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ORIGINAL RESEARCH

# Multilayer biopolymer/poly(ε-caprolactone)/polycation nanoparticles

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**Abstract**
Combining two or more materials for carrier construction is one of the topical approaches to avoid/diminish deficiencies and to increase functionality in delivery systems for bioactive compounds. In this context, here, multilayered nanoparticles comprising both natural (atelocollagen—AteCol; hyaluronic acid derivative—HA) and synthetic [poly(ε-caprolactone)—PCL; polyethylenimine—PEI; poly(L-lysine)—PLL] polymers were prepared and characterized. The combination of a modified double-emulsion method with polymer modification reactions allowed improvement of the polymer particle's functionality. Fourier transform infrared spectroscopy (FTIR), UV–Vis spectroscopy, fluorescence spectroscopy, dynamic light scattering, transmission/scanning electron microscopy and fluorescence microscopy investigations confirmed the obtention of the envisaged nanomaterials with the expected composition and structure. The double-layered biopolymer/PCL-based nanoparticles formed in a first synthesis step could be successfully coated with PEI and PLL. The gel electrophoresis assay attested the DNA packing ability of the formed nano-vehicles involving surface grafting of the former biopolymer/PCL-based nanoparticles in the case of both cationic polymers, for N/P ratios of 10 (PEI coating) and 3.5 (PLL coating), respectively. According to the FTIR registration, the protein's native form was preserved. Considering the advantage of biocompatibility and high versatility (controlled size, tuned chemistry and biodegradation rate) some of the resulted nanomaterials may appear as potential candidates for biomedical uses (i.e., drug/gene delivery and tissue engineering).

**Keywords** Nanocapsules · Biomaterials · Atelocollagen · Cationic polymers · Grafting · Non-viral gene delivery

## Introduction

To alleviate the drawbacks of current methods of bioactive agent's delivery and to reach more control in therapy's administration by achievement of multifunctionality and performances required by this application domain, most recent research efforts were dedicated to the development of biomimetic materials, making use of the advances in the world of micro- and nanomaterial technology [1, 2]. Micro- and nanoparticles (NPs) became some of the most studied classes of carrier systems toward the design of bio-inspired multifunctional vehicles [3]. The increased interest for nanoparticulate systems is related to the large range of applications (cosmetics, pharmaceutics, electronics, agriculture, nanomedicine, food, etc.), which gave rise to the elaboration of a variety of fabrication methods and techniques, aiming to make their production possible at industrial level [4, 5]. The selection of the nanoparticulate materials, that are safe and effective in loading/delivery of therapeutic agents, is a real challenge. In this context, the use of biopolymers seems to play a pivotal role, collagen and hyaluronic acid being the favored ones [6, 7]. Due to its biocompatibility, biodegradability, low immunogenicity, non-antigenicity, availability and reach chemistry, collagen has found success in a broad range of biomedical applications. Its applications encompass drug/gene delivery, tissue engineering, development of bioactive wound and burn dressings, sutures, haemostatic agents, etc., or in combination with other biopolymers or different synthetic polymers [8–10]. The less immunogenic version atelocollagen (AteCol), obtained by removal of antigenic epitopes from collagen, due to its increased purity, reproducibility, water solubility and processing ability, replaced the originating protein successfully in some biomedical uses [11, 12].

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