Interfacial Mechanisms of Silicone Oil Emulsification in Model Aqueous Humor: Role of Proteins and Viscosity

Barbora Kamenická[1], Věra Pěnkavová[1*], Eliška Lyko Vachková[1,2], Sandra Orvalho[1], Mária Zedníková[1,2], Petr Stavárek*[1], Natalie Jaklová[1], Monika Reháčková[3,4], Patrik Rajs[3,4], Miroslav Veith[3,4], Petr Klusoň[1,5]

[1]*Institute of Chemical Process Fundamentals of the Czech Academy of Sciences, Rozvojová 135, 165 00 Prague, Czech Republic, *corresponding author, e-mail: stavarek@icpf.cas.cz*
[2]*University of Chemistry and Technology Prague, Technická 5, 166 28 Prague, Czech Republic*
[3]*Ophthalmology Clinic of the University Hospital Kralovske Vinohrady, Šrobárova 50, 100 34 Prague, Czech Republic*
[4]*Third Faculty of Medicine, Charles University, Ruská 87, 100 00 Prague, Czech Republic*
[5]*Institute for Environmental Studies, Faculty of Science, Charles University in Prague, Benátská 2, 110 00 Prague, Czech Republic*

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Abstract: Silicone oil (SO) is widely used as an intraocular tamponade in retinal detachment surgery; however, postoperative emulsification is associated with clinically relevant complications. In this work, we examine SO emulsification from a chemical engineering perspective, with emphasis on the physicochemical and interfacial mechanisms that govern droplet formation and stabilization in vitro. Specifically, we investigate biomolecule-driven effects at the oil–water interface using a model aqueous humor containing albumin and γ-globulins. Depending on the water-to-oil ratio, both oil-in-water and water-in-oil emulsions were formed. Protein-rich conditions markedly increased emulsion stability and substantially modified interfacial rheology. Interfacial viscoelasticity measurements with SO (971 mPa·s) indicated enhanced interfacial elasticity and structuring in the presence of proteins. In contrast, the interface between the model aqueous humor and higher-viscosity SO (4990 mPa·s) exhibited more dissipative behavior, despite a slightly higher complex modulus compared with SO (971 mPa·s). By comparison, inorganic salts and elevated temperature exerted only minor effects, whereas mechanical agitation was essential for emulsion formation. The generation of stable, small oil-in-water droplets suggests a plausible pathway for droplet transport into the anterior chamber and through the trabecular meshwork, potentially contributing to chronic inflammatory and intraocular pressure–related sequelae. Overall, these findings provide mechanistic insight into SO interfacial behavior in contact with biologically relevant fluids and underscore the central role of protein-mediated emulsification in the performance of intraocular biomaterials.