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The Effect of Static Magnetic Field on *E. coli*, *S. aureus* and *B. subtilis* Viability

Khaled A. Al-Khaza'leh[1*] Abdullah T. Al-fawwaz[2]

1. Department of Physics, Al-albayt University, PO box 130040, Mafraq, Jordan
2. Department of Biological Sciences, Al-albayt University, PO box 130040, Mafraq, Jordan

Abstract

This study investigated the effects of low static magnetic field on the growth of three bacterial strains (*Escherichia coli, Staphylococcus aureus and Bacillus subtilis*) that plays a versatile role in infecting wounded tissues. The viability of these bacteria was measured with and without different magnetic fields (30, 50, and 80) mT after 24 hours. Results illustrate that magnetic field decreased the growth rate of *Escherichia coli* and *Staphylococcus aureus* bacteria, while increased the growth rate of *Bacillus subtilis* after 24 hours of exposure.
Keywords: Magnetic field, *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*.

1. Introduction

Nowadays living tissues are exposed to various types of electric and magnetic fields from power lines, electromagnetic fields (EMF) from cellular phones, and computers (Ikehata *et al.* 1999). Many studies found that magnetic fields have some biological effects on different livingcells and tissues (Ahuja *et al.*1999; Faten 2014; Masahiro *et al.* 2000, Molouk *et al.* 2010, Pérez *et al.* 2010, Samarbaf *et al.* 2006, Svedenstal *et al.* 1999 and Zmyslony *et al.* 2000). Several studies indicate that the effect of magnetic fields was variable depending on the type of the microorganism (Masahiro *et al.*2000). A lot of studies have been done on the effect of magnetic field on biological cells, tissues, and living organisms. The effects are not fully understood, since some of the results have been inconsistent (Nakasono and Saiki 2000). In other cases the results often contradict each other, where an increase or decrease in the rate of cell division at different physiological conditions in *E. coli* were detected (Makarevich, 1999, Okuno *et al.*1993, Strašák *et al.*2002).The general stress response to a magnetic field is found in all bacteria, plant and animal cells and is remarkably conserved across species (Pérez *et al.*2010). Ikehata *et al.* (1999) reported that strong static magnetic fields can cause mutations in *S. typhimurium* and *E. coli*. Samarbaf *et al.* (2006) reported that the static magnetic field had no effect on *Pseudomonas aeroginosa* strains. They also found that cephalothin-resistant bacteria suspension supplied with 16 µg/ml cephalothin and subjected to electromagnetic field duration reduced the biomass of bacteria to less than 1/6 of its original population.

In this study, three types of bacterial species were used to investigate the impact of static magnetic field on the growth rate of bacteria and to confirm the effect of magnetic field on living cells.

2. Materials and Methods

The effect of low static magnetic field on bacterial growth were studied using three bacterial strains (*Escherichia coli, Staphylococcus aureus* and *Bacillus subtilis*). The bacterial cultures were cultivated in a nutrient agar medium and incubated at 37°C for 24 hours, and then bacterial colonies were picked by a loop and inoculated in 10 ml nutrient broth. Each bacterial culture was subjected to different magnetic fields (30, 50 and 80) mT. The magnetic fields were measured by Teslameter (model F.W.Bell 4048) in Physics Department, faculty of Science, Al al-Bayt University, Mafraq, Jordan.

In this work 0.1 ml of stock bacterial suspension was inoculated into four groups in tubes each contains 5 ml of nutrient broth. Three groups of tubes were subjected to magnetic fields (30, 50 and 80) mT respectively. While the fourth group was used as a negative control (no magnetic field was subjected). All tubes were incubated at 37 ºC for 24 hours. The effects of different magnetic fields on growth rate were evaluated by measuring the optical density at 600 nm using spectrophotometer (JENWAY 6300) (Fouad *et al.* 2014).

On the other hand, a serial dilution using the bacterial culture was performed to determine the colony forming unit (CFU) value per ml. A volume of 100 µl of a ($1x10^6$) dilution factor was inoculated in agar plates by spread plating. Several plates were made for more accuracy. After incubation, the colonies formed on the plates were visually counted.

3. Results and Discussion

The magnetic field influenced the growth of the three used types of bacteria; *E. coli* (gram negative), *Bacillus subtilis* (gram positive) and *Staphylococcus aureus* (gram positive). The influence of static magnetic field on the growth of *E. coli* bacteria is not fully confirmed by previous studies. Indu *et al.* 2012 and Indu *et al.* 2014 found that the magnetic field reduces the growth of *E. coli* bacteria. Other studies such as Marsahiro *et al.* 2000 and

Morteza *et al.* 2012 showed that there was no effect of the magnetic fields on bacterial growth. In this study applying a magnetic field decreased the growth of *E. coli* bacteria after 24 hours. It can be seen that increasing the intensity of the applied magnetic field decreases the growth of *E. coli* bacteria (figure 1a). The number of bacterial colonies without the effect of magnetic field was 47 x10^9 /ml, while it was (20, 15, 11) x10^9/ml under the impact of 30, 50, and 80 mT static magnetic field, respectively. Figure 1b shows the absorbance of light by the growth medium containing the *E. coli* bacteria. More absorbance indicates a larger number of bacteria in the growth medium. So, figure 1b shows that increasing of static magnetic field decreases the number of bacteria in the growth medium, which confirms the previous result. This result confirms the one that was found by Indu *et al.* (2012) and Indu *et al.* (2014).

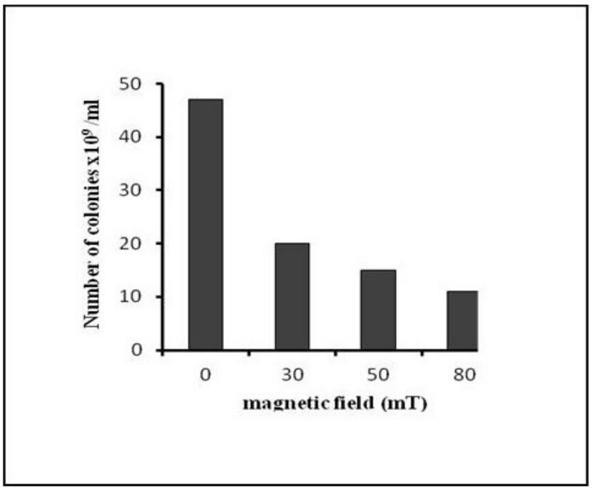

Figure 1 (a): Variation of the number of *E. coli* colonies with different magnetic field strengths

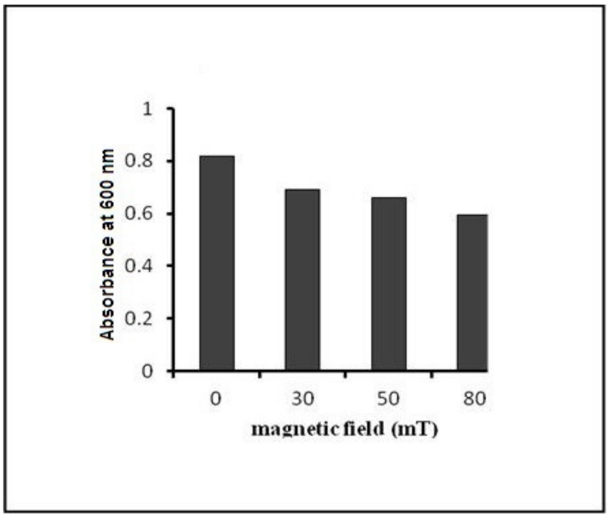

Figure 1(b): Absorbance of *E, coli* cells under the effect of different magnetic field strengths

The effect of static magnetic field on the growth of gram positive *Bacillus subtilis* is shown in (figure 2 a and b). It is clear that *Bacillus subtilis* growth is also sensitive to the magnetic field. Increasing the strength of the static magnetic field increases the growth rate of *Bacillus subtilis* bacteria which opposes the effect on *E. coli* species. The number of bacterial colonies without the effect of magnetic field was 26 x10^9/ml, while it was (93, 105, 138) x10^6/ml under the impact of 30, 50, and 80 mT static magnetic field, respectively. Figure 2b confirms the previous results, where the light absorption by the medium containing the *Bacillus subtilis* bacteria is the highest at 80 mT magnetic field and the least at 0mT magnetic field. This means that the medium under the influence of 80 mT has much more bacteria cells than that under 0 mT static magnetic field. Ceon and Martin (2005) showed that low level magnetic field induced an increase in the growth rate of *Bacillus subtilis* mutant strain when exposed to pulsatile electromagnetic field strength. On the other hand, Moore (1979) reported that the growth rate of *Bacillus subtilis* increases when exposed to 150 gauss (15mT) and decreases when exposed to more than 300 gauss (30mT).

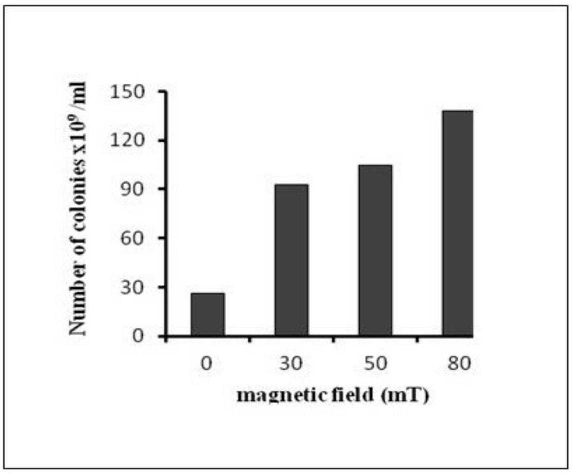

Figure 2 (a): Variation of the number of *Bacillus subtilis* colonies with different magnetic field strengths

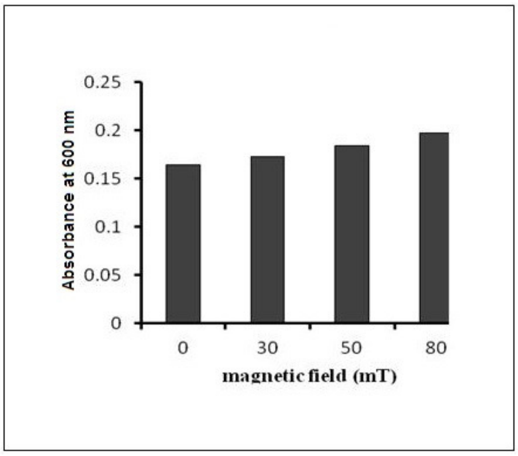

Figure 2(b): Absorbance of *Bacillus subtilis* cells under the effect of different magnetic field strengths

For gram positive *Staphylococcus aureus* bacterial, Masahiro *et al.* (2000) showed that the ferrite magnet caused strength dependent decreases in the growth rate when cultured under anaerobic conditions. Pérez *et al.* (2010) found that the static magnetic field affects the growth dynamics of the bacterium *S. aureus* in which the number of CFU decreases with the magnitude of the applied static magnetic field. Figure 3 (a and b) shows the effect of static magnetic field on the growth rate of *S. aureus* bacteria. A reduction of growth rate of *S. aureus* with increasing of applied magnetic field can be seen from figure 3a. The number of *S. aureus* colonies was 311, 252, 210 and 119 x10^9/ml under a magnetic field of 0, 30, 50 and 80 mT, respectively. Figure 3b confirms this result since the light absorption decreases by increasing of magnetic field. This result is in consistent with the previous studies of Masahiro *et al.* (2000) and Pérez *et al.* 2010.

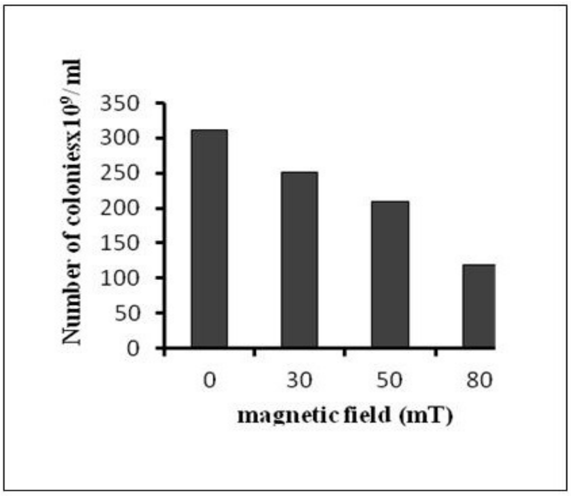

Figure 3 (a): Variation of the number of *S.aureus* colonies with different magnetic field strengths

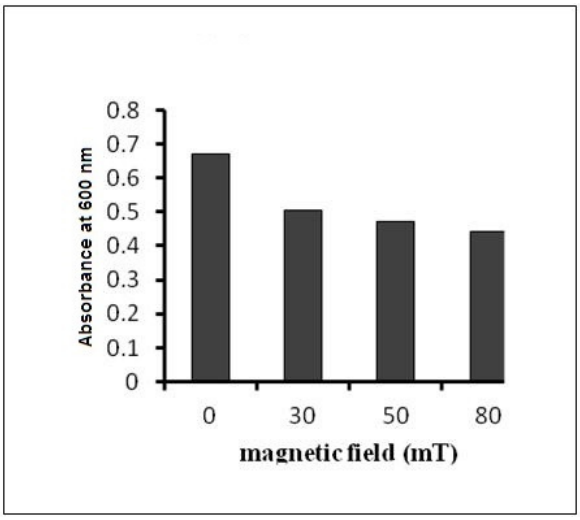

Figure 3 (b): Absorbance of *S.aureus* cells under the effect of different magnetic field strengths

It can be seen from these results that the impact of static magnetic field on the bacterial growth rate is independent of the type of bacteria which is consistent with the study of Indu *et al.* (2014).

4. Conclusion

The growth rate of *E. coli* and *S. aureus* bacteria strains was decreased by increasing the static magnetic field, while the growth rate of *Bacillus subtilis* was increased by increasing it. All samples subjected to the magnetic field exhibited changes in their growth rate compared to the negative control samples. The results provide important indication towards selecting the optimal parameters to promote therapeutic effect for possible treatment of diseases and infected tissues.

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