

From Nature to Nanotherapeutics: Engineering Advanced Delivery Systems for Next-Generation Medicine

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Abstract:

Nature-derived bioactive compounds represent a vast and largely untapped reservoir of therapeutic agents with significant potential for next-generation medicine. This talk presents an integrated perspective on green nanomedicine, highlighting how nanoscale engineering can overcome intrinsic limitations of phytochemicals such as poor solubility, low bioavailability, insufficient tumor targeting, and rapid degradation. By combining natural products with advanced nanodelivery platforms—including polymeric nanoparticles, metal oxide nanostructures, host-guest macrocyclic systems, dendrimers, and lipid-based nanovesicles—novel hybrid therapeutics can be developed that enhance stability, cellular uptake, and anticancer efficacy while minimizing systemic toxicity.

Several case studies from our research program illustrate these principles. Chitosan-coated boswellic-acid-enriched nanoparticles loaded with platinum drugs demonstrated diffusion-controlled release, enhanced cellular internalization, and significant apoptosis induction in colorectal cancer models. Green-synthesized ZnO nanoparticles carrying Asplatin showed improved cytotoxicity and tumor-selective release under acidic microenvironmental conditions. Essential oils from *Pistacia lentiscus* encapsulated in niosomal vesicles exhibited sustained release, increased apoptosis, and cell-cycle arrest in breast and ovarian cancer lines. Host-guest inclusion complexes using cucurbit uril dramatically improved the solubility and cytotoxic potency of psoralidin, while multifunctional PAMAM dendrimers co-delivering polyphenols and chemotherapeutics produced synergistic anticancer activity.

Collectively, these findings demonstrate that nature-inspired nanotherapeutics provide a versatile platform for designing sustainable,

targeted, and highly effective anticancer strategies. By bridging phytochemistry, supramolecular chemistry, and nanotechnology, this approach offers a promising route toward safer precision oncology and environmentally responsible drug development.