# EFFECT OF STATIC MAGNETIC FIELD ON THE ELECTRICAL PROPERTIES AND ENZYMES FUNCTION OF RAT LIVER

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*Abstract.* The aim of present work is to evaluate the effect of static magnetic field (SMF) of intensities 10, 14, 18 and 22 mT on the dielectric properties and some liver function tests in rats. The rats were, whole body, exposed to these intensities one hour daily for one week. The dielectric constant (ε), electrical conductivity (σ) and relaxation frequency (*f*s) were measured over frequency range 50 Hz to 2.5 MHz. Also, the rat liver function was studied through analysis of glutomic oxaloacetic transaminase (GOT), glutamic pyruvie transaminase (GPT) and total protein (TP) after exposure to the magnetic fields. The same biochemical parameters have been evaluated in the blood serum of rats. The obtained results showed noticeable variations in normal values of ε, σ of liver tissue after the exposure to all the stated magnetic fields intensities. The levels of GOT and GPT were increased up to three times their values during the period of exposure to the magnetic fields. These variations were recovered during one week after stopping exposure but they did not return to its original control values before exposure.

*Key words*: Static magnetic field, dielectric constant, rat liver enzymes.

## INTRODUCTION

The automation medical and research instruments which generate magnetic fields (MF) are widely diffused in recent years, and the people are frequently exposed to it. Despite that the study of the effect of electromagnetic fields (EMFs) on living organisms is a complex problem, but it is of more interest to give insight into the expected hazards and the proper ways of its use and protection. The EMF penetrate the human body and act ions on all organs, altering the cell membrane potential and the distribution of ions and dipoles [3, 6, 16]. MFs were observed to influence enzyme action, signal transduction, protein synthesis and gene expression. These activities play an important role in regulating cell growth and processes important to promotion [18]. Furthermore, alterations may influence biochemical processes in the cell, thus changing both biochemical parameters and enzyme activities of the blood serum. Recent electron microscopy studies on hepatocytes and liver tissue have shown that constant magnetic fields exhibited

Received: July 2008;
in final form October 2008.

ROMANIAN J. BIOPHYS., Vol. 18, No. 4, P. 337–347, BUCHAREST, 2008

structural changes in hepatocytes, primarily in the mitochondria and also split cell membrane [17, 20]. Moreover, constant and low frequency MFs exert a preponderant controlling influence on the thermoregulation, metabolism and hematology in rats [1, 5]. The exposition of rats 1 hour/day for 10 consecutive days to a Static MF of 128 mT induced an increase in hematocrit, hemoglobin, plasma fuel metabolites and tissue enzymes releases within the blood [26]. Several authors suggested that chemical and physical processes at the atomic level are the bases of reactions between biomolecules in an EMF, since the field can magnetically affect the chemical bonds between adjacent atoms with consequent production of free radicals (21, 27, 29).

The magnetic field effects seem to be an ideal means for investigating biological function. Significant area would be better understood if knowledge on magnetic field effects on biological membrane is measured by physical parameters such as impedance *Z*, dielectric parameter (έ) and conductivity (σ).

The physical mechanism for the effects of weak electromagnetic field ranging from microwave to radio waves had been discussed [2, 10] by the dielectric nature of all biological molecules especially those constituting the biological membrane. A variety of techniques [8, 24, 28] were used for measuring the dielectric parameters of biological tissues at fixed temperature and frequencies from 100 to over 1000 kHz after exposure to static and low frequency MFs.

This paper is interested in studying the changes in the dielectric properties and some liver function tests due to static magnetic field. Also, the study pays attention to patients under investigation to these tests to be protected against exposure to any source of magnetic field.

## MATERIALS AND METHODS

### ANIMALS

The experiments were carried out with a total of 54 adult albino rats weighing 120 g on average that were purchased from the holding company for biological products and vaccine, Cairo, Egypt. The rats used in the present work complied with legal requirements and institutional guidelines. The rats were housed individually in plastic boxes kept in a shielded chamber to reduce the normal ambient environmental electric field under similar conditions of temperature, illumination, acoustic noise and ventilation and received the same diet during the course of experiments [8, 23].

### MAGNETIC FIELD EXPOSURE

An electromagnet constructed in the Department of Physics; Faculty of Science, Benha University was used as the SMF generator. The method of magnetic field

exposure was followed as that adopted by Watanabe *et al*. [31]. The cylinder bore of the electromagnet (EM) was 200 mm in diameter. A uniform magnetic field was produced over a 200 mm diameter area around the center of the bore. One cage (6 rats) was placed in the center of the bore of the EM. The temperature inside the irradiation chamber was periodically measured through the use of a thermocouple thermometer, which can give readings for the temperature variations within ±0.3 ºC. The group of rats was exposed to SMF (10, 14, 18 and 22 mT) for one hour daily over one week, and another cage was placed in another cylinder placed in the same temperature-controlled room for use as a control free of magnetic effects.

## BIOCHEMICAL ANALYSIS

Liver tissues of the experimental animals were immediately removed after exposure to MF. Weighed tissue samples were homogenized by a glass homogenizer after dilution by distilled water then the supernatant fluid was separated by centrifugation at 3000 rpm for 15 minutes, and stored at –20 ºC for biochemical analysis. Liver glutamic oxaloacetic transaminases (GOT) and glutamic pyruvic transaminases (GPT) were determined using the method adapted by Fischbach and Zawta [9]. Alkaline phosphatase was determined using the method adapted by Bessey *et al*. [4] and total protein content was determined using the method adapted by Henery [12]. Blood serum was collected after blood centrifugation and stored at –20 ºC for biochemical analysis.

## THE DIELECTRIC AND CONDUCTIVITY MEASUREMENTS

Liver tissue suspensions were measured at room temperature 20 ± 1 ºC by impedance meter (Model PM 6304) in the frequency range from 10 kHz to 300 kHz. The dielectric cell consists of two platinum electrodes with a distance between them of 1 cm and an electrode area of 0.45 $cm^2$. The measurements of dielectric parameters were taken before and after SMF, and these parameters are:

$$\acute{\varepsilon} = \frac{Cd}{\varepsilon_0 A} \tag{1}$$

where $A$ is the area of electrode, $d$ the distance between the two electrodes, $\varepsilon_0$ is the permittivity of free space and $\acute{\varepsilon}$ is the dielectric constant. The dielectric loss $\varepsilon''$ is calculated from the relation:

$$\varepsilon'' = \acute{\varepsilon} \operatorname{tg} \delta \tag{2}$$

where $\delta$ is the loss angle.
The electric conductivity $\sigma$ is given by:

$$\sigma = \frac{d}{RA} \tag{3}$$

where $R$ is the resistance of the sample.

## RESULTS AND DISCUSSION

In the present work, we studied the effects of SMFs (10, 14, 18 and 22 mT) on GOT, GPT, TP and dielectric properties of rat liver after whole body exposure. Also, a recovery study was carried out after one week from stopping the exposure to MFs. The changes in liver enzymes and total protein from tissue analysis are shown in Table 1 and Figure 1 and changes from blood serum analysis are shown in Table 2 and Figure 2.

The values of GOT, GPT and total protein TP showed significant higher values ($p < 0.05$) depending on the MF intensity as compared to values for the control group. These significant changes showed a gradual decrease during one week of recovery for all doses but did not reach the control values. In a previous study on the effect of static electromagnetic fields on the liver, kidney and spleen tissues of rat showed that the liver tissue is more affected by SMF than the other tissues [22].

*Table 1*

Average values of total protein TP, the glutamic oxaloacetic GOT and glutamic pyruvic GPT transaminases of liver tissue after exposure to SMFs 10, 14, 18 and 22 mT and recovery values after one week. Values are the average of 6 experiments and $p < 0.05$ as compared to values for the control group

| Group | Recovery | | | Exposure | | |
|---|---|---|---|---|---|---|
| MF Intensity (mT) | GOT U/g tissue | GPT U/g tissue | TP mg/g tissue | GOT U/g tissue | GPT U/g tissue | TP mg/g tissue |
| Control | 38.054 | 21.162 | 16.97 | 38.054 | 21.162 | 16.97 |
| 10 | 70.313 | 41.727 | 24.49 | 71.532 | 42.55 | 25.12 |
| 14 | 73.37 | 37.565 | 20.61 | 105.469 | 66.094 | 28.59 |
| 18 | 47.222 | 24.898 | 18.26 | 89.423 | 41.051 | 49.47 |
| 22 | 52.697 | 27 | 20.76 | 81.855 | 34.628 | 22.27 |

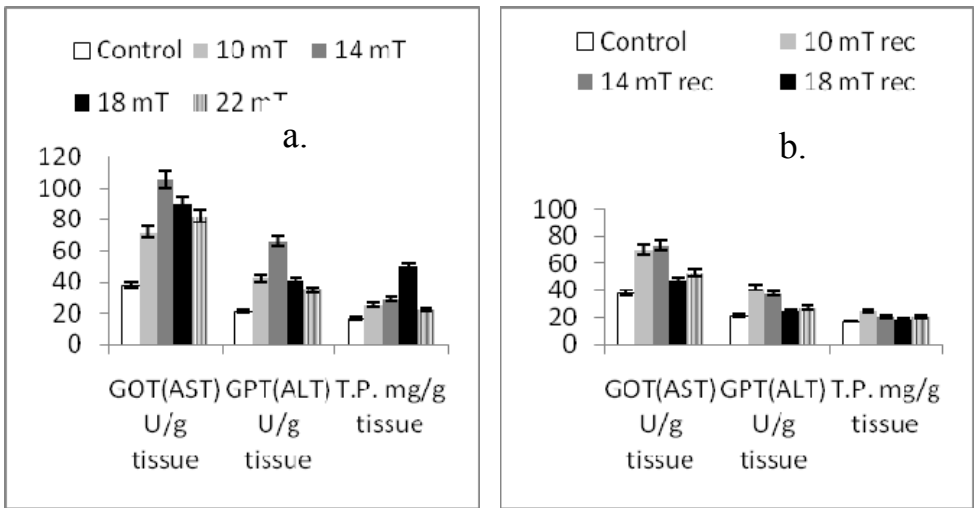


Fig. 1. Values of total protein g/L, glutamic oxaloacetic U/L and glutamic pyruvic U/L for liver tissue; a. After exposure to SMFs 10, 14, 18 and 22 mT and b. recovery values after one week.

*Table 2*

Average values of total protein TP, the glutamic oxaloacetic GOT and glutamic pyruvic GPT transaminases of blood serum after exposure to SMFs 10, 14, 18 and 22 mT and recovery values after one week. Values are the average of 6 experiments and $p < 0.05$ as compared to values for the control group

| Group | Exposure | | | Recovery | | |
|---|---|---|---|---|---|---|
| MF Intensity (mT) | GOT U/L | GPT U/L | TP g/L | GOT U/L | GPT U/L | TP g/L |
| Control | 86 | 48 | 56 | 86 | 48 | 56 |
| 10 | 194 | 151 | 76 | 92 | 66 | 62 |
| 14 | 202 | 170 | 84 | 112 | 95 | 65 |
| 18 | 266 | 182 | 92 | 122 | 113 | 68 |
| 22 | 340 | 221 | 98 | 156 | 123 | 72 |

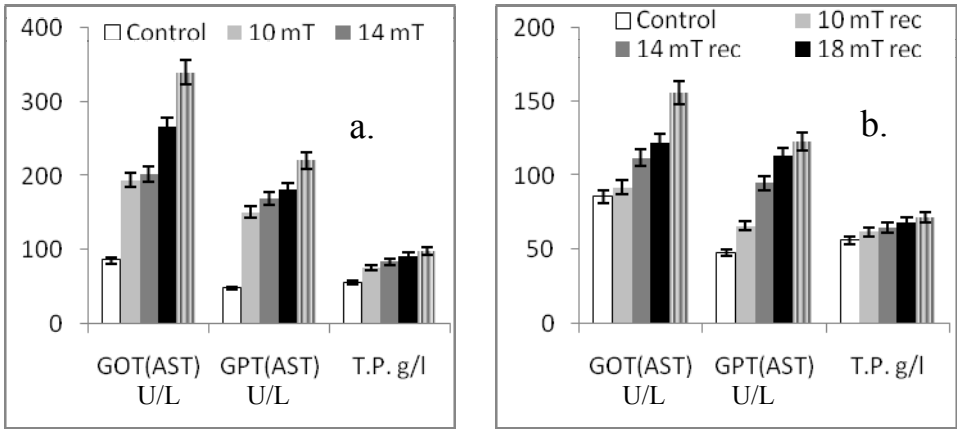


Fig. 2. Values of total protein g/L, glutamic oxaloacetic U/L and glutamic pyruvic U/L of blood serum; a. After exposure to SMFs 10, 14, 18 and 22 mT and b. recovery values after one week.

The obtained data showed that SMF produced alteration in biochemical parameters of the liver transaminases GOT and GPT which have been widely utilized in mammalian toxicology as biomarkers of specific organ dysfunction. In general the increase in transaminases activity is usually associated with hepatocyte damage. These results are in agreement with the results recorded by Sihem *et al*. [26]. The authors studied the effects of sub-acute exposure to magnetic field on blood hematological and biochemical parameters in female rats and found that the serum GPT activity remained unchanged in treated rats, while GOT activity was increased. Our present results agree with observations obtained by many authors [13, 14, 25]. Ibrahim *et al*. [14] studied the effect of 50 Hz magnetic field on liver function and attributed the increase in the liver enzymes such as alanine aminotransferase (ALT), aspartate aminotransferase (AST) and protein as a result of the damaged cells which leak into circulation after exposure to magnetic field. Also, exposure to a pulsed magnetic field at 1.5 mT caused significant changes on plasma proteins in rats [13]. Erdal *et al*. [7] suggested that long term ELF-MF exposure may enhance the oxidative/nitrosative stress in liver tissue of the female rats and could have a deteriorative effect on cellular proteins rather than lipid by enhancing 3-nitrotyrosine formation. It was found that the static magnetic field applied alone or applied during x-irradiation caused variations in the serum components level and enhanced liver damage [33]. These observations support the hypothesis that the state of physiological equilibrium of a biological system is crucial to its response to a potentially effective electromagnetic field [25].

Valberg *et al.*, [30], showed that the exposure to time varying magnetic field induces electric field and this in turn may cause large structural changes of the protein molecules imbedded in the cell membrane forming a new membrane conformation. In this new conformation, the ions are able to pass through the membrane by binding temporarily with the protein molecule, thus “hopping” through the membrane.

Figure 3 shows the variation of the dielectric constant έ with frequency of liver tissue for rats exposed to SMFs Figure (3a) and the recovery values after one week, Figure (3b). There is a shift in the position of the relaxation frequency (*f*s) towards lower frequencies together with a decrease in the peak value of permittivity after exposure for all doses, and these changes attained their control values for 18 mT and 22 mT exposure only.

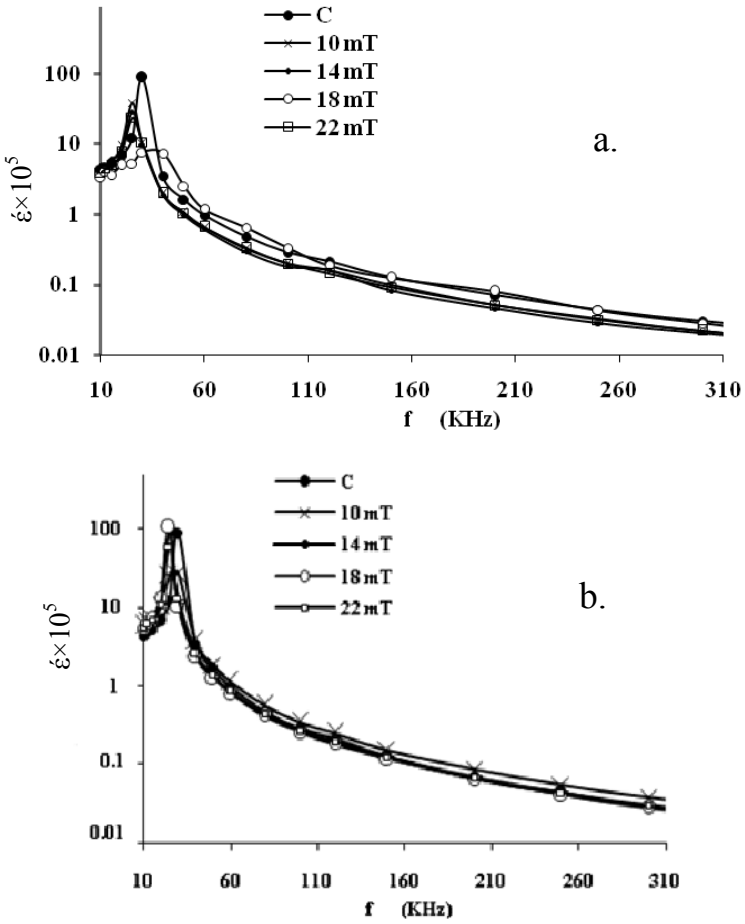


Fig. 3. The variation of permittivity with frequency within the range 10 – 300 kHz of the liver tissue suspension; a. After exposure to SMFs 10, 14, 18 and 22 mT and b. recovery values after one week.

There was a pronounced decrease in conductivity of liver tissue suspension with frequency for all doses as shown in Figure 4. The decrease in conductivity due to field exposure, 14, 18 and 22 mT returned approximately to the control value during the recovery period, while conductivity at 10 mT showed a significant higher value of about 30% greater than the control value.

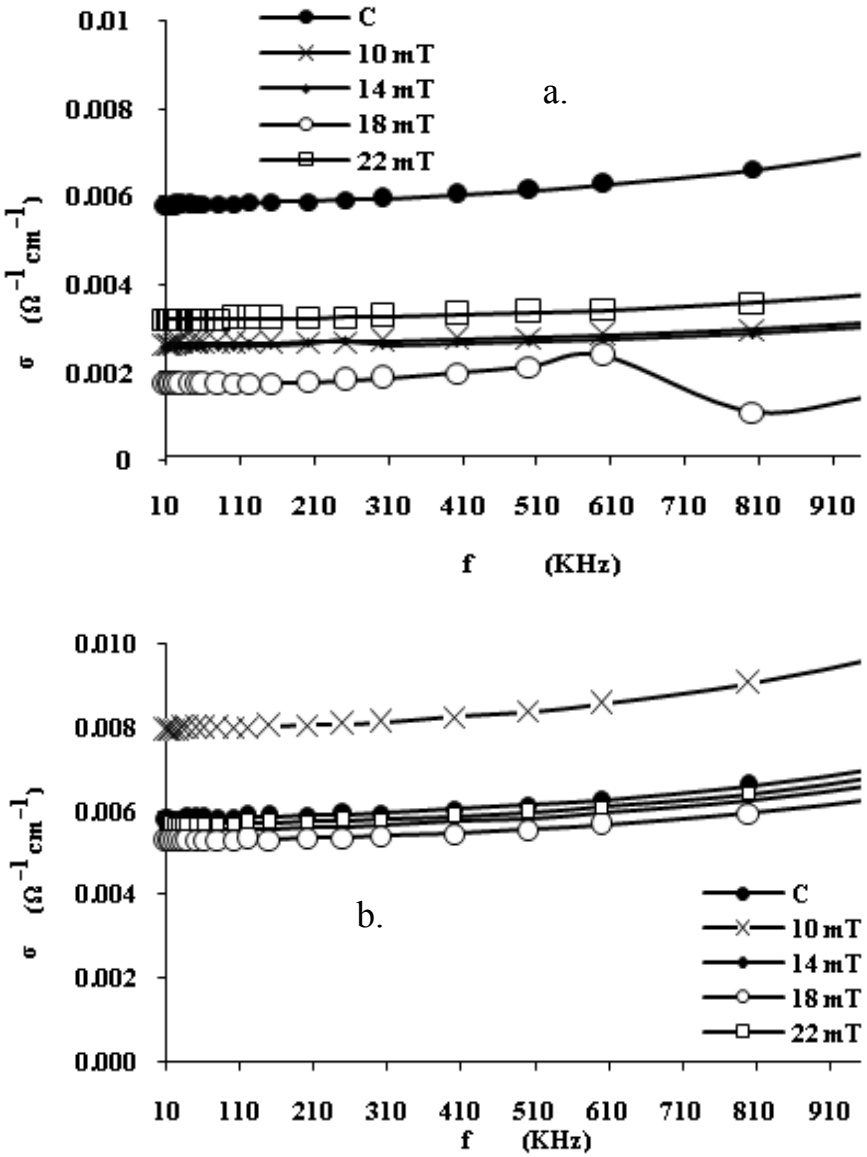


Fig. 4. The measured conductivity in the frequency range 10 – 1000 kHz of the liver tissue suspension; a. After exposure to SMFs 10, 14, 18 and 22 mT and b. recovery values after one week.

The relative high control value of hepatocytes membrane permittivity (έ) and conductivity (σ) may be attributed to the high value of the membrane capacitance and conductance due to normal activity of GOT and GPT and normal values of cell membrane potential and distribution of ions and dipoles. So, the low values of the membrane permittivity, relaxation frequency and conductivity after exposure to

different doses of SMF are due to the lipid peroxidation, which causes destruction of cell membrane [19, 20]. Furthermore, the lower values of dielectric parameters ($\sigma$ and $f_s$) after exposure agree with Gorczynska [11] who suggested that in hepatocytes, magnetic field exposure induced foamy cytoplasm, and increase glycogen deposits.

During recovery, the changes in relaxation frequency did not return to its control value and the conductivity was approximately returned to the control value except at 10 mT it attained a higher value than the control value.

These alterations agree with data obtained by Wolf *et al.* [32] who suggested that free radicals have pleiotropic effects which may vary from cytotoxic to mitogenic responses depending on the concentration, the duration of exposure, and the type of cell or tissue. Also it will be attributed to the influence of the decrease in GOTand GPT activity. Watanabe *et al.* [31] showed that activities of GOT and GPT in the plasma, as indicator of hepatotoxicity, may alter the cell membrane potential and distribution of ions and dipoles. Also, appearance of a high characteristic peak for $\acute{\varepsilon}$ was frequency dependent, maybe due to polarization of molecules and ions in suspension. Kula *et al.* [15] reported that the physicochemical action of an electromagnetic field consists of electron, ion, dipolar, macrostructural and electrolytic polarization. Other factors may also play a role, such as molecular excitation, biochemical activation, generation of radicals, weakening of chemical bond and hydration change may alter relaxation protein fractions of serum.

Finally, this study suggests that, in humans under investigation, the activities of GOT and GPT in the liver may increase and the conductivity may decrease by exposure to SMF generated during MRI or NMR procedures.

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