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CONTROLLING REACTIONS OF BIOLOGICAL OBJECTS OF AGRICULTURAL PRODUCTION WITH THE USE OF ELECTROTECHNOLOGY

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Abstract

Usage of electro technology in agricultural production is a well-known way of increasing the efficiency. Its goal is to raise productivity, and to reduce power consumption of the processes. In practice, required modes of influence on biological objects are determined experimentally. In this way, marginal changes of parameters of equipments or modes of its work make it necessary to repeat the whole procedure of research. Thus, finding the common principles of using electrotechnology in procedures of processing the objects of agricultural production is an important task, fulfilling which can lead to advancement of technology and equipment. To solve this task usage of different approaches to describe reactions of biological objects was analyzed by the authors of the article. Utilizing the energy approach has shown that the principle of energy saving does not always determine behavior of biological objects. That is why this principle cannot be taken as the basic one. Using adaptive reactions while describing the influence of electrotechnology gave a possibility to formulate the rules of applying electrophysical impacts on agricultural biological objects. With the help of thermodynamicalapproach it was shown that a biological object from all possible states “prefers” that one which allowed it to get good result in the past. Informational approach allowed to formulate universal principles which should be considered in control of biological reactions of agricultural objects with the use of electro technology. Approaches proposed in the article are approved by the techniques which are used in practice to increase productivity of agricultural production.

Keywords: Electro technology, biological objects, microwave field, thermal processing of grain, field strength, adaptive reactions.

Introduction: Usage of electrical technologies in agricultural production is a direction of intensification of processes. However, specifics of agricultural productions creates definite problems in utilization of electrical technologies. One feature of technological processes of agricultural production is that work is conducted with biological objects. As a result, following problems arise during organization of production and control over technological processes and equipment:

- lack of operative control over stage of biological object;

- significant delay between the moment of external impact and the moment when reaction appears;

- uncertainty of parameters linked to those technological qualities of agricultural products which need to be controlled;

- dependency of technological qualities of products on electromagnetic fields;

- variability of reactions of biological objects following from different possible options of prehistory of their formation and development;

- irrecoverable character of changes which happen in biological object after faults in control (irreversibility of processes).

Besides, biological objects have their proper reserved energy, so it is possible to try to guide it in order to decrease energy consumption of technological processes. It should be also noted that reactions of such objects can be seen even under low-energy impacts. Numerous experiments prove that it is possible to control technological qualities of an object with the help of electrical technology impacts. Mentioned features serve as a premise for the question:does there exist common principles of usage of electrical technology for the purpose of controlling the reactions of biological objects of agricultural production? There are quite many works dedicated to the study of the influence of electrical technology on the processes of grain drying and increasing grain productivity with the use of preplant processing. That is why those works were taken as the basis and are used in the article to describe reactions of biological objects.

Materials and Methods

In order to answer the question it was decided to use such methods as energetical approach, thermodynamic approach, theory of adaptation, informational approach. In energetic approach [1, 2], it is necessary to defineenergy costs of forming a seed and growing a plant. Research results show that with some set of external factors energy costs of a seed (or plant) for development will be minimal. If land productivity is the goal of production, then the minimum of energy costs will lead to the maximum of productivity – this is proved by a number of investigations of agronomists and selectionists. For any crop there are possible favorable natural, climate, and agrotechnical factors which provide maximal yield. Another side of energetic approach is shown in the work of R. Rosen [3], which states that optimal structure is such one which provides minimal expenditures of metabolic energy with other equal conditions (considering that spent energy is sufficient to satisfy needs of an organism). Applying this principle to seed grain, it is possible to say that with various changes of different external factors plant forms and passes to its seeds such qualities, which provide developments with minimal expenditures of energy. From its “experience” of formation and development, seed derives and establishes scheme of behavior for germination and formation of a plant. If after sowing seed gets into conditions which are different from conditions of the previous year, the plant in its development will still use “previous experience”, which allowed it to survive.

On the basis of described features following conclusions were made:

- Statement about minimal expenditures of energy cannot be accepted as fundamental, as it does not always dominate reactions and development of a biological object;
- “previous experience” obtained by a plant (and seeds) can be a limitation for using the whole range of its potential capacities.

In order to determine reactions of biological objects on changes of external impacts, elements of adaptation theory were used [4, 5, 6]. Research [4] has shown that systems responsible for protection of an organism increase their responding activity if they react impacts of medium strength.Inthiscaseprotective reactions of an organism are not suppressed. At the same time these impacts are not that weak, so biological system cannot just ignore them. Activity of the systems responsible for protection should be increased. Intensification of activity is usually conducted in several stages. Each of the stages is characterized with definite level of nonspecific resistance of an organism. Primaryactivation (thefirststage) isformed in six hours, and is active during 24-48 hours after the impact [4].

At this stage sensitivity of biological object increases, so in order to go to the second stage it is necessary to reducemagnitude of the impact. The whole process is periodic, i. e. after reducingdosage it is necessary to increase it in some measure, then – to reduce it again, etc. The next stage of activation reaction is the reaction of “stable activation” [4]. The way of how biological object changes its resistance under stress and activation is shown in the Fig. 1. The foregoing allowed to express a hypothesis that preplant processing of seeds should be conducted in a similar mode. It is only necessary to determine correlation between the level of resistance of seeds and their sowing qualities.

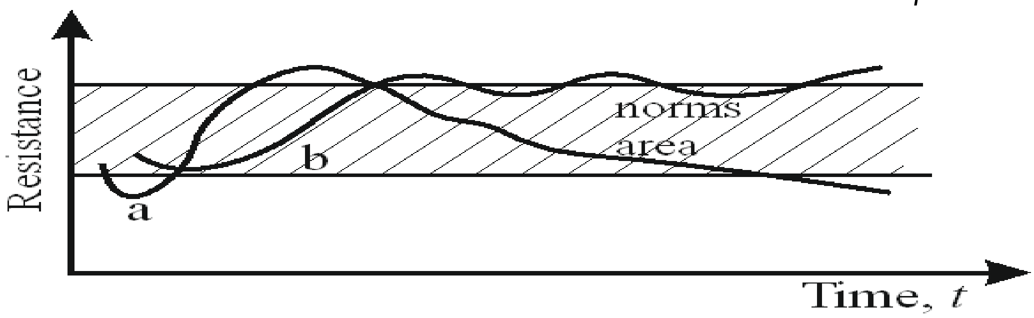


Figure1 – Changes of resistance of biological object a – under stress; b – during the process of activation [4].

In his work [4] Harkavy clarifies that strengthof stimulus is a relative value: reaction gets developed depending not on the magnitude of impact, but on increase in the magnitude. Thus, it is necessary to consider not only the magnitude if external impact, but also its changes, while conducting processing of seeds for improving their sowing qualities. Duringtheprocess, itisalsonecessarytopay respect to natural border conditions, otherwise outcome can be negative. So, forexample, seedsshouldnotbeheatedhigherthan 55-60^{o}C, in the opposite case sowing qualities of the seeds will worsen.

In the source [4] it is said that in experiment it is necessary to change the strength if acting factor only for 20% in order to realize transfer from one mode of reaction to another neighboring one. Harkavy has shown [4] that in a biological object there are different levels and ranges of resistance (reactivity). Within these ranges corresponding quantitative and qualitative relations are established. Those stimuli which can be treated as weak ones, for given range cause reaction of training, medium stimuli cause reactions of quiet or heightened activation. Stimuli which can be treated as strong ones according to the power of impact, cause the reaction of stress (Fig. 2).

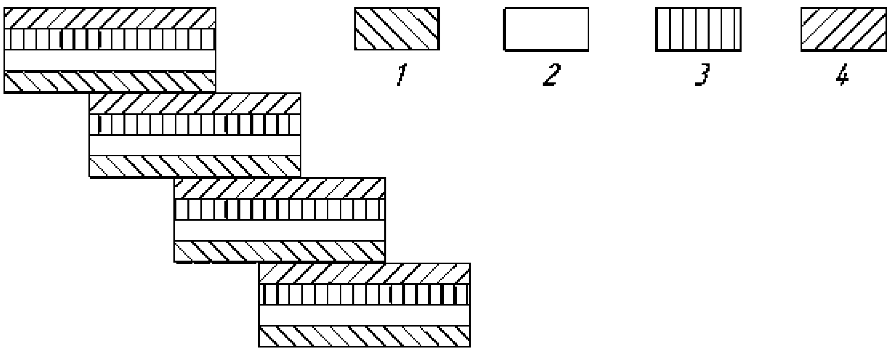


Figure 2 – Sequence of changing the ranges of adaptation reactions.

1 – training; 2 – quiet activation; 3 – heightened activation; 4 – stress

Biological object has two scales to measure strength of impact: the first one is relative (in relation to current level of resistance) and it defines the type of adaptation reaction, the second one is absolute and it defines the level of activity. Nonlinearity of reactions appears as at each level of reactivity, as in transfers from one level to another.

Such sequence of changes of adaptation reactions gives biological object possibility to adapt to any change of external impact.Due to this there also happens an extension of range of potential external impacts allowing the object to survive. Hence, the system of multilevel regulation of homeostasis is supported by periodicity of ranges of adaptation reactions [5, 6].

On the basis of the aforesaid a conclusion was made, that in order to increase resistance of seeds, which will improve their sowing qualities, it is necessary to follow the next principles:

- Initial external impact should have characteristics allowing adaptation reactions to run in the lower levels of resistance.

- Impact on biological object should not stay constant, it should be monotonously growing, its durations should allow the object to "perceive" the impact.

- Impact should be harmonic. Frequency may be individual as for every object, as for particular objective of the impact.

In thermos dynamical approach [7, 8, 9] todefiningreactionsofbiologicalobjectsonexternalimpactsit is accepted that the main property is reaching stationary conditions in them. In the process of development and interaction with environment, biological object passes from one stationary state to another.

Response reactions of an object to external impacts correspond to Ziegler's principle, the sense of which is that an isolated systemseeks in the shortest time to reach the state characterized by the maximal entropy.

Scientific research and industrial activities show, that a caryopsis reacts an external impact in accordance with previous experience which resulted in positive outcome.

Suchbehaviorbecomes a norm for biological object, and sticking with the norm is more important than decline of energy expenditures. Conservatism of the systems prevails over the search for a new state. Inthiscaseapplyingtheprincipleoftheentropy maximum is not sufficient.

Results and Discussion

Further it was decided to use informational approach [10, 11] to defining reactions of biological systems on external impacts. In this approach it is considered, that in order to obtain desired result of reaction of a biological system on external impact, it is necessary to provide maximum of mutual knowledge between conditions of environment and reactions:

$$I(X,Y) \rightarrow max,$$

Where X is the external impact on biological object; Y is the response reaction of biological object on external impact.

It is possible to write the principle of information maximum in two forms [10]:

$$I(X,Y) = H(X)- H(X/Y)= H(Y) - H(Y/X) \rightarrow max_{xy}. \quad (1)$$

The first variant of notation expresses adaptability of biological system to various external impacts. In this case constancy of reactions must be provided alongside with minimal variability of reaction results. This variant of the formulation shows adaptability of biological system to its environment. The second variant of notation shows, that biological system can increase variability of responsive reactions to external input. At the same time, it should solve the task of reducing conditional variability of these reactions.

The maximum of information, which can be reached, is conditional, as actually there are some limitations connected with potential possibilities of technical means or technological qualities of resulting product. In order to consider limitations in equation (1), they are introduced with the help of Lagrange multiplier. As a result, the next equation is obtained [10]:

$$I(X,Y) = H(X) - H(X/Y) - \lambda U(X,Y) \rightarrow max. \quad (2)$$

It was mentioned above, that the maximum of mutual knowledge corresponds to the reaction of biological system, which is desired by us. That is why it is logical to replace the condition of maximum of information with the maximum of usefulness $L= I(X,Y)$. Changesofconditionalentropy$H(X/Y)$ influence usefulness in the most significant way.

Reaction opposite to usefulness is disutility. For the case, when only one conditional probability is considered, its relation has the following view [12]:

$$-L = \{H(X/y_1) + [\lambda(U(x_1,y_1) - U(x_0,y_1))]p(x_1/y_1)\}p(y_1) +A, \quad (3)$$

or

$$-L = \{H(X/y_1) + Kp(x_1/y_1)\}p(y_1) +A, \quad (4)$$

Where $H(X/y_1) = H(x_0/y_1) + H(x_1/y_1)$;

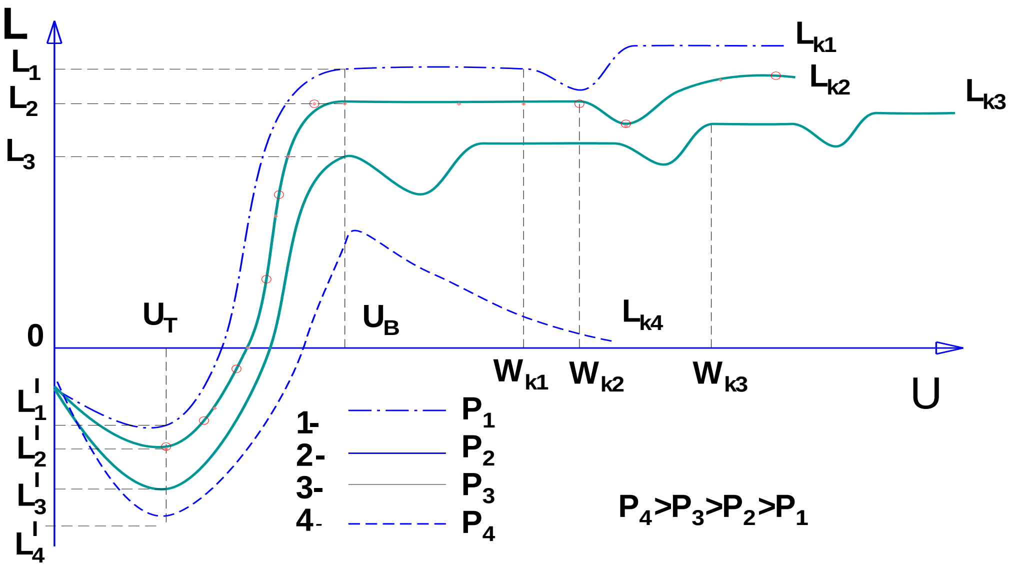
$A$is a sum and containing members of the equation not dependent upon $p(x_1/y_1)$; $x_0$is a stimulus which affects biological object and decreases conditional entropy$p(x_1/y_1)$;$x_1$is a stimulus which increases conditional entropy when affecting an object.

System has a possibility to control conditional probability by manipulating the values of x_0иx_1. Responsive reactions of an object are expressed in this way.

It is possible to continue viewing the responsive reactions of biological objects on the example of technological process of grain drying.

Flow of hot air is a controlling/external impact in this case. For the purpose of having more visual clearness it is possible to present the change of usefulness of caryopsis reactions on external impacts as the graphs in the Fig. 3.

Dynamical process of reaction can be built in scales of usefulness (L) and energy of impact *($U = P\tau$)*, whereτ – is the time of impact.



*P*ispowerofexternalimpact; $W_k$isfinalmoisturecontentofgrain; $L_k$isfinalusefulnessofreactionof a caryopsis; $U_T$is the maximum of energy of proactive suppression; $U_в$is the maximum of energy of stimulation

Figure 3: Dynamics of reaction of a caryopsis on external impact depending on its power.

In Fig. 3 it is possible to see several key moments in reaction of a caryopsis on blowing with hot air. It is assumed that the process starts at the same point for every variant of the impact. On the first stage, usefulness of reaction of a caryopsis starts to decrease (segment[0; U_T]). This is the phase of reaction when biological system “stands against” what is happening. The object mobilizes its internal forces in order to keep the initial state. Convective heat exchange leads to increase in the temperature of surface of the caryopsis and its partial dehydration, that is why its reaction will be directed towards decreasing the temperature and increasing its moisture content. This will lead to transfer of moisture from inner layers for the purpose of cooling the surface. Thisstageiscalledthephaseofprimary (proactive) suppression. From the principle of maximum of information it follows that the process of drying lead to an increase in mutual knowledge. However, in order to decrease energy consumption of the process, it is necessary to use such modes which will make caryopsis stay in the state of proactive suppression as often and as long as possible.

Internal resources of a caryopsis are limited. Rate of movement of moisture from the center of a caryopsis to its surface is less than the heating rate of the surface. That is why at the time which corresponds to the point U_7there happens failure of regulation. Newstateofacaryopsiscouldbeconsideredstable, if external impact helped to save the state. It was mentioned earlier, that under any external impact a biological system should finish transfer process in such state that usefulness of its reactions on external impact was the best from all possible variants. In Fig. 3 there are different graphs of usefulness for different levels of external impact. From the graphs it is possible to see that the final value of usability of grain biological reactions is different for different technologies of processing. Stability of biological processes in a caryopsis depends on the value of usefulness at which the process has finished. Value of use fullness at the end of process of drying corresponds to the final stable stationary state. It allows to state that each technology of processing brings a seed to corresponding stationary state.

Even if seeds of the same crop are dried to the same standard moisture content with different methods, stationary states of homeostasis will still stay at different levels. Because of this, the seeds will have different biological possibilities, which will manifest itself in their sowing and technological qualities.Inequality of external influence on particular seeds even within the same technology of postharvest processing. If drying is performed on a dense layer of grain, this inequality increases. Thatiswhy “individuality” ofstationarystatesofeverycaryopsis, whichisestablished during the process of its development, is also supported in the technological procedures of processing and storage.

In this examples influence of only one factor (temperature) and only one reaction of the biological object on it are viewed. In practice in reality it is not possible to find a separately taken external impact. Generally, simultaneous combination of several external impacts is present. Thus, in utilization of heated air for preplant seed processing, it is possible to view parameters of air including its temperature, humidity, and speed of passing through a grain layer, as external impacts. Besides, gas composition of the air can also be of significant influence. Therearenoreasonstothink, thatchangeofevery particular of these parameters causes its separate biological reaction. Notation duality of the principled of the information maximum (equation 1) exactly describes these features of the reactions. Atthepresenttimeitisdifficulttosaydefinitely, which “internal” regulatory effects in a biological object control reactions on definite external impacts. Itismadeevenmorecomplexwiththeassumptionthatthereeven mightbeseveral “internal” controlled parameters in a biological system.Eachcontrolledparametermaybeinfluencedbyseveraldisturbing and regulating effects. In this case it is correct to talk about multifactor external impact on a biological system.Influence of external impacts on usefulness of reactions of a biological system can be presented graphically as a surface in the Fig. 4.

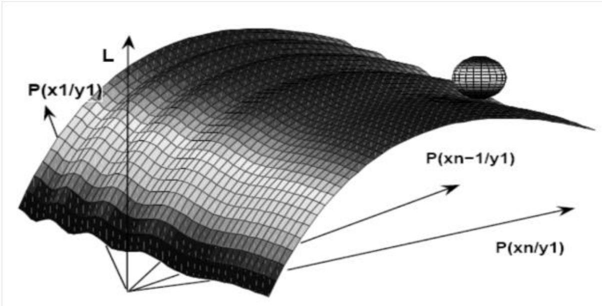


Figure 4 – Graphical representation of influence of external impacts on usefulness of biological system reactions.

In Fig. 4 the surface represents variants of reaction usefulness for a biological system depending on external impacts. Position of the sphere shows the value of usefulness of reactions depending on definite combinations of external impacts.

There is a possible option, that maximal usefulness of a caryopsis reaction on one impact will appear to be a minimum of reaction on another one. This possibility should be taken into account when defining required impact on the caryopsis.

From the point of view of drying process efficiency, it is preferable if reaction of a caryopsis stays in the zone of proactive suppression. At this stage all “internal forces” of the caryopsis are directed to the transfer of moisture from the center to the surface. With this behavior caryopsis expends saved energy on the needs of the drying process.

With the use of this approach in 1986 a new way of gray drying was developed [13, 14], much work on which has been done by professor Fomichev. Proposedmethodwas based on the idea of controlling the biological state of a grain layer by putting it into the state of “physiological arousal”. It was supposed to control the state of “physiological arousal” with the help of conductivity of the grain layer. The way, however, was not implemented in practice. There as on for that was that it was not possible to perform stable maintenance of the desired state in experimental research thought it was possible to reach it. As it was mentioned, even low-energy but continuous effects can transfer a biological object to a new stable state.

It is impossible to change reaction of a caryopsis on external impact directly. However, it is quite acceptable to do so indirectly, by changing the external impact. This task, though, is very difficult to realize. To do so,itisnecessarytohaveprecisecriterion of biological activity of a caryopsis, required means of control for this criterion, adequate information about the change of controlled parameter on the whole grain layer, and also to have access to controlling inputs.Due to these difficulties that interesting idea was not implemented technically, and it was not possible to explain the problem at that moment.Using informational approach not only allows to explain the problem, but also shows the way to solve it. It opens opportunities to develop principally new ways of grain drying.

Usage of the principle of the mutual knowledge maximum gives possibility to conduct comparative analysis of drying technologies and to make theoretical reasoning for possibilities and ways of implementation of resource-saving ways of drying. Analysis of grain behavior under external impact shows that simply supplying drying agent to it, it is not possible to use bioenergetical resources of the object in a full manner. In straight-through drying machines, where temperature of the air changes if the temperature of grain changes, the phase of proactive suppression is not used to full extent. That is why they are not effective. In technological processes of drying, where grain of different temperature and moisture content is mixed, or moist grain is heated for a short time, or grain settling is applied, it practically happens that different external impacts are alternated. In this way, multiple reiterations of proactive suppression mode are guaranteed, and with this bioenergetical potential of the seeds is used for drying. Information on energy consumption of different types of grain dryers approve relevancy of such theoretical conclusions.

In the presented materialan option was considered to increase mutual knowledge during the process of grain drying by decreasing mutual entropy. From equation (1) it follows, that it is possible to increase the value of mutual information by raising the value $H(X)$, which is unconditional entropy. For grain drying it means that external impact on a grain layer must completely define its state.In this case, conditional entropy$H(X/Y) \to 0$, and unconditional entropy $H(X) \to max$. In the best variant

$$I(X, Y) = H(X) \to max$$

During grain drying with heated air there is a probable situation, that state of each caryopsis within a grain layer is defined by parameters of the drying agent. That is, there is a deterministic dependency which allows to uniquely predict state of a caryopsis taking into account parameters of the drying agent. Obviously, state of the grain in the dryer has an influence on implementations of such modes.

Usage of fluidization, when active surface of heat exchange is maximal, leads grain layer to the state, when condition of full certainty of state of a caryopsis is provided. In this case conditional entropy is minimal, unconditional entropy is maximal, and mutual knowledge is maximal.

In practice, such ways of drying are either used in their pure form, or in combination with drying in a dense low-active layer, or in dense active layer.

In grain drying, usage of a combination of two methods, which allow to increase mutual knowledge, provides a way to develop principally new technologies and equipments.

In the examples which were given above only binary interaction was considered, i. e. an interaction with one impact and one reaction. Application of ozonized air or air saturated with aeroions, or usage of electroosmosis allow to perform additional external impact on a caryopsis. In this case, it is wrong to view reaction of a caryopsis on impact in two-dimensional coordinate system. Considering the equation of usefulness, for three coordinates it has the following view:

$$-L = \{H(x_0/y_1) + H(x_1/y_1) + H(x_2/y_1) +$$

$$+[\lambda(U(x_1,y_1) - U(x_0,y_1) - U(x_2,y_1))]p(x_1/y_1)\} \cdot p(y_1) + A \quad (5)$$

or

$$-L = \{H(x/y_1) + [\lambda(U(x_1,y_1) - U(x_0,y_1) - U(x_2,y_1))]p(x_1/y_1\} \cdot p(y_1) + A \quad (6)$$

Where x_0 is the impact of the drying agent; x_1 is the absence of any external impact (effect of natural conditions); $x_2$is the effects of electric technology; $y_1$is reaction of a caryopsis on external impact.

It should be noted that the effect of electrical technology impact (x_2) should have the same direction, as the main impact (x_0).

From the equation (5) it follows, that additional introduction of electrical impact adds to the number of summands for conditional entropy (6), and to the number of subtrahends for energetic component of the impact. It is noteworthy, that the value of ratio “effect of the impact to the energy of the impact” ($U(x_2, y_1)/\lambda \cdot U(x_2, y_1)$ can be higher for electrical technology impact, than for hot air impact (x_0). Utilizing electrical technology as an external impact on a biological system has a whole range of advantages compared to the other types of impact. First of all, the advantage is the low energy consumption of the impact. For example, usage of electromagnetic fields of direct current and electromagnetic field of alternating current of different frequencies requires a generator with a power of not more than several tenth of Watts. Besides, rather compact dimensions of these devices allow to place it even in already operational technical equipment. An important point is also that it is possible to embed those kinds of impacts into mass production technological lines.

As it has been shown, efficiency of control over the technological process of grain drying depends on the number of phases of proactive suppression, through which a caryopsis goes. Number of the phases can be increased by changing the type of external impact. It is possible to control the process of emersion of proactive suppression phase by changing the main controlling impact–temperature of the drying agent, but it will have no influence on the speed of drying. And if in the process of grain drying one does not change air temperature, but changes the other external impacts, it can considerably influence energy consumption of the process. Such reaction of biological systems shows great potential of agile control over the process of grain drying.

Increasing the value of unconditional entropy is the second variant of getting the maximum of mutual knowledge. With the use of electric technology in grain drying, analogous effect can be obtained by utilizing for processing microwave electromagnetic fields. Application of the principle of the information maximum helped to formulate three main methods, usage of which will allow to decrease energy consumption of the process [15]:

- changing external impact in accordance with a periodic law;
- changing the type of external impact during the period of processing;
- using external impacts which completely define state of a biological system.

Above it has been shown, that usefulnessof internal reaction of a caryopsis depends on the energetics of external impact. The higher is the energetics, the lower is usefulness. In the technology of grain drying, active aeration is considered to be one of the processes with the lowest energy consumption. So in this case practice also approves statements which follow from the principle of the information maximum. Maximal usefulness of internal reactions of seeds during the process of active aeration is expressed in the fact, that after such drying grain ripens better and has the best sowing qualities.

Setups of active aeration, in different variants of their design, in Russia are mostly required in natural-climatic zone of the South Federal District. As far as in those conditions rainy weather during harvesting happens only one time in 5-8 years, grain-producing farms do not consider it reasonable to purchase grain dryers. Besides, recently many farms prefer early varieties of sunflower, that is why it is also harvested with low moisture content. Powerful grain-drying equipment remains demanded for large volumes of production of corn.

Setups of active aeration are multifunctional. Possibility to use these setups as for grain storage, as for grain dryingmakes them attractive. However, low productivity of these setups, and rather highirregularity of drying of a grain layer in them are the factors, which limit the efficiency of their application.

Taking as the basis the principle of the information maximum and experience of practical implementation of new technologies in the process of grain drying, it is possible to say that for intensification of the process of grain active aeration it is possible to apply the following methods:

- changing the direction and speed of air;
- changing magnetic and electrical impact;
- changing the flow of charged particles.

The maximal effect can be achieved if electrical technology impact is performed periodically. In this way it is possible to increase the number of periods of proactive suppression, significantly reducing power consumption of the process in this way.

Reasonability of the given theoretical research is proved by experiments and works of the other authors on application of electric technology for intensification of grain drying [16,17,18,19,20]. Usageofelectroactivatedair saturated with aeroionsgives effect in the rate of drying and energy expenditures. Implementation of the same, but cyclicimpact gives an addition effect, emersion of which can be put on the account of biological reactions.

Conclusions

Informational approach to explaining the reasons of reactions of biological objects is better that the energetic, thermodynamic, and adaptation ones in the sense how it allows to explain changes in grain which is processed in technical equipment. That is why it served as a base to formulate the principles of usage of electric technology for the purpose of intensification the processes involving biological objects, reducing their power consumption, and increasing efficiency. Thefollowingprincipleswereformulated:

1. Electrical technology impact should have “low power”.
2. Electricaltechnologyimpactshouldchangeonperiodiclaw.
3. In order to increase efficiency, it is desired to change the type of electric technology external impact.
4. It is desirable to create such conditions for a biological object, which would allow to completely define its state with electrical technology impact.

Abovementioned allows to state that electrical technology impacts can be efficient, low-energy controlling inputs for agricultural processes with biological objects.

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