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Optimizing technological process of hydroponic germination of wheat grain by graphic method

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Abstract:
An essential factor which inhibits the large scale use of products based on germinated wheat grain in human nutrition is the lack of reasonable technologies of germination adopted with regard to public catering. The effective solution to this problem is to develop the technology of wheat germination by hydroponics method. A new improved method of germination aimed at reduction of process time and provision of microbiological purity of germinating seed materials has been suggested based on the complex use of physical factors: electrochemically activated water, extremely low frequency magnetic and electric fields, day and night artificial illumination by light-emitting-diode lamps.
When soaked and geminated wheat grain, water with pH 7,7 and electrochemically activated water have been used produced in water ionizer Chanson EDEN. The exposure to extremely low frequency magnetic and electric fields has been carried out on the experimental installation made by Institute for Research on Storage and Processing of Agricultural Produce (Krasnodar). The optimization the soaking process and wheat germination is aimed at reduction of process time in dependence on typical and varietal composition of wheat, the exposure of materials to magnetic and electric fields and so on. For all this, the admissible set for the soaking process has been limited by weight fraction of moisture in wheat grain, while the target value being the ratio between the soaking media and materials for germination. The target value for germinating process has been the minimization of root length together with the reduction of process time, while the permissible set was limited by germ length, the target value being pH of water medium. Equation of constrains has been obtained by bicubic spline of interpolation of experimental data in software Statistica v.10, which enabled to solve the problem of optimization by graphic method, along the level curve of the function of two variables determining the permissible set. It has been established that the use of electrochemically activated water with pH 3.5 having irrigation module 2,7 as a medium of soaking provides the required moisture of grain (from 30 % to 32 %) for the period of time which is by 4.5 hours shorter as compared to control. It has been proved that when electrochemically activated water is used for wheat germination and preliminary soaked materials are exposed to extremely low frequency magnetic and electric fields (current frequency is 20 Hertz, intensity of a current is 10A, day and night artificial illumination by light-emitting-diode lamps (red is 660 nanometers, blue is 430 nanometers, infrared is 730 nanometers) the germination process is intensified and the time for wheat germs production is reduced by 34 hours.

Keywords: Wheat, water soaking, germination, electrochemically activated water, extremely low frequency magnetic and electric fields

INTRODUCTION

In connection with the growing volume of agricultural products in Russia, and namely, in Krasnodar region, according to Decree of the President of the Russian Federation dated 6 August 2014 № 560 "About adopting special economic measures to provide security of the Russian Federation, there is an urgent need for cheap and affordable, import-substituting foodstuff. [1, 2].One of the provisions of the doctrine on Food safety is to provide healthy human nutrition. [3]. Today in Russia special attention is paid to the production of foodstuff able to enrich our diet by biologically active substances, functional ingredients having favorable influence on general well-being and metabolism in human body.

Various raw materials are used to enrich our diet, including grain. Wheat takes the first place in grain production in Russia and in the world. Such significance of wheat is caused by its high yield and valuable properties of protein, carbohydrate and enzyme complex. Grain is an affordable foodstuff for any groups of eaters. Germinated wheat grain is of particular interest as one of possible sources to enrich human diet due to the wide spectrum of useful properties; it is gaining a great popularity among the population and widely introduced into products of mass consumption. [4].

For millions of years of evolution plants have developed mechanisms to complete their own life cycle by accumulating complex reserve food materials in their seeds, from which when exposed to moisture simple and easily assimilable nutrients are synthesized which provide the development and protection of a renewed plant. [5].

Germinated seeds have a great energy potential, contain all essential life components and are provided with the system, which contributes to their assimilation [6-12], and recommended for diet and therapeutic nutrition, since they have bactericidal properties, high bioactive power, able to stabilize nervous system, stimulate and increase performance [13-18].

When eating products based on germinated grain, the load on digestive system is decreased by 90 %, since with these products a human gets not only split elementary substances, but also the additional enzyme system which improves digestion, facilitates evacuation function of intestine almost by 90 % and optimizes metabolism [19, 20].

During grain germination the whole range of complex processes take place, and namely,

–physiological – the development and growth of grain germ ;

– biophysical – the movement of enzymes from aleurone layer to endosperm and simple substances from endosperm to germ.

– biochemical – grain respiration which takes place under the influence of oxidase, the hydrolysis of reserve food materials in endosperm, the synthesis of new substances, growth of new tissues, aroma and flavor substances [3, 21].

When germinating grain changes its chemical composition significantly. Being in endosperm inactive substances regulating growth are activated and speed up the synthesis of enzymes, controlling hydrolytic and oxidizing processes. The formed enzymes decompose complex reserve food materials into simple ones, which are important for germinating grain to build new tissues [22, 23].

Starch is transformed into sugar, proteins into amino acids, and fats into fatty acids accompanied by the elevated level of essential amino acids, while the total content of fats is decreased. At the same time, there is an increase in the levels of polyunsaturated fatty acids, while the level of insoluble dietary fibers is falling down and the level of soluble dietary fibers is growing, and the content of phytates , gluten and other substances being decreased.[24].

Simultaneously absorption of essential macro and micro-nutrients from water takes place and polyribosomes responsible for protein synthesis are formed, active phytohormones facilitating the growth work, vitamins are synthesized, the amount of antinutrious substances decreases significantly while the proteolytic activity grows [23].

One of the main properties of wheat germs is their ability to synthesize water-soluble vitamin C, while it is not available in dry grain. Apart from vitamin C, germs can be the source of vitamins A, B, E, folic acid. Germinated wheat has vitamin C and B_6 content 5 times higher after germination, vitamin B_1 content is 1.5 times higher, vitamin B_2 is 4 times higher, vitamin E content is three times higher. The concentration of natural antibiotics and growth-stimulating substances increases rapidly [25, 26].

For the use of products based on germinated wheat in public catering there is a need to study the process of germination specifically, to analyze factors stimulating the success of germination, to register the changes in physiological, biochemical and technological properties.

Germination is a set of physical and biological changes which take place in a germ when making the transition from dormancy state of to active vital functions, completed by the formation of a germ. The process of germination consists of number of consistent phases each of which is characterized by a certain duration, biochemical and morphological changes which occur in grain, as well as by certain requirements to the environment [27]**:**

1) water absorption;
2) upswelling which is completed by chitting
3) growth of embryo roots;
4) the growth of a germ ;
5) germ generation.

Soaking is the main stage in grain germination, since water is a trigger which starts all biochemical processes from the moment when moisture reaches its critical point. Well - organized process of upswelling provides an opportunity to optimize parameters of germination and prevents losses of dry solid matter and nitrous agents in grain. At the same time, overexposure of grain in water leads to the opposite result, seeds are out of air, covered with mucus and do not germinate [27].

The difference in quality of some grain, various level of water content by the beginning of germination leads to quite long intervals for grain chitting, which means that the degree of metrical uniformity in seed batch determines the rate of upswelling and germination of grain [27].

The time of grain soaking is also caused by temperature, the higher the temperature, the faster organic colloids are swelled (proteins, starch, cellulose), the higher is the rate of water diffusion (about 2 % per 1° C**)** [27].

The physical nature of upswelling process consists of interaction of water with water-receptive and hydrophobic substances. When upswelling, protein substances can absorb water up to 250 % or more, starch from 30 % to 35 %, mucus up to 800%. Hydrophobic substances do not swell in water and are not dissolved. These are fats and other lipids, coloring agents soluble in fats, carotenoids, chlorophyll pigment, fat-soluble vitamins and others. A part of substances in grain are dissolved in water, which are sugars, free amino acids, phosphates, the most of levulezan and others). Substances which are able to swell in wheat grain constitute from 80 % to 85 % [28].

The process of upswelling also depends on morphological properties of seeds, their composition and ratio between hulls and the kernel. In their structure seeds belong to capillary-porous substances. Capillary structure is more typical for hulls, since the seed kernel has more densified structure. Intercellular structure is penetrated by pervasive and blind capillaries; colloidal substances are also located in cells [27].

First few hours after soaking grain in water, oxygen present between the germ kernel and hulls provides normal conditions of respiration and prevents the process from being converted into anaerobic type. Under the influence of capillary effect water comes inside the seed through its bran, comes into contact with seed-coat, which covers wheat bran. Seed -coat swells gradually and fills the space between the germ kernel and hulls, providing the direct contact of germ kernel and endosperm with water. From this moment the upswelling of germ kernel and endosperm, as well as the expansion of hypocotyl start [27].

Germinated seeds are considered to be only those which have the completely shaped germ (appearance of a sprout with embryo roots). The complexly of germinating process is determined not only by the fact that it is connected with numerous morphological and physical and biocheminal phenomena showing themselves sequentially, but also that the substantial set of external factors has a great influence on that. All effects regulating germinating process are called factors of germination retarding or facilitating biochemical transformations and causing deep changes in physiological processes which determine the character and the rate of germination [29].

Technological requirements to conditions of germination are characterized by the following indices: temperature, at which seed is germinated at certain stages, moisture content of grain, the ratio between oxygen and carbon dioxide in the seed layer at particular stages of germination, the time of germination [3].

The process of germination takes a significant time; therefore, it is essential to speed up this process keeping the quality of a target product at a high level [1].

Nowadays various methods intensifying the technology of germination are applied, based on the use of special conditions for soaking and germination, inhibiting respiration processes which lead to the decrease in Anthocyanogen content and the facilitation of softening process in cell walls of endosperm: the use of growth activators (lactic acid, diammonium phosphate, endogenous gibberellic acid, potassium bromide and others), exposure to physical factors including ultrasound, electric field, Y-rays and others, as well as the use of enzymatic agents [30-34].

Enzymatic agents as well as other chemical agents are known to be used to facilitate grain germinating process. However, not all of them are safe for a human.

The use of reagentless methods for the processing of raw materials gives wide opportunities to modernize technological processes, to reduce time of processing and to improve the quality of output [35].

Production of products based on germinated grain directly depends on the process of germination carried out in a proper way, one of its criteria being the lack of contaminating microorganisms [36].

Cereal crops are affected by microorganisms in ripening process, and the development of microbial flora in grain takes place on a field, in storage facilities and at the stage of germination [37].

Microbial flora living inside and outside the kernel forms its epiphytic (external) and subepidermic (internal) bacterial flora. The coexistence of microorganisms and grain is connected with physiological and biochemical changes in the latter, since microorganisms have high intensity and ductility properties of metabolism between a cell and environment. Contamination of grain by microorganisms facilitates the deterioration of technological and organoleptic indices, pollution with cancer - causing mycotoxins, being the secondary metabolites of microfungi, are recognized as one of the most harmful factors for human health. The potential and real danger is growing significantly since they are highly resistant to various unfavorable effects, among which are boiling, exposure to mineral acids, alkalies and other agents [36, 38].

It is known that some physical factors also have a stabilizing effect, inhibiting the growth of microorganisms. For example, the use of Y-rays, ultrasound, electron-ion technology and other physical methods of grain processing give positive results. However, microorganisms are sensitive to physical factors in different ways. For instance, filamentous fungi are resistant to Y-rays, but, on the contrary, infrared rays inhibit the activity of filamentous fungi, but have less impact on bacteria [37].Thus, neither of these methods provides the complete destruction of viruses and fungi.

In this connection it is essential to search for disinfectants decontaminating kernels of cereals from pathogenic forms of microorganisms, which are able to destroy storage compounds and change the quality of grain, when growing on its surface and under the hull. It is also important to search for stimulants which are able to reduce the time of germination.

The given results of investigations show that various methods and ways of grain preparation for germination have been developed which allow seeds to break the dormancy of grain and to stimulate the growth of wheat germ, to facilitate enzymatic processes and to reduce high microbial population germinating materials.

One of the prospective and the most ecologically friendly methods to activate germination is processing of grain with electrochemically activated water. Electrochemical activation of water is a physical and chemical process which under condition of minimal heat generation means the set of electrochemical and electro - physical effects on liquid containing ions and molecules of soluble substances in the area of a charge cloud located near the surface of an electrode (anode or cathode) in the electrochemical system when the unbalanced charge is transferred over the «electrode- electrolyte» boundary by electrons. Electrochemical activation of water results in metastable (activated) state, showing higher reacting power in various physical and chemical processes for a few hours. [39]. Cathodic liquor forming in the cathodic area of the divided electrolyzer has a bio-stimulating effect, while the analyte formed in the anodic zone of the divided electrolyzer has biocidal properties [40].

Among chemical, mechanical and electrophysical methods intensifying the process grain germination electromagnetic fields of different frequency have the most advantages, providing decontamination of seed materials. It is prospective to use extremely low frequency magnetic and electric fields as a physical non-thermic barrier for microbial_contamination. Such barrier belongs to technologies which have soft impact on a product, energy conserving, ecologically safe and guarantees natural appearance of a product after removing pathogens or spoilage microorganisms. The efficiency of this method has been confirmed by scientific results [41].

The objective of this research is to confirm and give scientific credence to the expediency of integrated use of physical factors, namely, electrochemically activated water, extremely low frequency magnetic and electric fields in order to reduce the time of germination process, and to decrease microbial contamination and losses of valuable nutrients in seed materials.

TARGETS AND METHODS OF RESEARCH

Spring wheat of soft varieties «Altayskaya 105» and «Pobla Runo» harvested in 2015-2016 has been used as a target of research. These varieties are available in large quantities on the consumer market in Krasnodar region.

The analysis of wheat grain has been carried out in a standard way: grain probes are selected regulated by GOST № 13586.3-2015, grain moisture by GOST 13586.5-2015, kernel hardness by GOST 10987-76, grain unit by GOST R 54895-2012, and the mass of 1000 grains by GOST10842-89, protein weight fraction complying with requirements of GOST 10846-91, germinating power by GOST 12038-84.

Grain of both varieties has been exposed to soaking and germination under the same conditions while physical factors being different:

–medium is water with pH 7.7 and electrochemically activated water (anode is water with pH from 3.5 to 6.5, while cathodic is water with pH from 8 to 10,8);

– day and night artificial illumination by light-emitting-diode lamps (red is 660 nanometers, blue is 430 nanometers, infrared is 730 nanometers) **;**

– temperature interval of environment is 20-22 ^{o}C;

After soaking germinating materials have been exposed to extremely low frequency magnetic and electric fields with the following parameters: frequency is 20 Herz, current intensity is 10 A, and time of exposure is 20 minutes**.**

Electrochemically activated water has been produced by water ionizer Chanson EDEN. Exposure of seed materials to extremely low frequency magnetic and electric fields has been carried out on the installation made at Institute for Research on Storage and Processing of Agricultural Produce (Krasnodar), i.e. (the branch of Federal State Scientific Institution "North Caucasian Federal Scientific Center of gardening, viniculture and wine-making. [41].

Wheat grain has been germinated by hydroponics method.

Analytical methods have been applied to determine the indices of germination.

The share of geminated wheat grain D, % has been determined in accordance with the formula:

$$\mathbf{D} = \frac{(\mathbf{N_{24}}+\mathbf{N_{48}}+\mathbf{N_{72}})}{\mathbf{500}} \cdot \mathbf{100}\,\%, \tag{1}$$

where N_{24} is the amount of germinated grain for 24 hours;

N_{48} is the amount of germinated grain for 48 hours;

N_{72} is the amount of germinated grain for 72 hours.

The average time of germination $T_{av,}$ days, has been determined in accordance with the formula:

$$\mathrm{T}_{av} = \frac{(\mathbf{N_{24}}+2\cdot\mathbf{N_{48}}+3\cdot\mathbf{N_{72}})}{\mathbf{N_{24}}+\mathbf{N_{48}}+\mathbf{N_{72}}}. \tag{2}$$

The index of germination I_{sp} has been calculated using the formula:

$$\mathbf{I_{sp}} = \frac{\mathbf{10}}{\mathrm{T_{av}}}. \tag{3}$$

Since there are a lot of physical factors of soaking process and germination in the experiment, spline of interpolation of experimental data in software Statistica v.10 has been made with the view to identify general tendencies and to optimize the technological process. The task set and to be solved has been to minimize the time of the processes T in dependence on the type of wheat variety, exposure of materials to extremely low frequency magnetic and electric fields and so on.

Meanwhile, for grain soaking process the admissible set has been measured by limitation for moisture weight fraction W in wheat grain; the target value being the ratio between the media of soaking V and germinating materials. For the process of grain soaking the objective function together with minimization of process time has been to minimize root length h, and the admissible set has been determined by restrictions to germs length H, while the target value being pH of water medium.

Bicubic spline of interpolation has given equations of connection and the opportunity to solve the problem of optimization by graphic method along the level curve of the function of two variables determining the permissible set.

The research was carried out on the equipment of the CCU (Centre of collective usage) "Research Center for Food and Chemical Technologies", FSBEI HE (Federal State Budgetary Educational Institution of Higher Education) "Kuban State Technological University".

RESULTS AND THEIR DISCUSSION

The process of germination is divided into the stage of preparation of materials and germination itself. It is important for germination to have the regular income of water to wheat grain. Upon that, the level of moisture content grows in grain approximately from 12 % to 44 %. Water penetrates into cells of grain tissues not only under influence of physical laws but also biological forces, which display themselves through actions of fine cell mechanisms, regulating the income of water inside and its removal outside the cell. The absorbed water is included into biological metabolism which leads to dynamic changes of physical, chemical and technological properties of grain. [43].

Preliminary preparation of wheat grain consists of the removal of material other than grain, grain sorting, washing and grain soaking. Interaction of grain with water starts at the stage of washing and continues when grain is soaked and germinated. Meanwhile, grain absorbs water vigorously at the initial stage. Then, under fixed parameters the process is stabilized and moisture is redistributed to anatomic parts of caryopsis. The process of upswelling is retarded when grain reaches the level of moisture 45 %, this level of moisture is an equilibrium quantity, when hydrostatical pressure in cells is equal to osmotic pressure, created by cellular fluid [44].

The duration of wheat grain soaking fluctuates from 12 to 72 hours, which increases the time of germination significantly, therefore, the method of process intensification has been developed at the first stage.

Water absorbing capacity of grain and the rate of water penetration inside are caused by the range of factors, the most important of them being the following: crop variety, initial moisture, vitreousness and the quality of protein in grain (table 1).

It has been established, that the germinating capacity of wheat variety «Altayskaya 105» and «Poble Runo» meets the requirements of regulatory documents, which testifies to the suitability of the chosen varieties for germination.

The rate of water absorption by wheat grain depends mainly on the temperature of water. Warm soaking has been tested with the temperature of water from 20 ^{o} C to 22^{o} C, since the process of moisture absorption goes more slowly at lower temperatures, at higher temperature the process is faster, but uneven; also, grain respiration increases and multiplication of microorganisms which are always present on the surface of grain, is intensified, too. When the temperature of steep liquor is about 40 ^{o} C, germ losses its capacity to germinate and dies.

High moisture and room temperature favors the growth of microflora which has a negative effect on the quality and safety of germinating seed materials. In order to improve the safety of germinating materials the anolyte of electrochemically activated water has been used as steep liquor (pH ranges from 2,5 - 4,0),which has antiseptic and bactericidal properties. After soaking the quantitative and qualitative composition of micro flora in native grain and wheat grain has been determined (irrigation module is 1:1, exposure time is 24 hours).

It has been established, that microbiological contamination of original grain is quite high and it grows when grain is soaked in water: total viable count (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms) increases by 39.3 %, the amount of mold fungi and yeast grows by 28%, spore-forming bacteria is more by 40,6 %.

It has been discovered, that the most optimal medium to reduce microbiological contamination is electrochemically activated water with pH 2,5. At the same time, total viable count is higher by 71,4 %, the amount of fungi flora is reduced by 24 %, the number of spore-forming bacteria falls by 68,75 %.

On the base of the fact that the activity of proteolytic enzyme in wheat grain decreases at pH lower indices, the anolyte of electrochemically activated water with pH 3, 5 has been agreed as the optimal medium, allowing to reduce microbiological contamination of wheat grain: total viable count falls by 32 %, fungal microflora is less by 16 %, the amount of spore-forming bacteria decreases by 25%.

As a result of previous investigations it was established that relatively low moisture of grain was needed, which was from 30 % to 32 % to initiate germination.

During the experiment the minimal time of soaking and the amount of steep liquor were determined when wheat grain reached the moisture necessary to initiate the process of germination. For these purposes samples of wheat grain were covered with water with pH 7,7 and anolyte of electrochemically activated water with pH 3,5 and oxidation – reduction potential +720 mV, irrigation module being (from 1:1 to 1:4) was exposed in contact with the medium from 2 to 16 hours. Grain soaking was carried out at the temperature 20-22 ^{o} C and mass fraction in grain was determined at appropriate intervals.

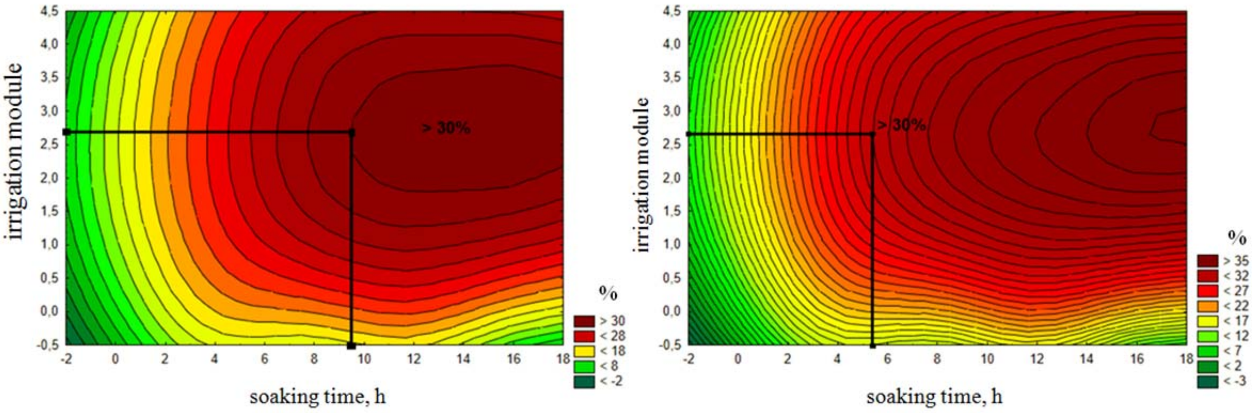
For soaking process the first stage to optimize technological process is to build bicubic spline of interpolation of defect 1 for the function W=W (T, V), determined by tabulated values, with interpolation nodes to smooth experimental data in triplicate.

Constraints W_{min} on mass fraction of moisture in wheat grain W give the constraint equation T from V in the form of implicit function W_{min}=W (T,V).The target function is T(V)$\rightarrow$min.

Drawing curves of the function level W=W (T, V) enabled to solve the given problem of optimizing by graphic method (see fig.1 and 2) : vertical straight lines of the target value T should touch contour lines of the level W_{min}=W(T,V), and horizontal concurrent line from the tangency point gives the target value V . When moisture content of wheat variety «Altayskaya 105» reaches W_{min} = 30 %, the obtained interpolation surfaces give the first critical point when materials are soaked in water for T = 9,5 hours at the ratio 1:2,7 (fig.1,a), when grain is soaked in electrochemically activated water T = 5,5, irrigation module being 1:2,7 = V (fig. 1,b)

Table 1 – Technological properties of wheat grain

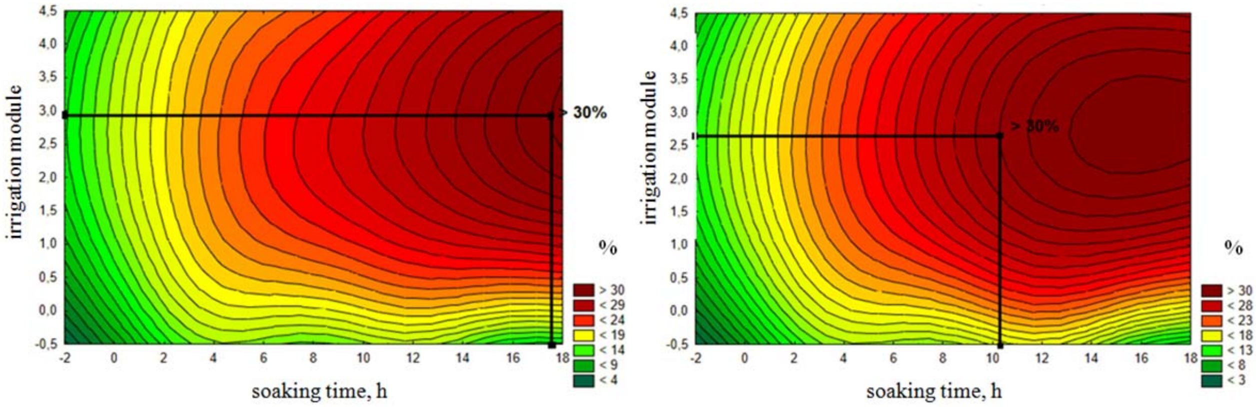
Wheat variety	Moisture, %	Vitreousness, %	Natural weight, г/л	Mass of 1000 grain, gram	Protein content, %	Germinating capacity, %
«Altayskaya 105»	5,60	54	813	36,38-36,40	13,0	93
«Poble Runo»	7,60	61	510	31,68-31,72	17,0	92



a) b)

a – soaking in water , b – soaking in electrochemically activated water

Figure 1 – Conditions of moisture content 30 % when wheat variety «Altayskaya 105» is soaked



a) b)

a – soaking in water, b – soaking in electrochemically activated water

Figure 2 – Conditions of moisture content 30 % when wheat variety «Poble Runo» is soaked

When moisture content of wheat variety «Poble Runo» reaches 30 %, interpolation surfaces give the first critical point when the materials are soaked in water for T = 17,5 hours, at the ratio 1:2,9 = V (fig 2, a), when grain is soaked in electrochemically activated water T = 10,5 hours, irrigation module being 1:2,7 = V (fig 2, b).

Changes of grain moisture in wheat variety «Altayskaya 105» and «Poble Runo» are proceeding in uneven manner, for the first few hours there is a sharp increase in moisture content from 5.6 % to 23-28 % and from 7.6 % to 22–23 % correspondingly, and then moisture saturation is retarded. The process of moisture distribution goes in accordance with thermodynamic characteristics of moisture transmission in main anatomical parts of grain.

Results of investigations (fig.1 and 2) show that the process of water absorption is influenced by the medium used for grain soaking and peculiarities of the chemical composition of geminating materials.

It has been proved experimentally that the use of anolyte of electrochemically activated water with pH 3,5 as a media of grain soaking, module being 2.7, will help to reach the required moisture content in wheat variety «Altayskaya 105» and «Poble Runo» for the period of time which is by 4 and 7 hours shorter in comparison with the controls correspondingly.

The spatial structure and higher capillary permeability of electrochemically activated water contributes to the intensification of the process, which enhances the moisture transport into germinating seed materials. Furthermore, during electrolysis the anolyte is saturated with molecular oxygen, active chlorine and hydrogen ions. The supply of wheat grain with optimal amount of oxygen at the beginning of growth phase is an important condition since its shortage can lead to anaerobic metabolism, whose products can have a significant influence on the quality of germinating seed materials.

Technology of grain germination by hydroponics method, when seeds are grown on artificial porous water retaining and air-retaining media, provides an opportunity to reduce production space significantly, however, it does not have any effect on time expenditures when germs are grown. In order to reduce the process time and to provide microbiological purity of geminating seed materials the improved method of germination has been suggested based on the complex use of physical factors mentioned above.

Light of certain spectral quality and sufficient intensity is indispensable to the normal growth and development of plants. The quality of light sources is becoming crucial in conditions of complete artificial lighting and supplementary lighting. If a particular spectral region is not available in light emission, it can lead to disruption of normal growth of plants. It is expedient to use light-emitting diode lamps for germination, which are able to give the necessary spectrum of natural sunlight. They do not produce any heat, there is no possibility of thermal overload for germinating seed materials. They also have low energy consumption, long lifetime, do not contain harmful substances in their composition, and the diversity of luminaire design allows installing them in different positions: pendant fixation, mounting to a wall or ceiling.

The use of electrochemically activated water, an anolyte having very high biocidal activity will promote decondensation of grain hull, acidulation of endosperm inducing enzyme synthesis and decreasing bacterial contamination of grain; a catolyte has a bio-stimulating effect, enhacing the transport of moisture and nutrients from endosperm to germ, which makes it possible to increase germinating capacity of grain.

Scientists of Krasnodar Scientific Research Institute on Storage and Processing of Agricultural Produce have determined the parameters of electromagnetic exposure: frequency and current intensity of electromagnetic field, the duration of exposure which can minimize microbial contamination by sporous aerobic bacillus Bacillus subtiis-mesentericus, which does not form sporous of Enterobacter type and yeast fungi Saccharomyces. [45]. Electromagnetic field also has a considerable effect on physiological state of the kernel: the permeability of cell membranes increases, work of enzymic mechanism is growing, resulting in the improvement of germinating capacity of seeds, intensity of growth increases , as well as chlorophyll content and vitamin content. The use of extremely low frequency magnetic and electric fields is caused by the fact that at higher frequencies not only the percentage of germination is higher but also the root system develops better which leads to the loss of nutrients in underground seedling and wheat germs.

When studying complex effect of physical factors on the efficiency of germinating conditions, medium parameters were varied (pH) together with simultaneous exposure to extremely low frequency magnetic and electric fields while the criterium to be achieved was to produce a germ 2mm long. Table 2 shows results of the most effective impact on indices of germination.

It has been shown that the use of electrochemically activated water with pH 5,5 as a medium and the exposure of materials to extremely low frequency magnetic and electric fields after soaking provides the largest share of germinated grain 98 % when the average time of germination is minimal. The use of germination conditions, when the amount of ungerminated grains being big is undesirable, since they often cause the infection of the whole batch of germinating seed materials.

As a result of obtained data (table 2) it has been established, that in spite of the equal share of germinated grain in wheat varieties being studied and the same conditions of germination, the index of grain germination in variety «Poble Runo» is lower, than in wheat variety «Altayskaya 105» which testifies to the slower dormancy breaking of a germ.

In order to produce the juice based on wheat germs, grain has been germinated until the plant stem achieves the length from 12 to 15 cm. Further growth of wheat germs is inexpedient which is connected with changes in the structure of a plant cell and reduction in cellular fluid; hence, it can lead to the drop in output when pressed and the increase of losses.

During the experiment the length of primary organs of wheat grain (wheat germs and roots) was measured at certain intervals in dependence on conditions of germination.

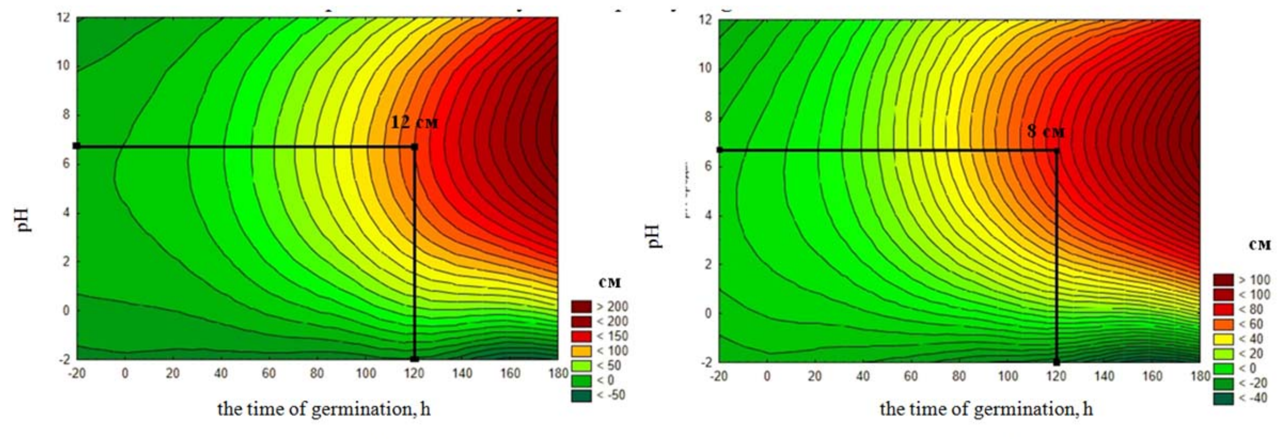
In order to determine optimal technological conditions of wheat grain statistical processing has been used, uniting all available data (typical and varietal composition of wheat, ph and water medium, electromagnetic exposure of materials) and able to present them in the illustrative graphical form, whose main requirement is to give the description of appropriate reaction of wheat grain on changes of main factors limiting the development of primary organs. When analyzing the interpolation surface the response for wheat grain germination was the length of germs and roots, while independent variables were the time of germination and pH of medium, therefore, the two individual graphs were drawn and with their further overlapping for visual analysis.

For germination process the target function, along with $T(pH)\rightarrow min$, is $h(T,pH)\rightarrow min$. The first stage of optimization of technological process is to build bicubic spline of interpolation of defect 1 for functions h(T,pH) and H(T,pH), by tabulated values by tabulated values with interpolation nodes in triplicate experimental data smoothing. Constraints H_{min} on the germ length of wheat grain H give the constraint equation T from pH in the form of implicit function H_{min} = H (T, pH).The target function is $T(V)\rightarrow min$.

Drawing curves of the function level H (T,pH) and h(T,pH) enabled to solve the problem of optimization by graphic method (fig. 3 and 4): straight lines of the target value T should touch contour lines of the level H_{min}=H(T, pH), should touch contour lines of the level pH, with simultaneous contact of the least admissible contour line of the function h(T, pH).

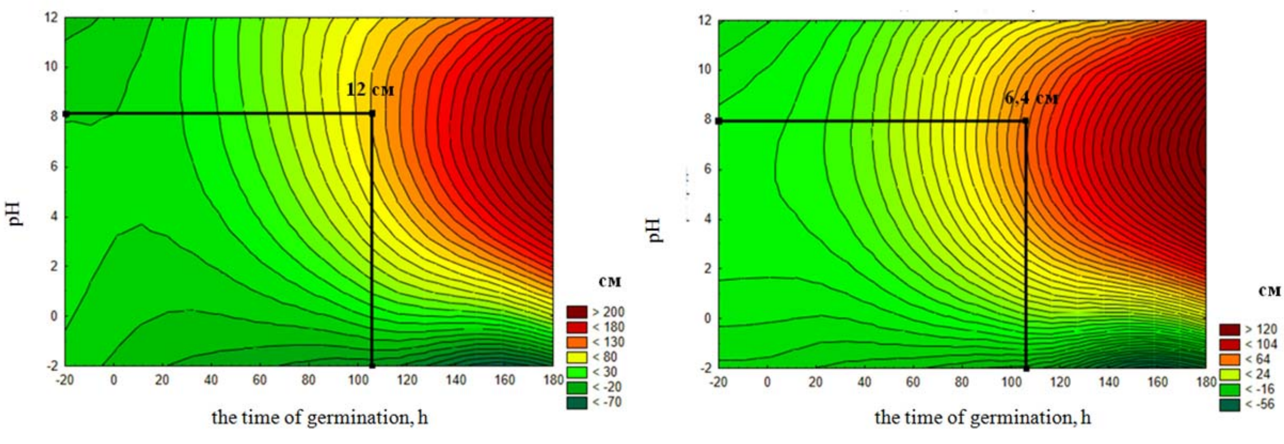
Table 2 –Indices of wheat germination:

Used medium	**Type of exposure**	**The amount of germinated grain, items**			**Share of germinated grain, %**	**The average time of germination, days**
		24 h	**48 h**	**72 h**		
«Altayskaya 105»						
electrochemically activated water pH = 6,5	without exposure	459	18	7	97	1,07
	extremely low frequency magnetic and electric fields	442	28	21	98	1,14
electrochemically activated water pH = 5,5	Without exposure	452	22	15	98	1,11
	extremely low frequency magnetic and electric fields	452	24	12	98	1,10
«Pobla Runo»						
electrochemically activated water pH = 10,8	without exposure	439	22	10	94	1,09
	extremely low frequency magnetic and electric fields	450	12	11	95	1,07
electrochemically activated water pH =5,5	without exosure	415	48	26	98	1,20
	extremely low frequency magnetic and electric fields	436	31	24	98	1,16



a) b)

Materials exposure to extremely low frequency magnetic and electric fields



a) b)

a – the length of germs; b– length of roots

Figure 3– Biometrical indices of germination in wheat variety Altayskaya 105» germinating in various Conditions

Graphical presentation of the dependence on germ length (fig.3,a) and roots (fig. 3,b) of wheat variety Altayskaya 105» has been given which shows the dependence on germination time in electrochemically activated water with day and night artificial illumination by light-emitting-diode lamps and the exposure of soaked grain to extremely low frequency magnetic and electric fields

Without materials exposure to extremely low frequency magnetic and electric fields

According to traditional technology it usually takes six days to produce wheat germs. The use of electrochemically activated water with pH 6,7 has intensified the germination process and reduced the time of germination in wheat variety «Altayskaya 105» by 24 hours, while the exposure of preliminary soaked seed materials to extremely low frequency magnetic and electric fields has intensified the germination process and reduced the germination time in wheat variety Altayskaya 105» by 41 hours, with pH of electrochemically activated water being 8.

In order to prevent the transfer of nutrients into the root system technological parameters of germination have been established in the process of research, which enable to produce the optimal length of germs, while the length of roots being minimal.

As a result of research it has been established, that the optimal length of wheat roots in variety Altayskaya 105» is 8cm when germinated in electrochemically activated water with pH 6, 7. When germinated in electrochemically activated water with pH 8 and the preliminary soaked materials exposed to extremely low frequency magnetic and electric fields, the length of roots is 6,4cm. Reduction in the length of roots under tested conditions is caused by the reduction of time necessary for germs to reach the optimal length for their further processing.

Since the enzyme activity grows when wheat grain is exposed to extremely low frequency magnetic and electric fields, the hydrolysis of reserve food materials takes place, carbohydrate, amino acid and fractional composition of phosphorus compounds changes and as a result dry substances are accumulated in bigger quantities, which leads to the increase in the rate of germ growth.

Graphical presentation shows the dependence of length of germs (fig.4,a) and roots (fig. 3,b) in wheat variety «Pobla Runo» on germination time in electrochemically activated water when illuminated by light-emitting-diode lamps day and night and exposed to extremely low frequency magnetic and electric fields.

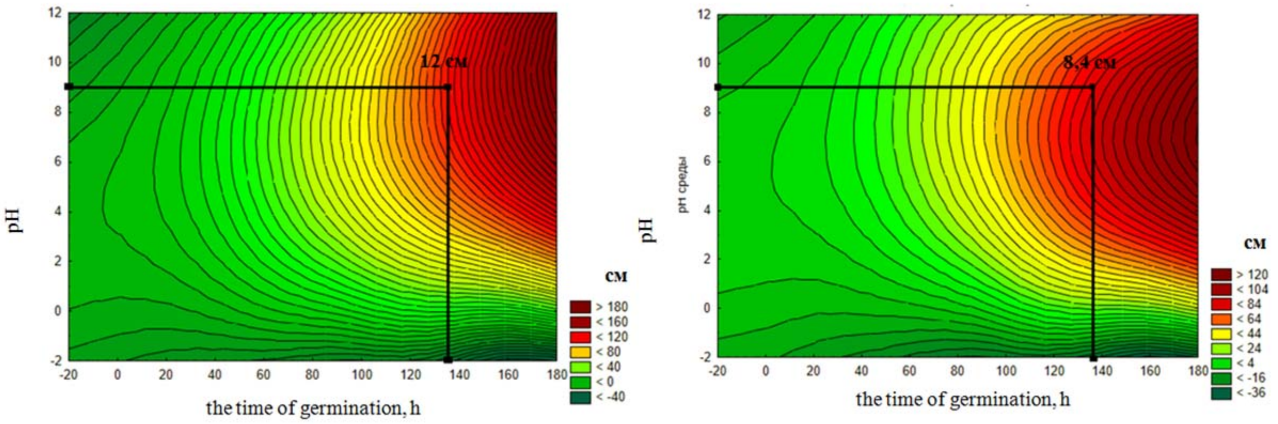
Without exposure of seed materials to extremely low frequency magnetic and electric fields

The use of electrochemically activated water with pH 9 for germination of wheat variety «Pobla Runo» has intensified the process and reduced the time of wheat germs production of optimal size (12 cm) by 6 hours in comparison with traditional technology, the length of root being 8,4 cm, while the exposure of preliminary soaked grain to extremely low frequency magnetic and electric fields and germination in electrochemically activated water with pH 9,5 has reduced the time of germination by 24 hours, the length of roots being 7cm.

Compiling the data of interpolation surface (figures 3 and 4) it is possible to conclude about general tendencies of the impact of examined physical factors on germinating seed materials.

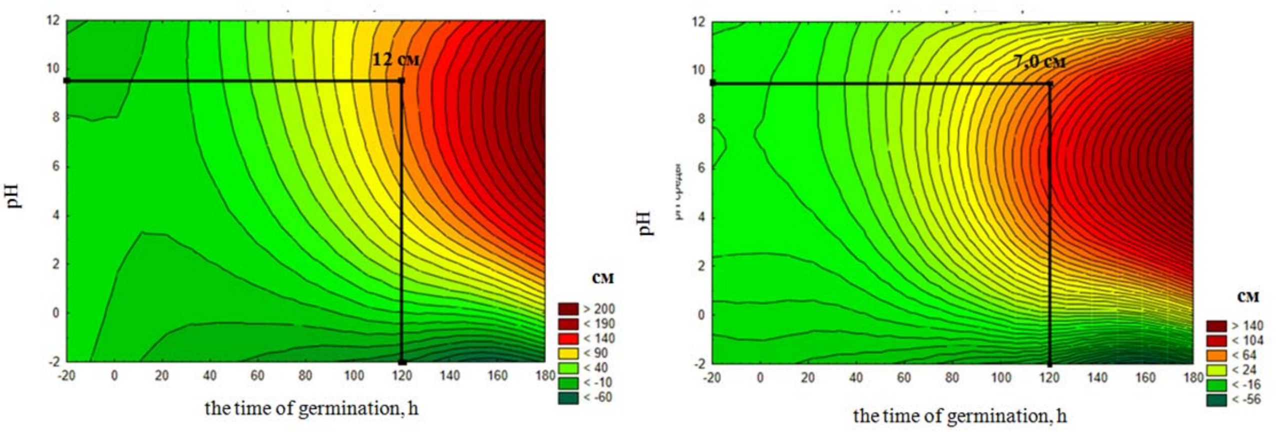
The main qualitative productivity indicator that shows the impact of various factors on the process of germination in wheat grain is the growing energy of germs. At the final stage the growing energy of germs and the amount of juice based on them have been determined. (Table 3)

It has been determined that complex use of factors considered above increases the yield of juice based on wheat germs «Altayskaya 105» by 50 %, and «Pobla Runo» by 47 %.



a) b)

Exposure of seed materials to extremely low frequency magnetic and electric fields



a) b)

a – the length of stem at the age of a germ, b – the length of roots in wheat grain

Figure 4 – Biometrical indices of geminating wheat variety «Pobla Runo» when germinating in different conditions

Table 3 – the Yield of juice based on wheat germs:

Type of medium	The amount of juice, ml/g			
	«Altayskaya 105»		«Poble Runo»	
	Without exposure	With exposure to extremely low frequency magnetic and electric fields	Without exposure	With exposure extremely low frequency magnetic and electric fields
Germination without soaking				
Water, pH 7,0	0,54	0,62	0,55	0,61
Soaking and germination in the medium				
water, pH =7	0,67	0,68	0,67	0,67
electrochemically activated water, pH =4,5	0,72	0,74	0,72	0,73
electrochemically activated water, pH =5,5	0,79	0,81	0,76	0,78
electrochemically activated water, pH =6,5	0,80	0,81	0,79	0,81
electrochemically activated water, pH =10,8	0,71	0,73	0,71	0,74

CONCLUSIONS

When germinating in a traditional way, the germinating capacity of wheat variety «Pobla Runo» and «Altayskaya 105» are 92 % and 93% correspondingly, which leads to the conclusion about the suitability of chosed wheat varieties for germination and their meeting general technical conditions.

It has been established, that the index of germination for wheat variety «Pobla Runo» is lower than that for wheat variety "«Altayskaya 105», which testifies to slower dormancy breaking of a germ.

The hydroponics method of wheat grain germination has been developed which includes moisturization of grain by electrochemically activated water with pH 3.5 till moisture reaches 30 % at the temperature of steep liquor 20-22 ^{o} C, irrigation module being 1:2.7, for 5.5 hours, the exposure of wheat grain to extremely low frequency magnetic and electric fields has been carried out after grain soaking at the following parameters: current intensity is 10 A, frequency is 20 Herz, the time of exposure is 20 minutes, and production of foodstuffs made of germinated grain:

– germinated grain with the length of germ 2mm when geminated at the temperature of air and medium 20-22 ^{o} C in electrochemically activated water with pH 5,5 with their day and night illumination by light-emitting-diode lamps for 12 hours;

– wheat germs 120mm long when germinated at the temperature of air and medium 20-22 ^{o} C in electrochemically activated water with pH 8,0 with their day and night illumination by light-emitting-diode lamps for 110 hours;

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