UDC 631.563:66.086.4:633.11
DOI https://doi.org/10.15673/gpmf.v21i4.2262

Yu. Kovra[1], Chemist of the First Category, *E-mail: yuriykovra@gmail.com*
http://orcid.org/0000-0001-6264-6454, Researcher ID: U-2141-2018
G. Stankevych[2], Doctor of Technical Sciences, Professor, *E-mail: georgii.stn@gmail.com*
http://orcid.org/0000-0002-0583-8174, Researcher ID: F-8557-2016, Scopus Author ID: 56184710800
A. Borta[2], PhD Tech. Science, Associate Professor, E-mail: borta.alla@ukr.net
http://orcid.org/0000-0001-9790-4732, Researcher ID: F-9893-2016
[1]*Food Safety Laboratory (FSL) of the Test Center of FE "SGS UKRAINE"*
[1]*Foreign enterprise "SGS UKRAINE", Chornomorskogo kozatstva Str., 103, Odessa, Ukraine, 65003*
[2]*Odessa National Academy of Food Technologies, Kanatna Street, 112, Odessa, Ukraine, 65039*

STUDY OF PROPERTIES OF WHEAT GRAIN PROCESSED BY ELECTROMAGNETIC FIELD FOR DIFFERENT PURPOSES USE

Abstract

The results of studies of the influence of the electromagnetic field (EMF) and the duration of wheat grain storage of varieties Guzel, Arista, Obrana and Shestopalivka on their technological and seed quality properties are presented. Grain processing was carried out by EMF with frequencies of 10...30 Hz with a magnetic induction of 10 mT for 6 minutes. It is shown that the processing of wheat grain with EMF increased the content of raw gluten by 1.0...3.2% for the Gyuzel variety and by 1.0...2.6% for the Obrana variety. For variety Arista, the content of crude gluten increased by 1.0% only when treated with EMF at a frequency of 16 Hz, and at other frequencies it decreased within the error. For these varieties of wheat, EMF treatment with a frequency of 16 Hz increases the amount of crude gluten, depending on the variety, by 1.0...3.2%, which increases the class of grain. However, grain processing with a frequency of 16 Hz reduces the quality of gluten in the Guzel and Arista varieties, and it passes from the 1st to the 2nd quality group. When storing wheat grain treated with EMF for about 8 months, the sedimentation index, which comprehensively characterizes the strength of flour, increases by 3 ml (by 4.6%) compared to the control only at a frequency of 16 Hz at a storage temperature of 9 °C and a relative humidity of 82%, and after storage for almost 14 months, it grows by 2 ml (by 3.1%). An increase in the sedimentation index by 6...9 ml (by 10.7...16.1%) was noted when processing grain with EMF frequencies of 10...30 Hz during storage for about 14 months at a temperature of 9 °C and a relative humidity of 33%. Under other storage conditions and EMF processing frequencies, the sedimentation index may not change or decrease to 13 ml (up to 20.0%), which indicates a deterioration in the quality of gluten. Studies of the falling number (FN) of wheat samples of varieties Guzel, Arista, Obrana and Shestopalivka showed that their EMF treatment changes the FN indicator only within acceptable deviations. The exception was a grain sample of the Shestopalivka variety treated with EMF at a frequency of 30 Hz. After its storage for 12.8 months at a temperature of 23 °C and a relative humidity of 35%, the FN index decreased by 52 seconds compared to the control. In samples of wheat varieties Guzel and Arista with a low initial after EMF treatment, germination decreased by 1.06...1.71 times compared with the control. In the wheat variety Obrana with an initial germination of 80% EMF treatment increased the germination rates. The greatest effect was obtained by processing grain with an EMF frequency of 10 Hz, at which the germination increased by 14%, reaching 94%. An increase in the EMF frequency to 16, 24, and 30 Hz led to an increase in germination by 9, 8, and 4%, respectively.The vitreousness of the wheat of the Shestopalivka variety treated with EMF after its storage for 9…13 months in 58% of the samples decreased by 1…17% compared to the control, and only in 29% of the samples it increased by 1…8%. However, 67% of all vitreous changes are below the margin of error. A steady decrease in grain vitreousness by 2...12% at a frequency of 10...30 Hz was noted, which persisted for about 12.5 months at a relative humidity of 33% and a temperature in the range of 9...23 °C. Significant increase in vitreousness was observed only in grain treated at a frequency of 16 Hz, after storage for 9.2 months at a relative humidity of 35% and a temperature of 23 °C.

Key words: wheat grain, electromagnetic field, magnetic induction, grain processing, grain properties, grain storage.

Formulation of the problem

Wheat grain, one of the most common crops, is a raw material for the production of many food products. Post-harvest processing of wheat grain, its storage and subsequent targeted processing are based on the use of certain technological properties and quality indicators.

It is known that the quality of the grain is formed during the ripening process, but it does not remain constant and changes during post-harvest processing and subsequent storage under various conditions. Many different factors can influence the change in grain quality [1].

The quality of wheat grain is determined by a number of indicators given in the regulatory documentation. Among these indicators there are class-forming ones that determine the class of wheat grain. These include indicators of the quantity and quality of gluten, which are important for grain processing, falling number (FN), vitreousness, and others.

It is known from the literature [2] that the properties of grain gluten can be influenced by an electromagnetic field (EMF). Although the properties of EMF have long been used in various industries, only in recent decades has there been a trend towards an increase in its use for agricultural purposes.

Scientists from different countries have conducted many studies of the effect on grain quality by irradiation with EMF of ultrahigh frequency (microwave range) [3-6]. Researchers [6] found that under direct exposure to EMF of ultrahigh frequency (UHF) on seeds of spring wheat with low quality indicators, their change is observed, depending on the time of exposure to EMF on seeds. The variability in protein content is on average higher than in the amount of gluten. It was found that the treatment of seeds with an EMF with a frequency of 2.45 GHz with a power of 1200 W for 5 sec. leads to a significant improvement in quality control indicators. The average indicators of the quality of wheat grain (the protein content and crude gluten content) undergo significant changes towards improvement with microwave exposure for 5 second, within 10 s second, on average, leads to a decrease in quality indicators.

Given that the determination of such an important indicator as gluten is rather cumbersome and has certain problems with reproducibility of results, it would be advisable to use a highly productive and reliable sedimentation method to assess the quality of EMF-treated grain. It was developed and proposed by domestic scientists [7] for an indirect assessment of the strength of wheat flour (grain). The method is based on preliminary autolysis of wheat in acetic acid solution and subsequent sedimentation with sodium dodecyl sulfate (SDS). Sedimentation volume (ml) has a very high correlation with the key quality indicator, dough strength, and does not correlate with total protein content.

One of the main indicators of the quality of wheat grain can be attributed to grain vitreousness. But for grains for various purposes (cereals, pasta, bakery products), this indicator is not equivalent. Vitreousness is an external sign of grain quality, reflecting the structure of the internal tissues of the grain. Powdery endosperm is characterized by a weak bond between starch grains and protein. In the vitreous endosperm, this bond is very strong. The total vitreousness indicator does not give a complete picture of which fraction in terms of grain vitreousness prevails in the batch – vitreous, partially vitreous or farinaceous. That is, you can evaluate the quality of a batch of grain, but you cannot manage it [8]. At the same time, there is no information in scientific sources about the possible effect of EMF on the vitreous index.

In recent years, interest has increased in the use of extremely low frequency (ELF) EMF for the processing of agricultural products, in particular grain, which has a number of advantages. It is close to the geomagnetic field of the Earth, which makes it safer, has less energy consumption, does not lead to heating, etc. Researchers explain the effect of ELF EMF on biological objects by the participation of enzymes as primary receptors that respond to EMF [9]. Taking this into account, it would be appropriate to study the effect of ELF EMF on such an indicator of wheat quality as the falling number (FN), because its changes are caused by the activity of α-amylase, an amylolytic enzyme that is activated during grain germination and affects grain germination.

In pre-sowing preparation of seeds, an effective way to increase the germination of plants is the use of low-frequency electromagnetic fields. Researchers have shown that the use of low-frequency EMF on seeds increases the germination energy and laboratory germination of treated seeds of peas, barley and spring wheat by 2...4%. The use of seeds treated in this way increased the yield of spring wheat in relation to the control by 0.25 t/ha (8.4%) [10].

There are also known studies of the effect of EMF on the grain quality and food products produced from them. Ukrainian scientists studied the effect of water-thermal treatment and the duration of electromagnetic treatment on the quality of flattened whole grain cereals from Emer wheat [11]. They showed that when using optimal grain processing parameters (moisturizing by 1.0% and irradiating the grain with EMF for 80...100 s), it provides an output of high-quality whole grain rolled cereals of 91.7...92.3% with a culinary rating of 7.3 points.

There are publications of specialists indicating the possibility of extending the shelf life of grain through a combination of various physical methods using EMF processing [12]. The literature describes the method and modes of pre-sowing treatment of grain of different crops, which allows not only to increase their germination and productivity of the production line, but also to extend the shelf life of grain. To do this, seeds before sowing are treated with a constant magnetic field and at the same time with EMF, phase-modulated ELF (extremely low frequencies) waves for 40...60 minutes, at a field strength of 120…1400 A/m. The authors also proposed a method for extending the shelf life of grain seeds under the influence of low-frequency EMF [13]. However, one should keep in mind some problems that arise when studying the effect of EMF on biological objects, which are also grain, as indicated by separate publications of scientists [14, 15].

The review of scientific sources shows that information on the processing of grain by an electromagnetic field (EMF) is quite contradictory. Various authors suggest the use of processing by electric and magnetic fields in a fairly wide range of parameters. The impact on grain crops of weak low-intensity fields (non-thermal) in order to improve the quality of grain during storage has not yet been studied enough. This motivated us to carry out our experimental studies.

The aim of the work was to establish the effect of EMF on the technological and seed properties of wheat grain, which will allow correcting individual indicators of grain quality and improving the efficiency of its storage and use.

Research objectives. Determination of the influence of the frequency, intensity and duration of wheat grain processing with EMF of an extremely low frequency range on the technological indicators of grain quality (gluten content and quality, falling number, vitreousness, ostentatious sedimentation, fatty acid composition, germination) as well as their changes during storage.

Materials and methods of research.

Experimental studies were carried out on wheat grain varieties Guzel, Arista, Obrana 2019 harvest and variety Shestopalovka 2020 harvest grown in the Odessa region.

Wheat grain samples were treated with EMF of an extremely low frequency range, with different magnetic induction and duration of processing and storage, and a number of indicators of its quality were determined – gluten content and its quality, vitreousness, falling number, sedimentation index, fatty acid composition and germination.

Processing grain EMF ELF. The processing of wheat grain was carried out on an experimental stand, consisting of a cylindrical polymer tube (grain container), a solenoid coil, a GZ-112/1 electromagnetic oscillation generator, and a low-frequency power amplifier. The output signal of the generator was set in the form of a sinusoid and controlled with an S1-78 oscilloscope.

The studies were carried out using ELF (extremely low frequencies) frequencies of 10, 16, 24, and 30 Hz. The magnetic induction of grain processing was constant and equal to 10 mT. The required value of EMF frequencies in the range of their extremely low values was set on the generator of electromagnetic oscillations GZ-112/1.

The required value of the current strength in the experimental stand to provide the indicated magnetic induction was 1 A. To do this, before the start of each experiment on grain processing, the required value of the current strength controlled by a universal (combined) digital voltmeter B7-38 was set with the power regulator of the LF amplifier.

The duration of grain processing was τ = 6 min, which was justified on the basis of the results of preliminary studies of the effect of EMF ELF.

The determination of the quality indicators of processed and unprocessed (control) grain was carried out immediately after processing with EMF, as well as after different storage periods (almost up to 14 months).

Grain storage under controlled conditions. To store grain under controlled conditions in desiccators, a given temperature and relative air humidity were maintained, simulating the conditions of grain storage at different times of the year. The required temperatures (9 and 23 °C) were provided in a thermostat and a refrigerator and controlled by thermometers TU 25-1102.043-83 TC-4 Mk 0-100 °C with a scale division value of 1 °C.

To create certain relative air humidity, about 1…2 dm3 of sulfuric acid solution of the required density was poured into the desiccators, which provided the required values of relative air humidity (33%, 35%, 82.0% and 82.5%). At the same time, to ensure more accurate results, the concentration of sulfuric acid solutions in desiccators was prepared taking into account the dependence of its density on temperature. The density of sulfuric acid and its solutions was controlled using a set of hydrometers.

Method for determining the quantity and quality of gluten (GOST 13586.1-68 Grain. Methods for determining the quantity and quality of gluten in wheat).

To determine the amount of gluten, the ground grain 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 filled with water. The volume of water for kneading dough with a sample weight of 25 g is 14 cm3. After that, the dough is kneaded.

The dough formed into a ball is placed in a bowl and covered with glass (or a second cup) for 20 minutes. After that, the gluten is washed under a weak stream of tap water over a thick silk or nylon sieve, slightly kneading the dough by fingers. At first, washing is carried out carefully, not allowing pieces of dough to come off together with starch and shells, after removing starch and shells – more vigorously. Accidentally torn off pieces of gluten are collected and connected to the total mass of gluten.

Having finished washing the gluten, it is squeezed between the palms, which are wiped dry with a towel from time to time. The pressed gluten is weighed, washed again for 2…3 minutes. Press again and weigh. Laundering of gluten is considered complete by the difference in mass between two weighings of not more than 0.1 g. The raw gluten is expressed in mass fractions, as a percentage of a sample of crushed grain.

For kneading the dough, washing and determining the quality of gluten, ordinary tap water is used, the temperature of which must meet the requirements of 18 ± 2 ºC.

The quality of gluten is understood as the accumulation of its physical strengths: tension, elasticity, viscosity, the ability to maintain physical properties over time. The spring values of gluten were determined in the same scale units of the VDK-7 device (gluten deformation was calculated).

A piece weighing 4 g is separated from the washed gluten (kneaded 3…4 times with fingers), after which a ball is formed and placed for 15 minutes in a bowl with water, the temperature of which must meet the requirements of 18 ± 2 ºC. If the gluten after washing is a spongy, lightly torn mass and does not form a ball, then it is assigned to group 2 without determining the quality on the device.

After 15 minutes of soaking in water, the gluten ball is placed in the center of the table of the VDK-7 device and the button for switching on the time relay "Start" is pressed. The punch falls freely on the gluten and compresses it. On the display panel of the device, a number is indicated that characterizes the magnitude of the elasticity of the studied gluten standard in conventional units of the device scale.

Permissible discrepancy for the amount of gluten is ±2.0% and for the quality of gluten is ±5 arb. units device.

The falling number was determined in accordance with GOST 30498-97 “Cereals. Determination of the falling number, based on the rapid gelatinization of an aqueous suspension of flour in a boiling water bath, followed by measurement of the degree of liquefaction of the starch gel under the action of α-amylase. The falling number was determined on a PChP-7 instrument (OOO “Analyt pribor”). The falling number is the time in seconds it takes for the viscometer stirrer to mix and free falling a certain distance in hot slurry of diluted flour and water. Permissible deviation is ±10% of the arithmetic mean.

Determination of vitreousness of wheat grain, reflecting the structure of the internal tissues of the grain, was determined according to GOST 10987-76. "Corn. Methods for determining vitreousness” with the introduction of a diaphanoscope. The essence of the method is to illuminate 100 whole grains with a stream of light from the side of the groove and count the number of grains that are well translucent, partially and not translucent at all.

Determination of the sedimentation index. The sedimentation index is an indirect method for assessing the strength of wheat flour (grain). The method is based on preliminary autolysis of wheat in acetic acid solution and subsequent sedimentation with sodium dodecyl sulfate (SDS).

For research, wheat grain is crushed in a mill and thoroughly mixed. Next, a sample weighing 3.2 g (two parallels) is poured into a polymer cup, poured into 10 ml of a 2% solution of acetic acid and stirred. The glass is covered with a lid and placed in a water bath (t = 30 °C) for 30 minutes. After that, the cup is removed from the bath, 10 ml of a 4% solution of acetic acid, tinted with methylene blue indicator, is added with a dispenser. The mixture is shaken and poured into the cylinder up to the 50 ml mark, marking 2 minutes. Next, the cylinder is closed with a lid, placed in an automatic device for mixing "Kvant-1", rotating 5 times. After rotation, 5 minutes are noted and 100 ml of 2% SDS solution is added to the cylinder to the mark. The cylinder is closed with a lid and rotated again in the device 3 times for 5 minutes. Then measurements are taken. Unit of measurement is ml [7].

Definition of germination. The seed properties of the grain were characterized by the indicator of laboratory germination, determined by DSTU 4138 2002 "Seeds of agricultural crops. Methods for determining quality. The essence of the method was to germinate wheat grain under optimal conditions for 8 days. Filter paper was used as a substrate, the germination temperature in the thermostat was stable and amounted to 20 ± 2 °C, the analysis conditions were in the dark, and the counting was carried out on the 8th day. Permissible deviations of the germination of wheat grain in individual samples from the average value were within the limits provided for by DSTU 4138 2002.

Results and discussion

The quantity and quality of raw gluten in wheat grains are one of the important indicators of quality in Ukraine and other post-Soviet countries. The study of the effect of processing wheat grain with EMF was carried out at the first stage of experimental studies. Wheat grain of varieties Guzel, Arista were processed on 11/21/2019 with the characteristics (frequency, magnetic induction and treatment duration) of EMF ELF taken in the studies, and the Obrana variety was processed on 12/04/2019 with the same characteristics. The determination of the quantity and quality of raw gluten was carried out according to the above GOST 13586.1-68. The results obtained are presented in Table 1.

From the given data it can be seen that the processing of wheat grain with EMF with a frequency of 10...30 Hz increased the content of raw gluten by 1.0...3.2% for the Gyuzel variety and by 1.0...2.6% for the Obrana variety. For variety Arista, the content of raw gluten increased by 1.0% only when processing EMF with a frequency of 16 Hz, while at other frequencies, on the contrary, it decreased by 0.2...0.6%, which is within the experimental error.

Thus, EMF grain processing leads to an increase in the amount of gluten in all varieties only at a frequency of 16 Hz, and it is the largest – by 1.0...3.2%, depending on the variety. This means that the quality of the grain in terms of the amount of gluten is improved.

If a batch of wheat after EMF treatment is intended for export, then it is clear that this is beneficial, since the amount of gluten increases after EMF treatment. This means that if all other class-determining quality indicators are within the limits of the contract, then the class of the processed batch of wheat will increase and, accordingly, its price will be higher.

However, when processing grain with EMF with the indicated frequency, the quality of gluten in the two varieties Guzel and Arista decreases. From the results of the experiments it can be seen that the quality indicators of gluten of untreated wheat (control) of these varieties were within the 1st group (45...16 Hz, the quality of their gluten deteriorated and moved to the 2nd quality group (20...40 units VDK). Such a result is unacceptable for wheat for food purposes, in particular, for processing grain into flour, since the gluten of the grain will have a degraded quality and, accordingly, the grain will have a lower price.

Compared to the gluten deformation index (IDK, unit VDK), a sedimentation index (swelling) provides faster, more accurate and more objective information about the quality of gluten. It is a complex indicator by which the "strength" of grain (flour) is judged [7].

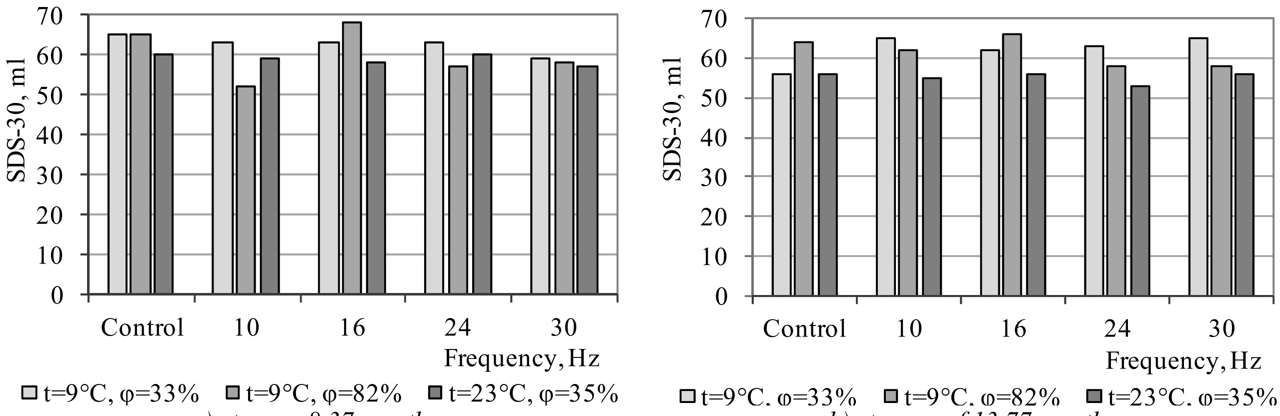
To assess changes in the quality of gluten in terms of sedimentation, wheat grain of the Shestopalivka variety with a moisture content of 12.4% was treated on September 22, 2020 with an EMF with frequencies of 10.. 30 Hz, magnetic induction of 10 mT. The processing time was 6 minutes. The treated grain and control samples were stored for 8.37…13.77 months under controlled conditions at temperatures of 9 and 23 °C and relative air humidity of 33…35% and 82.0%. The results of the change in the sedimentation index during the storage of samples under various indicated conditions depending on the frequencies of the EMF are shown in Figs. 1.

It can be seen from the data obtained (Fig. 1-a) that when storing grain for about 8 months in the best autumn-winter conditions for storage (temperature 9 °C,relative humidity 33%) with an increase in the frequency of EMF compared to the control (without processing grains) the sedimentation index gradually decreases. The largest decrease (by 6 ml or 9.2%) was noted for a grain sample treated with a frequency of 30Hz.

In the samples stored at the same temperature, but at an air humidity of 82%, at all frequencies except 16 Hz, the sedimentation index decreased by 7...13 ml

Table 1 – Effect of wheat EMF treatment on the content and quality of raw gluten

Wheat variety	Crude gluten content,%					Gluten quality, units VDK				
	Control	Processing frequency, Hz				Control	Processing frequency, Hz			
		10	16	24	30		10	16	24	30
Guzel	22.7	23.7	25.9	25.0	24.2	45.0	50.2	39.4	35.6	56.0
Arista	19.8	19.3	20.8	19.6	19.2	48.9	58.2	38.3	54.0	49.8
Obrana	23.9	25.2	26.5	24.9	25.3	48.2	69.3	54.2	54.3	72.0



a) storage 8.37 months *b) storage of 13.77 months*

Fig. 1 – Dependence of the sedimentation index of treated and untreated (control) wheat on the frequency of EMF and grain storage conditions

(10.1...20.0%), of which the largest decrease was the frequency of 10 Hz. At a treatment frequency of 16 Hz, there was a slight increase in the sedimentation index by 3 ml (4.6%).

When storing grain in summer conditions at a temperature of 23 °C and a relative humidity of 35%, there was a decrease by 5 ml of the sedimentation index in the control sample. Practically at the same level (1...3 ml) the sedimentation indices of the samples treated at the EMF frequency of 10...30 Hz remained – the decrease was 0...3 ml.

A somewhat different situation was observed after storage of processed grain under controlled conditions in the autumn-winter period for almost 14 months (Fig. 1-b). At a temperature of 9 °C and a relative humidity of 33%, the gluten of the grain treated at all EMF frequencies increased its quality ("strength") relative to the control, which was reflected in the increase in the sedimentation index by 6...9 ml (by 10.7...16.1%).

At the same temperature, but at a relative humidity of 82%, the values of the sedimentation index slightly fluctuated relative to the control from a decrease by 2…4 ml (by 3.1…6.2%) at a frequency of 10, 24, and 30 Hz to an increase by 2 ml. at a frequency of 16 Hz (3.1%).

Storage in summer conditions (temperature 23 °C, relative humidity 35%) during grain processing at all EMF frequencies, the sedimentation indicators practically did not differ from the control – they were less than it by 1...3 ml (by 1.8...5.4%), which close to acceptable errors.

It should be noted that at the end of storage of wheat grain at a temperature of 23 °C and a relative humidity of 82.5%, the samples deteriorated (moldy), which did not allow determining the sedimentation number.

Thus, the processing of wheat grain with EMF with a frequency of 16 Hz during its storage within 8…14 months increases the sedimentation rate by 4.6…3.1%, respectively, which indicates an improvement in the quality of gluten.

Considering the effect of EMF on grain intended for baking purposes, it is important to take into account one more quality indicator – the falling number (FN). It is a measure of α-amylase activity and is widely used to characterize the baking properties of flour. The state of emergency makes it possible to judge the state of starch in grain and flour and the activity of enzymes (amylases) that break down starch. In dry grain and flour, amylases are in an inactive state. In the presence of water, amylases are activated and begin to break down starch into more conventional molecules.

Experimental studies to establish the effect of ELF EMF on FN were carried out on wheat grain of the Guzel, Arista, Obrana 2019 harvest varieties and the Shestopalivka 2020 harvest variety. Grain processing lasting 6 min was carried out at EMF frequencies of 10, 16, 24 and 30 Hz – varieties Guzel, Arista on November 21, 2019, and variety Obrana on December 4, 2019. The values of the FN indicators determined in each wheat variety Guzel, Arista processed according to the above modes are given in Table 2.

According to GOST 30498-97, the deviation of the FN values from the average results should not exceed 10%, that is, for the obtained results, the FN should be within 29.5...47.8 s.

Considering that all the obtained changes in the FN of grain relative to the control is in modulus within 1...23 s, that is, within acceptable limits, we can conclude that there is no effect of EMF grain treatment on the FN indicator for wheat varieties Guzel, Arista, Obrana 2019 harvest .

In further studies, the changes in FN were determined in samples of wheat grain of the Shestopalivka variety treated at different frequencies after their storage under controlled conditions simulating different seasons. Untreated grain (control) was stored under the same conditions for comparison.

The processed grain was stored in the air temperature range of 9 and 23 ºC and its relative humidity of 33 and 82.5%, simulating the conditions of active ventilation and grain storage at different times of the year.

The processing of grain samples was carried out on September 22, 2020 and placed for storage in prepared desiccators. To ensure the ambient temperatures accepted for research, two desiccators, in which a relative air humidity of 33% and 82% was created, were placed in a refrigerator with a temperature of 9 °C, the second two, in which a relative air humidity of 35% and 82.5% was created in a thermostat at a temperature of 23 °C. Each desiccator was loaded with weighing bottles of grain about 5 g. The experiments were carried out in 2 parallels.

Grain processing modes, storage conditions and the obtained results of determining the FN are given in Table 3. Comparing, as in previous studies, the FN for other varieties of wheat, it can be seen that the range of changes in the FN indicators, which will indicate their significance, when storing processed grain for 6...7 months is 39.2...44.7 s, and when stored for about 13 months is within 42.3...49.5 s. From the Table 3 it can be seen from the data that significant changes in FN appeared only in wheat grain of the Shestopalivka variety treated with an EMF frequency of 30 Hz, which persisted for 12.8 months at a temperature of 23 °C and a relative humidity of 35%. At the same time, the FN indicator decreased by 52 s, which may indicate some activation of the α-amylase enzyme. The rest of the changes in the FN relative to the control were within the acceptable limits of the accuracy of their determination.

The activity of the grain enzymatic system, as well as the falling number, is also related to the quality of seed grain, which is characterized by the germination rate. Wheat grain of varieties Guzel, Arista were processed on 11/21/2019 with the characteristics (frequency, magnetic induction and treatment duration) of ELF EMF taken in the studies, and the Obrana variety was processed on 12/04/2019 with the same characteristics. After storage of the treated and control samples of wheat grain (cultivars Guzel, Arista after 11.1 months, selected after 12.2 months), the laboratory germination of the studied wheat varieties was determined using the method described above (DSTU 4138 2002). The data obtained are presented in Table 4. From the above results of determining the germination of grain, it can be seen that the untreated samples of wheat varieties Guzel and Arista had a very low germination (36 and 26%, respectively). They also reacted negatively to EMF treatment at all studied frequencies – the germination decreased by 1.06...1.71 times compared to the control. This indicates the low quality of such grain as seed material and the impossibility of improving it through EMF treatment.

Wheat of the same variety Obrana showed itself much better, both in the control sample and in the samples treated with EMF of different frequencies. From the results of the studies, it can be seen that EMF

Table 2 – Indicators of FN of treated EMF and untreated wheat grains of different varieties

Wheat variety	Falling number (NC), s					Changes in the FN of grain in relation to control, s			
	Control	Processing frequency, Hz				Processing frequency, Hz			
		10	16	24	30	10	16	24	30
Guzel	295	314	318	313	313	19	23	18	18
Arista	280	284	274	281	284	4	–6	1	4
Obrana	498	478	495	492	497	–20	–3	–6	–1

Table 3 - Change in the falling number (FN) of treated and untreated grain (control) of wheat after storage under controlled conditions

Storage conditions	Duration of storage, months	Control, s	EMF frequencies, Hz							
			10	16	24	30	10	16	24	30
Storage 6-7 months										
At the beginning	0	337	Falling number, sec				Changes in FN regarding control, s			
t=9 °C, φ=33 %	7.3	411	397	412	408	406	–14	1	–3	–5
t=9 °C, φ=82 %	6.1	392	391	418	406	412	–1	26	14	20
t=23 °C, φ=35 %	7.1	447	435	417	423	450	–12	–30	–24	3
t=23 °C, φ=82.5 %	The grain has spoiled									
Storage for about 13 months										
At the beginning	0	337	Falling number, sec				Changes in FN regarding control, s			
t=9 °C, φ=33 %	13.2	433	440	449	441	445	7	16	8	12
t=9 °C, φ=82 %	13.1	423	449	441	437	432	26	18	14	9
t=23 °C, φ=35 %	12.8	495	502	470	470	443	7	–25	–25	–52
t=23 °C, φ=82.5 %	The grain has spoiled									

Table 4 – Germination rates of treated EMF and untreated wheat grain of different varieties

Wheat variety	Grain germination, %					Changes in grain germination relative to control, %			
	Control	Processing frequency, Hz				Processing frequency, Hz			
		10	16	24	30	10	16	24	30
Guzel	36	34	28	15	21	–2	–8	–21	–15
Arista	26	16	14	11	17	–10	–12	–15	–9
Obrana	80	94	89	88	84	14	9	8	4

processing has benefited and the germination scores have improved. It can be seen that the processing of grain with the lowest frequency of EMF – 10 Hz, at which the germination increased by 14%, gave the greatest effect. Increasing the EMF frequency to 16, 24, and 30 Hz also led to an increase in germination, but with a lesser effect – the germination increased by 9, 8, and 4%, respectively. We also note that the greatest changes in germination occurred at the lowest frequency of EMF processing (10 Hz) – the germination increased from 80% to 94%. It can be expected that the future wheat crop will also increase.

In the wheat samples of the Shestopalivka variety, treated with EMF on September 22, 2020 and stored under the controlled conditions described above, in addition to the FN indicator, another indicator, important for grain processing, grain vitreousness was determined using a diaphanoscope. The obtained results of determining the vitreousness according to GOST 10987-76 depending on the frequencies of EMF processing and the shelf life of Shestopalivka grain are given in Table 5.

It can be seen from the obtained data that the vitreousness of the EMF-treated and untreated wheat grain after its storage in 14 out of 24 samples decreased in absolute value compared to the control by 1...17% and only in 7 samples increased by 1...8%. Considering that the permissible discrepancies in vitreousness between the results of the initial and repeated or control determinations according to GOST 10987-76 should be no more than 5% (relative), then we can conclude that EMF processing of grain with a frequency of 10...16 Hz and after grain storage for 6...13 months is extremely insignificant. One can only note a steady decrease in grain vitreousness at all studied frequencies (10…30 Hz), which persisted for almost 13 months at a temperature of 9°C and a relative humidity of 33%. A significant increase in vitreousness was noted only in the grain treated at a frequency of 16 Hz, after its storage for 9.2 months at a relative humidity of 35% and a temperature of 23 °C.

Table 5 – Change in the total vitreousness of treated and untreated grains (control) of wheat after storage under different controlled conditions

Storage conditions	Duration of storage, months	Control, sec	EMF frequencies, Hz							
			10	16	24	30	10	16	24	30
	Storage for 9 months									
			Vitreousness, %				Changes in control,%			
t=9 °C, φ=33 %	9.6	66	61	68	65	67	–5	2	–1	1
t=9 °C, φ=82 %	9.4	79	62	80	75	74	–17	1	–4	–5
t=23 °C, φ=35 %	9.2	53	53	61	47	55	0	8	–6	2
t=23 °C, φ=82.5 %	The grain has spoiled									
Storage for 12-13 months										
			Vitreousness, %				Changes in control,%			
t=9 °C, φ=33 %	12.8	52	44	45	40	42	–8	–7	–12	–10
t=9 °C, φ=82 %	12.8	52	54	55	50	52	2	3	–2	0
t=23 °C, φ=35 %	12.4	51	49	49	48	49	–2	–2	–3	–2
t=23 °C, φ=82.5 %	The grain has spoiled									

Conclusions

1. It is shown that the processing of wheat grain with EMF with a frequency of 10...30 Hz increased the content of raw gluten by 1.0...3.2% for the Gyuzel variety and by 1.0...2.6% for the Obrana variety. For variety Arista, the content of crude gluten increased by 1.0% only when treated with EMF at a frequency of 16 Hz, while at other frequencies, on the contrary, a slight decrease was noted within the experimental error. For all studied 3 varieties of wheat, EMF treatment at a frequency of 16 Hz makes it possible to increase the amount of crude fiber, depending on the variety, by 1.0...3.2%, which increases the class of grain and is positive for export batches of wheat grain. However, EMF grain treatment with a frequency of 16 Hz reduces the quality of gluten in the Guzel and Arista varieties – it passes from the 1st (good) to the 2nd (satisfactory strong) quality group, which is unacceptable for baking wheat.

2. Evaluation of the quality of wheat gluten of the Shestopalivka variety according to the complex indicator of sedimentation showed that when stored for about 8 months at a temperature of 9 °C of the processed EMF at a frequency of 10...30 Hz, the sedimentation indicator decreases by 2...6 ml compared to the control 33% and 7…13 ml at 82% humidity. The exceptions are a frequency of 16 Hz and a relative humidity of 82%, at which the sedimentation index increases by 3%. When storing grain at a temperature of 23 °C and a relative humidity of 35%, the sedimentation index of the control sample decreases by 5 ml, and in relation to it in the treated samples it decreases by 0...3 ml.

After storing the treated grain for almost 14 months at a temperature of 9 °C and a relative humidity of 33%, the sedimentation index increased by 6...9 ml (by 10.7...16.1%), which indicates an improvement in the quality of gluten at all studied EMF frequencies. At the same temperature and relative humidity of 82%, the sedimentation index decreased by 2...4 ml (by 3.1...6.2%), except for the frequency of 16 Hz, when it increased by 2 ml (3.1%). When storing grain at a temperature of 23°C and a relative humidity of 35%, the sedimentation indica tors were equal to the control, except for the frequencies of 10 and 24 Hz, at which they decreased by 1...3 ml (by 1.8...5.4%), respectively.

3. Studies of the falling numbers (FN) of samples of wheat varieties Guzel, Arista, Obrana and Shestopalivka showed that their EMF treatment at a frequency of 10...30 Hz, a magnetic induction of 10 mT and a duration of 6 min changes the FN indicator upwards or downwards only within the limits of permissible deviations. The exception was a grain sample of the Shestopalivka variety treated with EMF at a frequency of 30 Hz. After its storage for 12.8 months at a temperature of 23oC and a relative humidity of 35%, the FN index decreased by 52 seconds compared to the control, which may indicate some activation of the α-amylase enzyme.

4. It was shown that samples of wheat varieties Guzel and Arista with very low germination (36 and 26%, respectively) reacted negatively to EMF treatment at EMF frequencies of 10...30 Hz – their germination decreased by 1.06...1.71 times compared to the control, which indicates the impossibility of its increase during the treatment with EMF. In wheat variety Obrana with an initial germination of 80%, EMF treatment increased the germination rates. The greatest effect was given by the treatment of grain with the lowest EMF frequency – 10 Hz, at which the germination increased by 14%, reaching 94%. An increase in the EMF frequency to 16, 24, and 30 Hz also led to an increase in germination, but with a lesser effect: the increase was 9, 8, and 4%, respectively.

5. It has been established that the vitreousness of the treated EMF at frequencies of 10...30 Hz of wheat grain of the Shestopalivka variety after its storage for 9...13 months in 58% of the samples decreased in absolute value compared to the control by 1...17% and only in 29% of the samples slightly increased by 1…8%. However, 67% of all vitreous changes are below the margin of error. A steady decrease in grain vitreousness by 2...12% at a frequency of 10...30 Hz was also noted, which persisted for about 12.5 months at a relative humidity of 33% and a temperature within 9...23 °C of grain after storage for 9.2 months at relative humidity 35% and a temperature of 23 °C.

REFERENCES

1. *Trisvyatskij L.A. Hranenie zerna. M.: Agropromizdat, 1985. 351.*
2. *Vakar A.B. Klejkovina pshenici. M.: Akademiya nauk SSSR, 1961. 252.*
3. *Boshkova I.L.,Volgusheva N.V. Primenenie mikrovolnovogo metoda obrabotki rastitelnyh materia-lov v razlichnyh tehnologiyah: monografiya. Odessa: Bondarenko M.A., 2017. 224.*
4. *Microwave technology applied in post-harvest treatments of cereals and legumes. / Dalmoroa A.,et. al.// J. Chemical engineering transaction.2015. № 44, P. 13-18. https://doi.org/10.3303/CET1544003*
5. *Effects of low-power microwave fields on seed germination and growth rate / L Raghaet. al. // Journal of Electromagnetic Analysis and Applications.2011. № 3, C. 165-171. http://doi:10.4236/jemaa.2011.35027*
6. *Kondratenko E.P., Soboleva O.M., Egorova I.V., Verbickaya N.V. Izmenenie kachestva zerna pshenicy pod vozdejstviem elektromagnitnogo polya sverhvysokoj chastoty. Vestnik Altajskogo gosudarstven-nogo agrarnogo universiteta 2015, 5(127). 30-37.*
7. *Rybalka O.I. Yakist pshenytsi ta yii polipshennia / O.I. Rybalka. K.: Lohos, 2011. 496.*
8. *Steklovidnost kak pokazatel kachestva zerna pshenicy / S.V. Zverev, I.A. Pankrateva, O.V. Politu-ha, N.A. Igoryanova, V.B. Zajcev // Hranenie i pererabotka zerna, 2017, 11. 33–34.*
9. *Obrabotka selskohozyajstvennogo syrya elektromagnitnym polem nizkoj chastoty. Teoriya i praktika: monografiya / Kasyanov G.I. ta in. Sankt-Peterburg: Troickij most, 2016. 296 c. URL: http://e.lanbook.com/book/90693 (data zvernennya 21.10.2021).*
10. *Erohin A.Yu. 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. DOI: 10.24411/2309-348X-2018-10010*
11. *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 Dec. 6.11 (108):17-26. URL https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3761027*
12. *Marcus Schmidt, Emanuele Zannini, Elke K. Arendt. Recent Advances in Physical Post-Harvest Treatments for Shelf-Life Extension of Cereal Crops // Foods, 2018. 7(45). https://doi.org/10.3390/foods7040045*
13. *Kasyanov G.I., Syazin I.E., Grachev A.V., Davidenko T.N., Vazhenin E.I. Features of usage of electromagnetic field of extremely low frequency for the storage of agricultural products J Electromagnetic Analysis and Applications. 2013 May. 5(5):236-241. URL: https://www.scirp.org/pdf/JEMAA_2013052413410885.pdf*
14. *Inozemtsev H.B. Suchasni realii i problemy zastosuvannia elektromahnitnoi enerhii v roslynnytstvi // Tekh-nika ta enerhetyka, 2013, 184, 28–31.*
15. *Sapogov A.C. K voprosu o nevosproizvodimosti magnitobiologicheskih opytov. Biofizika. 1992. 37(4): 769-771.*

Ю.В. Ковра[1], хімік першої категорії, *E-mail: yuriykovra@gmail.com*
Г.М. Станкевич[2], д-р техн. наук, професор, *E-mail: georgii.stn@gmail.com*
А.В. Борта[2], канд. техн. наук, доцент, *E-mail: borta.alla@ukr.net*
[1]Лабораторія харчової безпеки (FSL) Випробувального центру ІП "СЖС УКРАЇНА"
[1]Іноземне підприємство "СЖС УКРАЇНА", вул. Чорноморського козацтва, 103, Одеса, Україна, 65003
[2]Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

ДОСЛІДЖЕННЯ ВЛАСТИВОСТЕЙ ЗЕРНА ПШЕНИЦІ РІЗНОГО ПРИЗНАЧЕННЯ, ОБРОБЛЕНОЇ ЕЛЕКТРОМАГНІТНИМ ПОЛЕМ

Анотація

Наведено результати досліджень впливу електромагнітного поля (ЕМП) та тривалості зберігання зерна пшениці сортів Гюзель, Арiста, Обрана та Шестопалівка на їх технологічні та насіннєві властивості. Оброблення зерна проводили ЕМП за частот 10…30 Гц з магнітною індукцією 10 мТл тривалістю 6 хв. Показано, що обробка зерна пшениці ЕМП збільшила вміст сирої клейковини на 1,0…3,2 % для сорту Гюзель та на 1,0…2,6 % для сорту Обрана. Для сорту Арiста вміст сирої клейковини збільшився на 1,0 % лише за обробки ЕМП з частотою 16 Гц, а за інших частот відмічено зменшився межах похибки. Для вказаних сортів пшениці обробка ЕМП частотою 16 Гц збільшує кількість сирої клейковини залежно від сорту на 1,0…3,2 %, що підвищує класність зерна. Однак оброблення зерна з частотою 16 Гц знижує якість клейковини у *сортах Гюзель та Аріста і вона переходить з 1-шої до 2-гої групи якості. При зберіганні близько 8 місяців обробленого ЕПМ зерна пшениці показник седиментації, який комплексно характеризує силу борошна, зростає порівняно з контролем на 3 мл (на 4,6 %) лише за частоти 16 Гц при температурі зберігання 9 °С і відносній вологості 82 %, а після зберігання майже 14 місяців – він зростає на 2 мл (на 3,1 %). Зростання показника седиментації на 6…9 мл (на 10,7…16,1 %) відмічено за обробки зерна з частотами ЕМП 10…30 Гц при зберігання біля 14 місяців за температури 9 °С та відносної вологості 33 %. За інших умов зберігання та частот обробки ЕМП показник седиментації може не змінюватись або зменшуватись до 13 мл (до 20,0 %), що буде свідчити про погіршення якості клейковини. Дослідження числа падіння (ЧП) зразків пшениці сортів Гюзель, Аріста, Обрана та Шестопалівка показали, що їх оброблення ЕМП змінює показник ЧП лише в межах припустимих відхилень. Виключення склав зразок зерна сорту Шестопалівка оброблений ЕМП з частотою 30 Гц. Після його зберігання протягом 12,8 місяців за температури 23 °С та відносної вологості 35 % показник ЧП порівняно з контролем зменшився на 52 с. У зразків пшениці сортів Гюзель та Аріста з низькою початковою після оброблення ЕМП схожість порівняно з контролем знизилась у 1,06…1,71 разів. У пшениці сорту Обрана з початковою схожістю 80 % оброблення ЕМП збільшило показники схожості. Найбільший ефект дало оброблення зерна з частотою ЕМП 10 Гц, за якої схожість зросла на 14 %, досягнувши 94 %. Збільшення частоти ЕМП до 16, 24 та 30 Гц призвело до зростання схожості відповідно на 9, 8 та 4 %. Скловидність обробленого ЕМП зерна пшениці сорту Шестопалівка після його зберігання впродовж 9...13 місяців у 58 % зразків зменшилась порівняно з контролем на 1…17 % і лише у 29 % зразків збільшилась на 1…8 %. Однак 67 % серед всіх змін скловидності менше припустимих похибок. Відмічено стійке зниження скловидності зерна на 2…12 % за частот 10…30 Гц, що зберігалось близько 12,5 місяців за відносної вологості 33 % та температури в межах 9…23 °С Значиме зростання скловидності відмічене лише у обробленого за частоти 16 Гц зерна, після його зберігання 9,2 місяці за відносної вологості 35 % та температури 23 °С.*

Ключові слова: зерно пшениці, обробка електромагнітним полем, властивості, показники якості, зберігання зерна.

ЛІТЕРАТУРА

1. Трисвятский Л.А. Хранение зерна. М.: Агропромиздат, 1985. 351.
2. Вакар А.Б. Клейковина пшениці. М.: Академия наук СССР, 1961. 252.
3. Бошкова И.Л.,Волгушева Н.В. Применение микроволнового метода обработки растительных материалов в различных технологиях: монография. Одесса: Бондаренко М.А., 2017. 224.
4. Microwave technology applied in post-harvest treatments of cereals and legumes. / Dalmoroa A.,et. al.// J. Chemical engineering transaction.2015. № 44, P. 13-18. https://doi.org/10.3303/CET1544003
5. Effects of low-power microwave fields on seed germination and growth rate / L Raghaet. al. // Journal of Electromagnetic Analysis and Applications.2011. № 3, С. 165-171. http://doi:10.4236/jemaa.2011.35027
6. Кондратенко Е.П., Соболева О.М., Егорова И.В., Вербицкая Н.В. Изменение качества зерна пшеницы под воздействием электромагнитного поля сверхвысокой частоты. Вестник Алтайского государственного аграрного университета 2015, 5(127). 30-37.
7. Рибалка О.І. Якість пшениці та її поліпшення / О.І. Рибалка. К.: Логос, 2011. 496.
8. Стекловидность как показатель качества зерна пшеницы / С.В. Зверев, И.А. Панкратьева, О.В. Политуха, Н.А. Игорянова, В.Б. Зайцев // Хранение и переработка зерна, 2017, №11. 33–34.
9. Обработка сельскохозяйственного сырья электромагнитным полем низкой частоты. Теория и практика: монография / Касьянов Г.И. та ін. Санкт-Петербург: Троицкий мост, 2016. 296. URL: http://e.lanbook.com/book/90693 (дата звернення 21.10.2021).
10. Ерохин А.Ю. Влияние электромагнитного поля низкой частоты на посевные качества семян и урожайность гороха, ячменя и яровой пшеницы. Зернобобовые и крупяные культуры. 2018, № 2(26): 17-22. DOI: 10.24411/2309-348X-2018-10010
11. 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 Dec. 6.11 (108):17-26. URL https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3761027
12. Marcus Schmidt, Emanuele Zannini, Elke K. Arendt. Recent Advances in Physical Post-Harvest Treatments for Shelf-Life Extension of Cereal Crops // Foods, 2018. 7(45). https://doi.org/10.3390/foods7040045
13. Kasyanov G.I., Syazin I.E., Grachev A.V., Davidenko T.N., Vazhenin E.I. Features of usage of electromagnetic field of extremely low frequency for the storage of agricultural products J Electromagnetic Analysis and Applications. 2013 May. 5(5):236-241. URL: https://www.scirp.org/pdf/JEMAA_2013052413410885.pdf
14. Іноземцев Г.Б. Сучасні реалії і проблеми застосування електромагнітної енергії в рослинництві // Техніка та енергетика, 2013, 184. 28–31.
15. Сапогов А.С. К вопросу о невоспроизводимости магнитобиологических опытов. Биофизика. 1992. 37(4): 769-771.

Received 09.10.2021 **Revised 17.11.2021**
Reviewed 31.10.2021 **Approved 03.12.2021**

Cite as Vancouver Citation Style

Kovra Yu., Stankevych G., Borta A. Study of properties of wheat grain processed by electromagnetic field for different purposes use. Grain Products and Mixed Fodder's, 2021; 21 (4, 84): 38-46. DOI https://doi.org/10.15673/gpmf.v21i4.2262

Cite as State Standard of Ukraine 8302:2015

Study of properties of wheat grain processed by electromagnetic field for different purposes use. / Kovra Yu. et al. // Grain Products and Mixed Fodder's. 2021. Vol. 21, Issue 4 (84). P. 38-46. DOI https://doi.org/10.15673/gpmf.v21i4.2262