

Herbal Nanotechnology: A Modern Approach to Traditional Medicine – A Review

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ABSTRACT:

Traditional herbal medicines have been widely utilized for disease prevention and treatment for centuries. However, their clinical effectiveness is often limited by poor aqueous solubility, low bioavailability, instability, and inadequate tissue targeting. **Objective:** This review aims to evaluate the role of nanotechnology in enhancing the therapeutic potential of herbal medicines and to summarize recent advancements in nano-herbal drug delivery systems. **Methods:** A comprehensive literature review was conducted using published articles, review papers, and scientific databases focusing on herbal nanotechnology, nanocarrier systems, phytopharmaceuticals, and nano-enabled drug delivery approaches. **Results:** Various nanocarrier systems, including polymeric nanoparticles, solid lipid nanoparticles, magnetic nanoparticles, liposomes, dendrimers, nanocrystals, nanospheres, and nanocapsules, have demonstrated significant improvements in the solubility, stability, bioavailability, controlled release, and targeted delivery of herbal compounds. These systems have shown promising applications in cancer therapy, inflammatory diseases, infectious disorders, cardiovascular diseases, and personalized medicine. **Conclusion:** Herbal nanotechnology bridges traditional medicine and modern pharmaceutical science by overcoming the limitations of conventional herbal formulations. Continued advancements in formulation strategies, quality control, and regulatory frameworks are expected to facilitate the clinical translation and commercialization of nano-herbal therapeutics.

Keywords: *Herbal Nanotechnology, Nanocarriers, Phytopharmaceuticals, Drug Delivery Systems, Traditional Medicine, Green Nanotechnology, Bioavailability Enhancement.*

INTRODUCTION:

Herbal medicines have been integral components of healthcare systems since ancient civilizations. Unlike conventional synthetic medicines that generally contain a single active ingredient, herbal formulations consist of multiple bioactive compounds that often act synergistically

to produce therapeutic effects. Despite their widespread use, many herbal drugs face significant challenges including poor water solubility, low absorption, chemical instability, rapid metabolism, and inconsistent bioavailability. These limitations reduce therapeutic efficacy and restrict their clinical application.

Nanotechnology has emerged as a revolutionary approach to overcome these barriers. By incorporating herbal bioactive compounds into nanoscale delivery systems, researchers can improve drug solubility, stability, targeted delivery, and controlled release. Nano-formulations can enhance tissue penetration, protect phytoconstituents from degradation, and reduce toxicity while improving therapeutic outcomes.



Figure 1. Nanocarrier

MATERIALS AND METHODS:

Literature Search Strategy:

A comprehensive review of the literature was conducted using scientific journals, review articles, textbooks, and electronic databases focusing on herbal nanotechnology and nano-based drug delivery systems.

Inclusion Criteria:

The review included:

- Studies related to herbal nanoparticle formulations.
- Research on nanocarrier-based delivery of phytoconstituents.
- Articles describing advantages, limitations, and applications of nano-herbal medicines.
- Publications addressing green synthesis and regulatory considerations.

Data Collection and Analysis:

Information was collected and analyzed under the following categories:

- History and development of herbal nanotechnology.
- Types of nanocarriers.

Recent advances in nanomedicine have facilitated the development of novel herbal formulations such as nanoparticles, liposomes, nano emulsions, phytosomes, nanomicelles, and dendrimers. These innovations have significantly expanded the therapeutic potential of traditional medicines and support their integration into modern healthcare systems.

- Advantages of nano-herbal delivery systems.
- Therapeutic applications.
- Challenges and future perspectives.

RESULTS:

Historical Development of Herbal Nanotechnology:

Medicinal plants have been used since ancient times in traditional systems such as Ayurveda, Traditional Chinese Medicine, and indigenous healing practices. Scientific advancements during the nineteenth and twentieth centuries enabled the isolation of active phytoconstituents and their incorporation into modern dosage forms.

Recent developments in nanotechnology have further transformed herbal therapeutics by facilitating the design of nanoscale delivery systems capable of improving the pharmacological performance of plant-derived compounds.

Common Herbal Medicines and Therapeutic Uses:

Several medicinal plants continue to play important roles in healthcare:

Herbal Drug	Therapeutic Uses
Echinacea	Immune enhancement and respiratory infections
Ginger	Anti-inflammatory, digestive aid, antiemetic
Chamomile	Anxiety relief, sleep promotion, digestive support

Turmeric	Anti-inflammatory and antioxidant activities
Garlic	Cardiovascular protection and antimicrobial effects
Dandelion	Liver support and diuretic activity
Licorice Root	Respiratory and gastrointestinal disorders

Table: 1 Herbal Medicines and Therapeutic Uses

Advantages of Nano-Herbal Drug Delivery Systems:

Nano-herbal delivery systems provide several benefits:

- Enhanced permeation and retention (EPR) effect.
- Improved bioavailability and absorption.
- Reduced dosage requirements.
- Targeted delivery to diseased tissues.
- Controlled and sustained drug release.
- Increased stability of phytoconstituents.
- Reduced toxicity and side effects.
- Improved pharmacokinetic profiles.

Types of Nanocarriers Used in Herbal Drug Delivery:

- **Polymeric Nanoparticles:** Biodegradable carriers composed of polymers such as chitosan, alginate, gelatin, and PLGA. They provide controlled release and protection of herbal compounds.
- **Solid Lipid Nanoparticles (SLNs):** Lipid-based nanosystems that improve stability, bioavailability, and intestinal absorption of hydrophobic herbal drugs.
- **Magnetic Nanoparticles:** Iron oxide-based carriers capable of targeted drug delivery under external magnetic fields.
- **Metal and Inorganic Nanoparticles:** Gold, silver, silica, and zinc oxide nanoparticles exhibiting antimicrobial, antioxidant, and anticancer properties.
- **Quantum Dots:** Semiconductor nanocrystals used for imaging, diagnostics, and theragnostic applications.

- **Polymeric Micelles:** Self-assembled nanostructures that enhance solubility and delivery of hydrophobic phytoconstituents.
- **Phospholipid Micelles:** Biomimetic systems that improve membrane permeability and oral absorption.
- **Colloidal Nano-Liposomes:** Lipid bilayer vesicles capable of encapsulating both hydrophilic and lipophilic herbal compounds.
- **Dendrimers:** Highly branched macromolecules with high drug-loading capacity and precise targeting capability.
- **Nanocrystals:** Pure nanosized drug particles designed to improve dissolution and bioavailability.
- **Nanospheres:** Matrix-type nanoparticles that provide sustained release and improved stability.
- **Nanocapsules:** Core-shell structures that protect herbal compounds and allow targeted delivery.

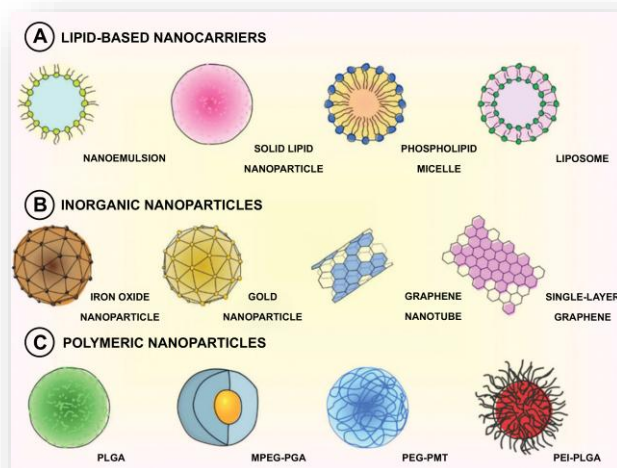


Figure 2. Classification of Nano-Technology

Applications of Herbal Nanotechnology:

The literature revealed extensive applications of nano-herbal systems:

- **Cancer Therapy:** Nano formulations improve targeting of anticancer phytochemicals such as curcumin,

enhancing therapeutic efficacy while minimizing toxicity.

- **Anti-inflammatory Therapy:** Nano-herbal systems improve the delivery of anti-inflammatory phytoconstituents and enhance treatment outcomes.
- **Cardiovascular Disorders:** Nano-encapsulation improves bioavailability and therapeutic effects of cardioprotective herbal compounds.
- **Infectious Diseases:** Nanoparticles enhance antimicrobial activity and targeted delivery of herbal antimicrobials.
- **Neurological Disorders:** Nanocarriers facilitate crossing of biological barriers such as the blood-brain barrier, improving treatment of neurological conditions.
- **Personalized Medicine:** Nano-herbal systems support individualized treatment approaches through targeted and controlled drug delivery.

DISCUSSION:

The findings of this review indicate that nanotechnology has significantly advanced the field of herbal medicine by addressing major limitations associated with conventional herbal formulations. Most phytoconstituents suffer from poor aqueous solubility, low stability, and limited bioavailability, which restrict their therapeutic effectiveness.

Nanocarrier systems effectively overcome these barriers by enhancing drug solubility, protecting bioactive compounds from degradation, improving pharmacokinetics, and enabling targeted delivery. Among the various systems, polymeric nanoparticles, liposomes, and solid lipid nanoparticles have demonstrated particularly promising results in improving herbal drug performance.

Green synthesis approaches further contribute to sustainable nanotechnology development by utilizing plant-derived materials for

nanoparticle production while minimizing environmental impact.

Despite these advantages, several challenges remain, including large-scale manufacturing, standardization of herbal extracts, safety evaluation, quality control, and regulatory approval. Future research should focus on clinical validation, long-term toxicity studies, and development of globally accepted regulatory frameworks.

The convergence of traditional medicine and nanotechnology represents an important step toward scientifically validated and personalized herbal therapeutics.

CONCLUSION:

Herbal nanotechnology represents a transformative approach that integrates traditional medicinal knowledge with advanced pharmaceutical technologies. Nano-based delivery systems successfully address major challenges associated with herbal medicines, including poor solubility, instability, and low bioavailability.

Various nanocarriers such as polymeric nanoparticles, liposomes, solid lipid nanoparticles, dendrimers, nanocrystals, and nanocapsules have demonstrated significant potential in enhancing therapeutic efficacy, improving targeted delivery, and reducing adverse effects.

With continued advancements in nanomedicine, standardization, and regulatory support, herbal nanotechnology is expected to play a vital role in the future development of safe, effective, and personalized healthcare solutions.

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