

Design and Optimization of Electrostatically Assembled Protein-Polysaccharide Nanostructures for Nutrient and Drug Delivery Systems

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INTRODUCTION & AIM

Biopolymer-based nanostructures, formed through the self-assembly of proteins and polysaccharides, offer a versatile and sustainable platform for the encapsulation and delivery of bioactive small molecules. Owing to their biocompatibility, biodegradability, and non-toxic nature, as well as their eco-friendly preparation routes, these materials are highly attractive for applications across food technology and biomedical science.

Aim: To design, fabricate, and characterize protein-polysaccharide nanocarriers by biocompatible self-assembly methods with controlled physicochemical properties for the efficient and stable delivery of functional bioactives.

METHOD

A biocompatible method without any added reagent consisted of electrostatic complexation at pH where protein and polysaccharide are of opposite charge and subsequent thermal treatment for protein-protein aggregation. Static, dynamic and electrophoretic light scattering, small-angle neutron/X-ray scattering, microscopy, and spectroscopy (ATR-FTIR, fluorescence, UV-Vis) were used to characterize nanostructure formation, morphology, and the encapsulation behavior of hydrophobic compounds.

RESULTS & DISCUSSION

Small-angle neutron scattering (SANS) was used to probe the internal structure of chondroitin sulfate-bovine serum albumin nanoparticles stabilized by thermal treatment (Fig. 1). SANS revealed internal rearrangements and protein morphology changes under varying solution conditions. Analysis with a three-level hierarchical Guinier/power-law model identified BSA globules, clusters of globules, and larger aggregates [1]. The biocompatible method using electrostatic complexation at acidic pH followed by thermal treatment produced xanthan gum/BSA nanoparticles with well-defined size and molar mass, stable at higher pH. Thermal treatment alters BSA secondary structure, while nanoparticles retain hydrophobic domains and pH-dependent charge. Xanthan-BSA nanoparticles effectively bind (Fig.2) and protect curcumin at neutral pH, demonstrating XG's potential for protein-based bioactive nanocarriers [2]. Chondroitin sulfate-hemoglobin nanoparticles (Fig. 3) where proved to have spherical shape by TEM [3].

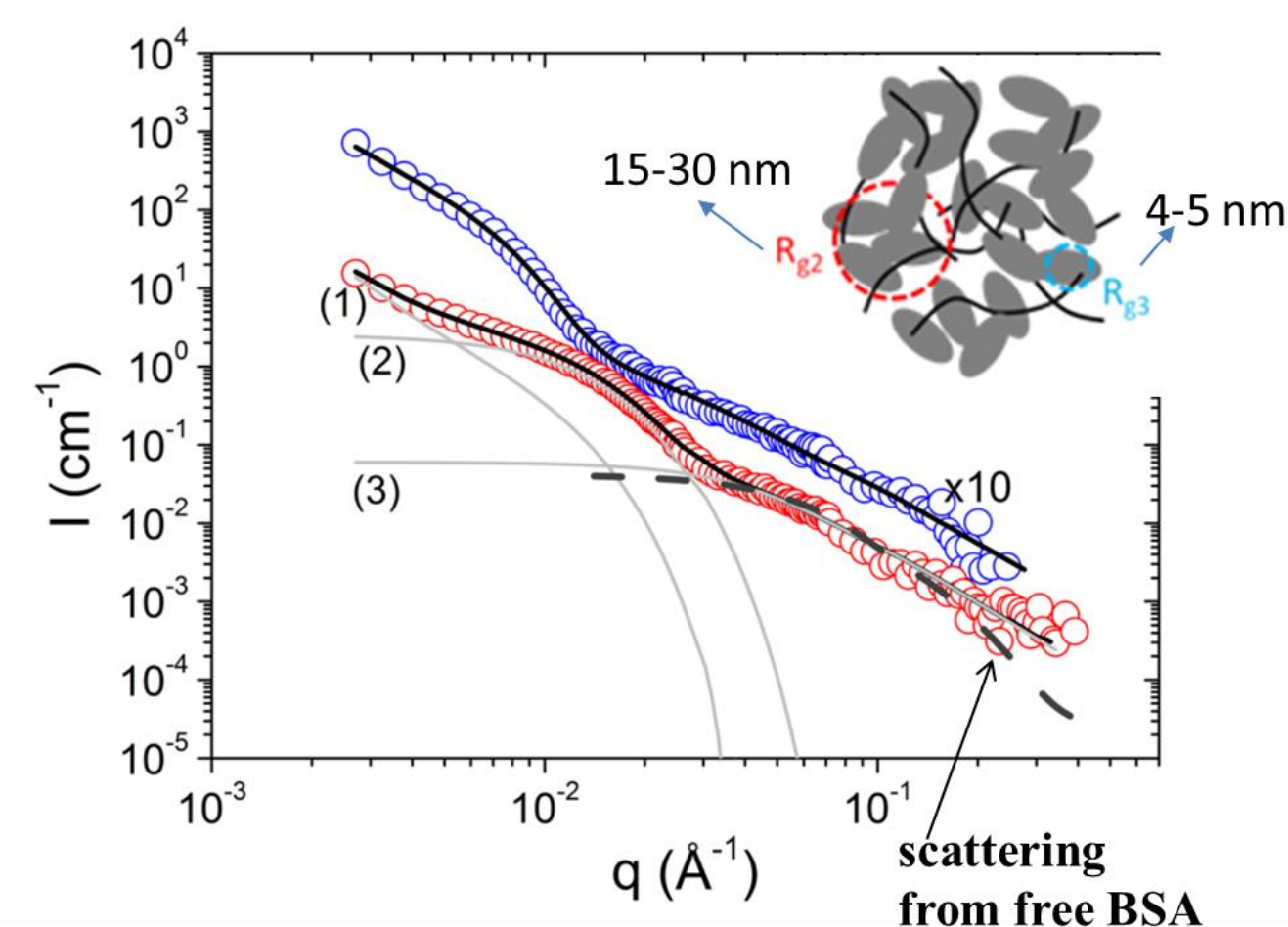


Figure 1 Hierarchical structure obtained by SANS in chondroitin sulfate/BSA nanoparticles with low (red) and high (blue) chondroitin sulfate content stabilized by thermal treatment [1].

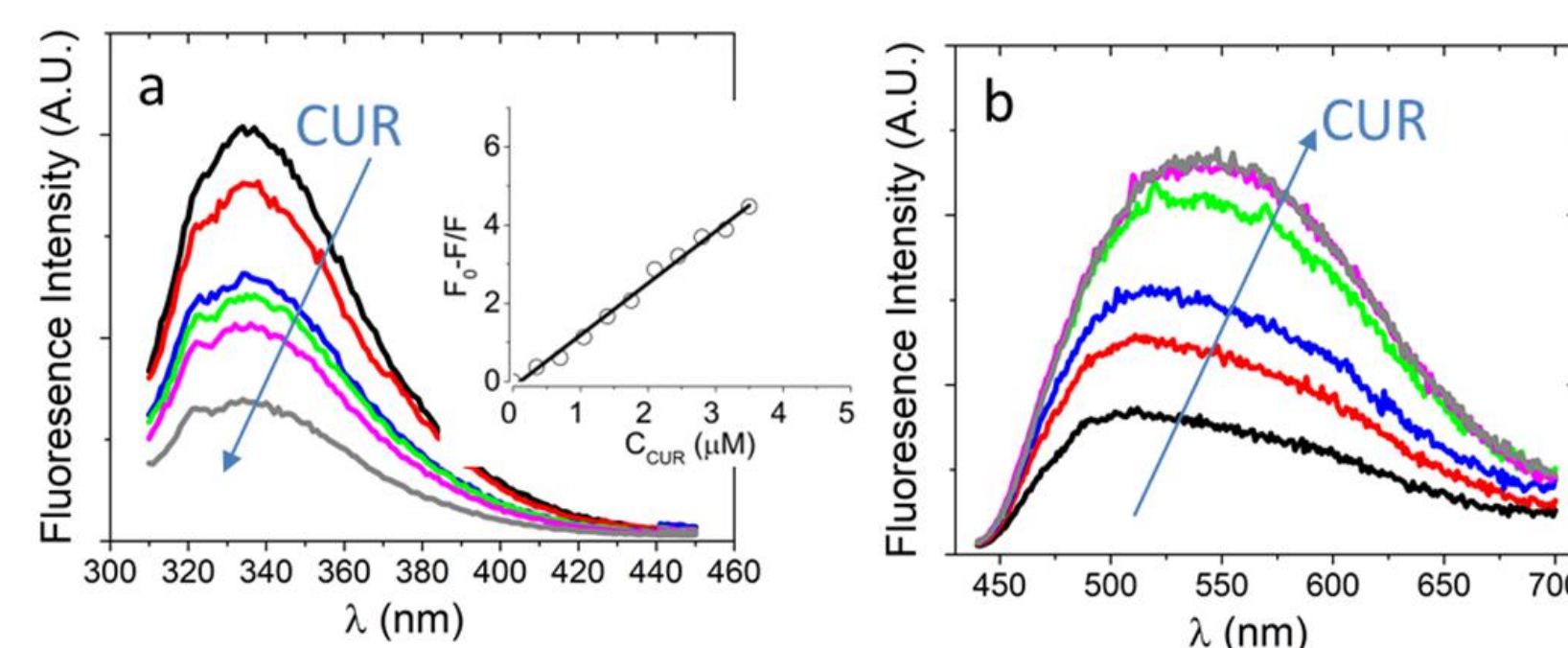


Figure 2 (a) Tryptophan fluorescence and (b) curcumin fluorescence upon binding of curcumin on thermally stabilized xanthan-BSA nanoparticles [2].

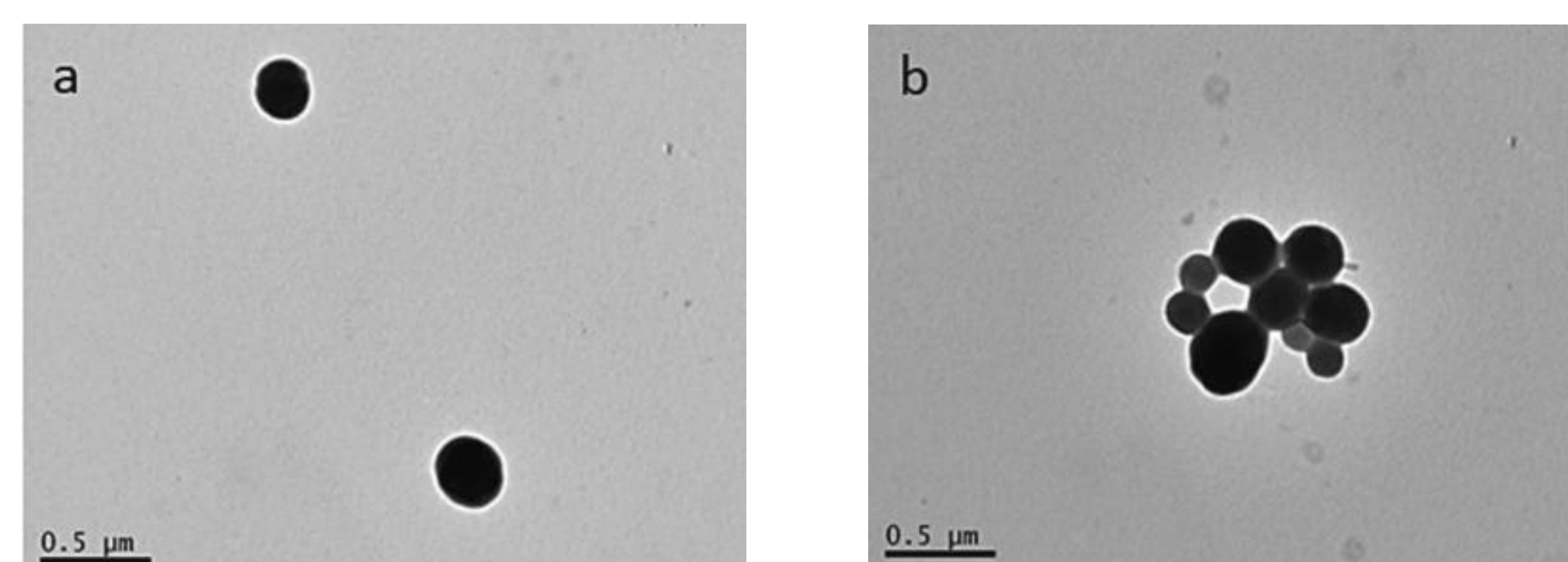


Figure 3 TEM images of chondroitin sulfate-hemoglobin nanoparticles (a) and their aggregates (b) [3].

FUTURE WORK / REFERENCES

Future work:

- Test encapsulation and release of diverse nutraceuticals and drugs.
- Evaluate bioavailability, cellular uptake, and targeted delivery in vitro and in vivo.
- Investigate scalability and reproducibility for industrial applications.

References:

- [1] [Carbohydrate Polymers, 218, 2019, 218-225](#)
- [2] [Carbohydrate Polymer Technologies and Applications, 2, 2021, 100075](#)
- [3] [Biophysical Chemistry 304, 2024, 107127](#)

CONCLUSION

- Protein-polysaccharide nanostructures can be fine-tuned through protein-to-polysaccharide ratio, pH, and thermal treatment.
- Optimization of these parameters enhances nanoparticle stability and encapsulation efficiency for hydrophobic compounds.
- Composition and structure of the nanocarriers critically influence their affinity for bioactive molecules.
- These insights provide a rational framework for designing biopolymer-based delivery systems for nutraceutical and pharmaceutical applications.