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Repurposing milk components into functional nanoplatforms



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Milk is a naturally occurring, biocompatible, and widely consumed source of supramolecular structures that can be repurposed as nanocarriers for bioactive compounds. In this study, we investigate the concept of “deconstructing” milk into its main colloidal components—exosomes, casein micelles, and milk fat—derived nanoparticles—and reassembling them as versatile encapsulation platforms. Bovine milk exosomes were isolated and characterized as lipid bilayer vesicles capable of functionalization and targeted delivery to specific cells. Both native and restructured casein micelles were evaluated as protein-based nanocarriers with high binding capacity, offering gastric stability and potential as nutraceuticals. In parallel, nanoparticles derived from milk fat globules (MiGlon) and their membrane fractions were developed as lipid carriers for poorly water-soluble compounds, combining high loading efficiency with oxidative protection. Comparative analyses reveal that differences in composition, size, surface chemistry, and biological origin result in distinct encapsulation mechanisms and preferred administration routes. These findings demonstrate that milk-derived nanostructures provide a coherent, scalable, and food-grade toolbox of carriers that can be tailored for targeted delivery, enhanced bioavailability, and controlled release. This “dairy-to-nano” strategy opens new opportunities for designing safe, sustainable nanocarriers for functional foods, nutraceuticals, and drug-delivery applications.

Short Bio

Claudia Nunes (CN) completed her PhD in Pharmaceutical Sciences – Medicinal and Therapeutic Chemistry (FFUP) in 2011, followed by a five-year postdoc at LAQV-REQUIMTE, supported by FCT fellowships. She secured an FCT Investigator position in 2016 and, in 2022, became an assistant researcher under CEEC.

CN works at the interface of nanomedicine, biophysics, and drug delivery, exploring how molecular interactions at biological membranes can be used to design the next generation of therapeutics. Thus, CN's research focuses on drug–membrane interactions using biomimetic models and biophysical techniques, alongside the development of colloidal nanomedicine systems. CN has extensive experience in the design, development, and physicochemical characterization of lipid-based nanoparticles, including liposomes, solid lipid nanoparticles (SLNs), and nanostructured lipid carriers (NLCs), for drug delivery applications. CN focuses on understanding how the composition, structural organization, and surface properties of nanoparticles influence stability, drug encapsulation, and interactions with biological membranes. CN applies a range of biophysical and analytical techniques to optimize nanosystems for improved therapeutic performance. A key aspect of CN research is the use of sustainable, biocompatible sources to reduce environmental impact while maintaining high functionality. This includes exploring naturally derived lipids and renewable materials as alternatives to conventional synthetic components, aligning nanomedicine development with principles of green chemistry and sustainability.

CN has co-authored over 115 peer-reviewed papers and 7 book chapters (h-index 315 >4300 citations), with a strong presence in Q1 journals. She has supervised numerous students, including 1 postdoc, 4 PhDs, and 15 MScs. She also supervised more than 10 research trainees, during their graduation. Additionally, she has been involved in mentoring and tutoring many foreign students in mobility programs.

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