Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 23s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Nanoformulation-Based Drug Delivery of Phytoconstituents for Targeted Cancer Therapy: A Pharmaceutical Approach to Enhance Bioavailability and Therapeutic Index

Dr Ashwini A Zanke[1], Kiran P Gaikwad[2], Prof Chaitali P Jaiswal[3], Prof Vikas N Ghait[4], Prof Ananta G Titare[5], Dr Ankush K maskar[6]

[1,2,3,4,5,6]Assistant professor Pharmaceutics Dr Rajendra Gode college of pharmacy Malkapur 443101 Maharashtra India

Cite this paper as: Dr Ashwini A Zanke, Kiran P Gaikwad, Prof Chaitali P Jaiswal, Prof Vikas N Ghait, Prof Ananta G Titare, Dr Ankush K maskar, (2025) Nanoformulation-Based Drug Delivery of Phytoconstituents for Targeted Cancer Therapy: A Pharmaceutical Approach to Enhance Bioavailability and Therapeutic Index. *Journal of Neonatal Surgery*, 14 (23s), 256-258.

ABSTRACT

Background: While phytochemicals are known for their anticancer potential, their clinical impact is limited due to poor bioavailability and inadequate targeting. Utilizing nanoformulation-based delivery systems has emerged as a promising strategy to address these shortcomings and improve the overall therapeutic performance of plant-derived compounds.

Methods: A systematic review was conducted by analyzing literature from 2012 to 2024 using PubMed, Scopus, and ScienceDirect. The studies included focused on nanoparticle-mediated delivery of phytoconstituents for cancer treatment, evaluating aspects such as bioavailability, targeting precision, cytotoxicity, and therapeutic success.

Results: Among the 38 relevant studies, delivery systems such as liposomes, polymeric and solid lipid nanoparticles, and nanoemulsions were reviewed. Nanoformulations of phytochemicals like curcumin, quercetin, and resveratrol showed 3–10-fold improvement in cellular absorption and preferential tumor site accumulation. Liposomal curcumin notably achieved up to 80% tumor inhibition in mouse models. Polymeric carriers provided prolonged circulation and minimized side effects. Overall, these formulations boosted bioavailability by around five times and significantly enhanced therapeutic indices.

Conclusion: Nanotechnology-enhanced delivery offers an effective route to improve the performance of plant-based agents in oncology. However, advancing these therapies into clinical settings requires more rigorous trials and regulatory harmonization.

Keywords: *Nanotechnology, Herbal Drug Delivery, Cancer Treatment, Bioavailability, Therapeutic Efficacy*

1. INTRODUCTION

Cancer continues to be a major global health challenge. Although chemotherapy remains a cornerstone of treatment, its effectiveness is often limited by issues like drug resistance, systemic toxicity, and poor solubility. Plant-based bioactives such as curcumin, quercetin, and resveratrol exhibit strong anticancer activity, but their clinical utility is hindered by poor water solubility, rapid degradation, and nonspecific tissue distribution.

Nanotechnology-based delivery platforms offer a promising solution by encapsulating these bioactives in nanoscale carriers, enhancing drug absorption, stability, and site-specific release. This paper evaluates the role of nanoformulated herbal compounds in cancer therapy, focusing on their ability to improve targeting, bioavailability, and overall treatment outcomes.

Nanocarriers exploit the enhanced permeability and retention (EPR) effect to passively accumulate in tumor tissues. Additionally, modifying nanoparticles with targeting ligands enables more precise delivery to cancer cells while sparing healthy tissues, thus improving safety profiles. The integration of sustainable and biocompatible carriers with natural compounds may lead to more effective and less toxic cancer treatments.

This review synthesizes recent progress in the nanoformulation of phytoconstituents and outlines future research priorities for bringing these therapies into clinical practice.

2. MATERIALS AND METHODS

Study Design: A systematic review was conducted in accordance with PRISMA guidelines.

Inclusion Criteria:

- Studies on nanoformulation of phytoconstituents for cancer therapy.

- Reports with in vitro, in vivo, or clinical data on bioavailability and therapeutic effects.
- Publications from 2012 to 2024.

Exclusion Criteria:

- Non-nanoparticulate delivery studies.
- Studies not involving phytoconstituents.
- Review articles and non-peer-reviewed literature.

Search Strategy: Databases searched included PubMed, Scopus, and ScienceDirect. Search terms included: "nanoformulation," "phytoconstituents," "targeted drug delivery," "cancer therapy," and "bioavailability."

Data Extraction: Two reviewers independently extracted data on nanoformulation type, phytoconstituent, cancer type, bioavailability, therapeutic efficacy, and targeting efficiency.

3. RESULTS

Study Characteristics:

- Total studies: 38
- Cancer types: breast (29%), lung (21%), colon (18%), liver (14%), others (18%)
- Nanocarrier systems: liposomes (34%), polymeric nanoparticles (26%), solid lipid nanoparticles (21%), nanoemulsions (19%)

Table 1: Summary of Cancer Types and Nanocarrier Systems Used

Cancer Type	Percentage of Studies	Nanocarrier Type	Percentage Usage
Breast	29%	Liposomes	34%
Lung	21%	Polymeric Nanoparticles	26%
Colon	18%	Solid Lipid Nanoparticles	21%
Liver	14%	Nanoemulsions	19%
Others (e.g., prostate)	18%	—	—

Table 2: Performance Metrics of Nanoformulated Phytoconstituents

Phytoconstituent	Nanocarrier Type	Bioavailability Enhancement	Tumor Accumulation / Targeting Efficiency	Therapeutic Efficacy
Curcumin	Liposomes	5.4-fold (oral)	3.2-fold higher tumor accumulation	Up to 80% tumor inhibition (xenograft models)
Quercetin	Polymeric Nanoparticles	Not specified	78% targeting efficiency (murine models)	65% tumor volume reduction, minimal toxicity
Resveratrol	Solid Lipid / Nanoemulsions	Improved lymphatic transport	Sustained release	2.5× increase in apoptosis markers vs. free drug

Comparative Performance: Nanoformulated phytoconstituents consistently outperformed their free-form counterparts in bioavailability, targeting efficiency, and therapeutic efficacy.

4. DISCUSSION

Nanoformulation strategies have revolutionized phytoconstituent-based cancer therapy by addressing the limitations of herbal drugs. Improved solubility, enhanced permeability, targeted delivery, and controlled release are notable advantages across nanoparticle systems.

Among nanocarriers, liposomes offer excellent biocompatibility and tumor-specific accumulation via the EPR effect.

Polymeric nanoparticles demonstrate structural versatility and prolonged circulation time. Solid lipid nanoparticles and nanoemulsions provide high drug loading and sustained release.

Recent research explores smart nanocarriers responsive to internal (pH, redox) or external (ultrasound, magnetic fields) stimuli for precise drug release. These innovations promise improved site-specific delivery and reduced systemic exposure.

Additionally, co-delivery of phytoconstituents with conventional chemotherapeutic agents in nanoformulations has shown synergistic effects, potentially reducing the required dosage of cytotoxic drugs. This approach may enhance patient compliance and minimize adverse effects.

Despite promising preclinical outcomes, challenges such as scale-up production, regulatory approval, and clinical validation must be addressed for successful translation.

5. CONCLUSION

Nanoformulation-based delivery of phytoconstituents is a transformative pharmaceutical strategy in cancer therapy. It effectively enhances bioavailability and specificity, resulting in better therapeutic outcomes and lower systemic toxicity. Future research should focus on standardized manufacturing, pharmacokinetic modeling, and robust clinical trials.

Successful clinical translation will require collaboration between pharmaceutical scientists, clinicians, and regulatory bodies. With continued innovation, nanoformulated phytoconstituents could redefine cancer treatment paradigms.

REFERENCES

[1] Prasad S, et al. Nanotechnology in delivery of phytochemicals: A review. Biotechnol Adv. 2020.

[2] Mukherjee S, et al. Liposomal curcumin for cancer therapy. Int J Nanomedicine. 2019.

[3] Wang Y, et al. Polymeric nanoparticles for quercetin delivery. J Control Release. 2021.

[4] Singh D, et al. Resveratrol nanoemulsions in cancer therapy. Curr Pharm Biotechnol. 2022.

[5] Zhang L, et al. Bioavailability enhancement of herbal drugs via nanocarriers. Drug Deliv Transl Res. 2023.

[6] Ahmad N, et al. Targeted delivery of phytochemicals using nanocarriers for cancer therapy. J Drug Target. 2021.

[7] Sharma G, et al. Stimuli-responsive nanocarriers for delivery of herbal bioactives. Mater Sci Eng C. 2020.

[8] Chen Y, et al. Nanoparticles for improved bioavailability of herbal extracts. Pharmaceutics. 2019.

[9] Ali I, et al. Role of phytoconstituents in nanomedicine-based cancer therapy. Biomed Pharmacother. 2021.

[10] Patra JK, et al. Nanoformulation of natural products: Recent developments and future prospects. Drug Discov Today. 2020.

[11] Jain A, et al. Phytochemical-loaded nanocarriers for cancer treatment: Advances and challenges. J Nanobiotechnol. 2022.

[12] Raza K, et al. Lipid-based nanocarriers for cancer therapy: A review. Artif Cells Nanomed Biotechnol. 2019.

[13] Sahoo SK, et al. The role of nanotechnology in cancer treatment: A review. Drug Discov Today. 2021.

[14] Banerjee A, et al. Design and development of curcumin-based nanoformulations for cancer therapy. J Exp Pharmacol. 2023.

[15] Bhatt PC, et al. Nanocarriers for resveratrol delivery in oncology: Challenges and advances. Expert Opin Drug Deliv. 2022.