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Research on Effects of Low Frequency Magnetic Fields on Survival and Morphology of *Escherichia coli* and *Saccharomyces cerevisiae*

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Abstract.

The article is devoted to research of the low frequency magnetic fields' effects on survival and morphology of *Escherichia coli, Saccharomyces cerevisiae.* The bacteriostatic effect caused by exposure to low frequency electromagnetic radiation was discovered. The bactericidal effect is discovered in the case of the low frequency electromagnetic fields. Comparative analysis of resistance of *E. coli* and *S. cerevisiae* to this radiation is discovered also.

Keywords: low frequency electromagnetic radiation, magnetic fields, *Escherichia coli, Saccharomyces cerevisiae.*

INTRODUCTION

Today, many facts of biological effects of electric and magnetic fields on different organisms, organ systems and cells are known. Microorganisms are also susceptible to low frequency electromagnetic effects. It is established that a weak magnetic field in the frequency range 7-11 Hz affects the cells genotoxic and carcinogenic action on the *Escherichia coli* [1], at 50 Hz and in their viability and redox change activity [2]. In a pulsed electric field is survival significantly reduced, for example, *B. pumilus, E. coli, S. enterica* [3-5], membrane permeability changes in Gram-positive and Gram-negative microorganisms [6].

The intensity of the biological effects of electric and magnetic fields depends on their frequency, induction, duration of exposure [7-8], as well as on external environmental factors (pH, temperature) [9-10].

The article presents the investigation concerning the effects of the low frequency magnetic field on the typical representatives of two different classes of microorganisms: *Escherichia coli* (a class of bacteria) and *Saccharomyces cerevisiae* (yeast class). The bactericidal and bacteriostatic effect is discovered in the case of the low frequency electromagnetic fields effects, comparative analysis of resistance of *E. coli* and *S. cerevisiae* to this radiation is discovered also. The change of the susceptibility of microorganisms to electromagnetic exposure at different ambient temperatures was investigated.

In earlier papers, we established the physiological and morphological changes in organisms that were induced by the low frequency electromagnetic radiation. For example, in the studies conducted with the culture of *Xanthomonas campestris*, have been marked fluctuations in the intensity of synthesis of exopolysaccharides and the activity of the yeast culture [11]. In the articles [12-15] parameters of low frequency electromagnetic exposure were found in which a strain of *Escherichia coli* demonstrated an almost complete suppression of reproductive activity of bacteria. The impact was made in the frequency range of 1-20 Hz, the tension was 10^{-2} A/m.

The aim of this work is to study and to make the comparative analysis of the low frequency electromagnetic fields effect on *E. coli* and *S. cerevisiae*.

MATERIALS AND METHODS

For the study the strains of *Escherichia coli K12* and *Saccharomyces cerevisiae 230* was used. In independent experiments, the aliquot of cell suspension was 2 ml. The impact of low frequency magnetic field (the electric component was negligible) was in the range 1 – 15 Hz with induction of 0.005 T, with the help of Helmholtz coils where a number of turns was 14800 and resistance was 7200 Ohms. An electrical signal was fed to the coil with a low frequency generator G3-118. The impact of the magnetic field was carried out in a grounded metal, multi-chamber for screening the background of electromagnetic radiation. Measurement and control of induction and frequency of the magnetic field was carried out by measuring the induction by SH1-8 gaussmeter and the frequency by CH3-54. The error in determining the frequency and the induction does not exceed 0.2%. Duration of exposure of low frequency magnetic fields on microorganisms was 60 seconds, and then cells were incubated for 60 min. The test samples were thermostatically controlled with a liquid TSZH-2-03 and air TS-1/80 thermostats. The error in temperature measurement was ± 0.1°C. Control samples of suspensions of cells *E. coli* and *S. cerevisiae* subjected to the same manipulations as the experienced, but without the filing of low frequency signal to the coil.

After the exposure of the magnetic field on the culture of *E. coli* the samples in a sterile environment were placed in Petri dishes with meat-peptone agar. Then the Petri dishes were placed in an incubator at 36°C. At the end of 72 and 168 hours the number of cell formed units (CFU) and the estimations of microorganisms survival done. Cells of *S. cerevisiae* after exposure to the low frequency magnetic fields were cultivated on wort-agar in Petri dishes at 32°C for 72 hours and CFU was estimated. The error in calculating the CFU did not exceed 5%.

Photos of cells were obtained using an optical microscope Carl Zeiss Axio Imager with 400^{x} magnification.

RESULTS AND DISCUSSION

The survival of *E. coli* and *S. cerevisiae* cells, depending on the frequency of the magnetic field studies showed that at different frequencies the survival of both bacterial and yeast cultures may change. This dependence in the range frequency 1-15 Hz at the temperature of 20°C is presented in Figure 1.

As can be seen from the figure, the influence of low frequency magnetic fields on microorganisms in some cases leads to a bactericidal effect when it was not observed any viable cells. This effect intensively became apparent in the case of the magnetic field influence on a bacterial culture of *E. coli* at frequencies of 1, 3, 5, 9, 11, 15 Hz. In the case of the yeast S. *cerevisiae* influence at frequencies of 3 and 13 Hz, the degree of inhibition of bacterial cells were significantly higher.

The obtained experimental results confirm and complement the established fact of high sensitivity of *E. coli* to different radiation of electromagnetic nature (UV and ionizing radiation) compared to other types of microorganisms. It is known that in the case of the same UV dose or ionizing radiation, the *E. coli* survival rate is considerably smaller than in the case of *S. cerevisiae*.

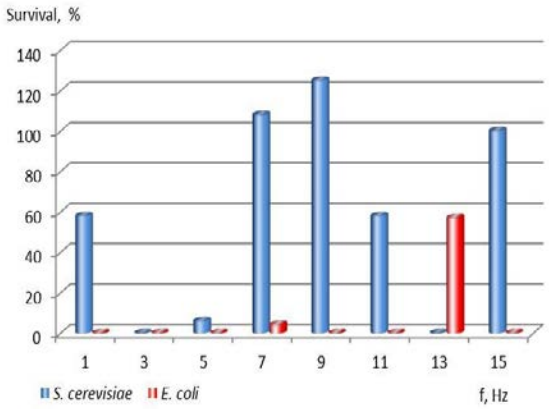


Figure 1: The *S. cerevisiae* and *E. coli* survival at different frequencies of the magnetic field variability.

It should be noted that the effect of low frequency magnetic field led not only to oppression but also to stimulation of microorganisms growth when survival exceeded 100% relative to the control sample. For *S. cerevisiae* yeast culture this effect was observed at 7 and 9 Hz frequency.

With increasing time of cultivation for bacterial culture *Escherichia coli* it was detected the bacteriostatic effect caused by exposure to low frequency electromagnetic radiation. Figure 2 shows the survival of *E. coli* during cultivation 72 and 168 hours.

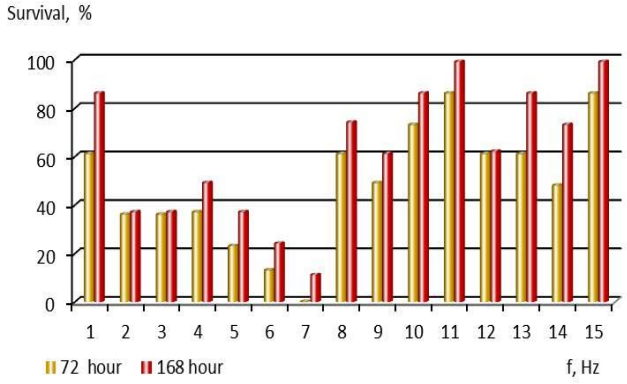
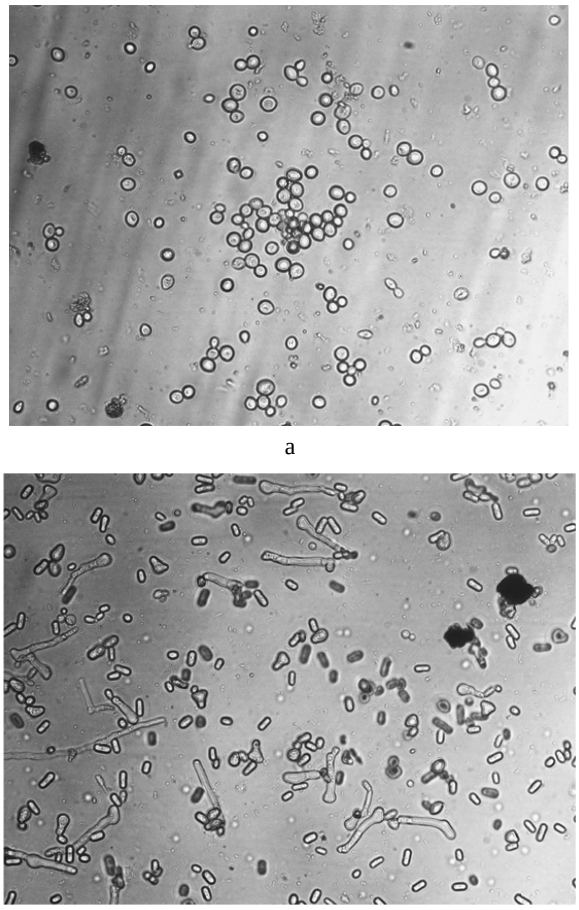


Figure 2: Survival of *E. coli* at different frequency magnetic field at the cultivation time of 72 and 168 h.

When exposed to electromagnetic fields at a frequency of 7 Hz after 72 hours of cultivation the death of 100% of bacterial cells was observed. Comparison of the survival of microorganisms after 72 and 168 hours shows that when exposed to electromagnetic fields at certain frequencies (2, 3, 6, 12 Hz) survival has not changed. However, when exposed to electromagnetic fields whose frequency was 1, 4, 5, 8-11, 13-15 Hz, a marked increase in survival of bacterial culture was revealed. Consequently, the presence of the low frequency magnetic field led to the cessation of reproductive activity in some of the microorganisms on a fairly long period (up to 168 hours or more), followed by exit from this state.

In addition to changes in cell viability, *S. cerevisiae* under the influence of magnetic field characteristic change in their morphology was observed (Figure 3), which is well known in practical microbiology and is associated with nutritional deficiencies or changes in vital processes, such as their significant slowing under the influence of adverse factors. Knowing that during the research of microorganisms the supply of nutrients was in sufficient quantities, it can be assumed that the effect of low frequency electromagnetic fields led to a change in the biochemical processes of cells of *S. cerevisiae*, which is reflected in the growth characteristics of the cultures studied. Another factor influencing the morphology of the cells can be modified semi penetrability cell membrane, such as found in the study of pulsed electric fields on cells *Escherichia coli* [6]. The important role in the effects of low frequency magnetic fields on biological objects emits the structure of liquid water in the membrane region and the cells within it. Based on different theories and structural model of water [16-17], attempts to explain the mechanism of action of weak electric and magnetic fields.



a

b

Figure 3: The cell morphology *S. cerevisiae*, changing its normal form to elongated under the influence of magnetic field (a – normal form, b – modified by the elongated shape) in 400^{x} magnification.

Our studies have shown that the effect of the low frequency magnetic field on the nature of impacts on microorganisms can be compared with the temperature factor, which represents one of the most important environmental factors affecting the metabolism cage. At different temperatures, the microorganisms reacted differently to the effects of magnetic field, which was reflected in the changes in their survival (Figure 4). The range of temperatures at which *E. coli* and *S. cerevisiae* evolve favorably and actively ranges from 20 to 36°C. For *E. coli* temperature optimum 36 ºC, for baker's yeast temperature optimum 32°C. Consequently, at these temperatures and at the other favorable conditions the microorganisms must demonstrate rapid growth and form colonies, but this does not occur. On the contrary, there is a very low survival rate (for example, at temperatures of 20, 26, 28°C, Figure 4).

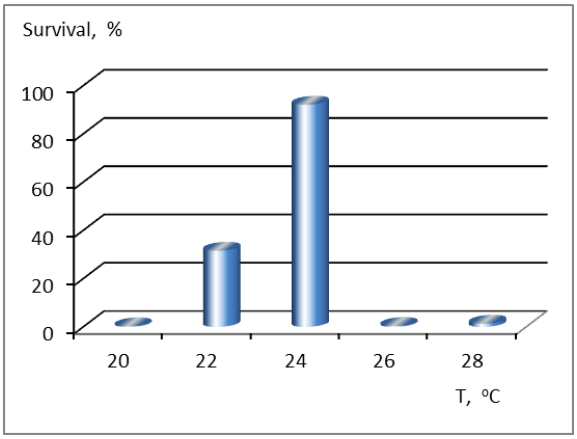


Figure 4: Changing of the survival of *S. cerevisiae* under the influence of electromagnetic fields at different temperatures.

This fact seems paradoxical, knowing that the energy of the low frequency magnetic field is negligible compared with the thermal energy, even if we consider the quantum of heat [18]. From this perspective, the impact of low frequency magnetic field is not able to induce significant changes in the cells of microorganisms and therefore should not affect their survival.

CONCLUSIONS

Studied in this paper, the problem of low frequency magnetic effects is of great interest from the viewpoint of practical application. Today, the magnetic field is being promoted in various spheres of human activity: industry, medicine, agriculture, etc. Using the magnetic effects, increase productivity of various crops, it is possible to reduce the amount of applied fertilizer, improve treatment, smooth, or completely remove the side effects of certain drugs, etc. However, despite the progress in the practical application of low frequency magnetic fields, to date there is no clearly legitimate model or mechanism of its action on various biological systems.

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