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Non-conventional methods of storage of grain for manufacture of organic produce

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The purpose. To determine and justify methods which ensure protection of grain at storage, for manufacture integrally net produce without application of any chemically aggressive substances. **Methods.** Analysis of known non-conventional methods of protection of grain during storage: thermal disinfection, treatment by microwave field, ozonation, control gaseous medium, laser bombarding radiation. Own researches in storage of grain of corn in conditions of modified gaseous medium. **Results.** Features of different methods of protection of grain and parameters of modified gaseous medium which ensure long-term resistant storage of corn depending on its temperature and damp are probed. Thermal disinfection is an efficient method in technique of storage of grain for struggle against warehouse pests. Treatment by microwave field is disinfection of grain from microorganisms which during the vital activity produce poisonous substances. Ozonation is physical and chemical method of disinfection of grain. Time of biological longevity of different crops on indexes of their vital activity is specified. **Conclusions.** Method of storage of grain of corn in the modified gaseous medium with the following parameters is offered: O_2 (content of oxygen) — 4–5%, W (damp of grain) — 10–12%, t (temperature of grain) — 3–10°C. Other methods are unstable and their efficiency depend on state of bulk grain.

Key words: *grain, storage, methods of protection, gaseous medium, quality factors.*

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Dry grain is a fairly stable object and can be stored for a long time without degradation due to its own stability. However, in the grain mass there are various undesirable components (microorganisms, pests), which due to their livelihoods lead to losses and lower quality of products. According to the World Health Organization, about 25% of stored grains hit toxic microorganisms. Therefore, the grain protects during storage, that is processed chemically aggressive substances for a living organism - insecticides, fungicides. However, at the same time, there is a risk to the health of the grain and its products, as they are also exposed to chemicals. That is why the concept of MPC is introduced, or the maximum (maximum) is permissibleconcentration of toxic elements (mycotoxins, pesticides, heavy metals) on any grain that is proposed for consumption.

Recently, the chemical protection of grain and grain products has become increasingly limited in connection with the expansion of production of organically pure products and safe food for humans. Instead, various non-traditional methods are proposed to protect the grain during storage. However, as practice shows, the effectiveness of these methods is quite different and depends on a set of factors, first of all, the state and purpose of grain, technical equipment and technological execution.

The purpose of research is to identify and substantiate methods that provide grain protection during storage for the production of organically pure products without the application of any aggressive chemicals.

Materials and methods of research. The research was carried out in the laboratory of methods of preservation and standardization of grain of the DU Institute of grain crops of the NAAS of Ukraine. The analysis of known methods of protection of grain during its storage, which did not involve the use of insectofungicides, was carried out on the basis of literary sources. These included thermal decontamination of grain (1), processing by microwave field (2, 3), ozonation (4, 5), controlled gas environment (6), laser radiation (7, 8). Also laid experiments on storage of maize under conditions of modified gas environment. The medium was created by sealing the grain mass under certain parameters:

on the oxygen content, moisture content and temperature of the grain. The impact of the gas environment was assessed using the similarity indicator, which best describes the health and quality of the living organism.

Seed germination was determined according to DSTU 4138 (9), the content of oxygen in the grain mass using the gas analyzer "Search-2 M". Also, according to the DSTU 4138 methods, the microflora was affected by infection with pests. In experiments, grain of hybrids of corn of breeding of the DU Institute of grain crops of NAAS, in particular, Dneprovsky 181 SV, Kremen 200 SV, Soloniansky 298, Monica 350 MB were used.

Research results. The analysis of different methods of grain storage showed that thermal decontamination reduces the number of living pests until they are completely extinct under the influence of high temperatures. For this, the grain is heated in the dryers to a temperature that is lethal for a certain type of pest and is maintained for a specified time. Thermal decontamination is best carried out in recirculation driers, equipped with a heating chamber and a heat exchanger, which provides intense and even heating of the grain. When using direct-current dryers it is desirable to use recirculation. The grain that is passed through a dryer is necessarily checked for the presence of live pests and when they are detected, the operation for decontamination is repeated.

Hence, thermal decontamination is an effective measure of storage technology for controlling stockpile pests, but two circumstances must be taken into account: firstly, it is necessary to have highly qualified trained personnel for such an operation; and secondly, the moisture content of the grain, and therefore its weight after drying may decrease, which is undesirable for the owner.

The treatment of the microwave field, in the first place, is aimed at disinfecting the grain from microorganisms, which in the course of their lifetime produce toxic substances. Such microorganisms include, above all, fungi of the family Aspergillum, Penicillium, Fusarium and others. Under the influence of microwave energy in the cellular structure of microorganisms there are critical changes, depression and sterilization of living organisms.

The test, conducted with different cultures, showed a positive effect of microwave sterilization of grain of food, forage and seed purposes. At the same time, the features of such sterilization were discovered, firstly, the instability of the effect, and secondly, there was no equipment for industrial microwave processing that would ensure full safety for the personnel.

Ozonation refers to the physic-chemical methods of disinfecting the grain from pathogenic microorganisms and storage pests. Disinfection occurs under the influence of ozone - triatomic oxygen (O_3), which, depending on the concentration can stimulate, or vice versa - to suppress the activity of living organisms. Therefore, in an environment with high concentrations of ozone, the activity of microorganisms and insects is quickly suspended until their complete extinction. It was found that ozone-treated foods do not contain any mutagenic and carcinogenic substances. In some countries, ozone is approved as a disinfectant, including for the treatment of grain of various uses. However, in Ukraine, the use of ozone is restrained by its inadequate study, the absence of industrial testing in wide range. The influence of ozone as a highly aggressive substance on technical and technological equipment used in the process of grain storage is also not established.

Controlled gas environment, or controlled atmosphere (CA), is a way of preserving grain without the use of chemically toxic elements. The essence of the controlled atmosphere is that the mass of the grain significantly reduces the oxygen content, but instead increases the content of inert gases (nitrogen, carbon dioxide). The change in the atmosphere can take place in two ways: the first - natural, due to the breathing of the sealed grain mass; the second - artificially, by supplying inert gases in a sealed storage. In the first case - the atmosphere is changing relatively slowly, the oxygen content is reduced to 4-6%, in the second - quickly, and the oxygen content is 1-3%. The positive protective effect of controlled atmosphere is the slowing of physiological and biological processes in the grain mass, suppression and destruction of microorganisms and harmful insects.

Hence, the controlled atmosphere relates to innovative modern grain protection technologies with the aim of developing environmentally friendly and organically safe food from it. The only thing to keep in

mind is the creation of a complete sealing of stored grain. Recently, high-tech polymeric acrylic or polyurethane mineral coatings with a guaranteed lifetime of up to 15 years are recommended for sealing reinforced concrete and metal silos.

Laser irradiation also refers to sanitary-safe methods for protecting grain during storage. Its efficiency is that the laser beam is biologically active and in different ways influences the vital functions of biological objects and depends on the mode of exposure (wavelength, its power and exposure). Depending on the mode, laser treatment can stimulate and suppress the activity of living organisms. In intensive modes, monochromatic light from a laser destructively affects the state of macromolecules of proteins and nucleic acids, which leads to their complete denaturation and death of living objects.

But the industrial application of laser treatment is complicated by the fact that for each group of microorganisms it is necessary to establish and maintain individual lethal regimes depending on a number of biological and abiotic factors of grain storage.

Taking into account the noted advantages and disadvantages, we conducted a study of grain corn storage in a modified gas environment. This storage method is one of the options for controlled atmosphere (CA), but it is much cheaper and requires less energy for its implementation.

It was found that when stored in a modified gas environment, the state of the grain varies depending on the environment and the packaging method (Table 1). When packing in polyethylene, the humidity was almost unchanged, the fluctuation was within 1%. The stabilization of moisture was achieved due to the action of various factors: physical - when the sorption-desorption of moisture was stopped by grain; physiological - when the intensity of respiration of the grain mass in the airtight state significantly decreased.

1. Humidity of corn grain under different storage methods (average 2013-2015), %

Initialhumidity	Waystorage	Humidity of grain during storage				Fluctuations in humidity for a year
		spring	summer	autumn	winter	
9	Open	9,0	14,0	13,0	14,5	9-15,2
	Sealed	9,9	9,5	9,7	10,0	9-10,0
12	Open	15,8	14,8	13,3	15,0	12-15,8
	Sealed	12,5	12,0	12,0	12,8	12-12,8
15	Open	16,5	15,0	13,4	15,5	15-16,5
	Sealed	15,3	15,0	13,4	15,5	15-16,5

In paper packaging, these factors intensified, so the grain moisture fluctuated within a significant range - up to 6.2%. The oscillation had a certain pattern, the grain was humidified during the winter-spring period, and dipped in summer-autumn, approaching the equilibrium humidity with the environment.

The different condition of the seed, which is due to storage methods, has affected its similarity (Table 2). When stored in standard conditions (humidity 12-13%, packing in paper), the seeds had a conditional similarity for 2 years, and with a decrease in moisture to 9-10% - during 3 years.

2. Similarity of maize seeds depending on humidity and storage conditions (2011-2015), %

Method of storage of grain	Initial moisture content of grain,%	The similarity of grain in the process of storage over the years				
		2011	2012	2013	2014	2015
Open	9	98	95	92	73	60
	12	95	92	90	70	51
	15	91	90	84	63	30
Sealed	9	99	98	98	96	95
	12	97	96	95	92	85
	15	87	85	61	33	0

Hermetic packaging of seeds at the same levels of humidity increased the shelf life to 4 and 5 years, respectively. Seeds of individual hybrids (Dniprovsky 181, Dniprovsky 310 MW) during packaging in polyethylene and at a moisture content of 9-10% retained conditional similarity for 5-9 years, depending on the conditions of harvesting and methods of post-harvest treatment.

Grain with a moisture content of 15% when loaded for storage reduced already in the first year the similarity of seed packed in a paper by 4-7%, in polyethylene - by 10-12% compared to dry. Therefore, the storage of grain with such a moisture can only be allowed as a short-term measure (4-5 months), with packaging only in paper.

Another, not less important indicator that affects the storage of grain, is its temperature. In our experiments, it was found that when the temperature decreases, the stability of the seed increases and its similarity persists. In this case, the effect of reducing the temperature also depends on the moisture content of the grain (Table 3). So, after 5 years of storage at a temperature of 3-5 °C and a moisture of 9%, the germination of the seed was 96%, and at a temperature of 8-10 °C - 92%. At a moisture content of 12% and at similar temperatures, the similarity was 94 and 91% respectively. Particularly effective was the cooling of seeds with high humidity - up to 15%, it remained conditional for similarity for 3 years of storage.

3. Similarity of corn grain depending on temperature storage regimes (2011-2015), %

Temperature mode, °C	Initialgrainhumidity, %	The similarity of grain in the process of storage over the years				
		2011	2012	2013	2014	2015
Not adjustable	9	99	96	92	90	90
	12	98	94	90	87	85
	15	81	74	69	23	0
8–10	9	99	97	96	96	92
	12	99	96	95	94	91
	15	96	93	90	75	61
3–5	9	99	99	98	96	96
	12	99	99	96	94	94
	15	97	96	94	81	70

The organization of the technology of safe storage of grain must also take into account the biological stability and durability of a particular culture. It is established that from all grain crops the greatest durability is the wheat, then the oats are plum, sorghum, peas. They can be stored for 10-15 years or more. Their increased durability is due to a special chemical composition, high protein content and physiological and biochemical processes occurring in the grain. The least stable in storage are such crops as rye, millet, sunflower, soybean, rape, their biological longevity is 3-5 years. The low resistance of these crops is associated with the state of other chemicals - vegetable fats, primarily unsaturated fatty acids, which are rapidly oxidized, which leads to loss of grain viability.

Corn and barley occupy an intermediate place; their biological longevity is 5-10 years. At the same time, corn is marked by considerable fluctuations in terms of storage due to the fact that there are various botanical species (tooth-shaped, siliceous, sugar, starchy, waxy) and biological forms (hybrids, varieties, self-pollinated lines, etc.) with different degrees of durability.

In the process of storage, it was also found that the content of oxygen in the corn grain mass was 4-5%, subject to the sealing and suspension of air exchange with the environment. Reducing the oxygen content occurred during the process of breathing grain and slowing down the physiological and biochemical processes of all components of the grain mass. At the same time, there is a decrease in the activity of the microflora and a change in its qualitative composition.

Conclusions

The advantages and disadvantages of various non-traditional methods of protection of grain during its storage are established: thermal disinfection from pests and diseases; microwave processing; ozonation, laser irradiation; controlled gas environment. The influence of methods varied depending on the characteristics of the culture and the purpose of grain for the production of food products without the use of aggressive chemicals.

The method of storage of corn grain in a modified gas environment is proposed in accordance with the following parameters: O2 (oxygen content) is 4-5%, W (grain humidity) -10-12%, t (grain temperature) -3-10 ° C. Other methods is unstable and selective depending on the grain mass condition.

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