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Niosome vs Liposomes: Comparative Evaluation in Topical and Transdermal Drug Delivery

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ABSTRACT

Vesicular drug delivery systems have emerged as effective platforms for enhancing topical and transdermal drug transport by overcoming the barrier function of the stratum corneum. Among these systems, liposomes and niosomes have been extensively investigated due to their ability to encapsulate both hydrophilic and lipophilic therapeutic agents. This review critically compares niosomes and liposomes with respect to their structural composition, preparation techniques, drug loading capacity, stability, skin permeation efficiency, and therapeutic performance in topical and transdermal applications. Liposomes, composed of natural or synthetic phospholipids, offer excellent biocompatibility and resemblance to biological membranes; however, their clinical utility is often limited by chemical instability, high production costs, and susceptibility to oxidative degradation. In contrast, niosome, formulated using non-ionic surfactants, demonstrate enhanced physical and chemical stability, cost-effectiveness, and ease of large-scale manufacturing. The review further examines the influence of formulation parameters such as vesicle size, lamellarity, surfactant type, and cholesterol content on drug release kinetics and skin penetration behaviour. Evidence from recent studies suggests that niosomes often provide improved drug retention within the skin layers and sustained transdermal flux compared to conventional liposomes. Additionally, advances in vesicular surface modification and hybrid carrier systems are discussed to highlight future research directions. Overall, this review underscores the growing potential of niosomes as a robust alternative to liposomes and provides insights into their rational selection for optimized topical and transdermal drug delivery systems.

Keywords: Niosomes, Liposomes, Topical drug delivery, Transdermal drug delivery, Vesicular carrier systems, Skin permeation enhancement.

1. INTRODUCTION

Background of Topical and Transdermal Drug Delivery

Topical and transdermal drug delivery systems represent an important therapeutic approach aimed at delivering drugs either locally to the skin or systemically through the skin into the bloodstream. These routes offer several advantages over conventional oral and parenteral administration, including avoidance of first-pass hepatic metabolism, improved patient compliance, reduced dosing frequency, and minimized systemic side effects. However, the highly organized structure of the skin—particularly the stratum corneum—poses a significant barrier to drug permeation, limiting the number of drugs that can be effectively delivered through this route.

To overcome these challenges, various physical, chemical, and carrier-based strategies have been explored. Among carrier-based approaches, vesicular drug delivery systems have emerged as one of the most promising technologies due to their ability to encapsulate diverse drug molecules and modulate their interaction with the skin barrier.

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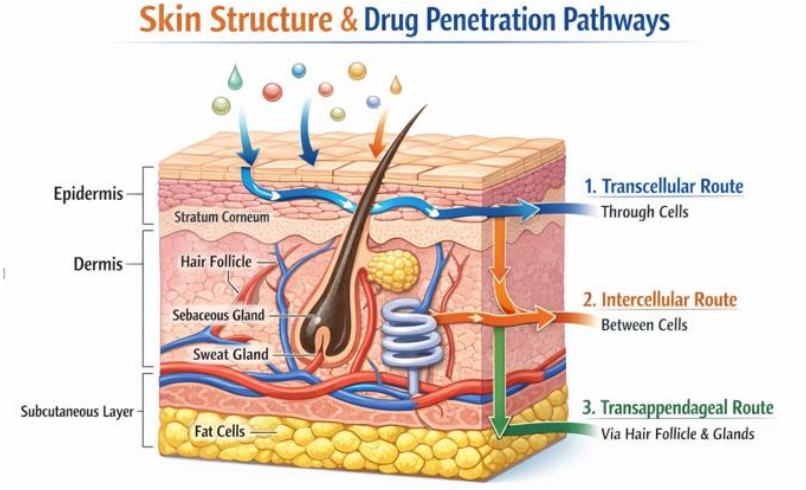

Figure 1.1: Structural organization of human skin and major pathways involved in topical and transdermal drug penetration. The stratum corneum acts as the primary barrier, restricting drug permeation via intercellular, transcellular, and appendageal routes.

Vesicular Drug Delivery Systems: An Overview

Vesicular systems are microscopic or nanoscopic structures composed of one or more concentric bilayers capable of entrapping drug molecules within aqueous or lipid domains. These systems enhance drug solubility, protect labile drugs from degradation, and improve skin penetration by altering drug partitioning into the stratum corneum. Common vesicular systems include liposomes, niosomes, ethosomes, transfersomes, and proniosomes.

Among these, **liposomes** and **niosomes** are the most extensively investigated and clinically relevant vesicular carriers for topical and transdermal drug delivery.

Liposomes: Historical Perspective and Characteristics

Liposomes are spherical vesicles composed primarily of phospholipid bilayers enclosing an aqueous core. Since their discovery in the 1960s, liposomes have been widely studied for their biocompatibility and ability to mimic biological membranes. They can encapsulate hydrophilic drugs in the aqueous core and lipophilic drugs within the lipid bilayer, making them versatile carriers.

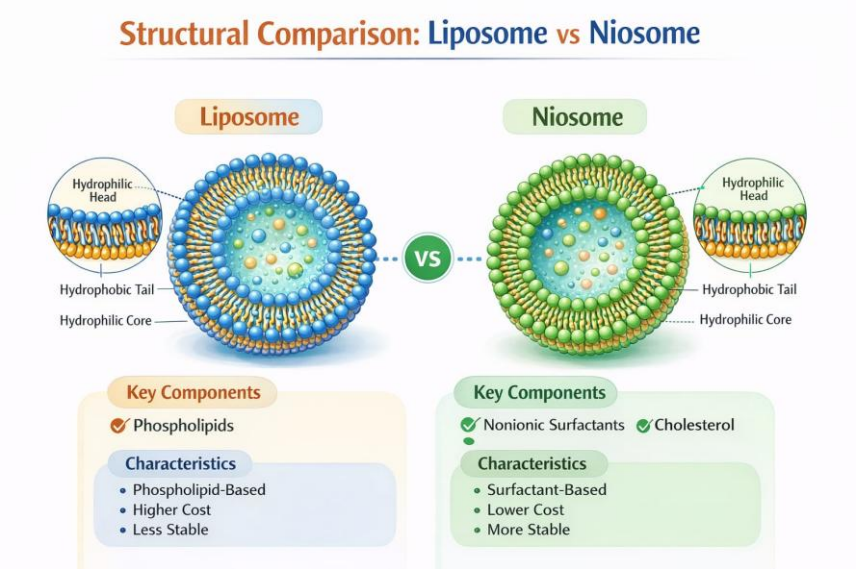

Figure 1.2 Structural organization of liposomes and niosomes illustrating differences in bilayer composition and drug encapsulation domains. Liposomes consist of phospholipid bilayers, whereas niosomes are formed from non-ionic surfactants, resulting in enhanced chemical stability.

Despite these advantages, liposomes suffer from several drawbacks such as chemical instability due to phospholipid oxidation and hydrolysis, high manufacturing costs, limited shelf life, and leakage of encapsulated drug during storage. These limitations have restricted their widespread commercialization, especially in large-scale topical formulations.

Niosomes: Emergence as an Alternative Vesicular System

Niosomes are vesicular systems structurally similar to liposomes but composed of non-ionic surfactants instead of phospholipids. The substitution of phospholipids with surfactants such as Span, Tween, or Brij significantly improves chemical stability and reduces production costs. Niosomes demonstrate high encapsulation efficiency, enhanced skin penetration, and better storage stability.

Due to these advantages, niosomes have gained considerable attention as a robust alternative to liposomes, particularly for topical and transdermal drug delivery applications.

Rationale and Scope of the Review

Although both liposomes and niosomes have been extensively studied, a critical comparative evaluation focusing on their performance in topical and transdermal drug delivery is essential for rational formulation design. This review aims to systematically compare niosomes and liposomes with respect to composition, preparation methods, physicochemical properties, stability, skin permeation behavior, therapeutic performance, and translational potential. Recent advances, formulation challenges, and future prospects are also discussed.

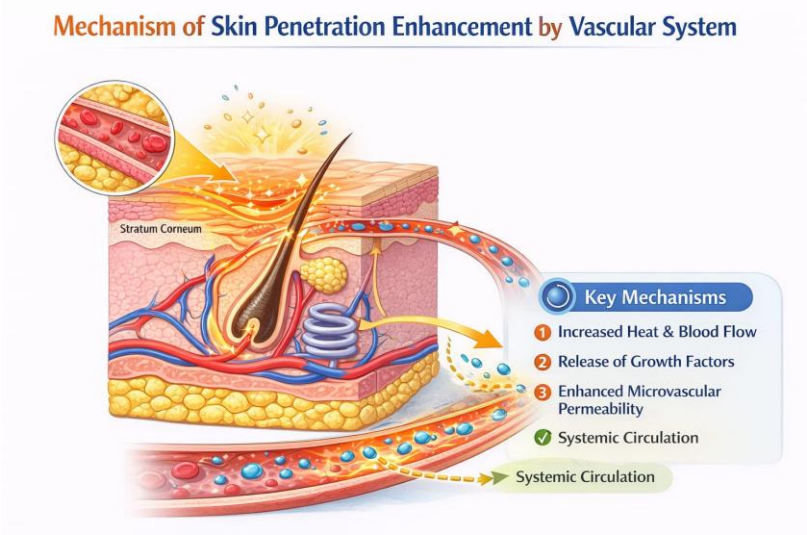

Figure 1.3 Proposed mechanisms by which vesicular carriers enhance topical and transdermal drug delivery. Niosomes promote surfactant-mediated lipid fluidization, while liposomes primarily act through membrane fusion and localized drug release.

2. COMPARATIVE EVALUATION OF NIOSOMES AND LIPOSOMES

Table 2.1: Fundamental Differences Between Liposomes and Niosomes

Parameter	Liposomes	Niosomes
Basic components	Phospholipids and cholesterol	Non-ionic surfactants and cholesterol
Cost of raw materials	High	Low
Chemical stability	Prone to oxidation and hydrolysis	Highly stable
Biodegradability	Excellent	Good
Shelf life	Limited	Prolonged
Ease of scale-up	Difficult	Relatively easy

Table 2.2: Comparison of Preparation Methods

Aspect	Liposomes	Niosomes
Common methods	Thin-film hydration, reverse phase evaporation	Thin-film hydration, ether injection, proniosomes
Energy requirement	Moderate to high	Moderate
Solvent dependency	High	Moderate
Reproducibility	Variable	High
Industrial feasibility	Limited	Favorable

Table 2.3: Physicochemical and Performance Parameters

Parameter	Liposomes	Niosomes
Vesicle size range	50 nm – 5 µm	100 nm – 10 µm
Drug encapsulation efficiency	Moderate to high	High
Drug leakage	Common	Minimal
Skin permeation	Moderate	Enhanced
Drug release pattern	Rapid to controlled	Sustained

Table 2.4: Advantages and Limitations in Topical and Transdermal Delivery

Feature	Liposomes	Niosomes
Skin retention	Moderate	High
Transdermal flux	Variable	Consistent
Formulation flexibility	Limited	High
Storage conditions	Refrigeration required	Room temperature stable
Clinical acceptance	Established	Emerging

3. MECHANISMS OF SKIN PENETRATION

Liposomes primarily enhance drug delivery by interacting with skin lipids and releasing the drug at the surface or within the upper layers of the stratum corneum. Their penetration is often limited by vesicle rigidity and instability.

Niosomes, in contrast, exhibit improved penetration due to surfactant-induced fluidization of stratum corneum lipids, vesicle deformability, and prolonged residence time within skin layers. These mechanisms collectively contribute to enhanced transdermal flux and sustained drug release.

4. THERAPEUTIC APPLICATIONS

Both systems have been explored for delivery of:

- Anti-inflammatory agents
- Antifungal and antibacterial drugs
- Anticancer agents
- Hormones and peptides
- Cosmetic and cosmeceutical agents

Niosomes show particular promise in chronic dermatological conditions requiring sustained drug action.

5. CHALLENGES AND FUTURE DIRECTIONS

Challenges include vesicle aggregation, limited drug loading for certain molecules, regulatory concerns, and lack of standardized evaluation protocols. Future research is focused on hybrid vesicular systems, surface-modified vesicles, stimuli-responsive carriers, and integration with physical enhancement techniques such as microneedles.

6. CONCLUSION

Niosomes and liposomes represent two important vesicular platforms for topical and transdermal drug delivery, each with distinct advantages and limitations. While liposomes offer superior biocompatibility and a long history of clinical use, their instability and high production costs restrict broader application. Niosomes, owing to their enhanced stability, cost-effectiveness, ease of manufacturing, and superior skin permeation characteristics, have emerged as a promising alternative. Comparative evidence suggests that niosomes often provide improved skin retention and sustained transdermal drug delivery, making them particularly suitable for chronic and long-term therapies. Continued advancements in formulation strategies and large-scale production technologies are expected to further strengthen the translational potential of niosomal systems. This review supports the rational selection of vesicular carriers and highlights niosomes as a future-ready platform in topical and transdermal drug delivery research.

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