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Dynamics of E. Coli in silica nanoparticles

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Antimicrobial resistance is rapidly increasing worldwide, calling for alternative strategies beyond conventional antibiotics. Silica nanoparticles (SiO_2 NPs) are promising nanocarriers, but their impact on bacterial dynamics at relevant length and time scales remains insufficiently understood. Here, we combine Ultra Small-Angle X-ray Scattering (USAXS) and X-ray Photon Correlation Spectroscopy (XPCS) at ESRF to investigate the structure and dynamics of Escherichia coli in the presence of Stöber silica nanoparticles of ≈60 nm diameter, either bare ($nSiO_2$) or covalently functionalized with carbohydrate ligands (Glu1, Glu3, Man1, Gal6). Suspensions of E. coli (OD_{600} = 3.9, 1.17×10^9 cells/mL in phosphate buffer) were mixed with SiO_2 NPs at 0.01 g/L (3.3×10^{10} NPs/mL). USAXS profiles show no shift in the first minimum, indicating the absence of significant nanoparticle adsorption onto the bacterial surface, while in the intermediate-q range (≈0.06–0.6 nm^{-1}) the bacterial membrane signal is masked by silica scattering. Heterodyne XPCS analysis reveals Brownian-like dynamics ($\alpha \approx 1$) for all samples, with relaxation rates scaling linearly with q^2. Short-time diffusion coefficients remain unchanged within experimental uncertainty upon nanoparticle addition and are independent of the surface functionalization ($D_0 \approx 0.23–0.26$ $\mu m^2/s$), demonstrating that the global bacterial diffusion is not measurably perturbed under these conditions. By quantitatively connecting nanoscale structure and collective bacterial dynamics in situ, this combined USAXS–XPCS framework contributes to a more mechanistic understanding of how nanocarriers behave in biological media, thereby supporting the rational design of more effective nanomedicines.

Abstract Title

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