Agarose-mesoporous silica composite systems for controlled drug delivery

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Controlled drug delivery remains a major challenge in the design of advanced therapeutic systems, particularly due to the difficulty in achieving sustained and predictable release profiles. Among various carriers, mesoporous silica materials are highly valued for their large surface area, tunable pore size, and the possibility of functionalization. However, they are often associated with rapid burst release effect, which can lead to suboptimal therapeutic outcomes [1]. To overcome this limitation, the incorporation of such systems into hydrogel matrices has gained increasing attention, as hydrogels can introduce an additional diffusion barrier, enabling more control over drug release while offering high water content and biocompatibility [2,3].
In this study, mesoporous silica materials were synthesized via a sol-gel condensation approach based on the controlled hydrolysis and condensation of tetraethoxysilane as a silica precursor, and co-functionalized with various organic groups introduced during the synthesis. A comprehensive physicochemical characterization was performed using scanning electron microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), nitrogen adsorption-desorption measurements, and elemental analysis, confirming the successful synthesis and functionalization of the materials. The obtained materials were loaded with diclofenac sodium (DICL) as a model drug for further release tests. The burst effect was observed, indicating rapid desorption of DICL from the silica surface and limited control over the release kinetics. To address this, we proposed a composite delivery platform by incorporating drug-loaded mesoporous silica within an agarose hydrogel matrix. Rheological analysis confirmed the formation of mechanically stable hydrogel networks to limit the burst release effect, and providing a prolonged DICL release.

References:

[1] R. Fatima, P. Katiyar, K. Kushwaha, *Front. Nanotechnol.,* 2025, 7, 1564188.
[2] F.V. Lavrentev, V.V. Shilovskikh, V.S. Alabusheva, V.Y. Yurova, A.A. Nikitina, S.A. Ulasevich, E.V. Skorb, *Molecules,* 2023, 28, 5931.
[3] N.H. Thang, T.B. Chien, D.X. Cuong, *Gels,* 2023, 9, 523.

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