From Nature’s nano-Secrets to Next-Level Innovations: Microalgal Extracellular Vesicles for Pharmaceutical and Cosmetic Applications

Extracellular vesicles (EVs) represent a frontier in nanomedicine, offering significant promise as natural vehicles for delivering both endogenous and exogenous bioactive compounds. However, challenges related to scalability and cost-effectiveness limit their broad therapeutic application. To address these limitations, our group has developed a sustainable and renewable platform centered on “nanoalgosomes”, a novel class of EVs derived from microalgae. Building on our foundational work establishing their biophysical and biological properties, this study explores their potential as a versatile therapeutic platform. We evaluated the intrinsic bioactivities of nanoalgosomes, their in vivo biocompatibility and effects, and their capacity for exogenous loading of therapeutic compounds. In vivo studies in mouse models confirmed their excellent biocompatibility and revealed a distinct biodistribution profile, most notably a strong tropism for bone tissue. Crucially, we demonstrated that nanoalgosomes can be successfully engineered to function as advanced delivery systems. They were efficiently loaded with chemotherapeutic agents, such as doxorubicin, and nucleic acids, like siRNA, enhancing the functional efficacy of the loaded cargo. Furthermore, in vitro skin model assessments revealed that nanoalgosomes possess significant antioxidant, anti-inflammatory, photoprotective, and anti-melanogenic properties, highlighting their inherent value for dermocosmetic applications. These findings establish nanoalgosomes as a potent and versatile bio-based platform, unlocking a direct pathway from nature's nanotechnologies to the development of next-level innovation for both the pharmaceutical and cosmetic industries.