INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Nano Herbal Drug Delivery System: Bridging Ayurveda and Nanotechnology

Sakshi Waje*, Ashwini Ippar, Riya Zole, Appasaheb Kuhile

SND college of pharmacy Babhulgaon.

ARTICLE INFO

Published: 08 Oct 2025
Keywords:
Nano herbal drug delivery system, Ayurveda, Nanotechnology, Phytochemicals, Nanocarriers, Bioavailability
DOI:
10.5281/zenodo.17295184

ABSTRACT

Ayurveda, the ancient Indian system of medicine, emphasizes holistic health through plant-derived natural substances known for their therapeutic potential and minimal side effects. Despite their benefits, conventional herbal medicines face challenges such as poor solubility, low bioavailability, instability, and limited target specificity, reducing clinical efficacy. This review highlights how nanotechnology can address these limitations by integrating with Ayurveda to develop Nano Herbal Drug Delivery Systems (NHDDS). Nanocarriers, including liposomes, niosomes, solid lipid nanoparticles, nanoemulsions, and microspheres, enhance solubility, stability, controlled release, and targeted delivery of bioactive phytochemicals such as curcumin, ashwagandha, tulsi, and neem. Recent advances, including artificial intelligence-assisted formulation design and green synthesis methods, further improve therapeutic outcomes and promote sustainability. The convergence of ancient Ayurvedic knowledge with modern nanoscience offers a promising platform for developing safer, more effective, and globally acceptable herbal therapies, bridging traditional wisdom with contemporary pharmaceutical innovation.

INTRODUCTION

Ayurveda emphasizes holistic health using natural plant-derived substances. Herbal medicines are widely recognized for their therapeutic potential, minimal side effects, and cultural acceptance. However, limitations such as poor solubility, low bioavailability, instability, and lack of target specificity restrict clinical efficacy.

Nanotechnology, dealing with particles sized 1–100 nanometers, offers strategies to enhance solubility, stability, controlled release, and targeted delivery of phytochemicals. Integration of Ayurveda with nanotechnology has led to Nano Herbal Drug Delivery Systems (NHDDS), improving therapeutic outcomes and global acceptance.

***Corresponding Author:** Sakshi Waje
Address: *SND college of pharmacy Babhulgaon.*
Email ✉: dattuwaje1972@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

India, known as the "Botanical Garden of the World," has a rich legacy of medicinal plant knowledge. Phytochemicals produced by plants exhibit antibacterial, antifungal, antioxidant, and anticancer effects. Despite these advantages, herbal drugs often face reduced bioavailability due to poor solubility, low absorption, and lack of target specificity.

This review provides a comprehensive overview of NHDDS, highlighting their potential to overcome conventional herbal medicine limitations and integrate traditional Ayurveda with modern nanotechnology.

Ayurveda: Historical Background and Significance:

Ayurveda, often referred to as the "Science of Life," is an ancient system of medicine that originated in India over 5000 years ago. It encompasses a holistic approach to health and well-being, emphasizing the balance between the mind, body, and spirit. Its roots are deeply embedded in the Vedic scriptures, including the Atharva Veda, Rig Veda, and Yajur Veda, where early references to medicinal plants, healing practices, and lifestyle management can be found. Over the centuries, Ayurveda has evolved into a comprehensive medical system with well-documented principles for diagnosis, prevention, and treatment of diseases. Central to Ayurveda is the concept of Panchakarma, a series of detoxification procedures designed to cleanse and rejuvenate the body, mind, and consciousness. Ayurveda also identifies five basic elements (Panchamahabhutas)—earth, water, fire, air, and ether—which combine in varying proportions to form the three doshas: Vata, Pitta, and Kapha. These doshas regulate the physiological, mental, and emotional functions of the human body. Each dosha has five sub-doshas that govern specific bodily functions, such as circulation, digestion, metabolism, and cellular activities. Ayurveda not only emphasizes herbal remedies but also incorporates diet, lifestyle, yoga, meditation, and therapeutic procedures to maintain health and prevent disease. Its holistic approach considers individual constitution (Prakriti), environmental factors, and seasonal variations in health management. The knowledge of medicinal plants in Ayurveda has been instrumental in the development of modern pharmacology. Historical texts describe the preparation of herbal formulations, identification of active phytochemicals, and their therapeutic applications.

Ayurvedic knowledge of medicinal plants has been crucial throughout human evolution. Notable plant-derived drugs include

1. Digoxin from Digitalis spp.
2. Quinine and quinidine from Cinchona spp.,
3. Vincristine and vinblastine from Catharanthus roseus
4. Atropine from Atropa belladonna
5. Morphine and codeine from Papaver somniferum.

Phytochemicals and Herbal medicines in Ayurveda :

Ayurveda makes extensive use of medicinal plants such as:

- Curcuma longa (Turmeric): Known for its antioxidant and anti- inflammatory effects.
- Withania somnifera (Ashwagandha): Acts as an adaptogen and supports neurological health.

- Ocimum sanctum (Tulsi): Possesses antimicrobial and immune -enhancing properties .
- Azadirachta indica (Neem): Exhibits strong antibacterial and antiparasitic activity.
- Tinospora cordifolia (Guduchi): Recognized for its immune boosting potential.

These herbs contain a wide range of active phyto constituents, including alkaloids, flavonoids, terpenoids, and glycosides. However, "Their therapeutic benefits are often constrained by challenges related to absorption, stability, and bioavailability."

Nanotechnology in drug delivery:

Nanotechnology entails the manipulation and control of materials at the nanoscale, generally between 1 and 100 nanometers . It provides distinctive properties and functionalities that can be leveraged to optimize drug delivery systems. In the realm of herbal medicine, nanotechnology-based drug delivery systems offer the potential to enhance the absorption, distribution, and targeted release of bioactive compounds derived from herbal sources.

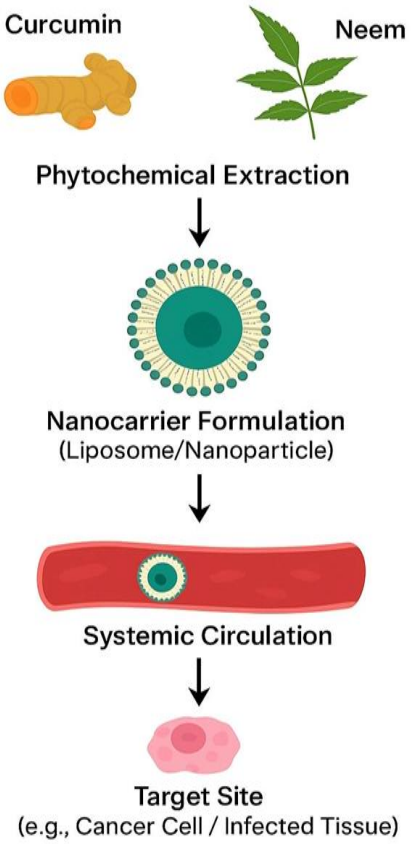

Figure 1: Schematic representation of Nano Herbal Drug Delivery System using Curcumin and Neem.

Nanoparticles:

Nanoparticles (NP) are colloidal drug delivery systems composed of natural, synthetic, or semi-synthetic polymers. Nanoparticles are classified according to their dimensionality, morphology, physical state, and chemical composition. They represent a unique category of nanomaterials in the

field of nanotechnology and are generally characterized by particle sizes ranging from 10 to 100 nm.

Nanoparticles can be broadly categorized into various types, including:

1. Solid Lipid Nanoparticles (SLNs)

2. Liposomes

3. Nanostructured Lipid Carriers (NLCs)

4. Fullerenes

5. Nanoshells

6. Quantum Dots

7. Superparamagnetic Nanoparticles

Nisosomes:

Niosomes represent a novel drug delivery system where the drug is encapsulated within vesicular structures. These vesicles consist of a bilayer formed by non-ionic surfactants, which is why they are termed niosomes. They are extremely small in size and exist at the microscopic scale.

Microspheres:

Microspheres are spherical particles with a typical size range of 200–500 µm, usually composed of proteins or biodegradable synthetic polymers. Various preparation techniques allow precise control over drug delivery, thereby enhancing therapeutic outcomes. By utilizing microspheres, many limitations associated with conventional therapies can be addressed, leading to improved drug effectiveness.

Liposomes:

A liposome is a microscopic vesicle in which an aqueous core is entirely enclosed by a lipid bilayer membrane. Also referred to as vesicles or colloidal spheres, liposomes are composed of cholesterol, non-toxic surfactants, sphingolipids, glycolipids, long-chain fatty acids, membrane proteins, and therapeutic agents. Their characteristics vary significantly depending on lipid composition, surface charge, particle size, and method of preparation. Moreover, the bilayer's rigidity, fluidity, and charge are determined by the specific components incorporated into its structure.

Nanoemulsion:

Nanoemulsions represent one of the most efficient dispersed nanosystems, with droplet sizes extending into the submicron range. Also referred to as sub-micron emulsions (SMEs) or mini-emulsions, they are thermodynamically stable, transparent or translucent systems consisting of oil and water. These dispersions are stabilized by an interfacial layer composed of surfactant and co-surfactant molecules, and typically possess droplet sizes smaller than 100 nm.

Applications of Nano- herbal formulations :

Recent studies demonstrate improved therapeutic efficacy by using nanocarriers for herbal extracts:

- Curcumin nanoemulsions exhibit enhanced antioxidant and anti-inflammatory effects due to increased solubility and stability.
- Ashwagandha loaded in polymeric nanoparticles shows improved neuroprotective activity by better blood-brain barrier penetration.
- Tulsi Nano formulations enhance antimicrobial and immunomodulatory properties.

- Neem solid lipid nanoparticles offer targeted antibacterial and antimalarial delivery.

Such systems significantly boost pharmacological action and patient adherence due to reduced dosing frequency, minimized side effects, and seamless integration with modern medical standards.

Comparison of herbal bioactive and their nanocarrier -mediated delivery benefits:

"Table 1: Enhancement of therapeutic properties of herbal compounds through various nanocarriers"

Herbal compound	Nanocarrier type	Therapeutic Area	Improved Properties
Curcumin	Polymeric nanoparticles	Anti- cancer, Anti-inflammatory	Enhanced bioavailability, sustained release
Berberine	Liposomes	Antidiabetic, Antimicrobial	Improved solubility and cellular uptake
Androgapholide	Solid lipid nanoparticles	Anti- inflammatory, Hepatoprotective	Increased oral bioavailability
Quercetine	Nanoemulsion	Antioxidant, Antiviral	Improved absorption and stability
Resveratrol	Nanogels	Neuroprotective, Anti-aging	Enhanced permeability and targeting

Future perspective:

In recent years, artificial intelligence (AI) and machine learning (ML) have become important tools for enhancing nano herbal drug delivery systems. These technologies enable scientists to design optimized drug formulations by analyzing large datasets quickly and accurately. As a result, herbal medicines can achieve improved solubility, prolonged stability, and precise targeting of therapeutic compounds. Personalized medicine approaches can also be developed, tailoring treatments to an individual's genetic and physiological characteristics, thereby increasing safety and efficacy.

Another promising development is the use of green synthesis methods for nanoparticle production. Unlike traditional chemical methods, green synthesis employs natural plant extracts to form nanoparticles, making the process environmentally friendly, safer for patients, and potentially enhancing the therapeutic properties of the herbal compounds themselves.

Combining AI-driven design with these eco-friendly production methods promises a future where herbal medicines are not only powerful and effective but also sustainable. Ongoing research, along with robust regulatory frameworks, will help translate these innovations into clinical practice. These innovations can lead to globally accepted, effective, and sustainable herbal therapies.

CONCLUSION:

Nano Herbal Drug Delivery Systems represent a revolutionary approach by merging the age-old wisdom of Ayurveda with the advanced technologies of modern nanoscience. Ayurveda, being an ancient holistic healing system, primarily uses natural plant extracts, but these often face challenges such as poor solubility, low bioavailability, and lack of targeted delivery. By leveraging nanotechnology, these limitations can be overcome through the use of nano-sized carriers which improve the solubility, stability, and controlled release of herbal compounds. This synergistic integration not only enhances the therapeutic efficacy but also ensures greater safety

and better patient adherence to treatments. Moreover, these advanced systems hold the potential to transform traditional herbal medicines into globally accepted, standardized, and effective healthcare solutions. With ongoing research focusing on optimizing formulations and ensuring regulatory compliance, Nano Herbal Drug Delivery Systems are poised to play a pivotal role in addressing major health challenges worldwide, paving the way for a sustainable future in natural medicine.

REFERENCE

1. Jaiswal Y. The forgotten history and principles of Indian traditional medicine. Pharmacognosy Reviews. 2016;10(20):1–7.
2. Narayanaswamy V. Origin and development of Ayurveda: A brief overview. Indian Journal of History of Science. 1981;16(2):1–10.
3. Gupta A, Sharma S. Ayurveda: The science of life. Encyclopedia of Complementary Medicine. 2001;1:1–5.
4. Kumar S, Singh A, Sharma S. The significance of Ayurvedic medicinal plants. Pharmacognosy Reviews. 2016;10(20):1–7.
5. Fatima N, Khan M, Ali S. Phytochemicals from Indian ethnomedicines. Pharmacognosy Reviews. 2021;15(30):1–8.
6. Ansari SH. Influence of nanotechnology on herbal drugs: A review. Pharmacognosy Reviews. 2012;6(11):1–8.
7. Ai S, Zhang L, Zhang X. A bibliometric analysis of herbal nanoparticles from 2004 to 2023. Journal of Nanobiotechnology. 2024;22(1):1–15.
8. Awlqadr FH, et al. Nanotechnology-based herbal medicine: Preparation, characterization, and applications. ScienceDirect. 2025.
9. Hasan F, et al. A comprehensive overview of phytochemical composition and pharmacological activities of medicinal plants. ScienceDirect. 2025.
10. Jain VK, et al. A comprehensive review on Ayurvedic plants and isolation of bioactive compounds. ScienceDirect. 2025.
11. Ashraf MV, et al. Phytochemicals as antimicrobials: Prospecting Himalayan medicinal plants. MDPI. 2023;16(6):881.
12. Mallajosyula SS, et al. Molecular simulations for Ayurvedic phytochemicals. International Journal of Ayurveda Research. 2024;15(2):1–8.
13. Patadiya A, et al. A review on the potential of herbal nanoparticles in drug delivery. E3S Web of Conferences. 2025;19:05005.
14. Sharma P, Yadav R. Integration of Ayurveda and modern nanotechnology: Opportunities for new drug delivery systems. Journal of Ayurveda and Integrative Medicine. 2021;12(4):489–500.
15. Patil S, Patil V. Ayurvedic herbal medicines: Phytochemistry and therapeutic potentials. Phytotherapy Research. 2022;36(6):2458–2471.
16. Narayan R, Singh A. Historical evolution of Ayurveda: Insights for modern therapeutics. Journal of Complementary and Integrative Medicine. 2020;17(3):1–11.
17. Sharma A, Sharma S. Panchakarma: Traditional detoxification and rejuvenation in Ayurveda. Ancient Science of Life. 2018;38(3):155–162.
18. Acharya R, Patwardhan B. Bridging Ayurveda and modern medicine: A review. Frontiers in Pharmacology. 2021;12:639.
19. Mishra P, Sharma V. Application of herbal medicines in modern therapeutics: A review. Journal of Herbal Medicine. 2019;16:100–110.
20. Singh N, Gupta S. Traditional knowledge and modern science: The Ayurveda interface.

Journal of Ethnopharmacology. 2019;231:123–134.

21. Kamboj VP. Herbal medicine in India: Historical perspectives and contemporary developments. International Journal of Alternative and Complementary Medicine. 2000;18(2):75–86.
22. Patwardhan B, Warude D, Pushpangadan P, Bhatt N. Ayurveda and traditional Chinese medicine: A comparative overview. Evidence-Based Complementary and Alternative Medicine. 2005;2(4):465–473.
23. Mishra LC, Singh BB, Dagenais S. Healthcare and disease management in Ayurveda. Alternative Therapies in Health and Medicine. 2001;7(2):44–50.
24. Singh RH, Narsimhan M. Ayurveda and integrative medicine: Science and evidence-based research. Evidence-Based Complementary and Alternative Medicine. 2015;2015:1–8.delivery systems and herbal medicines: A review. Pharmacognosy Reviews. 2013;7(14):1–10.

HOW TO CITE: Sakshi Waje*, Ashwini Ippar, Riya Zole, Appasaheb Kuhile, Nano Herbal Drug Delivery System: Bridging Ayurveda and Nanotechnology, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 10, 752-758 https://doi.org/10.5281/zenodo.17295184