Decontamination of grain by ultrasound

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Abstract. The article considers the method of grain processing in the medium of an anolyte, produced at the STEL type plant, with subsequent washing and drying to a humidity of not more than 14%. Decontamination of grain was carried out by ultrasound of low frequencies 24-26 kHz with ultrasound intensity no more than 1 W/cm². The method provides a reduction in the content of mold fungi in the grain, prevents the development of mycotoxins in it, reduces contamination with mineral impurities and insect pest.

1. Introduction
Grain is susceptible to infection by mold fungi and pests of grain stocks, which is a significant problem in the feed production and food industry. The defeat of grain with mycotoxins of mold fungi can lead to poisoning and even death at a significant concentration. Insects - pests of grain worsen its baking properties, reduce the weight of grain, contribute to the development of pathogenic microflora and lead to self-heating of grain. The aim of the study was to improve the technology of grain disinfection by intensifying the process with the help of low-frequency ultrasound.

2. Materials and methods
Mycotoxins were determined using the liquid chromatography technique according to standard methods [FR 1.31.2008.04629, MU 3184-84, GOST 28001-88]. Contamination by insect pests was determined according to GOST 34165-2017, pest contamination according to GOST 13586.6-93. Processing of grain was performed in laboratory ultrasonic installation UZU-4. Studies were carried out in the frequency range 22-35 kHz using an anolyte solution and without it, with a change in the intensity of ultrasonic waves from 0.3 W/cm² to 1.5 W/cm². The number of bacteria and mold fungi in the grain was determined according to GOST R 51278-99.

3. Results and discussions
The main sources of contamination of grain and grain products are infected storage facilities, reception areas and territories are situated near a storehouse, grain cleaning machines and mechanisms, containers, inventory, vehicles and infected grain [1]. The reason for the global spread of infection, according to A. A. Zhuchenko opinion, is the widespread distribution of unstable wheat varieties [2].

There are modern methods of biological (enzymatic) neutralization of mycotoxins [3], methods of detoxification of grain with various biologicals [4], anolyte solution [5], ultrasound [6] and others.
It should be noted that the existing methods of neutralization of mycotoxins do not have an optimal effect and have a sufficiently large number of disadvantages, so it is more appropriate to prevent the development of mold fungi, insect pests, but do not fight with the results of their life-sustaining activity.

Experimental studies were conducted with supplied for fodder purposes wheat. Mycotoxins were found in wheat samples: Aflatoxin B1 - 0.04 mg/kg (produced by Aspergillus spp.); t-2 toxin - 0.01 mg/kg (produced by Fusarium spp.); Ochratoxin A - 0.03 mg/kg (produced by Aspergillus and Penicillium spp.). According to Technical regulations TR CU 015/2011 of the Customs Union on "Grain safety", aflatoxin B1 exceeded the norm (more than 0.02 mg/kg).

Experimental studies have established, that impact on the grain the acoustic cavitation, generated by ultrasonic waves with a frequency of 24-26 kHz and with an ultrasound intensity of at least 1 W/cm², called the cavitation threshold, in the anolyte ANC solution, leads to a decrease in the content of mold fungi in the grain, prevents the development of mycotoxins in it, reduces contamination with mineral impurities and insect pests.

An anolite ANC (neutral) made on an installation "STEL" was used in the research. The combination of active substances in anolite does not allow mold fungi and microorganisms to adapt to its biocidal action, and the small total concentration of active oxygen and chlorine compounds guarantees complete safety for animals, people and the environment. However, the structure of the grain has a complex configuration and treatment with anolite does not give the desired results. Low-frequency ultrasound can enhance the bactericidal effect of the solution and created by ultrasound micro-currents actively wash and clean evenly the entire surface of the grain from mold, mineral contaminants and insect pests.

Contamination with mineral impurities was determined by measuring the areas of micro-contamination of grain, determining the total area of single areas of surface contamination in a sample of grains, based on the perimeters of their contour. The percentage of the contaminated area to the total surface area of the grains of the average initial sample was determined. The results of experimental studies have allowed us to conclude that the proposed method is capable of removing all mineral impurities from grain surface, without breaking the shell of the grain.

Processing of grain in a liquid medium with ultrasound 24-26 kHz at an intensity of 1 W/cm² gave the best results. Increasing the intensity of ultrasonic exposure or changing the frequency of ultrasound above or below the proposed parameters led to a violation of the grain structure, which is undesirable during storage.

Figure 1 illustrates the infected with mold fungi grains, without ultrasound treatment (a), with ultrasound treatment of 26 kHz in water (b), treated with ultrasound of 35 kHz in water (c), treated with ultrasound of 26 kHz in an anolyte medium (d).

![Figure 1. Infected with mold fungi grains, (160x):](image-url)
When grain is processed by 26 kHz ultrasound in an anolyte medium, a synergistic effect occurs. In studies of each processing method separately, the results were significantly worse. The mechanism of bactericidal activity of low-frequency ultrasound is that cavitation cavity, which is filled with liquid vapor, is formed in a liquid medium of microorganism’s cytoplasm. Pressure arises in the bubble, which leads to the disintegration of cytoplasmic structures. So ultrasound is used for sterilization of food products and disinfection of objects. The information about bactericidal effect of ultrasound can be found in various scientific articles [7-9].

Microbiological studies of grain were carried out according to GOST R 51278-99 Grains, legumes and products of their processing. The grain was examined for the presence of bacteria, yeast and mold fungi on the third, fourth and fifth day after sowing on a culture medium. Then there was the counting of the selected colonies in the Petri dish with agar medium. For clarity of the experiment, the processed grains were also placed in Petri dishes with culture medium and observed for five days. Grain processing was carried out with different ultrasound frequencies from 22 to 35 kHz at different treatment time in anolyte or water. The best result (suppression up to 98% of microorganisms) was when processing grain in an anolyte medium at an ultrasound frequency of 26 kHz, with an intensity of 1 W/cm² at 30 minutes of processing (figures 2 - 4).

![Figure 2. The control grain sample.](image)

![Figure 3. Grain treated with 26 kHz ultrasound in water.](image)

![Figure 4. Grain treated with 26 kHz ultrasound in anolyte.](image)

### 4. Conclusion
This technology of preventive processing of grain, allows preventing development in grain of mycotoxins, reducing pollution of grain by mineral impurity, microorganisms and insects-wreckers. The proposed method allows cleaning the surface of the grain from pests only at the initial stage of contamination. If insect pests are present in the grain for a long time and everywhere penetrate into the seeds, the result of processing does not give the desired effect.
Grain processing should be carried out in the medium of anolyte obtained at the STEL type installation by ultrasound of low frequencies 24-26 kHz with an ultrasound intensity of not more than 1 W/cm², with subsequent washing and drying of the grain to a humidity of not more than 14%.

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References
[1] Ganiev M M, Nedorezkov V D and Sharipov H G 2009 Pests and diseases of grain and grain products during storage (Moscow: Kolos) p 208
[2] Zhuchenko A A 2004 Resource potential of grain production in Russia (theory and practice) (Moscow, LLC "Publishing house Agrorus") pp 515-7
[3] Zhu Y, Hassan Y I, Watts C and Zhou T 2016 Innovative technologies for the mitigation of mycotoxins in animal feed and ingredients-A review of recent patents Animal Feed Science & Technology 216 19-29
[4] Pershakova T V, Lisovoy V V, Panasenko E Y, Kupin G A and Victorova E P 2016 Ways to ensure consistent quality of vegetable raw materials in the process of using biopreparations in storing Scientific Journal of KubSAU 117(03)
[5] Semenicenke S Ya, Belitskaya M N and Liholetov S M 2013 Phytosanitary improvement of grain and vegetable crops using electrochemically activated water Advances in current natural sciences 1
[6] Khodunova O S and Silantiyeva L A 2017 The effect of different processing methods on the microbiological parameters of germinated oat seeds Scientific journal NRU ITMO Series "Processes and Food Production Equipment" 1
[7] Feng H, Barbosa-Canovas G and Weiss J (2011) Ultrasound Technologies for Food and Bioprocessing, (Food Engineering Series) (Springer) pp 559-60
[8] Z J Dolatowski, J Stadnik and D Stasiak 2007 Applications of ultrasound in food technology Acta Sci. Pol., Technol. Aliment. 6(3) 89-99
[9] Antushev T I 2013 Some features of the influence of ultrasound on microorganisms Zhiviye biokosnye sist 4