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Dielectric parameters for cell model calculation

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The study of the dielectric properties of erythrocytes opens up wide opportunities in assessing various pathological conditions of living organisms, in the development of new technologies in the field of medicine, virology, biotechnology [1, 2]. In such dispersed systems as cell suspensions, in which cells are distinguished by a large variety of shapes and heterogeneity of structure, it is necessary to take into account the geometric and structural factors that make up the cell membrane. Suspension of erythrocytes in blood serum is a cellular matrix system. The role of the matrix is played by the fluid surrounding the erythrocytes; each erythrocyte with a shell assigned to it from the corresponding portion of the matrix medium can be considered as an elementary cell, of which the cell suspension consists. As you know, according to the structure of their surface, all red blood cells are a heterogeneous population. Under physiological conditions, the erythrocyte is stable, which is ensured by the rate of cell formation and destruction. In conditions of pathology of various origins, the erythrocyte system is characterized by molecular and biochemical changes, which have features of both a compensatory-adaptive and maladaptive nature.

This paper presents a brief description of mathematical modeling, which describes the effective dielectric constant of a suspension of erythrocytes, for the cases f three geometric shapes, when the erythrocyte is considered as a dispersed particle. The change in the values of the dielectric constant are calculated depending on the shape of the particle, and takes into account $\varepsilon_\circ$ and ε_p – the dielectric permittivity of the matrix medium and inclusions, δ – the volume fraction of inclusions, A_i – the depolarization coefficients of the particles-inclusions. To calculate the dielectric constant, the most suitable approximation model for an arbitrarily oriented particle is a suspension of balls. This approximation is accurate, since the arbitrary orientation of the particles averages the effect of their shape on the dielectric constant of the suspension. Indeed, for plates, the limiting values of the depolarization coefficients A_i are $A_i = 1$ (plate perpendicular to the field) and $A_2 = A_3 = 0$ (parallel orientation); for cylinders $A_i = 0$, (cylinders are field oriented) and $A_2 = A_3 = 1/2$. For small concentrations of erythrocytes in suspension, the maximum deviation in the dielectric constant of the suspensions associated with the cell shape is approximately 10% of the change in dielectric constant caused by the addition of particles to the dispersed medium. The lamellar shape of the particle gives a much larger change in dielectric constant compared to the cylindrical shape. The native shape of red blood cells is an oblate ellipsoid, and they can be approximated by plates. Experimental estimate of the change in the value of the dielectric constant caused by the change in the shape of the cell from an oblate ellipsoid to a sphere of approximately 0.3 units ε for the case $\delta = 0.02$. This value is approximately 2.5 times higher than the theoretically calculated one. This may be due to the fact that we do not take into account the mutual interaction of cells with each other, as well as the interaction of cells with the environment. More research is needed to account for such interactions. It follows from the foregoing that when studying any effects on erythrocyte suspensions (which in native conditions can be approximated by flattened ellipsoids of rotation), in addition to changes in the dielectric constant of cells, it is also necessary to take into account the change in the shape of cells and their aggregation (if it takes place and the shape of aggregates differs from the shape of the original particles). The presented results can be used to study biological suspensions and colloids.

References

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