

NANOPARTICLE-BASED HERBAL THERAPY: UNLOCKING NEW FRONTIERS IN MEDICINE

Tahmina Maqbool (Corresponding Author)

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Madinat al-Hikmah, Hakim Mohammed Said Road, Karachi, Pakistan

Email: Tahmina.adnan@hamdard.edu.pk & <https://orcid.org/0000-0002-6261-8055>

Postal Code # 74600

Zufi Shad

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Karachi

Hina Sharif

Department of Pharmacognosy, Faculty of Pharmacy, Hamdard University, Karachi, Pakistan

Bareeqa Maryam

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Karachi

Alishba Sohail

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Karachi

Soha Sohail

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Karachi

Vijaha Abdullah

Department of Pharmaceutics, Faculty of Pharmacy, Hamdard University, Karachi

ABSTRACT

Introduction: Nanoparticles (NPs) (1-100nm) have revolutionized the applicability of various sciences and technology, biomedical and pharmaceutical sciences in particular. Sustainable therapeutic use with least side effects leads to the growing enthusiasm towards herbal medications; therefore, to support the development of novel drugs, new drug delivery systems (NDDS) are needed in order to promote patient compliance and effectiveness of the treatment. Nanotechnology is an efficient methodology to enhance the delivery of herbal medications, and overcome the drawbacks associated with the use of plant-based treatment such as suboptimal drug delivery and low bioavailability, bulk of the drug does not reach the site of action, poor pharmacological effect and efficient tissue distribution.

Methodology: In this research, Google Scholar, ScienceDirect, Sci Finder, ResearchGate, and PubMed databases were studied to perform an extensive search for

the existing nanoparticle synthesis, formulation techniques and for the pharmacological activities too.

Results: Results emphasize the variety of manners to produce nanoparticles whilst improving the therapy potential of herbal drugs.

Key Words: Nanoparticles, Sustainable Therapeutic, Suboptimal Drug Delivery, Nanomaterials, Phototherapeutics.

INTRODUCTION:

The most essential element in creating a nanostructure is nanoparticles. Materials that fall between 1 and 100 nm in size are called nanoparticles (NPs) [1, 2]. They can be categorized into many classes according to their traits, shapes, or sizes. Rapidly evolving disciplines of research, nanoscience and nanotechnology focus on systems, devices, and structures that have unique properties and capabilities because of atomic arrangements [3]. Nanomaterials were already present in nature before scientists could have dreamed them up. For almost 4,000 years, people have been utilizing nanoparticles without fully comprehending the science underlying them [4]. The foundational speech "There's Plenty of Room at the Bottom" delivered by Nobel laureate Richard Feynman at the 1959 American Physical Society meeting is commonly credited with giving rise to the concepts of nanoscience and nanotechnology [5]. Nanoparticles possess distinct physical and chemical characteristics; their composition, size (distribution), and forms dictate these characteristics as well as possible uses [6]. NPs exhibit greater sensitivity, stability, strength, surface area, absorption, reactivity, and surface charge [4]. Global governments and businesses are investing more in nanotechnologies. It evaluates potential ethical, health, and environmental risks; it pinpoints areas in which more regulation is required; and it deals with the creation of new or improved materials [7]. It pertains to extremely small entities and can be applied in various research fields and scientific disciplines, including engineering, biology, electronics, chemistry, physics, information technology, medicine, materials science, energy, and informatics. The utilization of nanoparticles as transporters for both small and large molecules in the advancement of nanotechnology has attracted significant research interest over the last ten years. Various polymers are utilized to synthesize nanoparticles.[8] Using the special properties of nanoparticles, applications in electronics, energy, medicine and pharmaceuticals and other fields may be investigated. Synthesizing nanoparticles with the right size, structure, monodispersed, and morphology is crucial for the aforementioned uses [9]. As in medicine and pharmaceuticals, the use of herbal drugs has been increased as they have fewer side effects than modern medications [10]. The majority of developing nations still rely on these traditional remedies, probably due to the high cost of acquiring synthetic medications [11]. Since ancient times, people have used natural products and herbal remedies to alleviate ailments. Thousands of chemicals combine in herbal medications to fight illnesses, in contrast to the widely utilized allopathic system [12]. Because of their high first-pass metabolism, low bioavailability, poor permeability, instability in biological environments, and poor solubility, plant and herbal medicinal compounds provide significant challenges for drug administration. These restrictions on herbal medications can be removed by

encasing or connecting them to appropriate nanomaterials [10].

NOVEL DRUG DELIVERY SYSTEM (NDDS) AS “NANO CARRIERS” FOR “HERBAL REMEDIES”:

A systematic approach to improve patient compliance and avoid repeated doses, phytotherapeutics must distribute the components gradually [13]. The delivery, efficacy, safety, and selectivity of herbal medicine can all be enhanced by using nanoparticles to target certain organs. Application of nanoparticles enhances the solubility of herbal medications and aid in their localization to a particular location, hence improving their efficacy [14]. This can be achieved by creating NDDSs for ingredients found in herbs. In addition to lowering the need for recurrent medication administration, NDDSs also lessen toxicity, enhance therapeutic value, and boost the bioavailability of herbal drugs [15]. Due to the fact that therapeutic drugs can be attached to or encapsulated by nanostructures, which allow for a more precise and regulated release of the drugs into the intended tissues, Nano medicines have become more well-known recently [16]. Nanotechnology for producing nanoparticles is one such novel approach. Nanoscale herbal drug delivery systems may increase effectiveness [16]. Considerable benefits arise from using nano-based formulations in herbal formulation research for phytomedicine. The advantages encompass enhanced solubility and bioavailability, defence against toxicity, heightened pharmacological activity, enhanced stability, expanded tissue macrophage distribution, prolonged administration, and defence against physical and chemical degradation [17]. The role of nanotechnology in a few biological domains will be briefly examined in this overview, with an emphasis on medicine and the idea of drug delivery systems enabled by nanoparticles for the treatment of disease [18].

Therapeutically active herbs in nano nanoparticle drug delivery system

The information demonstrates developments in creating medicinally effective nanoparticles from natural plants. This innovation demonstrates that herbal medicine delivery systems with nanoparticles have a noticeably higher efficacy rate. The synthesis methods used improve bioavailability and solve problems with conventional plant-based treatments. These delivery techniques provide effective and tailored therapeutic alternatives by reducing herbs to the nanoscale. All things considered, the combination of herbal medicine and nanotechnology is a positive step toward increasing the efficacy of therapeutic interventions.

According to the study's findings, the following herbal medication nanoparticles exhibit equivalent and superior efficacy: (see table 1)

Curcuma longa:

Curcuma longa, often referred to as turmeric, this aromatic plant has been widely used to make a variety of pharmacological compositions. *Curcuma longa* can potentially improve the therapeutic effects of drugs for ailments like wounds, acne, the common cold, parasite infections, urinary tract infections, and liver illnesses by being incorporated into nanoparticle formulations [19].

Zingiber officinale:

Zingiber officinale, has a long history of medical use that dates back centuries. It is generally referred to as ginger. In order to maximize the medicinal effects of ginger, researchers have recently investigated the creation of ginger nanoparticles, leveraging its bioactive components. When compared to conventional antibiotics, copper nanoparticles (CuNPs) have better antibacterial action against Staphylococcus aureus. Effective pathogen inhibition results from their enhanced contact with bacterial cells at the nanoscale, which releases copper ions and causes oxidative stress. CuNPs are a possible substitute in the fight against antibiotic-resistant strains because of their special mechanism, which lowers the possibility of bacterial resistance. The creation of ginger nanoparticles represents the fusion of contemporary nanotechnology and traditional herbal knowledge for improved therapeutic outcomes [19].

Aloe barbadensis miller:

For centuries, aloe vera has been cherished for its remarkable benefits in health, beauty, healing, and skincare. Its soothing properties and natural goodness have made it a staple in various treatments and remedies across generations. Greek scientists believed aloe vera to be a universal panacea. "The plant of immortality" was the Egyptian name for aloe. Nowadays, dermatology uses the aloe vera plant for a variety of purposes [20]. Antibiotics, AgNP solution, and extract-stabilized AgNP were employed as test controls [21].

Foeniculum Vulgare:

Fennel, or Foeniculum vulgare, is a herb with several medicinal use that is known by a variety of regional names across the world. It belongs to the kingdom Plantae and the family Apiaceae. Foeniculum vulgare is recognized to enhance memory in addition to its antithrombotic, antioxidant, anti-inflammatory, hepatoprotective, antibacterial, antifungal, oestrogenic, and antidiabetic qualities. Metallic nanoparticles have attracted a lot of attention due to their UV-absorbing, photocatalytic, and antifungal properties [22]. The effect of Au nanoparticles made from the aqueous extract of Foeniculum vulgare seeds on common human breast cancer cell lines is evaluated in this study [23].

Coriandrum sativum:

Coriander (Coriandrum sativum) is a fragrant and medicinal herb that is widely grown worldwide. The essential oil of coriander is extracted by steam distillation from completely mature dried seeds or leaves [24]. At different dosages, CS-AgNPs showed notable antioxidant activity against superoxide and hydroxyl radicals when compared to traditional ascorbic acid. At different doses, the presence of an in vitro anticancer activity was confirmed on the MCF-7 cell [25].

Thymus vulgaris:

Thymus vulgaris has been used for therapeutic purposes since ancient times. The plant is also used to cure children's worms and chest conditions like whooping cough, pharyngitis, and bronchitis. [26]. Compared to SeNPs, which are more efficient, silver

nanoparticles are more toxic. SeNps enhanced with *T. vulgaris* extract can be used in place of products that are marketed in stores and have the capacity to operate as anti-inflammatory and antioxidant agents [27].

Cinnamomum zeylanicum:

In tropical medicine, cinnamon (*Cinnamomum zeylanicum* and Cinnamon cassia), an evergreen, belongs to the Lauraceae family. Cinnamon is one of the most important spices because it is used frequently around the world [28]. It has been demonstrated that CNPs are useful in the production of antibacterial drugs and in food processing.

Senna Alexandrina:

Cassia acutifolia, commonly known as *Senna alexandrina*, is a native of Egypt and comes in a variety of species. In other countries, like India, for example, the tropical American species *Cassia alata* Linn and *Cassia acutifolia* Delile are cultivated. A herbal tea that is used as a laxative is made from senna leaves and pods [29]. *Acinetobacter baumannii*/haemolyticus, *Escherichia coli*, *Staphylococcus epidermidis*, and Methicillin-resistant *Staphylococcus aureus* are among the significant multidrug-resistant pathogens (MDRPs) that these nanoparticles inhibited [30].

Table 1 Therapeutically Active Herbs in Nanoparticle-Based Drug Delivery

S.No	Formulations	Preparation Method	Analytical Technique	Pharmacological Action	Ref
1	Curcuma longa + AgNP	Using the green route method, the AgNPs were created from the leaf extract of <i>Curcuma longa</i> L. 10ml curcuma longa extract+ 1mM silver nitrate at 37°C → solution color changes from colorless to brown → spinning at 15000 rpm for 30mins → purified suspension of AgNPs.	UV-Vis Spectroscopy FTIR Analysis	Anti-cancer	17
2	Zingiber	After the ginger	UV-Vis spectral	Antibacterial	17

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

	officinalis + CuNP	was simmered for 30 minutes in 250 milliliters of sterile distilled water, its color changed from colorless to pale yellow, and it was filtered.	analysis FTIR analysis		
3	Aloe barbadensis miller + AgNP	Five milliliters of aloe vera gel and five milliliters of AgNO ₃ solution are diluted with one percent ammonia solution to change the medium's pH. Orange-colored appearance	UV-Visible spectroscopy.	Antibacterial	18,19
4	Foeniculum vulgare + AuNP	Extraction of Foeniculum vulgare with distilled water in microwave (100ml of HAuCl ₄ . H ₂ O + 1.5g of NaOH) in 50ml water + foeniculum vulgare extract → stirring at 25°C for 1h (dark yellow color indicates AUNPs formation) → ppt it → filtration → washed with	UV- Vis Spectroscopy	Anti-oxidant, Anti-cancer	21, 29

		water, ethanol & acetone → dried at 90°C			
5	Coriander sativum + AgNP	(30gm C.sativm leaves + 250ml water) boil for 20mins → filtration. Coriander extract + AgNO ₃ aq. → dilution → incubation for 10min9reduction of Ag ions → brownish yellow solution.	Scanning electron microscopy. Ultraviolet-violet spectroscopy. Energy dispersive X-ray (EDX analysis).	Antimicrobial, Anticancer.	22, 23
6	Thymus vulgaris + SeNP	(1g T.vulgaris + 40ml H ₂ O) boil for 20min → extraction. Na ₂ SeO ₄ (sodium selenite) + T.vulgaris extract → stand in magnetic stirrer → shaker → centrifugation → washed → dried → NP powder.	Ultraviolet (UV) spectrometry	Antibacterial, antioxidant and Anti-inflammatory.	24-25,29
7	Cinnamon NP's	PLAL - pulse laser ablation in liquid technique.	UV-Vis spectrophotometry Transmission Electron Microscopy (TEM), Chromatography-Mass Spectrometry (LC-MS)	Antibacterial	26
8	Senna alexandrina + AgNP	AgNO ₃ + Aq. S. Alexandria, mixed at diff ratios &	XRD analysis, FT-IR, TEM, and UV spectroscopy.	Anti-bacterial, anti-cancer & inhibit multidrug-resistant	27-28

		conditions, colour change indicates production of NPs.		pathogens (MDRPs).	
9	Nigella sativa + AgNP	20g NS seed powder + 400g DW → biling for 20mins → cooled → filtration (wattman paper 1) → storage (at 4°C) 0.1mm of AgNO ₃ (100ml) + 10ml NS extract → heated at 80°C (20min)→ colour change from light to dark brown due to Ag reduction and AgNP production → centrifugation → drying of NP	UV-Vis spectrophotometry XRD pattern FTIR Spectroscopy DLS of AgNPs produced by NS.	Photocatalytic activity.	29

FUTURE PERSPECTIVE:

Worldwide, studies on herbal remedies and natural items have been carried out. Numerous institutions are conducting basic and clinical trial research on the development of herbal medicines in drug delivery systems. The only requirement is the creation of more efficient delivery mechanisms for these drugs, both at the administration sites and throughout the body, at dosages that don't interfere with existing treatment regimens. In addition to alleviating adverse effects including toxicity and hypersensitivity reactions, the patient would want anything that will increase their internal strength. The idea of employing herbal nanoparticles to deliver cancer treatments may be appealing to some potential research institutions, and the outcomes could be noteworthy [31].

CONCLUSION:

Using environmentally friendly technologies, such as those that use plant extracts, to manufacture metal-based nanoparticles has shown to be a useful strategy over the years because the final product is easy to prepare and biocompatible with most

biological systems. As this research has demonstrated, a number of plant active substances have been effectively used to stabilize different metal ions, reduce them to their corresponding metal-nanoparticles, and transmit advantageous features, such biological activities, from the plants onto such manufactured nanoparticles. These nanoscale therapeutic compounds have already shown impressive efficacy for a variety of illnesses at the cellular level. Therefore, further research into their safe use could lead to the identification of novel therapeutic approaches.

REFERENCES:

- Khan, I., K. Saeed, and I. Khan, Nanoparticles: Properties, applications and toxicities. *Arabian journal of chemistry*, 2019. **12**(7): p. 908-931.
- Patil, A.A., Nanoparticles: properties, applications and toxicities. *Int. J. Innov. Sci., Eng. Technol.*, 2020. **8**(5): p. 246-261.
- Bayda, S., et al., The history of nanoscience and nanotechnology: from chemical–physical applications to nanomedicine. *Molecules*, 2019. **25**(1): p. 112.
- Khan, S., et al., A review on nanotechnology: Properties, applications, and mechanistic insights of cellular uptake mechanisms. *Journal of Molecular Liquids*, 2022. **348**: p. 118008.
- Joudeh, N. and D. Linke, Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists. *Journal of Nanobiotechnology*, 2022. **20**(1): p. 262.
- Barhoum, A., et al., Review on natural, incidental, bioinspired, and engineered nanomaterials: history, definitions, classifications, synthesis, properties, market, toxicities, risks, and regulations. *Nanomaterials*, 2022. **12**(2): p. 177.
- Dowling, A.P., Development of nanotechnologies. *Materials today*, 2004. **7**(12): p. 30-35.
- Kumar, R., M. Kumar, and G. Luthra, Fundamental approaches and applications of nanotechnology: A mini review. *Materials Today: Proceedings*, 2023.
- Khan, Y., et al., Classification, synthetic, and characterization approaches to nanoparticles, and their applications in various fields of nanotechnology: a review. *Catalysts*, 2022. **12**(11): p. 1386.
- Patil, R.Y., et al., Herbal drug nanoparticles: Advancements in herbal treatment. *Research Journal of Pharmacy and Technology*, 2018. **11**(1): p. 421-426.
- Bonifacio, B.V., et al., Nanotechnology-based drug delivery systems and herbal medicines: a review. *International journal of nanomedicine*, 2014: p. 1-15.
- Ansari, S., F. Islam, and M. Sameem, Influence of nanotechnology on herbal drugs: A Review. *Journal of advanced pharmaceutical technology & research*, 2012. **3**(3): p. 142-146.
- Sandhiya, V. and U. Ubaidulla, A review on herbal drug loaded into pharmaceutical carrier techniques and its evaluation process. *Future Journal of Pharmaceutical Sciences*, 2020. **6**: p. 1-16.
- Abirami, A., et al., Herbal nanoparticle for anticancer potential-a review. 2014.
- Namdari, M., et al., A brief review on the application of nanoparticle enclosed herbal medicine for the treatment of infective endocarditis. *Biomedicine & Pharmacotherapy*, 2017. **87**: p. 321-331.
- Jahangirian, H., et al., A review of drug delivery systems based on nanotechnology

- and green chemistry: green nanomedicine. International journal of nanomedicine, 2017: p. 2957-2978.
- Gunasekaran, T., et al., Nanotechnology: an effective tool for enhancing bioavailability and bioactivity of phytomedicine. Asian Pacific journal of tropical biomedicine, 2014. **4**: p. S1-S7.
- Yusuf, A., et al., Nanoparticles as drug delivery systems: a review of the implication of nanoparticles' physicochemical properties on responses in biological systems. Polymers, 2023. **15**(7): p. 1596.
- Venkatadri, B., et al., Green synthesis of silver nanoparticles using aqueous rhizome extract of *Zingiber officinale* and *Curcuma longa*: In-vitro anti-cancer potential on human colon carcinoma HT-29 cells. Saudi Journal of Biological Sciences, 2020. **27**(11): p. 2980-2986.
- Surjushe, A., R. Vasani, and D. Saple, Aloe vera: a short review. Indian journal of dermatology, 2008. **53**(4): p. 163-166.
- Logaranjan, K., et al., Shape-and size-controlled synthesis of silver nanoparticles using Aloe vera plant extract and their antimicrobial activity. Nanoscale research letters, 2016. **11**: p. 1-9.
- Jalalvand, A.R., et al., Chemical characterization and antioxidant, cytotoxic, antibacterial, and antifungal properties of ethanolic extract of *Allium Saralicum* RM Fritsch leaves rich in linolenic acid, methyl ester. Journal of Photochemistry and Photobiology B: Biology, 2019. **192**: p. 103-112.
- Chen, J., et al., Facile preparation of Au nanoparticles mediated by *Foeniculum Vulgare* aqueous extract and investigation of the anti-human breast carcinoma effects. Arabian Journal of Chemistry, 2022. **15**(1): p. 103479.
- Sharma, M. and R. Sharma, Coriander, in Handbook of herbs and spices. 2012, Elsevier. p. 216-249.
- Alsubki, R., et al., Green synthesis, characterization, enhanced functionality and biological evaluation of silver nanoparticles based on Coriander sativum. Saudi Journal of Biological Sciences, 2021. **28**(4): p. 2102-2108.
- Kuete, V., *Thymus vulgaris*. Medicinal Spices and Vegetables from Africa, 599–609. 2017.
- Pandiyan, I., et al., Antioxidant, anti-inflammatory activity of *Thymus vulgaris*-mediated selenium nanoparticles: An: in vitro: study. Journal of Conservative Dentistry and Endodontics, 2022. **25**(3): p. 241-245.
- Rao, P.V. and S.H. Gan, Cinnamon: a multifaceted medicinal plant. Evidence-Based Complementary and Alternative Medicine, 2014. **2014**(1): p. 642942.
- Tripathi, Y., *Cassia angustifolia*, a versatile medicinal crop. International tree crops journal, 1999. **10**(2): p. 121-129.
- Alhag, S.K., Biosynthesis of gold and silver nanoparticles using *Senna alexandrina* Miller extract against *Culex pipiens* L.(Diptera: Culicidae). Entomological Research, 2023. **53**(1): p. 3-11.
- Adeyemi, J.O., et al., Plant extracts mediated metal-based nanoparticles: synthesis and biological applications. Biomolecules, 2022. **12**(5): p. 627.