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

OPEN ACCESS

Review Paper

Pharmacosomes As Amphiphilic Vesicular Carriers: A Comprehensive Review

Praveena V A*, Sudhir M RR, Athmika S Haika, Divyamol A K, Aswathy Mohan, Gayathri P M, Krishna Haridas, Shabnam Shibu Sekumeeran

Department Of Pharmaceutics, Department Of Pharmaceutical Sciences, Rimsr, Cpas, Puthupally, Kottayam-686009.

ARTICLE INFO

Published: 06 Aug 2026
Keywords:
Pharmacosomes, Amphiphilic Vesicular Carriers, lipid-based vesicular drug delivery systems
DOI:
10.5281/zenodo.21820906

ABSTRACT

Pharmacosomes represent a transformative class of lipid-based vesicular drug delivery systems, designed to address the inherent limitations of conventional carriers such as liposomes and niosomes. Characterized as stoichiometric complexes formed between medicinal agents and phospholipids, pharmacosomes offer a unique structural paradigm where the drug molecule is covalently or non-covalently integrated into the vesicular membrane. This configuration ensures predetermined entrapment efficiency, high stability, and the elimination of drug leakage—a common challenge in physical entrapment systems. This review provides a comprehensive analysis of pharmacosomes, covering their fundamental principles, diverse formulation strategies including hand-shaking, ether injection, and supercritical fluid methods, and rigorous characterization techniques such as DSC, XRD, and electron microscopy. The article further explores the therapeutic potential of pharmacosomes in enhancing the bioavailability and targeted delivery of non-steroidal anti-inflammatory drugs (NSAIDs), antineoplastic agents, cardiovascular medications, and herbal constituents. Recent advances in process optimization using response surface methodology, the development of co-loaded antibiotic systems for H. pylori eradication (2025), and novel aggregates like lyotropic liquid crystals are also discussed. By improving membrane permeation and reducing systemic toxicity, pharmacosomes stand as a promising alternative for the delivery of challenging therapeutic molecules in modern nanomedicine.

INTRODUCTION

The evolution of pharmaceutical science has been marked by a continuous search for drug delivery

***Corresponding Author:** Praveena V A
Address: *Department Of Pharmaceutics, Department Of Pharmaceutical Sciences, Rimsr, Cpas, Puthupally, Kottayam-686009.*
Email ✉: pravprave3@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.

systems that can overcome the biological and physicochemical barriers of therapeutic agents. Among these, pharmacosomes are a potential vesicular drug delivery system that has garnered significant attention for its ability to enhance the delivery of both hydrophilic and lipophilic molecules (1).Traditionally, vesicular systems like liposomes have paved the way for nanomedicine; however, they often struggle with issues such as low drug loading, physical instability, and the rapid leakage of entrapped drugs. Pharmacosomes address these challenges by creating an amphiphilic complex where the drug itself becomes a part of the vesicular architecture (2).As amphiphilic lipid vesicular systems, pharmacosomes facilitate the efficient passage of poorly water-soluble and poorly lipophilic drugs through biological membranes, significantly improving their pharmacokinetic profiles(3) .The development of these systems involves a systematic approach to formulation and characterization, often utilizing sophisticated tools like FTIR and DSC to confirm the integrity of the drug-lipid complex (4). Over the past decade, research has expanded into advanced formulation strategies, including supercritical fluid processes and anhydrous co-solvent lyophilization, which offer improved stability and scalability(5). These systems not only enhance therapeutic efficacy but also contribute to a reduction in therapy costs and a decrease in drug-related toxicity (6). By 2025, the scope has further broadened to include co-loaded systems for multi-drug therapy and optimized analytical modeling for better quality control (25,28).

.

2. Conceptual Framework and Structural Advantages

2.1. Limitations of Conventional Vesicles

Conventional vesicular systems, including liposomes and niosomes, rely on the physical entrapment of drug molecules within an aqueous core or a lipid bilayer. This approach is often limited by low entrapment efficiency for certain drugs and the potential for premature drug release or leakage during storage. Furthermore, the stability of these vesicles can be compromised by environmental factors, leading to the fusion or rupture of the membranes (3,7).Recent comparisons also highlight that pharmacosomes offer superior stability over liquid crystalline systems and protein-based carriers due to their robust drug-lipid bonding (26).

2.2. The Pharmacosomal Paradigm

Pharmacosomes provide a robust alternative by ensuring that the drug is stoichiometricly linked to phospholipids, typically phosphatidylcholine. This linkage can be covalent, forming an amphiphilic prodrug, or non-covalent, resulting in a stable complex. The resulting amphiphilic molecule spontaneously assembles into vesicles that are more stable than conventional liposomes due to the absence of unentrapped drug and the inherent stability of the drug-lipid interaction (8).These vesicles can exist in various forms, including micellar aggregates and hexagonal assemblies, depending on the drug-to-lipid ratio and the polarity of the surrounding medium (19,25) .By selectively localizing drugs at infection or tumor sites, pharmacosomes reduce systemic toxicity and improve the biopharmaceutical qualities of the medication(9).

3. Formulation Strategies

3.1. Solvent Evaporation and Hand-Shaking Methods

The most common technique for preparing pharmacosomes is the solvent evaporation method, often coupled with hand-shaking (10). In this procedure, the drug and lipid are dissolved in

a volatile organic solvent like dichloromethane. The solvent is then evaporated, leaving a thin film of the complex that is subsequently hydrated with an aqueous phase. For instance, mefenamic acid pharmacosomes formulated via this method achieved a high entrapment efficiency of 90% (11). This approach remains a cornerstone of the field, as highlighted in 2025 reviews (25).

3.2. Ether Injection and Thin-Film Dispersion

The ether injection method involves dissolving the drug-lipid complex in diethyl ether and injecting it into a heated aqueous medium, which triggers vesicle formation as the solvent evaporates (13).This method is valued for producing vesicles with controlled size distributions and predictable in vitro release rates (14).Thin-film dispersion is another variant, particularly useful for herbal drugs like 20(S)-protopanaxadiol, where it produces stable vesicles with high encapsulation efficiency (24).

3.3. Advanced Technologies: Supercritical Fluid and Lyophilization

To address issues of scalability and residual solvents, advanced techniques such as supercritical fluid processes have been introduced (17.)These methods use supercritical carbon dioxide to facilitate the formation of pharmacosomes with high purity. Additionally, anhydrous co-solvent lyophilization is used to create stable, dry powders that can be reconstituted, enhancing the shelf life of the delivery system (17).Recent studies emphasize the importance of precise drug-to-lipid ratios during these processes to prevent premature degradation (26).

4. Comprehensive Characterization Techniques

4.1. Morphological Evaluation: SEM and TEM

Visualizing the physical structure of pharmacosomes is crucial. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) are employed to assess the surface morphology and shape of the vesicles (10,14,15).These techniques reveal that pharmacosomes typically form spherical or hexagonal aggregates, with the drug-lipid interaction clearly influencing the surface (texture (19,25).

4.2. Thermal Analysis: Differential Scanning Calorimetry (DSC)

DSC is a fundamental tool for assessing the thermal behavior and compatibility of the drug-lipid complex (15). A shift or disappearance of the drug's melting endotherm provides direct evidence of complex formation and a transition to a molecularly dispersed state (19). This is critical for predicting the stability and dissolution behavior of the pharmacosomes.

4.3. Crystalline State Assessment: X-ray Powder Diffraction (XRPD)

XRPD is used to determine the crystalline nature of the drug within the complex. A reduction in the intensity of crystalline peaks indicates that the drug has been converted to an amorphous state during the formulation of the pharmacosomes (10,15). This transition is directly linked to the enhanced solubility and faster dissolution rates observed in pharmacosomal systems.

4.4. Spectroscopic and Solubility Studies

FTIR and NMR spectroscopy are used to confirm the structural conformation and molecular interactions within the complex (14,15,19).Solubility determination, often using the shake-flask method, quantifies the biopharmaceutical improvements. For example, the solubility of diclofenac in a pharmacosomal

system was found to be more than double that of the plain drug (5,11). In 2025, analytical protocols for co-loaded systems have integrated sophisticated HPLC-PDA techniques to monitor drug release with high precision (28).

5. Mechanisms of Bioavailability Enhancement

5.1. Improved Membrane Fluidity and Permeation

One of the primary mechanisms by which pharmacosomes enhance bioavailability is through the modulation of membrane fluidity. The inclusion of phospholipids, which are natural components of cell membranes, allows the pharmacosomes to merge more effectively with biological barriers. This increases the permeation of the drug across the skin, intestinal wall, or blood-brain barrier (8,18,20).

5.2. Stoichiometric Complexation and Solubility

The formation of a stoichiometric complex ensures that every drug molecule is associated with a lipid molecule, maximizing the amphiphilic properties of the system. This results in significantly higher solubility for poorly soluble drugs, as the lipid component helps to shield the hydrophobic parts of the drug molecule from the aqueous environment (15,23). Recent advances suggest that this complexation also helps in overcoming bacterial resistance by improving the intracellular concentration of antibiotics (28).

6. Recent Advances and Optimization

6.1. Response Surface Methodology and DoE-Based Modeling

Modern research utilizes statistical tools like central composite design to optimize formulation parameters (21). In 2025, researchers introduced Design of Experiments (DoE) based modeling to optimize HPLC-PDA techniques specifically for pharmacosomes. This approach allows for the systematic adjustment of variables like buffer ratio and pH to achieve optimal resolution and sensitivity in drug release studies (28). Such modeling ensures that the formulations meet strict regulatory standards for linearity and precision.

6.2. Herbal Drug Delivery Successes and Green Metrics

Pharmacosomes are becoming a preferred carrier for herbal constituents due to their ability to bind active hydrogen atoms to lipid chains (27). Recent applications of response surface methodology to geniposide pharmacosomes resulted in a 20-fold increase in lipophilicity(22). Furthermore, new characterization methods for these systems are increasingly incorporating "green metrics" like the Analytical GREEnness Metric Approach to ensure environmental sustainability in pharmaceutical research (28).

7. Therapeutic Potential and Applications

7.1. NSAIDs and Cardiovascular Drugs: Atorvastatin and Diclofenac

Pharmacosomes have been extensively applied to NSAIDs to improve absorption and minimize gastric toxicity. Diclofenac pharmacosomes showed an enhanced solubility of 22.1 g/mL and improved release (5,15). In 2025, atorvastatin calcium was successfully formulated into pharmacosomes to enhance its delivery. These systems are characterized by specific entrapment efficiency metrics and release profiles monitored at 246.4 nm (29).

7.2. Antineoplastic Therapy: Taxol and 5-FUdR

In oncology, pharmacosomes facilitate the delivery of potent drugs like taxol and 5-FUdR. These systems improve the targeting of anticancer agents to tumor sites, reducing systemic side effects and enhancing the ability of the drug to cross the blood-brain barrier (5,14,15,21).

7.3. Infectious Diseases: Amoxicillin, Metronidazole, and Antivirals

A major advancement in 2025 is the development of co-loaded pharmacosomes containing both amoxicillin and metronidazole for the treatment of Helicobacter pylori infections (28). This co-loaded system is designed to provide synergistic effects and overcome the challenges of gastric pathogen eradication. Additionally, antiviral drugs like acyclovir and didanosine continue to show improved sustained release and reduced hemolytic toxicity when delivered via pharmacosomes (5,14,19).

7.4. Cardiovascular and Neurological Applications

Pharmacosomes have been successfully developed for cardiovascular drugs such as pindolol and bupranolol, improving their pharmacokinetic properties (4,5,14,15). They also offer a promising approach for treating neurological disorders by improving drug transport to the central nervous system through enhanced lipid-mediated permeation (16,20).

8. Challenges in Market Translation

Despite technical successes, several challenges hinder commercialization. These include the high cost of high-purity phospholipids, the complexity of large-scale manufacturing, and the need for more extensive clinical trials. However, the move towards optimized, DoE-validated analytical methods and more stable co-loaded formulations in 2025 suggests a path forward for meeting regulatory requirements (8,17,28).

CONCLUSION

Pharmacosomes represent a sophisticated and versatile platform for drug delivery, effectively bridging the gap between conventional vesicles and targeted therapy. By ensuring high entrapment efficiency and superior stability, they address many of the limitations of traditional lipid-based carriers. The recent emergence of co-loaded systems for infectious diseases and the application of rigorous statistical modeling for characterization in 2025 demonstrate the continued evolution of this field. As research continues to optimize these systems and explore new clinical applications, pharmacosomes are poised to play a critical role in the future of personalized and controlled drug delivery.

REFERENCES

1. Pintu Kumar De, Arnab De, Dibyalochan Sahoo. Pharmacosomes: a potential vesicular drug delivery system. International Research Journal of Pharmacy. 2012;3(3):102-105.
2. K. Selvaraju, K. Vengadesh Prabhu, K. Karthick, J. Padma Preetha, Arul Kumaran K. S. G. Pharmacosomes—An immense potential vesicular constructs. Research Journal of Pharmaceutical Dosage Forms and Technology. 2011;3(4):195-200.
3. Sonam Ranga, Amit Kumar. A Review on Pharmacosomes. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2014;2(2):1-7.
4. Ali Gamal Al-Kaf, Ahmed Mohamed Othman. Pharmacosomes: an updated review. Universal Journal of Pharmaceutical Research. 2017;2(1):33-36.
5. Ravindra R. Shinde, Bhagyashree Chaudhari, Anil Velhal, Vivekkumar K. Redasani.

Pharmacosome as a vesicular drug delivery system. Research Journal of Pharmaceutical Dosage Forms and Technology. 2022;14(2):149-154.

6. Preeti Khulbe. Vesicular Drug Delivery Systems: A Special Emphasis on Pharmacosomes. In: Advances in Pharmaceutical Product Development and Research. Hershey (PA): IGI Global; 2017. 99-121.
7. Tanu Goyal, Ashwani Singh Rawat, Meenakshi K. Chauhan. Pharmacosomes: opening new doors for drug delivery. International Journal of Pharmacy and Pharmaceutical Sciences. 2012. Vol 4(3) 25-29
8. Anil Jadhav, Indrayani D. Raut. Pharmacosomes: A Modified Vesicular Drug Delivery System. International Journal of Pharmaceutical Sciences and Nanotechnology. 2024;17(6). 7706-13
9. Vijay K. Singh, Anand Patel, Dinesh Chandra, et al. Pharmacosomes: a novel carrier for targeted and controlled vesicular drug delivery system. 2014.vol 3(5): 1221-1238.
10. Pandita, Archana, Sharma, Pooja, Pharmacos omes: An Emerging Novel Vesicular Drug Delivery System for Poorly Soluble Synthetic and Herbal Drugs, *International Scholarly Research Notices*, 2013, 348186, 10 pages, 2013.
11. Gurleen Kaur, Kirti Negi, Kapil Kumar, Deepak Teotia. Development and evaluation of pharmacosome formulations of mefenamic acid. GSC Biological and Pharmaceutical Sciences. 2021;16(3):229-234.
12. S. Naveen Taj, Y. Indira Muzib. A review on pharmacosomes as novel drug delivery systems. Bulletin of Environment, Pharmacology and Life Sciences. 2024;13(3):125-130.
13. Suresh Rewar, Dashrath Mirdha, Prahlad Rewar. A vital role of pharmacosomes on controlled and novel drug delivery. World Journal of Pharmacy and Pharmaceutical Sciences. 2015;4(10):300-315.
14. Kavitha D, Naga Sowjanya J, Shanker Panaganti. Pharmacosomes: An emerging vesicular system. International Journal of Pharmaceutical Sciences Review and Research. 2010;5(3):168-171.
15. A. Krishna Sailaja. Pharmacosomes: A novel carrier for drug delivery. International Journal of Sciences. 2016;5(7):36-42.
16. Nikita D. Gidde, Indrayani D. Raut, Manojkumar M. Nitalikar, Shrinivas K. Mohite, Chandrakant S. Magdum. Pharmacosomes as drug delivery system: An overview. Asian Journal of Pharmaceutical Research. 2021;11(2):122-127.
17. Popat S. Kumbhar, Tejaswini U. Shinde, Tejaswini P. Jadhav, Tejas S. Gavade, Rushikesh P. Sorate, Uma D. Mali, John V. D'Souza, Arehalli M. Manjappa. Pharmacosomes: An approach to improve biopharmaceutical properties of drugs—basic considerations in development. Research Journal of Pharmacy and Technology. 2021;14(8):4485-4490.
18. D. Nagasamy Venkatesh, K. Kalyani, K. Tulasi, S. Chandrasekhar Rao, K. S. Ramesh. Pharmacosomes: A potential vesicular drug delivery system. International Journal of Pharmaceutical Sciences and Drug Research. 2014;6(3):165-171.
19. Bommala Supraja, Saritha Mulangi. An updated review on pharmacosomes, a vesicular drug delivery system. Journal of Drug Delivery and Therapeutics. 2019;9(1-S):812-815.
20. Bwalya A. Witika, Madan S. Poka, Patrick H. Demana, Viness Pillay, Yahya E. Choonara. Lipid-based nanocarriers for neurological

disorders: A review of the state-of-the-art and therapeutic success to date. Pharmaceutics. 2022;14(4):836.

21. Zhang Zhirong, Wang Jiaxi, Lu Jian. Optimization of the preparation of 3′,5′-dioctanoyl-5-fluoro-2′-deoxyuridine pharmacosomes using central composite design. Acta Pharmaceutica Sinica. 2001;36(6):456–461.
22. Yue Peifeng, Zheng Qing, Wu Bin, Yang Min, Wang Mingsheng. Process optimization by response surface design and characterization study on geniposide pharmacosomes. Pharmaceutical Development and Technology. 2012;17(1):94–102.
23. Mohamed Dawoud, Mohamed Zaafan, Ahmed Saleh, Hossam Mannaa, Noha Sweed. Response surface optimization of a cardioprotective compound through pharmacosomal drug delivery system: in vivo bioavailability and cardioprotective activity potential. Drug Delivery and Translational Research. 2023;13(11):3005–3022.
24. Han Min, Chen Jie, Chen Shuang, Wang Xia. Preparation and study in vitro of 20(S)-protopanaxadiol pharmacosomes. China Journal of Chinese Materia Medica. 2010;35(7):842–846.
25. Priya M. Patil and Dr. Suma Naduvinamani (2025). REVIEW ON PHARMACOSOMES. World Journal of Pharmaceutical Science and Research, 4(1), 318-327
26. Overview and Application of Aquasomes, Pharmacosomes, Liquid Crystalline Systems, Protein and Peptide Based Drug Delivery Systems. In: Advanced Drug Delivery Systems. Boca Raton (FL): Taylor & Francis; 2025. Chapter 19.
27. Novel Drug Delivery Methods for Herbal Medicine. In: Nanotechnology in Herbal Medicines. Boca Raton (FL): Taylor & Francis; 2025. Chapter 15.
28. Gupta A, Saha M, Kunkalienkar S, Jha A, Kulkarni P, Samanth M, Chennamsetty S, Dsouza PA, Mutalik S, Moorkoth S. Analytical study of amoxicillin and metronidazole co-loaded pharmacosomes for *H. pylori* eradication using DoE-based modeling of an HPLC-PDA technique. J Appl Pharm Sci. 2025;15(07):094–109.
29. Afifa Bathool, Gowda D. Vishakante, Mohammed S. Khan, H. G. Shivakumar Development and characterization of atorvastatin calcium loaded pharmacosomes. Indian Journal of Pharmaceutical Sciences. 2025.vol3(6), 466-470

HOW TO CITE: Praveena V A, Sudhir M RR, Athmika S Haika, Divyamol A K, Aswathy Mohan, Gayathri P M, Krishna Haridas, Shabnam Shibu Sekumeeran, Pharmacosomes As Amphiphilic Vesicular Carriers: A Comprehensive Review, Int. J. of Pharm. Sci., 2026, Vol 4, Issue 8, 971-977, https://doi.org/10.5281/zenodo.21820906