100°C with 1°C divisions.

To create a certain relative air humidity, about 1–2 $dm^3$ of sulphuric acid solution of the required density was poured into the desiccators, which provided the above values of relative air humidity (33%, 35%, 82.0%, and 82.5%). For more accurate results, the concentration of sulphuric acid solutions in desiccators was prepared taking into account the dependence of its density on the temperature [22]. The density of sulphuric acid and its solutions was controlled using a set of hydrometers.

*Determination of the seeding properties of wheat grain.* The seeding properties of the grain were characterised by the parameter of laboratory germination capacity determined according to DSTU (State Standard of Ukraine) 4138-2002 “Seeds of agricultural crops. Methods for determining quality.” The method consisted in germinating wheat grain under optimal conditions for 8 days. Filter paper was used as a substrate, the germination temperature in the thermostat was stable, equal to 20±2°C, the analysis was carried out in the dark, and the counting was performed on the 8$^{th}$ day. Permissible deviations of the germination ability from the average value in individual samples were within the limits provided for by DSTU 4138-2002.

The *crude protein content* was determined by the standard Kjeldahl method with a nitrogen analyser Kjeltec™ 8400 (FOSS Analytical AB, Sweden). The principle of the method is as follows. Nitrogen of the organic compound of grain, when heated with concentrated sulphuric acid in the presence of catalysts, is converted into ammonium sulphate. Ammonia is displaced from it with a concentrated alkali and is distilled off into the receiver with a certain volume of titratable acid. After displacement of ammonia ends, the amount of acid remaining in the receiver is measured, from which the amount of ammonia in the sample and, consequently, the amount of bound nitrogen in the object tested are calculated.

***Method of determining the quantity and quality of gluten*** (GOST (State Standard) 13586.1-68 “Grain. Methods of determining the quantity and quality of gluten in wheat”). ISO 21415-1:2006, IDT

To determine the *quantity of gluten*, the ground grain (meal) is thoroughly mixed, and a sample weighing 25 g or more is isolated in such a way as to ensure the yield of raw gluten weighing at least 4 g. The meal is placed in a porcelain mortar or cup and covered with water. To knead dough from a 25 g sample, 14 $cm^3$ of water is required. After that, dough is kneaded.

The ball-shaped dough is placed in a cup and covered with glass (or another cup) for 20 minutes. After that, the gluten is washed out under a weak flow of tap water over a dense silk or nylon sieve, while slightly stirring the dough with fingers. At first, washing is carried out carefully, not allowing pieces of dough to come off together with starch and hulls, and more vigorously after starch and hulls are removed. Pieces of gluten that have torn off by accident are collected and added to the total gluten mass.

Having finished washing out the gluten, it is dried by squeezing between the palms, which are from time to time wiped dry with a towel. The squeezed gluten is weighed and washed again for 2–3 minutes. Then, again, it is dried by squeezing and weighed. Washing of gluten is considered complete if the difference in its weight after two weighings is not more than 0.1 g. Raw gluten is expressed in mass fractions, as a percentage of the weighed sample of crushed grain (meal).

To knead the dough, wash out gluten and determine its quality, ordinary tap water is used, the temperature of which should be 18±2ºC.

*The quality of gluten* is understood as a complex of its physical properties: extensibility, elasticity, viscosity, ability to retain physical properties over time. The elastic properties of gluten were determined in the conditional units of the scale of the instrument VDK-3 M (gluten deformation meter).

A 4 g piece is separated from the washed gluten, kneaded 3–4 times with fingers, shaped into a ball, and placed for 15 minutes into a container with water, the temperature of which must be 18±2 °C. If the gluten after washing is a spongy mass easily torn apart and does not form a ball, then it is classified as belonging to group 2 without determining the quality with the device.

After 15 minutes of soaking in water, the gluten ball is placed in the centre of the table of the VDK-3M, and the Start button is pressed to switch on the time relay. The punch falls freely on the gluten and compresses it. On the display panel of the device, a number appears indicating the value of the elasticity of the gluten sample under study in the conventional units of the scale of the device.

Permissible discrepancy for the gluten quantity is ± 2.0% and for the quality of gluten ±5 VDK units.

*The fatty acid composition* of the wheat grain treated with the ELF EMF was determined by gas chromatography. The samples were prepared according to the guidelines in ISO 12966–2:2011 "Animal and vegetable fats and oils – Gas chromatography of fatty acid methyl esters – Part 2: Preparation of methyl ester of fatty acids."

For analysis, a 1.0 g sample taken from grain ground in a laboratory mill LMT-2 is placed into a glass test-tube, covered with 10 ml of isooctane (2,2,4-trimethylpentane) poured in, closed with a stopper, and vigorously stirred for 1 min. Next, 2 ml of the extract is taken and transferred to a glass test-tube with the addition of 100 μl of 0.2 mol/l potassium methoxide solution. The solution is vigorously stirred for 1 min. Then it is allowed to stand for about 2 minutes, after which 2 ml of sodium chloride solution (40 g of NaCl in 100 ml of distilled water) are added, and the mixture is lightly stirred. After settling the solution, the upper organic layer is taken with a pipette, transferred to a test-tube, and about 1 g of sodium bisulphate is added, while the mixture is stirred. Then, using a pipette, part of the liquid (about 0.5 ml) is transferred into a vial, which is closed with a cap. The liquid is then examined on a gas-liquid chromatograph Agilent 7890 A according to ISO 12966–4 First edition 2015–06–01 "Animal and vegetable fats and oils – Gas chromatography of fatty acid methyl esters – Part 4: Determination by capillary gas chromatography."

## Results of the research and their discussion

***Study of the effect of treating wheat grain with the ELF EMF on its seeding properties.***

In the first two series of experiments conducted, respectively, on 11 March 2019 (series 1) and 26 March 2019 (series 2), we studied how the germination capacity of wheat grain of the cultivar Shestopalivka (harvested in 2018) depended on the characteristics of the EMF (the magnetic induction *B* and the frequency of the EMF) and the duration of the treatment of grain τ.

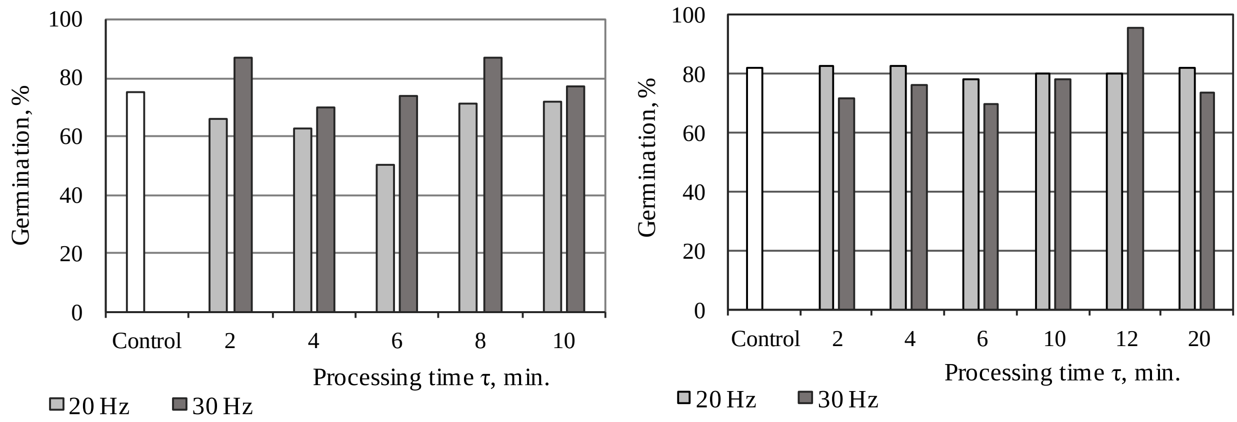
The moisture content of the grain in the experiments was 12.1%. In series 1, the magnetic induction B was taken at the level 10 mT, the EMF frequency was 20 and 30 Hz, the treatment duration τ varied from 2 minutes to 10 minutes, in increments of 2 minutes.

In series 2, the wheat grain was EMF-treated at the same frequencies (20 and 30 Hz), but at the magnetic induction B 2 times as low, 5 mT. Besides, experiments were added with the treatment durations 12 and 20 minutes, but as only a limited number of samples could be placed in the thermostats for grain germination, 8 minutes' treatment of a grain sample was excluded.

In all treated wheat samples and in the control one (not treated), the germination power of the grain was determined by the method described above. Based on the results obtained, histograms were constructed (Fig. 1), which give a clear view of the changes in the germination capacity of the grain depending on the EMF treatment modes.

As can be seen from the histograms, the germination capacity of the EMF-treated wheat grain depends on all the considered factors of an operational mode: duration of the EMF treatment, its magnetic induction, and frequency.

Treatment of grain with the EMF with the magnetic induction 10 mT (Fig. 1a) and the frequency 20 Hz for 2–10 minutes in all experiments reduced its germination ability, as compared with the control (untreated grain), by 3–25% (in absolute value). But after EMF-treating the grain at 30 Hz, the nature of the impact on the germination ability is different. When the grain was treated for 2, 8, and 10 minutes, the germination capacity increased by 2–12% compared with the control.




a) series 1 – magnetic induction *B* = 10 mT b) series 2 – magnetic induction *B*=5 mT

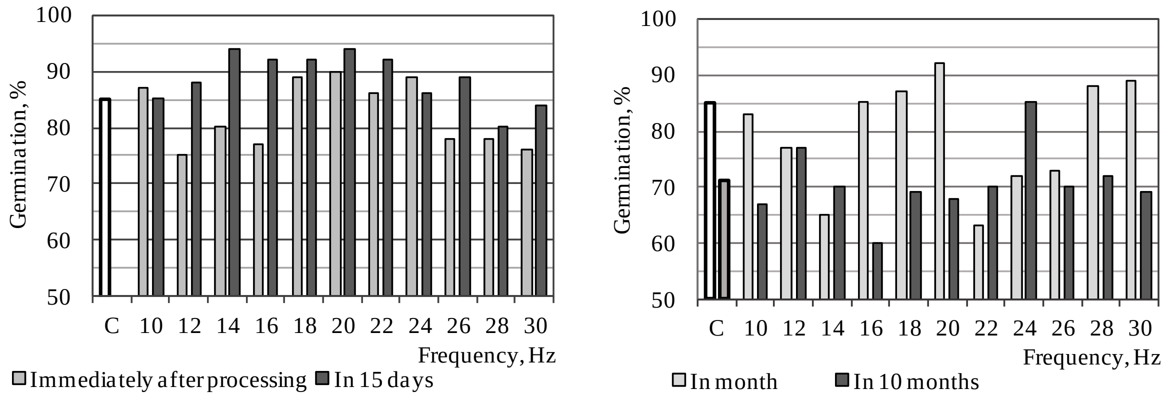
**Fig. 1. Comparative results of the germination capacity of the wheat grain Shestopalivka harvested in 2018, depending on the duration of treating the grain with the EMF at various magnetic induction and frequency**

And only with the duration of treatment within 4–6 min, a slight decrease in the germination capacity was observed (by 1–5%). That is, treatment of grain with the EMF frequency 30 Hz for 2, 8, and 10 minutes at the magnetic induction 10 mT leads to an increase in its germination capacity, as compared with the control (grain not treated with the EMF).

Treatment of the grain with an EMF at a lower magnetic induction, which was 5 mT (Fig. 1b), gave a smoother pattern of fluctuations in the germination power, as compared with the control. EMF treatment at the frequency 20 Hz and the magnetic induction 5 mT for 2–20 min slightly changed the germination power of the grain: its variances, as to the control (75%), were –4–+1%, which lies within the permissible errors. At the EMF frequency 30 Hz, the germination capacity only increased with the treatment duration 12 minutes and reached 96% (in the control sample, it was 82%). With another treatment duration, the germination capacity of the grain sample was lower than that of the control by 4–12%.

To study how different periods of storage of EMF-treated grain tell on its germination, the following two series of experiments were conducted: on 7 October 2019 (series 3) and on 8 November 2019 (series 4). Wheat grain was treated with the EMF for 6 min at the magnetic induction 10 mT, and the frequency varied from 10 to 30 Hz, in increments of 2 Hz.

In series 3, the wheat grain was treated with the EMF, its germination capacity was determined immediately after treatment and checked again 15 days after the treatment. In series 4, the grain was EMF-treated according to the same modes as in series 3, but its germination power was determined after a significantly longer storage period, one month and then 10 months after the treatment. To compare the changes in the grain germination capacity, it was also determined in the control (untreated) samples at the same time. The obtained results of determining the germination capacities of the wheat grain are shown in Fig. 2. The letter C indicates the value of the germination ability of the control sample.




a) series 3 – EMF processing 07.10.2019 b) series 4 – EMF processing 08.11.2019

**Fig. 2. Changes in the germination capacity of treated wheat grain depending on the frequency of the EMF and the duration of grain storage**

From these histograms (Fig. 2a), it can be seen that in the grain treated with the EMF at 10 Hz and 18–24 Hz, the germination ability, which was determined immediately after the treatment, exceeded that of the control samples by 1–5%. However, as early as 15 days after the treatment, the germination capacity, as compared with the control, increased significantly (up to 9%) at almost all studied frequencies in the range 12–26 Hz. The exceptions were the frequency 10 Hz, where the germination capacity did not change, and the frequencies 28 and 30 Hz, where it slightly decreased (by 1–5%). That is, by EMF-treating wheat grain 15 days before sowing at 14–22 Hz, it is possible to increase its germination capacity by 7–9% and reach the values 92–94%.

The results of the second series of experiments (Fig. 2b) have shown that after a month's storage of the EMF-treated wheat grain, its germinating capacity decreased by 2–22% at some frequencies, as compared with the control (85%), but nevertheless, at 18, 20, 28, and 30 Hz, it exceeded the control by 2–7%. The biggest increase in the germination power (by 7%, up to 92%) was achieved at the EMF frequency 20 Hz, and the biggest loss of the germination power (by 22%, up to 63%) was observed at 22 Hz. However, after 10 months' storage of the treated wheat grain, the germination capacity of the control (non-treated) sample decreased from 85% to 71%. But when the treatment frequency was 24 Hz, the germination capacity of grain did not change and remained at the level 85%.

Thus, by treating the grain with the EMF with the frequency 20 Hz, both after 15 days and after a month, it is possible to increase the germination ability of wheat by 9–7% compared with the control and reach the values, respectively, 94–92%.

***Effect of EMF treatment of wheat on the protein content.*** The wheat grain of the cultivar Shestopalivka harvested in 2020, with the moisture content 11.8%, was treated on 22 September 2020 for 6 min at the magnetic induction 10 mT and the EMF frequencies 10, 16, 24, and 30 Hz. Samples of the treated and untreated (control) grain were stored at the controlled temperature and relative humidity. The protein content in the wheat grain samples put up for storage was determined in the period from 7 November 2021 to 23 December 2021, that is, after 13.7–15.2 months of storage. The crude protein content on a dry basis was determined by the standard Kjeldahl method described above with a device Kjeltec (manufactured by FOSS). The results obtained are presented in Table 1.

As the results of the experimental studies have shown, in the grain samples treated with the ELF EMF at 10–30 Hz and then stored for 13.7–15.2 months under controlled conditions of various temperatures and relative humidity, the protein content on a dry basis (compared with the control) did not change.

***The quantity and quality of raw gluten*** in the wheat grain are important indicators of its quality in Ukraine and other post-Soviet countries. The effect of EMF treatment of wheat grain was studied at the next stage of the experimental research. Wheat grain of the cultivar Shestopalivka harvested in 2020 was treated on 22 September 2020, as in the previous series of studies, under the same characteristics of the ELF EMF (frequencies, magnetic induction, and duration of processing) stored for the same time under the same controlled storage conditions. The quantity and quality of raw gluten were determined according to the above-mentioned GOST 13586.1-68. The results obtained are presented in Table 2.

**Table 1 – Protein content (on a dry weight basis) in the control and the EMF-treated wheat grain samples after storage under controlled conditions for 13.7–15.2 months**

| **Storage conditions** | | **Control** | **EMF frequency, Hz** | | | |
|---|---|---|---|---|---|---|
| | | | 10 | 16 | 24 | 30 |
| t, °C | φ, % | Crude protein content, % | | | | |
| 9 | 33 | 16.5 | 16.5 | 16.5 | 16.4 | 16.3 |
| 9 | 82 | 16.5 | 16.2 | 16.5 | 16.5 | 16.5 |
| 23 | 35 | 16.4 | 16.2 | 16.3 | 16.5 | 16.5 |
| 23 | 82.5 | 16.6 | 16.5 | 16.6 | 16.6 | 16.6 |

**Table 2 – Quantity and quality of gluten in the EMF-treated wheat grain after its storage under controlled conditions for 15 months**

| **Storage conditions** | | **Control** | **EMF frequency, Hz** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **t, °C** | **φ, %** | | **10** | **16** | **24** | **30** | **10** | **16** | **24** | **30** |
| | | | Gluten content, % | | | | Changes, as compared with the control, % | | | |
| 9 | 33 | 38.9 | 37.8 | 38.3 | 39.9 | 38.4 | –2.78 | –1.54 | 2.57 | –1.13 |
| 9 | 82 | 38.4 | 37.9 | 38.2 | 38.3 | 37.8 | –1.15 | –0.52 | –0.10 | –1.36 |
| 23 | 35 | 40.0 | 39.2 | 39.8 | 39.6 | 38.9 | –1.90 | –0.30 | –0.80 | –2.70 |
| 23 | 82.5 | 28.0 | 30.4 | 33.8 | 32.3 | 30.1 | 8.57 | 20.71 | 15.36 | 7.50 |
| | | | Gluten quality, units VDK | | | | Changes, as compared with the control, % | | | |
| 9 | 33 | 112 | 124 | 116 | 117 | 110 | 9.88 | 3.56 | 4.09 | –2.36 |
| 9 | 82 | 116 | 118 | 113 | 118 | 112 | 1.63 | –2.66 | 1.72 | –3.78 |
| 23 | 35 | 108 | 99 | 110 | 105 | 112 | –8.40 | 1.48 | –3.00 | 3.32 |
| 23 | 82.5 | 77 | 88 | 115 | 115 | 90 | 14.29 | 49.35 | 49.35 | 16.88 |

From these data, it can be seen that the quantity and quality of gluten of the EMF-treated and untreated (control) grain vary depending on the frequency of the EMF and, to a greater extent, on the grain storage conditions. Unfavourable storage conditions – elevated temperature (23°C) and high relative humidity of the air (82–82.5%) – have an especially big effect on the quantity and quality of gluten of both treated and untreated grain.

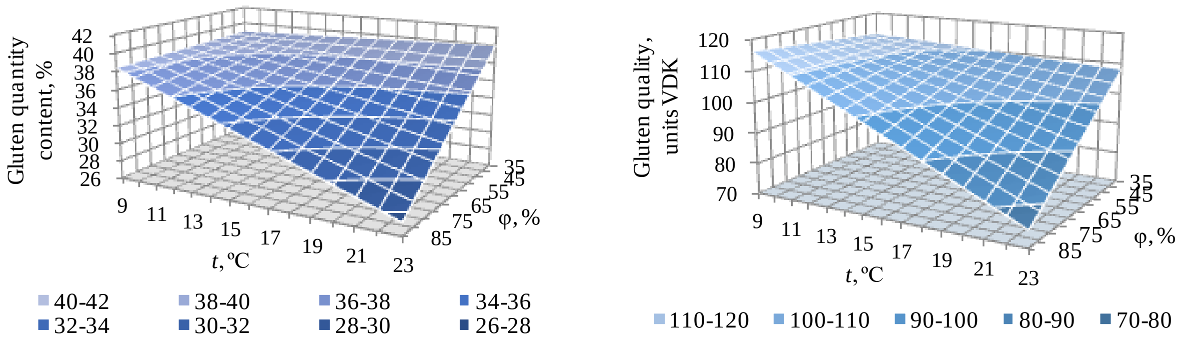
Processing of the obtained data by the method of least squares has made it possible to visualise the effect of the temperature and relative air humidity on the changes in the quantity and quality of gluten of the untreated wheat grain (control), which are shown in Fig. 3.

Fig. 3 clearly shows that the temperature and relative humidity of the air have an ambiguous effect on the change in the gluten content. Thus, due to the low relative humidity (35%), with an increase in the air temperature from 9°C to 23°C, the gluten content practically does not change. But when grain is stored at high relative air humidity (82.5%), the same increase in the temperature leads to a significant decrease in the amount of gluten (almost by 10%, from 38.4% to 28.0%).

If we consider the effect of relative humidity on the change in the gluten content, it can be seen that at low storage temperatures (9°C), an increase in the relative humidity from 35% to 82% practically does not change the gluten content. However, when grain is stored at 23°C, an increase in the relative air humidity from 35% to 82.5% leads to a sharp decrease in the gluten content – from 40.0% to 28.0% (by 1.43 times).

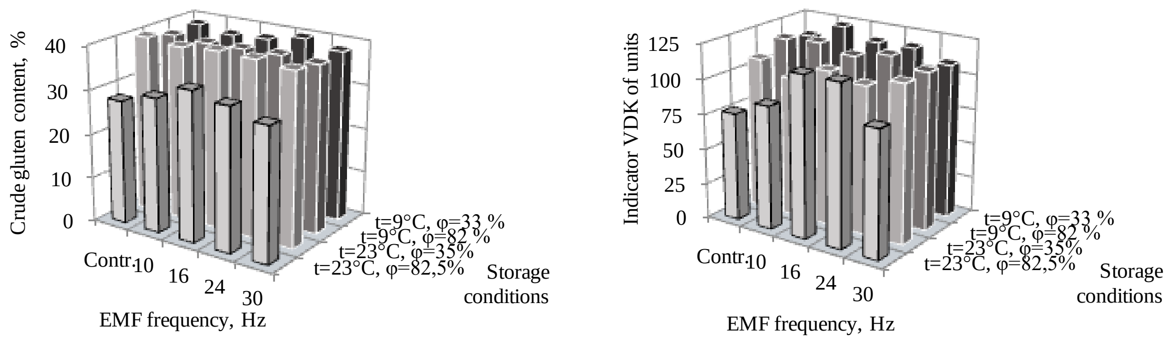
A similar effect produced by the storage conditions of untreated wheat grain is also observed in relation to changes in the quality of gluten. This effect is visualised in Fig. 3b. With a simultaneous increase in the temperature and relative humidity, the quality of gluten rapidly decreases. At the relative air humidity 82.5%, an increase in the storage temperature from 9°C to 23°C leads to a deterioration in the quality of gluten from 116 to 77 VDK units (by 1.51 times). When grain is stored at 9°C, an increase in the relative air humidity from 33% to 82% practically does not change the quality of gluten: it remains within 112–116 VDK units, that is, within the permissible error of its determination.

The frequency of the EMF during the treatment of wheat grain also affects the quantity and quality of grain stored under controlled conditions, as can be seen from Fig. 4.




a) quantity of gluten b) quality of gluten

**Fig 3. Effect of the temperature and relative air humidity on the changes in the quantity and quality of gluten of the untreated wheat grain (control) after storage for 14 months under controlled conditions**




a) gluten content b) gluten quality

**Fig. 4. Effect of the EMF frequency and the conditions of storage of treated grain on the quantity and quality of gluten**

An analysis of the histograms (Fig. 4) shows that the greatest decrease in the amount of gluten, in comparison with the control, occurred after storage of the EMF-treated wheat grain at the temperature 23°C and relative humidity 82.5%. However, storage of the grain EMF-treated at the frequencies 10–30 Hz under these conditions allowed increasing the gluten content, as compared with the control (28.0%), by 2.1–5.8%, or by 1.07–1.21 times. The greatest positive effect on the increase in gluten (from 28.0% to 33.8%) was obtained when the grain was treated with an EMF with the frequency 16 Hz, and a slightly smaller effect (from 28.0% to 32.3%) resulted from treating the grain at 24 Hz.

A similar effect on the gluten quality of the EMF-treated grain was observed after the treated grain was stored under the same unfavourable conditions (at the temperature 23°C and relative humidity 82.5%). When treating the grain at the EMF frequencies 16 Hz and 24 Hz, the gluten quality index was higher than in the control by 27.65 VDK units (by 1.49 times) This was practically at the level of the quality indicators of grain stored under much better conditions – 9°C and the humidity 33%.

At the last stage of the experimental studies, it was studied how EMF-treatment at ELF affected the fatty acid composition of wheat grain of the cultivar Shestopalivka harvested in 2020.

The treatment was carried out on the above-described test installation with the following EMF parameters: the magnetic induction in all experiments was 10 mT, the treatment time was 6 min, and the treatment frequencies were 10, 16, 24, and 30 Hz.

The grain was treated with the ELF EMF on 22 September 2020 (series 5). In the treated and untreated (control) wheat samples, gas chromatography was used to determine 6 essential fatty acids corresponding to the chemical composition of wheat grain [23], in particular, saturated (palmitic, stearic), monounsaturated (oleic, gondoic), and polyunsaturated (linolenic, α-linolenic). The determination of these fatty acids was carried out in stages: for the conditions of t=23°C, φ=35%, τ=12.47 months (01/10/2021); for the conditions t=9°C, φ=33%, τ=12.90 months (17/10/2021); for the conditions t=9°C, φ=82%, τ=13.00 months (14/10/2021); for the conditions t=23°C, φ=82.5%, τ=13.00 months. (17/12/2021).

The grain storage conditions and the results of the chromatographic analysis to determine the fatty acid composition of the untreated (control) samples of wheat grain are summarised in Table 3.

From these data, it can be seen that in the untreated wheat grain stored under various controlled conditions for 12.47–15.00 months, the content of individual fatty acids remained practically unchanged. Residues that remained unidentified when determining fatty acids in the control samples and in the EMF-treated ones (at 10–30 Hz) were in the range 0.1–0.8%.

To visualise the effect of treating grain with the EMF at the frequencies 10–30 Hz, the relative deviations (rel. dev., %) of the fatty acid content have been determined in comparison with the control, and based on them, the corresponding histograms have been constructed for each variant of the storage conditions (Fig. 5).

It can be seen that the contents of fatty acids detected in the EMF-treated wheat samples differ to a different extent, and individual fatty acids can both decrease and increase, compared with the untreated grain (control). It can also be seen that changes in the content of individual fatty acids depend not only on the frequency of the EMF, but also on the conditions and duration of grain storage.

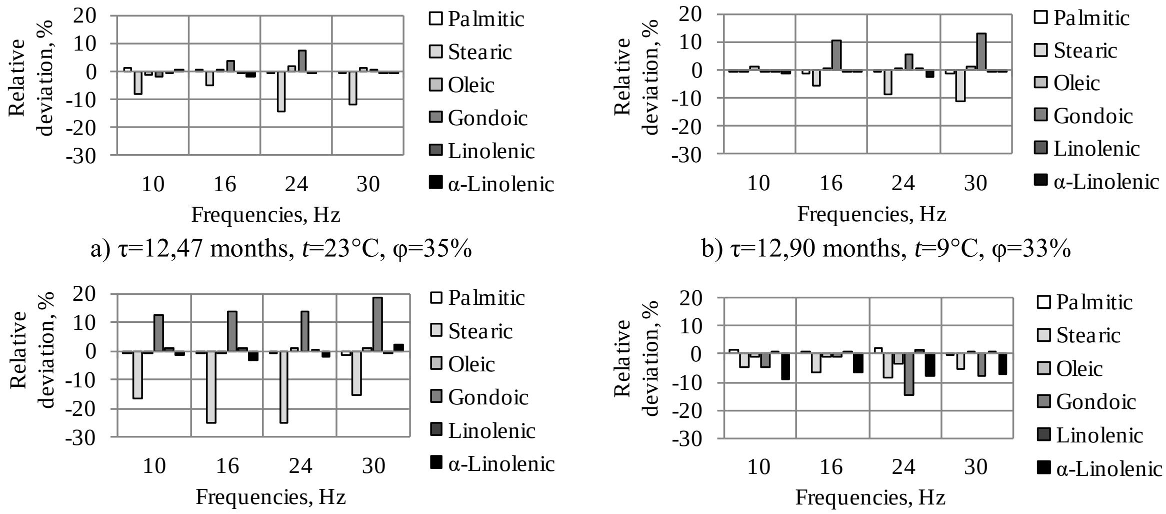
Analysis of the histograms has shown that after 12.47 months of storing the EMF-treated grain under warm and dry conditions (t=23°C, φ=36%), its fatty acid composition, compared with the control (untreated grain), changed in varying degrees (Fig. 5a). Only the relative content of gondoic acid increased slightly during EMF treatment with the frequency 16 and 24 Hz (by 3.6% and 6.2% respectively). The content of stearic acid decreased to somewhat bigger extent: at the frequency 10, 16, 24, and 30 Hz, respectively, by 8.3, 4.9, 14.6, and 11.9%.

The treated grain stored for 12.90 months under cool and dry conditions (t=9°C, φ=33%) showed an increase in the same gondoic acid. At the frequencies 16, 24, and 30 Hz, its relative content increased, respectively, by 10.55.3 and 13.2%, and at the same frequencies, the content of stearic acid decreased by 5.7, 8.5, and 11.3%.

The greatest changes in fatty acids in comparison with the control occurred during storage of the treated grain for 13 months under cool but humid conditions (t=9°C, φ=82%). Again, changes occurred in stearic and gondoic acids after treatment at all EMF frequencies under study. Thus, the relative increase in gondoic acid, corresponding to the increase in frequencies, was 12.5, 13.5, 13.5, and 18.7%, while stearic acid decreased by 16.7, 25.0, 25.0, and 15.5%.

**Table 3 – Fatty acid composition of the wheat grain not treated with the EMF (control) after different periods of storage under controlled conditions (p=0.05; n=3)**

| Storage conditions | | | Fatty acid composition of wheat not treated with the EMF (control), % | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Saturated | | Monounsaturated | | Polyunsaturated | |
| *t*, °C | φ, % | τ, months | Palmitic C16:0 | Stearic C18:0 | Oleic C18:1n9c | cis-11-Eicosenoic C20:1 (Gondoic) | Linoleic C18:2n6c | α-Linolenic C18:3n3 |
| 23 | 35 | 12.47 | 16.64 | 1.44 | 17.13 | 1.11 | 58.06 | 5.62 |
| 9 | 33 | 12.90 | 16.82 | 1.41 | 17.09 | 1.14 | 57.81 | 5.73 |
| 9 | 82 | 13.00 | 16.70 | 1.68 | 17.04 | 0.96 | 58.01 | 5.62 |
| 23 | 82.5 | 15.00 | 16.93 | 1.49 | 17.75 | 0.89 | 57.84 | 5.11 |




a) τ=12,47 months, *t*=23°C, φ=35%

b) τ=12,90 months, *t*=9°C, φ=33%

c) τ=13,00 months, *t*=9°C, φ=82%

d) τ=15,00 months, *t*=23°C, φ=82,5%

**Fig. 5. Relative deviations of the fatty acid content in the wheat grain EMF-treated at different frequencies and in the control, depending on the EMF frequency, terms (τ) and conditions (t, φ) of storage**

Finally, in the last variant of storage of treated grain (15 months under unfavourable warm and humid conditions at t=23°C, φ=82.5%), one can note no growth in the fatty acid content, but only its decrease. When treated at the EMF frequency 10 Hz, compared with the control, stearic acid decreased by 4.7%, gondoic acid by 4.5% and α-linolenic acid by 9.0%. At 16 Hz, stearic acid decreased by 6.7% and α-linolenic by 6.3%. At 24 Hz, stearic decreased by 8.7%, oleic by 3.3%, gondoic by 14.7%, and α-linolenic by 8.0%. At the frequency 30 Hz, stearic acid decreased by 5.4%, gondoic acid by 7.9%, and α-linolenic acid by 7.4%.

Thus, it can be concluded that, under various storage conditions, EMF treatment of grain most often affects the content of stearic and gondoic acids. The greatest changes were noted during storage at the temperature 9°C and the relative air humidity 82% at all frequencies within the range 10–30 Hz. At the same time, a steady increase in valuable monounsaturated gondoic acid was noted (by 12.5–18.7%), as well as a steady decrease in saturated stearic acid (by 15.5–25.0%). Under all other studied conditions of EMF treatment and storage of wheat grain, the changes in fatty acids are within the allowable errors.

## Conclusion

1. It has been shown that EMF treatment of grain with the frequencies 20 and 30 Hz and magnetic induction 5 and 10 mT for 2–20 min reduces the germination capacity of wheat, as compared with the control, by 1–12%. As an exception, in several experiments, the germination capacity increased, and the biggest increase (by 14%) was at the treatment duration 12 minutes, the frequency 30 Hz, and the magnetic induction 5 mT.

2. Treatment of grain with the EMF with the frequencies 10–28 Hz and magnetic induction for 6 min increases the germination capacity at the frequencies 10, 18–24 Hz by 1–5%, but after 15 days, at the frequency 12–26 Hz, the germination power increases by 1–9%. After a month, the germination capacity becomes higher than in the control by only 2–7% at 18, 20, and 28 Hz, and after 10 months of storage, only the experiment with the treatment frequency 24 Hz reached the control level. At all other frequencies, there is a significant decrease in the grain germination capacity. It has also been established that treating grain at 14–22 Hz 15 days prior to sowing increases the germination ability by 7–9% making it as high as 92–94%.

3. It has been shown that in the grain treated with the EMF at 10–30 Hz and stored for 14 months at the controlled air temperature 9–23°C and relative humidity 33–82.5%, the protein content on a dry weight basis, compared with the control (16.4–16.6%), does not change.

4. It has been established that the storage of grain EMF-treated for 6 min at the frequency 10–30 Hz and magnetic induction 10 mT allows increasing the gluten content by 1.07–1.21 times, compared with the control. The biggest increase in gluten is achieved at 16 Hz. At the same frequency, the quality of gluten after grain storage increases, compared with the control. Even under unfavourable conditions (at the temperature 23°C and relative humidity 82.5%), the quality of gluten improves by 27.65 conventional units of the device VDK (by 1.49 times), reaching the gluten quality level of the grain preserved under much better conditions – the temperature 9°C and the humidity 33%.

5. It has been shown that EMF treatment of grain at the frequency 10–30 Hz and magnetic induction 10 mT for 6 min under different storage conditions most often affects the content of stearic and gondoic acids.

The biggest changes in their contents at all the frequencies considered were noted during storage at the temperature 9°C and the relative air humidity 82%: valuable monounsaturated gondoic acid increased by 12.5–18.7%, and saturated stearic acid decreased by 15.5–25.0%. Under all other studied conditions of EMF treatment and storage of wheat grain, the changes in fatty acids are within the allowable errors.

**References:**

1. Boshkova IL, Volgusheva NV. Primenenie mikrovolnovogo metoda obrabotki rastitelnyh materialov v razlichnyh tehnologiyah: monografiya. 2017.
2. Dalmoroa A, Barba A, Caputo S, Marra F, Lamberti G. Microwave technology applied in post-harvest treatments of cereals and legumes. J Chemical engineering transaction. 2015;44:13-18. https://doi.org/10.3303/CET1544003
3. Sapogov AC. K voprosu o nevosproizvodimosti magnitobiologicheskih opytov. Biofizika. 1992; 37(4):769-771.
4. Belova HA, Lednev VV. Zavisimost gravitropicheskoj reakcii v segmentah steblej lna ot chastoty i amplitudy peremennoj komponenty slabogo kombinirovannogo magnitnogo polya. Biofizika. 2000;45(6):1108-1111. https://doi.org/10.1021/je000128w
5. Sarraf M, Kataria S, Taimourya H, Santos LO, Menegatti RD, Jain M, et al. Magnetic Field (MF) Applications in Plants: An Overview. Plants. 2020;9(9):1139. https://doi.org/10.3390/plants9091139
6. Erohin AI. Vliyanie elektromagnitnogo polya nizkoj chastoty na posevnye kachestva semyan i urozhaj-nost goroha, yachmenya i yarovoj pshenicy. Zernobobovye i krupyanye kultury. 2018;2(26):17-22. https://doi.org/10.24411/2309-348H-2018-10010
7. Kasyanov GI, Baryshev MG, Reshetova RS, Hristyuk VT, Zanin DE. Obrabotka selskohozyajstvennogo syrya elektromagnitnym polem nizkoj chastoty. Teoriya i praktika: Monografiya. 2016. http://e.lanbook.com/book/90693
8. Ragha L, Mishra S, Ramachandran V, Bhatia M. Effects of low-power microwave fields on seed germination and growth rate. J of Electromagnetic Analysis and Applications, 2011;May.3(5):165-171. https://doi.org/10.4236/jemaa.2011.35027
9. Sposob i ustrojstvo dlya obrabotki rastenij A.c. Franciya. № 2579412. kl. A 01 G 7/04, 9/02. s prioretetom 01.08.86. Opublikovano 03.10.86. Byul. №40. Zaregistrir. 15. 07.86.
10. Ijaz B, Jatoi SA, Ahmad D, Shahid M, Siddiqui SU. Changes in germination behavior of wheat seeds exposed to magnetic field and magnetically structured water. Afr.J.Biotechnol. 2012;11(15):3575-3585. https://doi.org/10.5897/AJB11.2927
11. Zhalnin EV, Shibryaeva LS, Sadykov ZhS. Nizkochastotnoe elektromagnitnoe obluchenie zerna v zernouborochnom kombajne. Selskohozyajstvennye mashiny i tehnologii. 2016;2:16-21. https://www.vimsmit.com/jour/article/view/123/79
12. Shabrangi A, Majd A, Sheidai M, Nabyouni M, Dorranian D. Comparing effects of extremely low frequency electromagnetic fields on the biomass weight of C3 and C4 plants in early vegetative growth. PIERS Proceedings. 2010; 593-598. https://www.researchgate.net/publication/268367 553
13. Barishev MG, Dzhimak SS, Kasjanov GI. The influence of low freguency electromagnetic field on the agricultural crops seeds germination. J. of Agricultural Science and Technologu. 2012;2(3):385-390.
14. Marinković B, Grujić M, Marinković D, Crnobarac J, Marinković J, Jaćimović G, et al. Use of biophysical methods to improve yields and quality of agricultural products. J Agricultural Sciences. 2008;53(3):235-242. http://joas.agrif.bg.ac.rs/sites/joas.agrif.bg.ac.rs/files/article/pdf/244-1450-81090803235m.pdf https://doi.org/10.2298/JAS0803235M
15. Danilov VI. Magnitnoe pole i selskoe hozyajstvo. Dubna, 1987.
16. Aksenov SI, Bulychev AA, Grunina BN, Turoveckij BB. O mehanizmah vozdejstviya nizkochastotnogo magnitnogo polya na nachalnye stadii prorastaniya semyan pshenicy. Biofizika 1996;41(4):919-924.
17. Zhong Han, Meng-jie Cai, Jun-Hu Chengand, Da-WenSun. Effects of electric fields and electromagnetic wave on food protein structure and functionality: A review. Trends in Food Science & Technology. 2018;75:1-9. https://doi.org/10.1016/j.tifs.2018.02.017
18. Pietruszewski S, Muszyński S, Dziwulska A. Electromagnetic fields and electromagnetic radiation as non-invasive external stimulants for seeds (selected methods and responses). Int. Agrophysics. 2007;21(1):95-100. https://www.researchgate.net/publication/26552199
19. Nair RM, Leelapriya T, Dhilip KS, Boddepalli VN, Ledesma DR. Beneficial effect of Extremely Low Frequency (ELF) Sinusoidal Magnetic Field (SMF) exposure on mineral and protein content of mungbean seeds and sprouts. Indian Journal of Agricultural Research. 2018; 52 (2):126-132. https://doi.org/10.18805/IJARe.A-4908
20. Kasyanov GI, Syazin IE, Grachev AV, Davidenko TN, Vazhenin EI. Features of usage of electromagnetic field of extremely low frequency for the storage of agricultural products J Electromagnetic Analysis and Applications. 2013;5(5):236-241. https://www.scirp.org/pdf/JEMAA_2013052413410885.pdf https://doi.org/10.4236/jemaa.2013.55038
21. Osokina N, Liubych V, Novikov V, Leshchenko I, Petrenko V, Khomenko S. et al. Effect of electromagnetic irradiation of emmer wheat grain on the yield of flattened wholegrain cereal. Eastern-European J of Enterprise Technologies. 2020;11(108):17-26. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3761027
22. Postoyannaya otnositelnaya vlazhnost nad nasyshennymi rastvorami solej v zavisimosti ot temperatury, a takzhe glicerina i sernoj kisloty v zavisimosti ot temperatury i koncentracii.

http://tehtab.ru/Guide/GuidePhysics/Humidity/SaturatedSaltSolutionsHumidity/ https://doi.org/10.15587/1729-4061.2020.217018

23. Kazakov ED, Kretovich VL. Biohimiya zerna i produktov ego pererabotki. 2-e izd. pererab. i dop. M.: Agropromizdat, 1989.

# ДОСЛІДЖЕННЯ ВПЛИВУ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ ВКРАЙ НИЗЬКИХ ЧАСТОТ НА ЯКІСТЬ ЗЕРНА ПШЕНИЦІ

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**Анотація.** Наведено результати досліджень впливу електромагнітного поля (ЕМП) вкрай низьких частот (ВНЧ), магнітної індукції ЕМП та тривалості обробки та зберігання зерна пшениці сорту Шестопалівка 2018, 2019 та 2020 років урожаю, вирощених в Одеській обл. на показники його якості. Обробка зерна ЕМП з частотами 20 і 30 Гцта магнітною індукцією 5 і 10 мТл протягом 2–20 хв. знижує схожість пшениці порівняно з контролем на 1–12%. Як виключення, у кількох дослідах схожість зросла і найбільше (на 14%) за тривалості 12 хв., частоти 30 Гц, та магнітної індукції 5 мТл. Обробка зерна ЕМП з частотами 10–28 Гц і магнітною індукцією протягом 6 хв. показала підвищення схожості за частот 10, 18–24 Гц на 1–5%, однак уже через 15 діб за частот 12–26 Гц схожість зросла на 1–9%. Через місяць схожість перевищувала контроль лише на 2–7% за частот 18, 20 та 28 Гц, а через 10 місяців зберігання на рівні контролю був лише дослід з частотою обробки 24 Гц. За всіх інших частот відбулося значне зниження схожості зерна. Встановлено, що обробка зерна за частоти 14–22 Гц за 15 діб до сівби підвищує схожість на 7–9%, досягаючи значень 92–94%.У обробленого ЕМП за частот 10–30 Гц зерна, що зберігалось 14 місяців за контрольованих температури повітря 9–23°С та відносної вологості 33–82,5%, вміст білка на суху масу порівняно з контролем (16,5%) не змінився. Зберігання зерна, обробленого впродовж 6 хв. ЕМП з частотою 10–30 Гц та магнітною індукцією 10 мТл дозволяє збільшити вміст клейковини порівняно з контролем в 1,07–1,21 рази. Найбільше зростання кількості клейковини досягається за частоти 16 Гц. Навіть за несприятливих температури 23°С та відносної вологості повітря 82,5% якість клейковини зростає на 27,65 ум. од. приладу ВДК (в 1,49 рази), досягаючи рівня якості клейковини зерна що зберігалась за значно кращих умов – температури 9°С та вологості 33%. Обробка зерна ЕМП за частот 10–30 Гц і магнітної індукції 10 мТл впродовж 6 хв. за різних умов зберігання найчастіше впливає на вміст стеаринової та гондоїнової кислот. Їх найбільші зміни відмічено при зберіганні за температури 9°С і відносної вологості повітря 82% – гондоїнова кислота зростає на 12,5–18,7%, а стеаринова зменшується на 15,5–25,0%. За всіх інших умов обробки ЕМП та зберігання зерна пшениці зміни жирних кислот знаходяться у межах припустимих похибок.

**Ключові слова:** зерно пшениці, електромагнітне поле, вкрай низькі частоти, магнітна індукція, обробка зерна, зберігання зерна, показники якості зерна.