INTERNATIONAL CONFERENCE ON RADIATION APPLICATIONS | In Physics, Chemistry, Biology, Medical Sciences, Engineering and Environmental Sciences
June 6-10, 2022 | Aristotle University Research Dissemination Center (KEDEA) | Thessaloniki | Greece
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ЯАР22

Investigation of frequency of dielectric relaxation of water molecules in blood cells of cancer patients

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Introduction

Biological membranes are cooperative structures in which any changes in the structure and composition of individual components cause changes in the structure as a whole. The study of dielectric properties of human erythrocytes can be a sensitive parameter that responds to various biochemical and biophysical actions. Based on the analysis of dielectric characteristics of dispersed systems in the microwave range, in particular dielectric constant and dielectric relaxation frequency, it is possible to draw conclusions about conformational and structural changes in membranes that occur under the influence of pathological factors.

Materials and methods

The paper presents the results of a biophysical study of the frequency of dielectric relaxation (f_d) of water molecules in blood cells (erythrocytes) of breast cancer patients (n = 32), under conditions of radiation exposure to the tumor (a single focal dose was 6 Gy), which were obtained for using the method of microwave dielectrometry, at a frequency of 9.2 GHz in the temperature range 2-47°C. The value of the real part of the dielectric permittivity (ε′) was determined by the change in the resonant frequency of the resonator with the sample relative to the empty resonator, and the imaginary part of the dielectric permittivity (ε″) was determined by the magnitude of the attenuation of the microwave field power due to the introduction of a dielectric into the resonator. The temperature of the test sample was recorded with an accuracy of ± 0.1 °C. Blood from healthy donors was used as a control (n = 30). Statistical processing of the obtained data was performed using the MATLAB program and Mann-Whitney nonparametric test.

Results

The temperature dependences of the frequency of dielectric relaxation (f_d) of water molecules in erythrocyte solutions in donors and patients with malignant neoplasms have a number of features that are deviations at certain temperatures from the monotonicity of changes in parameters. For the suspension of erythrocytes deviations of dielectric parameters are observed in the temperature range of 6-12, 12-17 ° C (donors) and 2-9, 9-17 ° C (patients). For the shadows of erythrocytes similar changes are observed in the temperature range of 6-8, 8-12 ° C (donors) and 6-8, 8-15 ° C (patients). In the temperature range of 42-46 ° C, changes in the slope of the dependences of the dielectric relaxation frequency of dielectric relaxation (f_d) of water molecules in the suspension and shadows of erythrocytes are observed for both donors and patients. The processes that take place in the systems are accompanied by changes in the activation energy of the dielectric relaxation of water molecules, which is reflected in the form of fractures in the Arrhenius dependences of the dielectric relaxation time of water molecules in erythrocyte solutions of donors and patients before and after therapy (fig. 1, 2).

Since the activation energy of the hydrogen bond is estimated at 12.5 kJ / mol, in the studied systems at temperatures below 17 ° C for the rotation of the water molecule requires the rupture of approximately two hydrogen bonds, and at higher temperatures, each molecule of water forms from 1.2 to 1.4 N - bonds with neighboring molecules.

The activation energy of the dielectric relaxation time of water molecules in the studied systems and the magnitude of the degree of hydration of the erythrocyte membranes of donors and patients before and after irradiation were calculated. It was found that at temperatures of 10-12 ° C, 20-23 ° C and 30-36 ° C structural changes of erythrocyte membranes of donors and patients with malignant neoplasms are observed, which are accompanied by changes in activation energy.

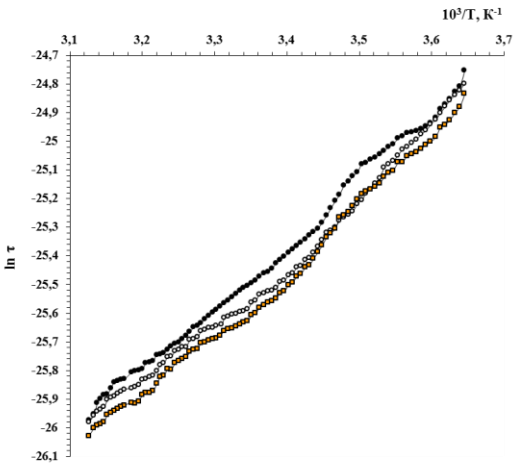

Fig.1. Arrhenius curves of the dielectric relaxation time of water molecules in erythrocyte solutions of donors and patients before and after therapy.
● - donors; □ - patients before therapy (compared to donors, $p \le 0.05$), ○ - after therapy ($p \le 0.05$).

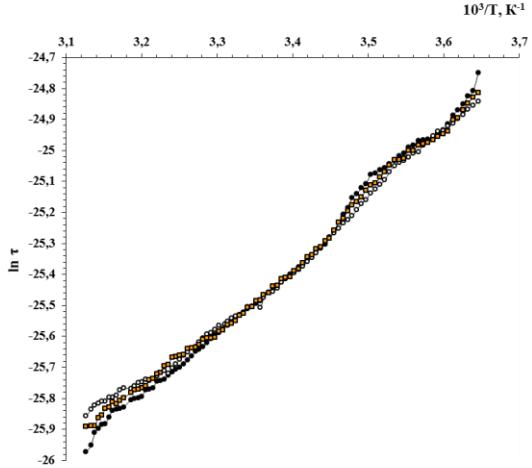

Fig.1. Arrhenius curves of the dielectric relaxation time of water molecules in shadows of erythrocyte of donors and patients before and after therapy.
● - donors; □ - patients before therapy (compared to donors, $p \le 0.05$), ○ - after therapy ($p \le 0.05$).

Summary

It was found that in the suspension of erythrocytes of patients with breast cancer at temperatures of 9-17, 23, 36 and 42-46 ° C there are changes of structure of membranes water which leads to loosening of the lipid bilayer of the membrane. It is established that at temperatures of 6-8, 8-15, 36 and 42-46 ° C structural changes of erythrocyte membranes are observed in patients with malignant neoplasms, which is accompanied by changes in activation energy. Identified features of complex dielectric constant of erythrocyte suspension and erythrocyte shadows of cancer patients can be universal and do not depend on the nosological form of the tumor.

Reference

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