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APPLICATION OF ELECTROPHYSICAL METHODS FOR PROCESSING OF GRAIN PRODUCTION AND PLANT MATERIALS IN AGRICULTURE

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ABSTRACT

In processing of grain material with a high probability a favorable environment for infection is created that promotes deterioration in properties and qualities of production which of him is made. Monitoring of one of the districts of Russia has been carried out. The analysis of various directions of application of HFEF grain processing of materials has been carried out. The developed technological process is based a combination of microwave heating with barothermal moisture-heat treatment.

Keywords: grain treatment, HFEF method, seed sweating, seed infection.

1. INTRODUCTION

Active infection and development of various types of activators (mycotoxins) is observed in the course of production and processing of grain lots and plant materials. Various types of toxins and their hit in products of processing of cereal crops and in other objects which have been infected promote existence of infection in the specified part of grain material (Figure-1).

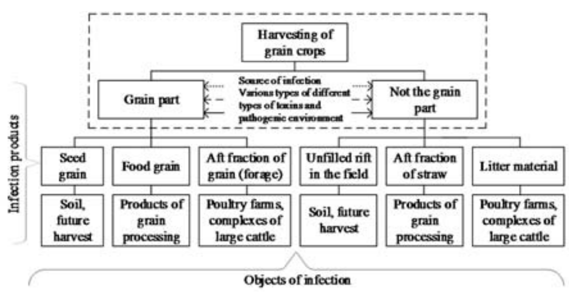

Figure-1. Infections of products and objects with toxins.

We have carried out the analysis of degree of contamination of a grain part of a harvest of various cereal crops. As a result the following data (according to the monitoring of the Southern Federal District of Russia) have been obtained (Table-1.) [1].

Table-1. Contamination of grain mycotoxins.

Samples of cultures	Number of samples	Percent of tests with excess of the most admissible levels on separate mycotoxins				
		T-2 toxin	Aflotoxin A, B1	Ochratoxin A1	Fumonisin B1	Zearalenone
Corn	26	35	18	28	50	17
Barley	30	46	15	46	4	4
Peas	4	100	50	33	0	0
Soybean	7	25	50	50	0	50
Wheat	20	14	7	36	7	7

Active increase in mycotoxins is observed when storing cereal crops. This effect is associated with an increase in the grain temperature (phenomena - self-warming) (Table-2, Figure-2).

Table-2. Contamination of grains mycotoxins at storage.

Cereal crops	Tests which are polluted by aflatoxins, %	Maximum maintenance of aflatoxins, %	The period preceding formation of aflatoxins, days
Rice-grain	10	330	6-11
Rye	16	125	8-10
Wheat	20-25	340	5-7
Corn	30-57	5000	3-4

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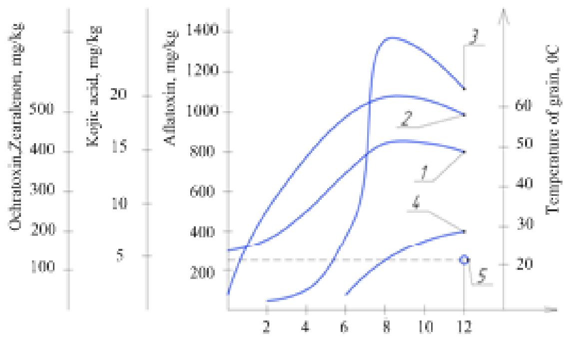

Figure-2. Accumulation of mycotoxins during self-heating of corn.

The growth of mycotoxins is also observed in the process of using the not grain part of the crop as a feed fraction [2].

At present, the problem of quality seeds in agriculture is quite acute. On the one hand it's is due to increased infection of seeds with pests, cephalic and other pathogens of plant diseases. On the other hand, the fact that often even the best quality seeds do not use their biological potential when germinating, and in the course of long-term storage, the seeding properties of seeds tend to weaken.

Chemical ways in the form of grain treatment by toxic chemicals of seeds before crops are more preferable now. However their systematic application leads to development of steady types of diseases and harmful organisms, environmental pollution, food and forages.

Chemical, biological and electrophysical impacts on seeds apply to an intensification of sowing indicators. All of them give a certain effect, however rather not stable (a gain of productivity from 0 to 15%) and not too expressed in economic effect.

One of ways of the solution of the above-stated problems use of new disinfestation technologies of materials on the basis of electrophysical energy influences.

The studied features of impact of energy of EMP microwave oven on seeds of agricultural plants have allowed developing the combined technological process of their stimulation and disinfecting. It's consisting of moistening of a surface of seeds special water solution, their sweating and subsequent microwave processing. Microorganisms which usually are in microcracks of a surface of seeds absorb special solution during the seed sweating. And the same time at seeds only the surface is humidified. At microwave processing there is a local heating of the humidified surface of seeds due to its big dielectric properties and death of the microorganisms which are there. At the same time there is seed draining and electromagnetic activation of their preseeding properties due to influence of microwave energy on activity the amylolytic enzymes.

2. MATERIALSANDMETHODS

Purpose of these researches is the use of electrophysical methods of action for disinfecting the harvest of cereals and imparting new properties to cereals and plant materials.

Among these methods, one should first of all include using biophysical features of the energy effect of high frequency electromagnetic field (HFEF) on agricultural materials, which provides a significant reduction in energy costs and the production of qualitatively new products.

Research and development of energy-saving microwave technologies is based on a deep theoretical and experimental study of all aspects of the impact of energy HFEF on agricultural materials, as biologically active objects [2].

Effects of HFEF influence should be considered in three directions:

- dielectric heating (temperature influence);
- influence electric making (tension) of the field on membranes of a biocage and a condition of cytoplasm;
- the information (resonant) exchanges of electromagnetic fields microwave ovens with own electromagnetic fields of bio-objects influencing metabolism of biocages.

Dielectric heating of materials super high-frequency energy is based on the phenomenon of dielectric polarization and generally rather well studied [2].

Active power density which defines amount of heat which is generated in case of a HFEF heating in volume unit of material ε' and tg $\delta$is calculated according to the classical Joule-Lenz law and is defined by dielectric properties of material and parameters of an electromagnetic field - strength *E* and the frequency *f*. These features cause some exceptional advantages of a HFEF heating:

- high efficiency of conversion of a very HFEF in thermal (the close to 100%);
- object inertialess heating "from within" with exclusively high intensity (temperature and speed of a HFEF are regulated by strength E and the frequency *f* of EMP);
- contact less environmentally friendly supply of energy;
- uniform heating on all mass of a product and it's selectiveness in case of inequality of dielectric properties (parameters $\varepsilon'$and tg δ).

Last feature practically means that at microwave heating water in their capillaries as dielectric properties of water are about tens times higher than own solid, for example, of grain or herbs will heat up first of all. At the macro level it will be shown in bigger heating of more damp materials in comparison with dry.

Features of dielectric heating in HFEF define regularities of heat and mass transfer in the processed agricultural materials during the drying, micronization and other thermal processes. At the same time it is important that the majority of these materials (grain, seeds, cormophyte mass of plants) have pseudo-capillary system and belongs to the capillary-porous bodies class, mass transfer (moisture transfer) in which depends on the sizes of capillaries.

For example, in the grain, there are capillaries with a prevalent radius (for a grain of wheat at a temperature of 250 °C) of 1.25×10^{-9} m and there are no macrocapillaries, that is, capillaries with a radius exceeding 10^{-7} m. Such a capillary size determines the patterns of moisture transfer in the grain at the nanoscale of molecular mass transfer.

In this case, a powerful source of heat P and a high gradient of the higher pressure of ∇p the air-gas mixture are created at a significant microwave heating rate inside the wet processed material. All kinds of diffusion transfer of heat and moisture are suppressed. Intensive molecular mass transfer of the type of gas filtration through dispersed media predominates. However, in the case where the rate of gas generation is greater than the rate of its filtration, the higher pressure of steam can lead to the destructuring of the material at the level of the capillaries and cells.

The general system of differential heat and mass transfer equations known in [3] can be transformed into a special case of intense microwave heating by eliminating a number of terms of the terms of the right-hand side of equations that determine the diffusion modes of heat and mass transfer. Then, assuming that the mass transfer in the material occurs mainly due to the vapor pressure, the simplified system of equations takes the form:

$$\frac{\partial T}{\partial \tau} = a\nabla^2 t + \frac{P}{c\,\rho_o}; \quad (1)$$

$$\frac{\partial p}{\partial \tau} = a_p \nabla^2 p. \quad (2)$$

where P - power density, p - excessive pressure of the steam-air mix in material capillaries, a_p - coefficient of molar diffusion of steam, a - thermal diffusion coefficient at microwave heating, kg/K°; c_o - material sample capacity in relation to damp air.

The intensive thermophysical effect of microwave electromagnetic radiation on plant materials (in particular, grain) can lead to the destruction of starch grains, the increase in the size of microcapillaries and, consequently, the porosity of the grain, and the transformation of the nutrients it contains along the chain from complex biopolymers to simple ones (Figure-1).

A number of phenomena that are associated with the non-thermal specific effect of HFEF on biologically active objects are observed when microwave energy is processed by agricultural grain and plant materials. Usually, this factor is manifested at the cellular and molecular levels, except for the results directly attributable to the temperature factor.

When the biological cells (for example, plant seeds) are irradiated with an HFEF, an electrical tension appears on their cytoplasmic membrane, which exceeds the magnitude of the cell's strength by a factor of D / 2d, where D is the cell size, and d is the thickness of the cell membrane. This tension increases the electrical conductivity of the sodium and potassium channels of the membrane and, at certain values, leads to a bioelectric breakdown of the membrane without the formation of a through electric spark channel.

3. RESULTS

Let us cite fragments of studies of various directions of application of an HFEF processing of grain materials.

Chemical, biological and electro physical effects on seeds are used in the disinfection of grain in the period of presowing seed preparation, in order to intensify the sowing indices. All these effects give a definite effect, however, it is quite unstable (an increase in harvest from 0 to 15%) and weakly expressed in the economic effect. Local heating of the moistened surface of seeds occurs during microwave treatment due to its large dielectric properties and the death of microorganisms there. At the same time, seeds undergo drying and electromagnetic activation of their presowing properties due to the influence of microwave energy on the activity of amylolytic enzymes.

According to the preliminary laboratory-field evaluation, seed germination can be increased in comparison with the control and, depending on the initial one, on average by 10-12%, the number of plants remaining to harvest is 15-20% higher; Increase in harvestis up to 20-30%. At the same time, energy consumption and material capacity in the proposed technology can be reduced by 3-5 times in comparison with the known ones.

We studied the effect of the heating rate of microwave energy on various types of pathogens. The rational parameters of the heating rates of various biological objects were determined by the use of technologies based on microwave energy; their dependencies and the effect on infectiousness of pathogens were revealed. An example of the dependencies found is presented on Figures 3 and 4.

At present, infrared (IR) heating is used for high-intensity heat treatment of grain products. However, it is technologically necessary to organize a layer of grain one grain thick, two-sided heating of it from IR-emitters or, with unilateral heating of the layer, mixing of grains. All this complicates and increases the cost of the installation. In addition, the practice of using IR heating for high-intensity heat treatment of grain products has shown that additional moistening and dressing operations cannot be avoided to obtain the desired treatment effect.

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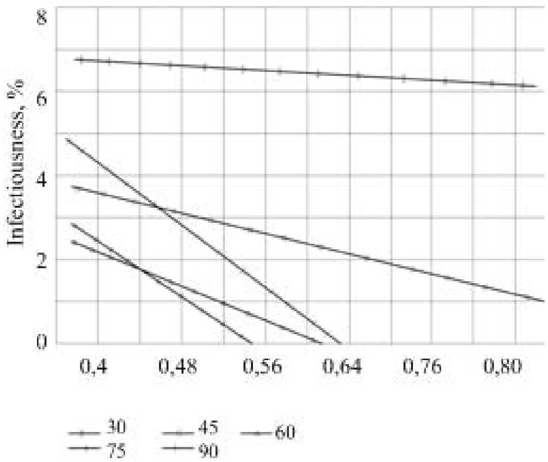

Figure-3. Influence of heating rate by microwave energy on infection of wheaten bran by FUSARIUM activators.

Table-3. Influence of heating rate by microwave energy on the contamination of wheat bran by activators of the genus FUSARIUM.

Sample No.	Mode		Temperaturet, ^{0}C	Infection, ufc/g (x10^2)		
	Exposition, day	Heating rate, ^{0}C/sec		Bran	Flour, first grade	Flour Extra Class
1	1	90	0.8	80	0	0
2	2	90	0.4	60	10	7
3	3	30	0.8	45	22	10
4	4	30	0.4	30	22	11
5	5	60	0.8	70	0	0
6	6	60	0.4	50	17	8
7	7	90	0.6	68	0	0
8	8	30	0.6	48	18	9
9	9	60	0.6	65	0	0
10	Control			21	12	8

Researches of haulm material desinfection for using as a floor covering in poultry farms, at technology of floor keeping of a bird have been conducted [4].

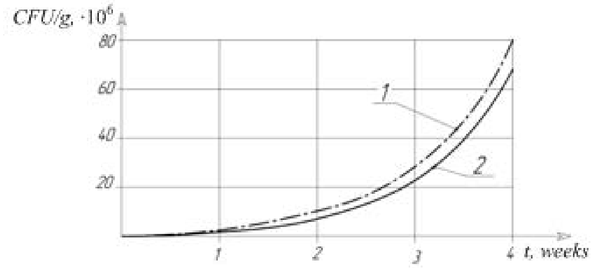

Figure-4. Growth of microscopic fungi in the straw litter of poultry farms.

1- dependence of growth under standard, standard, technology of disinfection; 2 - dependence of growth in decontamination technology using microwave energy.

The investigated samples of straw were subjected to electromagnetic treatment by microwave waves in the range of 2,450 MHz.

A well-known spatial resolution Nano Educator method using the scanning probe microscope was used to study the surface of a straw structure at the micro and nano level. We isolated a 12x12 micron sized section of straw during the research.

As a result of the relevant studies, the following results were obtained (Figures 5 and 6).

The surface of the original straw material is a smooth and relatively uniform surface in height, while the surface of the treated sample has an "acicular", rough surface and is unequal in height.

The 3-D model shows significant qualitative changes on the surface of the material. On Figure-5 the inhomogeneous outbursts in height are clearly visible.

We studied the transverse surface of the initial and processed samples (Figure-6). On the transverse section of the raw material, a porous structure with capillary septa is visible, but at the same time, after the exposure to microwave waves, these septa are not observed, which indicates the destruction of capillary septum data due to heating of the material in HFEF.

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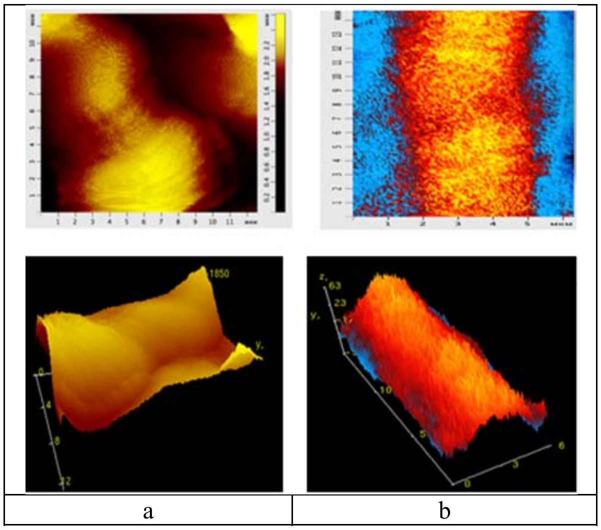

Figure-5. The histogram and 3-D model of a surface of solomisty material with a size of12x12 microns: a – the original; b-treated

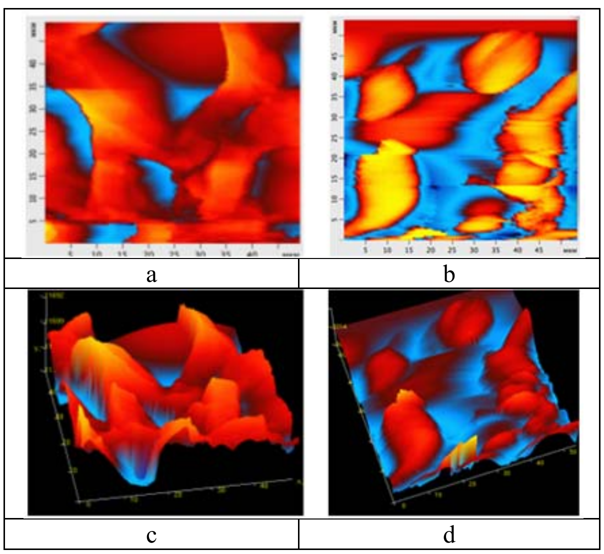

Figure-6. The histogram and 3-D model of the transverse surface of a straw material with a size of 12x12 microns: a, c - the original; b, d -treated.

A comparative analysis of the growth of microscopic fungi of straw litter treated according to a standard procedure and using technology using microwave energy showed a slower growth of microformations (Figure-6).

4. CONCLUSIONS

The integrated use of microwave energy in the processing of grain and not the grain parts of the crop allows to reduce contamination with pathogenic microbes and organisms at various stages of processing agricultural products, to obtain new better quality characteristics of the product, and to increase the shelf life of the product. As a result, with adequate indices in activating the inoculum properties, a more significant effect can be achieved simultaneously in the disinfection of seeds from pathogens.

According to the evaluation of laboratory-field seed germination in comparison with the control and depending on the initial one can be increased by an average of 10-12%. At the same time, the number of plants preserved for harvesting is more by 15-20%; the increase in yield is up to 20-30%, the energy intensity and material capacity in the proposed technology can be reduced by 3-5 times compared to the known ones.

The use of microwave energy in the process of high-intensity heat treatment of grain products avoids the main disadvantages of IR heating. The technological process, which we developed, is based on a combination of microwave heating with barothermal moisture-heat treatment. This ensured the necessary moisture-temperature regime, high qualitative indices of the final product (the degree of dextrinization of starch is more than 50%, the increase in the digestibility of cereals is 5-10 times), and the specific energy consumption is reduced by 1.5 times in comparison with analogues.

The optimum moisture content of the initial grain raw material corresponds to the usual moisture content of the stored grain and is within 10-14%.

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