Confined Drug Organization in Fe_3O_4@Dextran Nanostructures: Effect of Nanocarrier–Drug Ratio

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Dextran-coated magnetite nanoparticles (Fe_3O_4@Dextran) represent a model hybrid confined molecular system in which drug molecules are spatially restricted within a polysaccharide shell and at the organic-inorganic interface. In this study, the influence of the Fe_3O_4@Dextran-to-drug ratio on molecular confinement, interfacial interactions, and structural organization was systematically investigated in order to elucidate the mechanisms governing ratio-dependent loading behavior.

Crystallite size analysis based on the Debye-Scherrer equation revealed a progressive decrease from 17.1 nm for Fe_3O_4@Dextran to 15.69 nm (D1) and 13.7 nm (D2), followed by a slight increase to 14.96 nm at the highest drug ratio (D3), indicating that drug incorporation limits crystal growth and that surface saturation is reached at higher loadings [1]. FTIR spectroscopy further confirmed the involvement of dextran hydroxyl groups and surface Fe-O sites in hydrogen bonding and coordination with drug molecules. Electron microscopy evidenced well-dispersed magnetic cores embedded in an amorphous dextran matrix, forming nanoscale cavities and interfacial domains that act as confinement sites. Variation of the Fe_3O_4@Dextran/drug ratio resulted in pronounced changes in adsorption efficiency, interfacial packing density, and molecular distribution within the polymer shell.

The ratio-dependent loading behavior is attributed to the balance between available surface binding sites, polymer chain mobility, and steric crowding effects under confined conditions [2]. At lower drug ratios, adsorption is dominated by specific hydrogen bonding and coordination to Fe-O and -OH groups, whereas at higher ratios, saturation of interfacial sites and confinement-induced packing led to cooperative and competitive interactions, in line with theoretical descriptions of molecular organization in restricted polymeric environments.

These findings demonstrate that molecular confinement within Fe_3O_4@Dextran nanostructures can be finely tuned by the nanoparticle-drug ratio, providing fundamental insight into structure-interaction-confinement relationships in soft-hard hybrid systems.

References

1. Karimova, A., Hajizada, S., Shirinova, H., Nuriyeva, S., Gahramanli, L., Yusuf, M. M., et al. Surface modification strategies for chrysin-loaded iron oxide nanoparticles to boost their anti-tumor efficacy in human colon carcinoma cells. J. Funct. Biomaterials, 2024, 15 (2), 43. doi:10.3390/jfb15020043
2. Najafipour, I., Emami, N., Sadeh, P., Amoli, A., Mosleh-Shirazi, S., Amani, A. M., et al. Synthesis of Fe_3O_4@ MIL-101-OH/Chitosan for adsorption and release of doxorubicin. Polym. Test.,2025, 142, 108659. doi:10.1016/j.polymertesting.2024.108659