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ПРАКТИКА ИСПОЛЬЗОВАНИЯ ЭЛЕКТРО-АКТИВИРОВАННЫХ ВОДНЫХ РАСТВОРОВ В АГРОПРОМЫШЛЕННОМ КОМПЛЕКСЕ

THE PRACTICE OF USING ELECTRO-ACTIVATED WATER SOLUTIONS IN AGROINDUSTRIAL COMPLEX

Плутахин Геннадий Андреевич
канд. биол. наук, профессор
Кубанский государственный аграрный университет, Россия, 350044, Краснодар, Калинина, 13
ScopusID: 55102866400

Plutakhin Gennady Andreevitch
Cand.Biol.Sci., professor
Kuban State Agrarian University, Krasnodar, Russia
ScopusID: 55102866400

Кощаев Андрей Георгиевич
д-р биол. наук, профессор
Кубанский государственный аграрный университет, Россия, 350044, Краснодар, Калинина, 13

Koshchaev Andreyi Georgievitsh
Dr.Sci.Biol., professor
Kuban State Agrarian University, Krasnodar, Russia

Аидер Мохаммед
д-р техн. наук, профессор
Лавальский университет, Квебек, Канада

Aider Mohammed
Dr.Sci.Tech., professor
Université Laval, Quebec, Canada

В настоящей работе приведен обзор результатов экспериментальных работ авторов по использованию электроактивированных водных растворов в агропромышленном комплексе

In the present article the authors provide an overview of the results of experimental works for the use of electro activated water solutions in agroindustrial complex

Ключевые слова: АНОЛИТ, КАТОЛИТ, ЭЛЕКТРОАКТИВАТОР, ЭЛЕКТРОАКТИВИРОВАННЫЕ ВОДНЫЕ РАСТВОРЫ

Keywords: ANOLYTE, CATHOLYTE, ELECTRIC ACTIVATOR, ELECTRO ACTIVATED WATER SOLUTIONS

Water is the medium wherein all biochemical and biophysical processes originate in biological cell and its environment. In spite of simplicity of its molecule morphology water is capable to change its properties under series of physical actions. Electro activation occupies particular place among them [12, 16, 18]. Electro activation can be of two types – contact and noncontact [1, 2].

In the first case running electrolytic module or standing chambers divided by semipermeable nonselective membrane into two tanks are used; electrode is located in each of them. Upon connection constant-current source to electrodes electrochemical reactions occur on them in which participate dissolved in water electrolytes. As water itself is weak electrolyte its electrolysis is observed – oxygen is emerged at anode, and hydrogen – at cathode.

Recoverable in anode module chamber cations lead to hydrogen ions strengthening, as a result of which water is oxided. Dissolved molecular oxygen and other oxidizing substances give rise to that oxidation-reduction potential

(ORP) of anolyte receives high positive value. In order to increase electroconductivity sodium chloride is added into water that leads during electrolysis to the occurrence of available chlorine in it. Such water is identified as anolyte and it is used as sterilizing solution. In cathodic part the solution in this regard is alkalizated, oxidation-reduction potential (ORP) becomes negative. Acquired catholyte is possessed of good detergent properties.

In the course of noncontact activation labilized solution is separated from anolyte or catholyte by water-impermeable thin membrane (glass, teflon, polyethylene and others). As this takes place labilized aqueous solutions acquire abnormal metastable characteristics of activated liquid without fluctuating of their original chemical composition – such solution only ORP is modified; it receives negative value.

All electrochemically activated (ECA) aqueous solutions find a use for medicine, food industry, agriculture. This work consolidates results of our investigations on use of ECA solutions in agricultural practice. The research task was obtaining of ECA solutions with different characteristics and analysis of possibilities of their application in food industry, during processing of agricultural raw materials and in veterinary practice.

In conducted researches electro activation of aqueous solutions has been conducted by three methods. In the first case anolyte and catholyte have been received on the stand «Izumrud SI» (model 03 u). In the second method noncontact activation has been realized on the stand «Izumrud SI» (model 04 u) according to the principles attached by the manufacturer.

In the third case during electro activation of aqueous solutions for extraction and coagulation of proteins a facility has been used which scheme is given at the figure 1. Through the flowing electrochemical modular element FEM-1by means of peristaltic pump the solution of sodium chloride has been circulated from reservoirs 5 and 6; this solution returned to the initial reservoirs after passing through anodic and cathodic chambers of electrolyzer. In order to prevent thermal denaturation of proteins during extraction the speed of solution pumping and value of flow of direct current were selected in such a way that temperature of solutions during the process of electroactivation should not exceed 40 °C. Time has been selected such as achieving required value of pH.

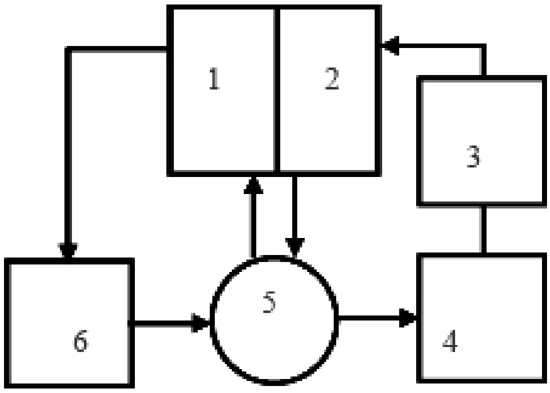


Figure 1 – The Scheme of the device for electric activation of water in a closed mode: 1, 2 – anodic and cathodic chambers of membrane electrolysis cell, 3 – capacity for the extracted material, 4, 6 reservoirs of anolyte and catholyte, 5 – peristaltic pump

During extraction of protein from sunflower oilseed meal and pea meal they filled plastic column 3, anolyte and catholyte were delivered from below. For coagulation reservoir with received protein extract has been connected to the cathodic chamber, electroactivation has been conducted during time required for achieving pH, appropriate to isoelectric point of proteins. Then proteins have been separated by centrifugation. During receipt of protein-and-vitamin concentrate Lucerne juice has been pumped through the anodic chamber.

The definition of rate of seeds' swelling has been conducted with soy beans, Vilane grade; seeds were poured over by solutions under consideration in Petri dishes. After definite time intervals seeds were taken out, dried out with filter paper and weighed. Then they were repeatedly poured with new solution.

In order to define intensity of barley germination Kondrat grade 10 grams of seed in plastic cups were poured by 30 milliliters of investigated solution. After 5 hours water has been changed by tap water. Henceforce change of electrically conducting water has been performed every 12 hours. At the expiration of 72 hours water has been poured off; seeds were covered by damp material. The whole process of germination was happened at the temperature equals to 20 °C. The analysis of results has been conducted after seven days by means of calculation of numbers of sprouted and non-sprouted seeds.

Oxidation-and-reduction potentials were measured by platinum electrode with respect to silver-chloride; concentration of dissolved molecular oxygen – by means of portable oximeter HI 9142. Determination of active chlorine content has been conducted with the help of iodometric titration in compliance with GOST 11086-76 «Hypocloride of Natrium. Technical Specifications».

Absorption spectrums of Romanovsky-Guimze coloring agent were taken at spectrophotometer UNICO 1201 (range 320-800 nanometer, interval is 10 nanometers) in centimetric glassy cuvets. When receiving ordinarily absorption spectrum distilled water were poured into cuvet of comparison. During reading differential spectrum measuring cuvet contained ordinary coloring agent solution; cuvet of comparison – electro activated.

Averaged values of received with the help of stands solutions are given in the table 1. From experiment to experiment they were modifying during contact electro activation that is connected with the speed of gassing at electrodes and instability of current magnitude transmitting through electrolyzers. The value of oxidation-and-reduction potentials during noncontact electroactivation could be securely controlled by the lead time.

Table 1 – Average characteristics of the received electroactivated aqueous solutions

Type of a solution	pH	ORP, mV	Salinity, ppm	Cl_2, mg/l	O_2,
Tap water	7,9	220	290	–	4,7
Non-contact activated	8,0	-125	285	–	4,6
Catholyte	11	-767	2470	–	4,2
Aanolyte	3,15	950	2310	400	7,3

More stable data were received during electroactivation in a closed condition that has been carried out till the moment of solution achieving of set point of pH. This method of electroactivation is turned out to be convenient for extraction and coagulation of proteins.

We used electroactivator in a closed-loop condition for coagulation of casein from non-fat milk. For that milk was pumped through anodic chamber till achieving pH 4,5, that corresponds to isoelectric point of casein. At the same time tap water without additives was pumped through cathodic chamber. Upon reaching in anodic chamber required acidity casein coagulated and easily separated from lactoserum.

In forage production Lucerne is featured an important place as a source of valuable proteins and vitamins. For that herbage is dried and granulated. Drying process is rather energy demanding; that is why energy efficient technologies are under development. Such technology is dehydration of Lucerne by means of pressing and juicing; together with this procedure proteins of cytoplasm and chloroplast are lost. An alternative method could be electroactivation of juice in anodic chamber where juice is acidizing [4, 5, 6]. Simultaneously juice is heating up at the expense of Joulean heat emission [13].

Electroactivation of protein solutions facilitates not only their coagulation without application of acids and alkalis. With definite pH of solution proteins are able to be extracted [7, 8, 9]. As one of protein source during preparation of combined fodder sunflower oilseed meal is used. In spite of its incomplete balance by nonreplaceable amino acids oilseed meal contains according to GOST 11246-96 in equivalent to absolute dry substance of protein 40-42% and 18-20% of cellulose. Big content of cellulose doesn’t let inserting it to forage in sufficient quantity. It is possible to separate protein from cellulose by means of its extraction from oilseed meal in acid medium, then precipitating by alkali. They made acidizing of oilseed meal suspension by anolyte in a closed conditions by means of pumping with the help of peristaltic pump [14, 15]. The necessity of closed conditions of circulation is accounted for the fact that oilseed meal is considerably alkalizating anolyte received by one-pass going through the chamber.

Oil-seed meal was located in reservoir 4, separated from below and from above with the help of capron filters; the process has been conducted till pH 10. The obtained protein extract was filtered and also in closed conditions it was going through the anodic chamber. When achieving pH 5,0 protein coagulated, after this it was separated by means of precipitation. In initial oil-seed meal the portion of protein substances in dry solid matter came to 26,0%. During chemical and electro-chemical extractions we separated 10,2% and 8,9% of protein correspondingly. These results have shown sufficiently high efficiency of extraction of sunflower proteins by means of activation of extracting solution in anodic chamber of electro-actovator and further precipitation of protein in cathodic chamber.

Inactivation of inhibitors of soya protease equal to 5–10% from total quantity of protein represents considerable interest for practice of forage production. This can be done by means of soya thermotreatment or by its greensprouting. In the last case usage of processing mediums which speed up the given process is more preferably instead of tap water application. We have studied the possibility of increasing seeds' hydration by means of their greensprouting in electoactivating water received in running electroactovator from the table salt solution [10]. Information is presented in the figure 2.

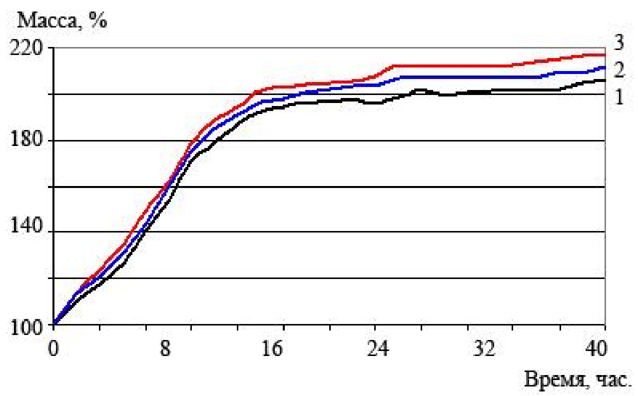


Figure 2 – Dependence of the mass of soybean of cultivar Vilena from the time of their soaking in the fresh water (1), catholyte (2) and anolyte (3)

As indicated on the picture, the application of anolyte and catholyte has provided higher degree of hydration in comparison with tap water usage. At the same time it is important to note that the best results have been shown by anolyte which increased degree of hydration in comparison with control (tap water) for 10–18%. A bit worse results were received from catholyte which showed increase of hydration only for 5–9% in comparison with control.

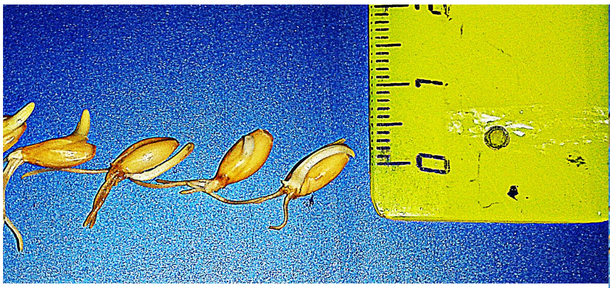
Hyperactivity of anolyte during watering of seeds can be explained by the fact that during the process of water electrolysis anolyte enriches itself by dissolved molecular oxygen. Water barbotage with air during seeds' watering accelerates their germination and intensifies growth of germs. In our experiment content of oxygen in anolyte was higher for 54% than in ordinary tap water. In catholyte it decreased for 12% (table 1).

In order to vindicate this supposition the influence of electro activated aqueous solutions on the intensity of greensprouting of forage barley of low germination was also investigated. The received results have shown the following (table 2). In a tap water the percentage of germinated seeds amounted 43,8%, in anolyte it was 84,4%, in catholyte it aggregated 55,0%.

Table 2 – Results of germinating barley cultivar Kondrat

Parameter	Control	Anolyte	Catholyte
pH	8,22	3,8	10,24
ORP, mV	222	960	475
O_2	4,76	7,33	4,2
Salinity, ppm	290	2470	2310
Sprouted, %	43,8	84,4	55,0
Mold	+	–	++

More intensively seeds were damaged with *Penicilium* during their greensprouting in catholyte; at the same time strong putrid smell occurred. Seeds watered by anolyte were absolutely clean and at the same time possessed detectable cucumber flavor. External appearance of seven days barley germs is presented in the figure 3.



1

Figure 3 – Seven days barley sprouts: 1 – control, 2 – anolyte

2

Apparently when watering in anolyte seeds were sterilized and high content of molecular oxygen facilitated their more intensive germination. Negative oxidation-reduction potential of catholyte has stimulated not only seeds' germination but development of mold also.

The role of oxygen and oxidation-reduction potential in stimulation of intensity of biological processes has been also confirmed in the experiment on activation of dry bakery yeast. Anolyte, catholyte and noncontact activated water were used in this experiment. Concerning relatively level of activation has been estimated by the speed of yeast suspension raising (figure 4).

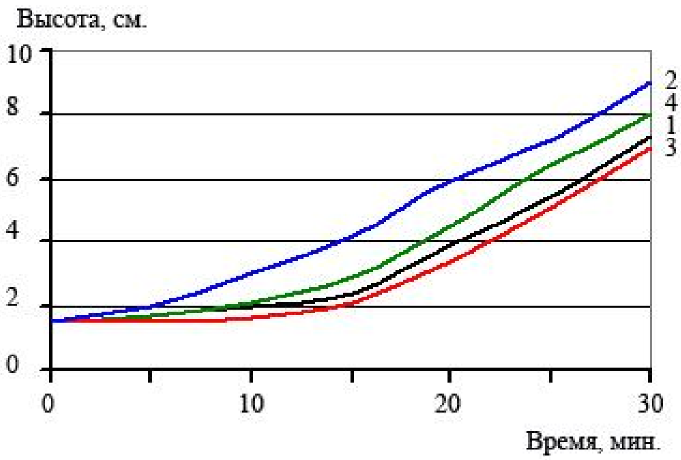


Figure 4 – The dependence of the level of yeast suspension from the time of their activation in different water solutions: 1 – control, 2 – catholyte, 3 – anolyte, 4 – non-contact activated water

Pursuant to this picture, the most actively yeasts were raising in noncontact activated water. Catholyte possessing negative oxidation-reduction potential and high pH, was less active in comparison with noncontact activated water. The least activation of yeast has been observed in anolyte. The last had high positive value of oxidation-reduction potential +950 мВ, low pH 3,15, increased like catholyte mineralization as opposed to the other solutions.

Results of baking both pan bread and hearth bread have shown the following (table 3). The bread, baked with the usage of noncontact activated water had the largest volume. The second was sample doughed at anolyte. The bread baked with the usage of catholyte during yeast's activation and dough has showed the lowest results [3].

Table 3 – The physical and chemical characteristics of the bread baked with different types of the electro-activated water

Water	Bread vol. cm^3	Specific weight, kg/cm^3	Humidity of crumb, %	Acidity of crumb, Deg.
Tap water (control)	340	2,47	41,0	1,2
Non-contact activated water	460	3,01	42,0	1,5
Anolyte	410	2,69	41,5	1,4
Catholyte	300	2,18	39,5	1,5

Results of baking differed from results on yeast activation in that in spite of mostly intensive activation of yeast by catholyte, bread with the application of this solution was of the lowest quality. There could be by different reasons. High activity of yeast led to the loss of their bearing capacity. The second reason can be reduced concentration of oxygen in catholyte and high value of pH solution that led to inhibition of gassing during proving. The baked bread was the best when using of noncontact activated aqueous solution during making dough. Apparently the main role has been played by low negative oxidation-reduction potential.

The bread baked with the usage of catholyte in making dough, in spite of its negative physical and chemical properties has given high-quality bread which surrendered a little to the bread baked with the usage of noncontact activated solution. The main stimulating component of yeast development in dough can be dissolved during electrolysis molecular oxygen. Thus, the content of oxygen in anolyte was higher for 55%, and lower for 11% in catholyte than in control.

As it has been shown negative oxidation-reduction potential (minus 500 ÷ 700) mV of aqueous solutions are reached by means of noncontact electroactivation or water saturation with hydrogen [11]. Conditions of obtaining of analogous properties of aqueous solutions in this connection are different considerably. Noncontact electroactivation does not require gaseous hydrogen; process life equals to about an hour and a half instead of required twenty four hours in case of hydrogen dilution in water.

Peculiarities of physical-chemical characteristics of aqueous solution, received by noncontact electroactivation method – is invariability of initial chemical composition and accomplishment of high negative oxidation-reduction potential. These features enable its application for the sustention of biological cells in good physiological condition. During artificial pollination of farm livestock frozen semen is used which is attenuated after defrosting by physical solution up to recommended concentration of sperm cells. Under such conditions sperm cells are perished very quickly. We have investigated the influence of noncontact electroactivation of physical solution on viability of bull's spermatozoids. In case of pharmaceutical sterile physical solution the value of oxidation-reduction potential amounted to –125 mV.

The sperm of bull for service received from Gosplemob'edinenie (Krasnodar) was diluted according to instruction by ordinary or electroactivated physical solution. Then three types of cells were defined by their mobility: moving in straight lines, oscillating and motionless. Recalculation of cells has been conducted every 10 minutes at a new drop of sperm. Findings on sperm cells quantity that left movable after 40 minutes from the beginning of this experiment are given in the figure 5.

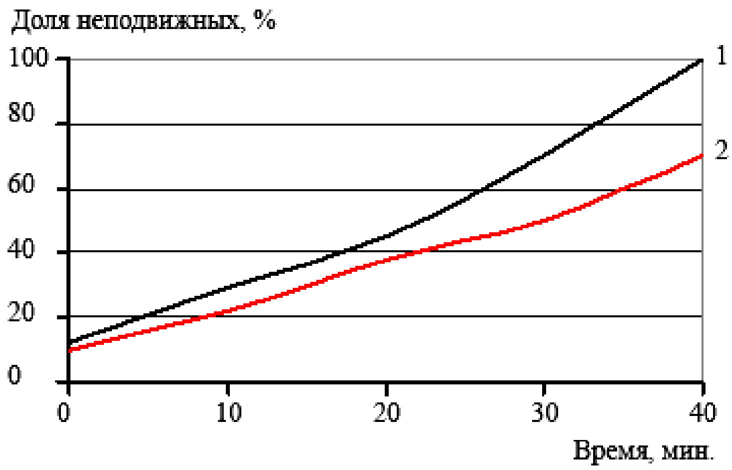


Figure 5 – The dependence of the share-motile sperm cells of the bull from the time of their incubation in normal (1) and non-contact activated (2) saline solutions

As can be seen from the picture, sperm cells were more vigorous in case of suspending in electroactivated solution. After forty minutes presence in the ordinary solution all cells became motionless, whereas after staying in electroactivated solution 25% of them remained active.

Pigments' colors which are capable to participate in oxidation-reduction reactions are also dependent from the value of oxidation-reduction potential. Pink acid eosin and blue alkaline azure are of such type. These pigments form the basis of Romanovsky-Guimze coloring agent that is used for coloring objects during microexamination of biological materials.

It colors acidophilus masses into different tinges of red color; basophilic masses – into colors from amaranth to blue. We have examined influence of noncontact electroactivation on coloring agent properties. After 60-minutes of activation coloring agent prepared for coloration distinctly modified color into brightly blue. Therefore we have withdrawn absorption spectrums of non-activated coloring agent and differential absorption spectrum «non-activated solution minus activated».

Spectrums are given in the figure 6. Absorption sprectrum of initial coloring agent possesses two maximum peaks at 490 and 620 nanometers. First maximum peak belongs to eosin, the second – to azure.

Displacement of oxidation-reduction potential to the negative side has fluctuated optical density in all range of coloring agent absorption. Thus, for the first absorption band it has decreased for 33%, for the second absorption band – for 25%.

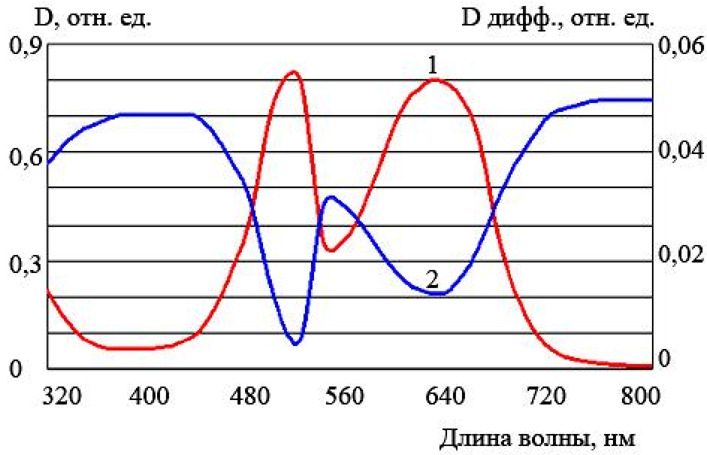
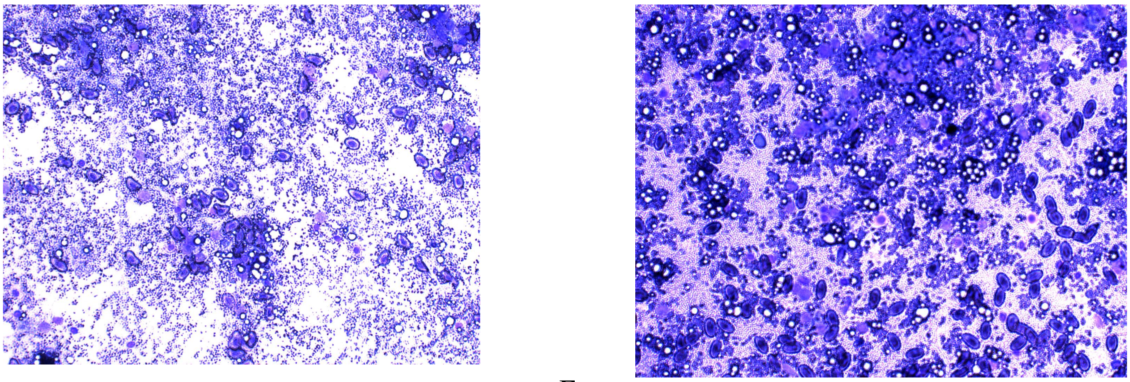


Figure 6 – Absorption spectrum (1) a d differential absorption spectrum «inactivated minus activated» (2) dye Romanovsky-Giemsa (absorbance values on the left and right axes, respectively)

The result of nonequivalent modification in eosin and azure spectrums became coloring agent discoloration in general (figure 7).



А Б

Figure 7 – Histological sections of chicken liver staining nonactivated (A) and contactless activated dye Romanovsky-Giemsa (B)

This led to the noticeable quality improvement of colored hystological section of chicken liver – saturation of tissues with color has been intensified both in blue and red spectral regions.

The results we obtained on application of various types of electroactivation of aqueous solutions let us make the following conclusion. Contact electroactivation enables to carry out extraction and coagulation of proteins by means of modification of solutions' and extracts' pH up to the values required for that. Anolyte, in spite of its negative physical-chemical characteristics for biological systems is able to stimulate vital processes in cells and tissues. In all occasions these processes are stumilated by noncontact-activated aqueous medium at the expense of negative value of oxidation-reduction potential. In case of noncontact activation pigmented solution color is changed, that modifies their coloring characteristics. Application of electroactivation in the manufacturing of foodstuff and forage, both in biotechnology and in agriculture enables to reduce an ecological load on surrounding environment.

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