Developing Robust Probiotic Delivery Systems: Evaluating and Enhancing Emulsification-Based Microencapsulation Techniques for Gastrointestinal Survival and Release

He, Ethan (School: Signature School)

Despite their widespread use in the food and healthcare industries, probiotics often die during storage and digestion and reduced therapeutic efficacy due to their environmental sensitivity, necessitating protective strategies like microencapsulation. While many studies have investigated individual microencapsulation techniques, the lack of comprehensive, standardized comparisons has prevented progress in determining optimal techniques for industrial applications. This study evaluated four emulsification-based microencapsulation methods using 3% soy protein isolate (SPI): water-in-oil-in-water (W/O/W) emulsion (MD), emulsion-based external gelation (ME), water-in-oil emulsion with pectin (MS), W/O/W emulsion with pectin (MDP), and introduced a novel hybrid W/O/W emulsion with external gelation (MDE) designed to maximize probiotic protection in digestion. Microparticle size distribution, encapsulation efficiency, storage stability, and enhancement of Lactobacillus rhamnosus GG (LRGG) viability in 8-week storage and simulated gastrointestinal digestion (2 hours gastric, 4 hours intestinal) were assessed. MD, ME, MDP, and MDE samples significantly improved LRGG viability by 67% versus free LRGG in storage. Externally gelled particles (ME, MDE) showed 30% higher LRGG viability than double emulsion microparticles (MD) after digestion. In contrast, MS and the addition of pectin in W/O/W emulsions (MDP) did not improve probiotic survival. These results reveal critical limitations in current SPI-pectin and liquid-based microencapsulation systems, and highlight SPI-based ME's and MDE's potential as robust, economical probiotic delivery systems, providing directions for future industrial microencapsulation strategies.

Awards Won: