

Calcium Ions-Modified Probiotics Reconfigure the Intestinal Niche via Biofilm Transformation

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Abstract

Excessive *Desulfovibrio* (Des) forms biofilm to enable dominant occupation of the intestinal niche, representing a common pathogenic driver of multiple inflammatory bowel disease (IBD) types. Colonization resistance constitutes the primary barrier to antagonistic probiotic efficacy, and this is driven by the pathogen-favorable microenvironment established by Des. Here, probiotic *Lactiplantibacillus* (Lap) is modified by calcium ions (Ca²⁺) and calcium-regulative polyphenol (kaempferol-3-O-rutinoside, KAE) via coordinate interaction to achieve intestinal niche reconfiguration. Targeting the tripartite mechanisms of Des-mediated colonization resistance, the Ca²⁺/KAE@Lap platform optimized niche competition through Ca²⁺-bridged interfacial binding with directional bactericidal activity, and this enables bacterial replacement at occupied sites. Ca²⁺/KAE@Lap reestablishes calcium homeostasis disrupted by Des via synergistic Ca²⁺/KAE regulation, dually restoring epithelial energy metabolism and mucus layer reconstitution, counteracting Des-induced colonized sites contraction and regenerated site impairment. This drives phenotypic shift in biofilm composition from Des-dominated to Lap-enriched consortia, which is concomitant with the redirection of intestinal colonization resistance from a pathogen-permissive to a probiotic-favored state. This calcium-based biofilm transformation strategy overcomes the transient colonization limitation inherent in conventional probiotic therapies by effectively disrupting colonization resistance in IBD treatment.

References

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