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A DIELECTRIC STUDY ON HUMAN BLOOD AND PLASMA

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Abstract: The paper reports electrical properties of human blood and plasma of belonging to different physiological and environmental conditions. Dielectric parameters such as dielectric constant, dielectric loss and electrical conductivity of human blood and plasma of groups A, B, AB and O are measured at the frequency of 1kHz using digital LCZ meter. It is found that the values of dielectric constant, dielectric loss and electrical conductivity are high in plasma, low in 90% packed erythrocytes and hemolysed blood, and in between in whole blood irrespective of blood group but these dielectric parameters are more or less same in 90% packed red blood cells (RBC) and hemolysed blood. Groupwise differences in dielectric parameters in the case of plasma are not evident, but could be found in whole blood, hemolysed blood and 90% packed RBC. The study reveals that the significant variation in dielectric parameters could be attributed to the cellular concentration and also due to the presence of erythrocyte membrane, which separates the cell interior (hemoglobin) and cell exterior (plasma). Hence, it is the cell membrane, which characterizes the electrical properties of the most biologically important tissue – the blood.
Key words: Human blood, Blood groups (a, B, AB & O),Dielectric properties, LCR meter.

1. Introduction

The blood serves as the principal transport medium of the body, carrying oxygen, and nutrients, messages to the tissues and waste product and CO_2 to the organs of excretion. In other words, blood is described as a fluid connective tissue. The blood plays many important roles in coordinating the individual cells into a whole complex organism.

Asami et al [1] reported the electrical properties like membrane capacitance C_m, dielectric increment ΔK, of yeast cells suspended in KCl solution by bridge method in the frequency range of 1kHz to 100 MHz. The C_m was obtained to be 1.6 $\mu F/cm^2$. They also developed the yeast cell model to explain their results.

Schwan [2] studied the electrical properties of biological cells and tissues at very low frequencies and discussed the mechanisms responsible for such properties.

Schwan [3] analysed the dielectric data of biological material obtained from advanced dielectric techniques. He proposed three major and distinct relaxation effects which characterise the total dielectric response from d.c. to GHz, and several minor ones are superimposed.

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Schwan [4] summarised the electrical properties of biological cells and tissues over the total investigated frequency range. He also discussed mechanisms responsible for observed frequency dependencies and indicated the most possible sites for electromagnetic field interactions.

Schwan [5] studied dielectric properties such as dielectric increment, membrane capacitance of biological cells by electro rotation method. He summarised biological effects of non-ionizing radiation, which is closely related to electro physiology.

Pethig [6] analysed proton transport in proteins along with pH effects on protein structure. He reviewed the work on electrical and dielectric properties of protein at low hydration content to indicate proton transport.

Takashima et al [7] measured dielectrophoretic properties of *micrococcus lysodeiktcus* in the frequency range of 20 Hz to 4 MHz as a function of ionic strength of suspending electrolyte. They concluded that low frequency DEP response is dominated by electrical properties of cell wall. The existing dielectric theories are insufficient in explaining the results, as they do not consider the inhomogeneous and charge structure of the organism.

Hawkes and Pethig [8] noted dielectric properties of lysozyme-compressed powder as a function of hydration and pH at which the samples were lyophilized. They concluded that the dielectric dispersion in α-region appear in the range 10^4 Hz to 10^5 Hz for lysozymes of hydration ranging from 5 - 20 % weight water is related to the state of ionization of acidic and basic groups in the protein structure.

Foster and Schwan [9] presented a very useful review of the work done on dielectric properties of tissues and biological particles in the past. It is a historical survey on electrical properties of biological materials. Various dielectric relaxation mechanisms and dielectric dispersions in tissues are described. Dielectric properties of some tissues like muscle, bone, blood are summarised.

Basharath Ali and Adeel Ahmad [10] studied anisotropy in permittivity and resistivity of fresh and oven dried ox muscle and heart tissues. They reported that anisotropy in permittivity and resistivity was significant in fresh tissues, while it was lacking in dry tissues. Further, dielectric constant, dielectric loss and conductivity were high and resistivity was low in fresh samples when compared to oven dry tissues.

Basharath Ali and Adeel Ahmad [11] investigated dielectric parameters (dielectric constant, dielectric loss, conductivity or resistivity) of different types of tissues of liver, kidney and brain of the animal Ox at 1 kHz frequency. They attributed significant variation in these parameters to the extent of hydration, molecular composition, presence of certain elements in traces, structural and morphological differences in cells and tissues, and concluded that structural constituents and molecular composition of tissues have integrated activity in influencing the dielectric properties of tissues.

The present investigation describes dielectric behavior of human blood and its constituents belonging to different groups A, B, AB and O. A conventional bridge technique is used to study dielectric properties such as dielectric constant, dielectric loss and conductivity of blood and its constituents (90% packed RBC, Plasma, Hemolysed blood) for different groups at the frequency of 1 kHz.

2. Materials and Methods

Normal human blood samples of volume nearly 20 ml of different groups A, B, AB and O were collected from a blood bank. Acid Citrate Dextrose (ACD) was used as an anti coagulant at the rate of 300 µl per20 ml of blood. The blood sample was centrifuged at the rate of 1500 rpm for about 15 minutes. The supernatant was separated which gave plasma, while residue contained about 90% packed erythrocytes. To get Hemolysed blood, one or two drops of distilled water was added to 90% packed cells.

To study the dielectric behavior of human blood and its constituents of different groups, the dielectric parameters such as dielectric constant, dielectric loss and conductivity were determined at the frequency of 1 kHz, using digital LCZ meter.

A standard conductivity cell was selected for dielectric studies of blood and its constituents. This cell contains two parallel plates, the leads of which plug directly into the live terminals of capacitance measuring bridge.

The dielectric constant, dielectric loss and conductivity can be calculated by the given formulae

Dielectric constant, $\in' = C_s / C_a = (C_s' - C_L) / (C_a' - C_L)$

where, C_s = Actual sample capacitance; C_L = Lead capacitance

C_a = Actual air capacitance; C_s' = Measured capacitance of cell with liquid

C_a' = Measured capacitance of cell without liquid, at 1 KHz frequency

Dielectric loss, $\in'' = (1.8 \times 10^{12}\ k) / \nu$

where, ν = Frequency; k = electrical Conductivity

Conductivity, k = GL / A

where G = Conductance; L = Distance between the plates of the cell

A = Area of the plates

3. Results and Discussion

A comparison of dielectric parameters such as dielectric constant, dielectric loss and conductivity of human blood and its constituents belonging to different groups, when measured at the frequency of 1 KHz is presented in Table 1.

Table 1 – Dielectric parameters of human blood and its constituents

Parameter	*Whole Blood*	*Plasma*	*90% Packed Cells*	*Hemolysed Blood*
		Group A		
Dielectric Constant, ε’	73.55×10^3	138.04×10^3	17.54×10^3	21.72×10^3
Dielectric Loss, ε”	222.70×10^7	322×10^7	96×10^7	93×10^7
Conductivity, K (mho-cm^{-1})	1.230	1.81	0.534	0.515
		Group B		
Dielectric Constant, ε’	76.12×10^3	138.31×10^3	19.65×10^3	19.95×10^3
Dielectric Loss, ε”	21.6×10^7	318×10^7	85.8×10^7	82.5×10^7
Conductivity, K (mho-cm^{-1})	1.12	1.77	0.47	0.46
		Group AB		
Dielectric Constant, ε’	51.74×10^3	137.81×10^3	30.24×10^3	34.33×10^3
Dielectric Loss, ε”	186.6×10^7	324×10^7	133.2×10^7	129.6×10^7
Conductivity, K (mho-cm^{-1})	1.04	1.81	0.75	0.72
		Group O		
Dielectric Constant, ε’	70.65×10^3	148.16×10^3	16.02×10^3	12.14×10^3
Dielectric Loss, ε”	216×10^7	322.2×10^7	79×10^7	71.3×10^7
Conductivity, K (mho-cm^{-1})	1.2	1.8	0.449	0.396

It is evident from Table 1 that the values of dielectric constant, dielectric loss and conductivity are high in plasma, low in 90% packed erythrocytes and Hemolysed blood, and in between in whole blood irrespective of blood group. But these dielectric parameters are more or less same in 90% packed RBC and Hemolysed blood. The significant variations in dielectric parameters could be attributed to the cell concentration. In the absence of erythrocytes in the blood i.e., in plasma, the values of dielectric parameters are very high. In whole blood where in about 45% erythrocytes are present, the values of dielectric parameters are moderate. When 90% packed RBC and Hemolysed blood are considered, the dielectric parameters values are low.

Therefore, one can conclude that the presence of erythrocyte membrane causes significant variations in the dielectric parameters of human blood, apart from proteins and salt solutions. Hence, it is cell membrane which characterizes the electric parameters of the most biologically important tissue – the blood.

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