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EFFECT OF WEAK MAGNETIC FIELDS ON BACTERIUM STAPHYLOCOCCUS AUREUS

(Efecto de campos magnéticos débiles en la bacteria Staphylococcus aureus)

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ABSTRACT

The effects of weak static and low-frequency magnetic fields on the growth rate of S. aureus are investigated. The measurements were performed at incubator cabinet with static magnetic fields with magnitude in range 0.0 Oe ≤ H_o ≤ 14.0 Oe, and low-frequency magnetic fields with fixed amplitude $H_o \cong$ 450 mT, and frequencies 0.0 ≤ f ≤ 1.0 kHz. The field was supplied by a cylindrical solenoid. The growth of these bacteria was negatively affected by increasing the static magnetic field. When exposed to an oscillating field, a positive effect was observed on the rate of growth of the colonies, after two hours of exposure. In both, static or ac magnetic field, the growth curves follow an exponential law, typical of asynchronous cell divisions.

Keywords: Asynchronous growth; Exponential growth; Magnetic field effect; S. aureus.

RESUMEN

El efecto de campos magnéticos estáticos débiles y de baja frecuencia sobre la tasa de crecimiento de la bacteria S. aureus es el objeto de la investigación. Las medidas fueron realizadas en una incubadora con el campo magnético estático de magnitud en el rango 0.0 Oe ≤ H_o ≤ 14.0 Oe, y campos de baja frecuencia en el rango 0.0 ≤ f ≤ 1.0 kHz y amplitud constante $H_o \cong$ 450 mT. El campo fue suministrado in-situ por una bobina colenoide cilíndrica. El crecimiento de estas bacterias fue afectado negativamente al incrementar la magnitud del campo estático. Cuando son expuestas al campo oscilante, se observa un efecto positivo en la tasa de crecimiento de las colonias, luego de 2 horas de exposición. En ambos casos, campos dc o ac, las curvas de crecimiento corresponden a una ley exponencial, típica de la división celular asíncrona.

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Palabras claves: Crecimiento asíncrono; Crecimiento exponencial; Efecto del campo magnético; S. aureus.

I. INTRODUCTION

Nowadays the exposure of living tissue to various types of electric and magnetic fields is a commonly encountered event: extremely low frequency from power lines, high frequency electromagnetic fields (EMF) from cellular phones, and computers [1].

Since this is a task of medical and technological importance, a number of attempts have been given to clarify the effects of electric and magnetic fields on biological cells. The effects are not fully understood, since some of the results have been inconsistent [2]. In other cases the results often contradict each other, which include an increase or decrease in the rate of cell division at different physiological conditions in Escherichia coli [3-5].

Some other studies found that magnetic fields could be a general stress factor in bacteria [6]. The general stress response to a magnetic field is found in all bacteria, plant and animal cells and is remarkably conserved across specie. In a study on the mutagenicity of magnetic fields exposure, Ikehata [1] also reported that strong static magnetic fields can cause mutations in S. typhimurium and E. coli.

In this paper, we outline the results of an experimental investigation on how static magnetic fields and low-frequency magnetic fields can affect the growth dynamics of bacteria Staphylococcus aureus. We have found that a weak low-frequency magnetic field ($H_o \cong$ 450 mT; f=0.0□1000 Hz) positively affect the growth of S. aureus.

Such an effect depends on the exposure time and on the frequency of the magnetic field. The opposite effect is observed when the cultures are exposed to a static field. The growth curves are mathematically described by exponential functions of the exposure time, typical for an asynchronous growth process. The main effect of the dc (ac) magnetic field is then to decelerate (accelerate) the mechanism responsible for this asynchrony.

The paper is organized as follows. In section II we describe the experimental procedure used in this study. Section III is devoted to discuss the results of our investigation. In section IV the main results are summarized.

II. EXPERIMENTAL

The magnetic fields were generated by a homemade 600 turned cylindrical coil (12 cm radius and 30 cm length). The cells were exposed to static magnetic fields with amplitude varying from 0.0 Oe to 14.0 Oe and ac magnetic fields (0.0 – 1.0 KHz) at fixed intensity of the order of 450 mT, and were determined by a Hall effect probe Gaussmeter. The magnetic fields inside the solenoid were approximately homogenous

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in a region ± 3 cm off the center of the coil. The device was kept at 37°C in an incubator cabinet and it was measured by a thermometer.

The bacterium Staphylococcus aureus (clinical strain) from the Laboratory Aníbal Zaidenberg of the Biology Department, of the Faculty of Science-LUZ, were used. Nutritive Broth (Merck, Darmstadt) and Plate Count Agar (Difco, Detroit) were used for cultivation of the bacteria. Salt solution 0.75% was used to make serial dilutions until 10^{-5}. Fresh bacterial cultures were used throughout the experiments. Control cultures were kept in the same conditions as the exposed ones except the sole exposition to the magnetic fields. The number of colony forming units (CFU) was used to quantify the results.

The samples were placed first into glass tubes on a nonconductive stand (homemade) along the axis of the coil, and then introduced inside to solenoid during exposure times from 0 h to 6 h. In order to reduce the uncertainty in our measurements and to obtain reliable results, each test was performed independently up to 4 times keeping the same experimental conditions.

III. RESULTS AND DISCUSSION

A. Effect of static magnetic fields

The main effect of the static magnetic field on the growth dynamics of the bacterium S. aureus is shown in Fig. 1. Each symbol is an average from 4 independent measurements performed previously. We found that the number of CFU increases with the time of exposure and decreases with the magnitude of the applied field.

These results qualitatively agree with studies in other bacteria such as E. coli [5]. It is also observed that the cells remain in lag state up to certain time of exposure, after which, cell division is activated growing in an exponential trend. To estimate the quantity τ, we assume that the growth dynamics is governed by some mechanism following the exponential law $e^{t/\tau}$, where t is the exposure time and τ is the time required for a cell division.

These functions are commonly used to describe asynchronous growth in bacteria cultures. In an asynchronous process, the division occurs at different times in each cell. The solid curves in Fig. 1 represent exponential functions with τ =0.48, 0.50, 0.53, 0.61, and 0.62 hours, for H_o=0.0, 6.0, 8.0, 12.0 and 14.0 Oe, respectively. These results are plotted in Fig. 2, and show that as the magnetic field intensity is increase the growth process is decelerated, but not stopped.

The dashed line is a guide to the eyes. Although the dc magnetic field decreases the number of colony forming units, is it not obvious that the cells loose their ability to divide. This means that the effect of the static field is not fully bacteriostatic in this range of magnetic fields. Since the growth curve of the control culture (H_o=0.0 Oe) is

Depósito Legal: PPI201002ZU3614. Volumen 1 Edición No 1 – Año 2010

also exponential, we conclude that this asynchrony is inherent of the preparation conditions, and independent of external agents such as a dc magnetic field.

B. Effect of low-frequency magnetic fields

When exposed to an oscillatory magnetic field, bacteria can behave unexpectedly. To study this behavior, treads of S. aureus were grown in-situ in presence of a magnetic field with frequency ranging from 0.0 Hz to 1.0 kHz. After an exposure time of about 6.0 h, we counted the number of CFU of the exposed cultures and compared with the control (f=0.0 Hz). The resulting growth curves of S. aureus are shown in Fig. 3 for several frequencies.

As in the case of the dc magnetic field the CFU increase with exposure time, but on the contrary, it increases rapidly with increasing frequency. These curves are adjusted to exponential functions of the type $e^{t/□}$ (solid lines), with □□□values depending on the frequency of the magnetic field, as shown in Fig. 4.

The dotted line represents the function □□(0)+a/f. According to these results, the growth dynamics in our cultures is governed by an asynchronous frequency-independent mechanism, and the effect of frequency is to accelerate the cell division process.

4. CONCLUSIONS

We have presented and discussed and experimental investigation on the effects of dc and ac magnetic fields on bacterium S. aureus. It was found that as prepared, the growth dynamics is governed by an asynchronous mechanism, quantitatively unaffected by a weak dc or low-frequency magnetic field. However, the number of CFU is decreased (increased) by the dc (ac) external field. This behavior is explained introducing a time □, associated with the activation of the cell division. Although this, it is not clear if the effect of the dc field is bacteriostatic, and more work in this direction is needed.

The question of how the growth dynamics of bacteria is affect by a magnetic field is not completely answered in this work, and still an open issue. The fact that the activation time for a cell division can be expressed as a function of the magnitude and frequency of the magnetic field, can be important to understand metabolic changes due to ion transport across the cell membrane.

Since a large quantity of biological products and foods are based on bacteriological as an application, our results suggest that ac magnetic fields can be used as an aid for growing large quantities of biological products like foods such as yogurt or cheese.

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FIGURE CAPTIONS

Figure 1. Dependence of the colony forming units (CFU) on the time of exposure for several magnetic field intensities. The solid curves are fits to the exponential function $e^{t/□}$, as described in the text. The curve for H_o=0.0 Oe (▲)□correspond to the control culture.

Figure 2. Activation time, □, as a function of the magnetic field strength. The dashed line is to guide to eyes.

Figure 3. Dependence of the colony forming units (CFU) on the time of exposure for several frequencies. Solid lines are fits to the exponential function $e^{t/□}$, as described in the text. The curve for f=0.0 Hz (▲)□□correspond to the control culture.

Figure 4. Activation time, □, as a function of the frequency of the ac magnetic field. The dotted line is a curve of the form □□(0)+a/f.

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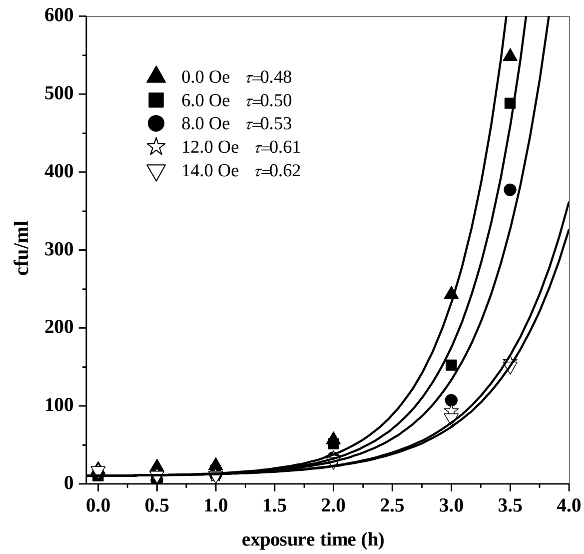

Figure 1. Pérez, et al.

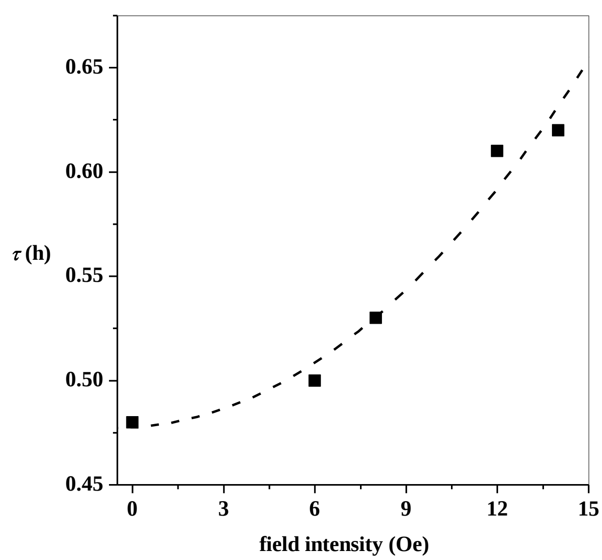

Figure 2. Pérez, et al.

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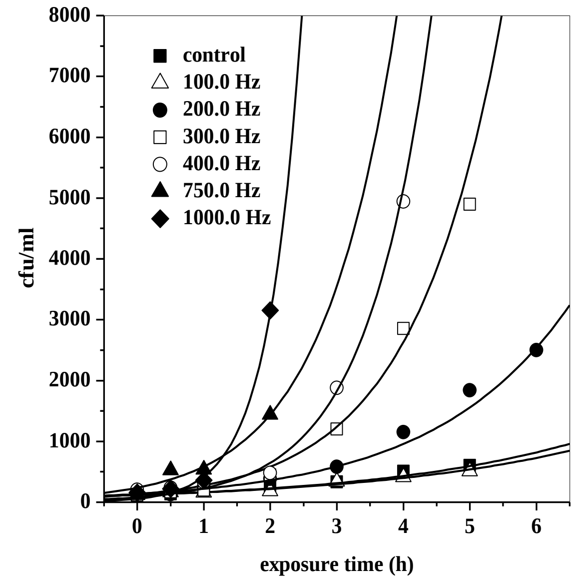

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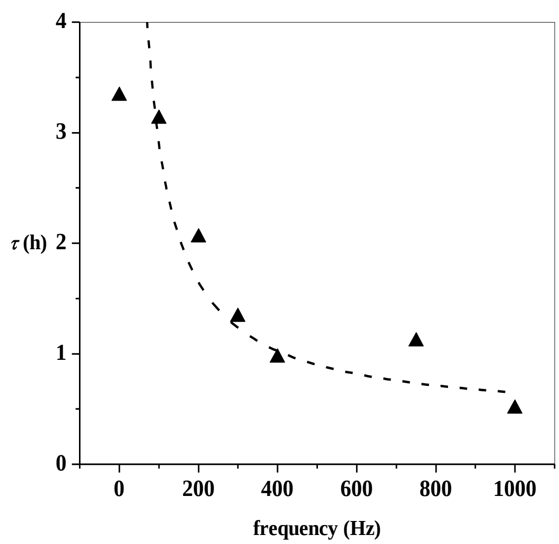

Figure 4. Pérez, et al.

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