Intestinally Retentive Redox Nanocarriers with Enzyme-Mimetic Function for in Gut Inflammation

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Uncontrolled accumulation of oxygen species is a key driver of chronic inflammation and epithelial degradation in gut inflammation. To address this pathological oxidative overload, we introduce an ingestible nano-intervention featuring a hierarchically porous silica matrix, embedded with ultrasmall cerium-based catalytic domains and coated with a polyphenol-derived interface. This multifunctional construct leverages defect-oriented carbon processing to strategically enhance electron exchange capabilities, transforming it into a highly responsive redox-balancing entity. Through tailored thermal modification, the structure achieves an optimized Ce^{3+}/Ce^{4+} configuration and a high density of oxygen coordination vacancies, enabling enzyme-mimetic activity akin to natural antioxidants. Insights from X-ray spectroscopic profiling and first-principles simulations confirm the restructured local environment critical to its elevated reactivity. Prior to in vivo evaluation, the therapeutic efficacy and redox-regulating capacity of this nanosystem were first validated using gut-like organoid models, where it effectively mitigated oxidative stress under oxidative insults. In a chemically induced gut inflammation mouse model, this system further demonstrated robust retention at inflamed intestinal sites, attenuated redox-driven tissue injury, and promoted epithelial repair. Altogether, our findings demonstrate a defect-engineered intestinal nano-intervention with strong potential for reshaping redox dynamics in gastrointestinal inflammatory disorders.

References

[1] E. Jeon, J. Kim, D. Kim, S. H. Song, J. Y. Lim, J. H. Park, H. J. Kim, K. D. Nam, J. W. Kim, J. H. Choi, J. Y. Lee, S. Y. Park, Adv. Healthcare Mater. 11 (2022) 2200389.
[2] J. Liu, B. Di, L. L. Xu, Cytokine Growth F. R. 71–72 (2023) 1–12.

Figures

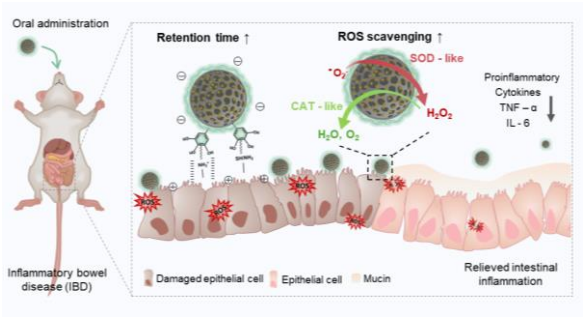

Figure 1: Schematic diagram highlighting their prolonged retention, superoxide dismutase (SOD)- and catalase (CAT)-like reactive oxygen species (ROS) scavenging, and reduction of inflammatory markers and tissue damage in IBD.