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# Niosomes in Nanotechnology: Pioneering Targeted Drug Delivery Systems for Enhanced Therapeutic Efficacy

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**ABSTRACT**

Exploring nanotechnology for targeted drug delivery has garnered significant focus, particularly for directing medications to specific disease sites, thereby minimizing the impact on healthy tissues. Overcoming the challenge of safe and effective drug delivery is crucial in pharmaceutical development. Niosomes represents a breakthrough in this realm, offering a novel vesicular system that secures drugs within a non-ionic surfactant bilayer. These particles, typically ranging from 10 to 100 nm, are favored for their stability and cost-effectiveness compared to liposomes. Their efficacy in enhancing drug action lies in their ability to prolong drug circulation, shield the drug from external biological factors, and concentrate its effects on targeted cells. Niosomes find diverse applications in cancer therapy, hemoglobin transport, oral peptide delivery, leishmaniasis treatment, ophthalmic applications, and skin drug delivery. This article reviews the composition, benefits, challenges, and several types of niosomes alongside preparation methods, characterization, future possibilities, ongoing studies, and practical applications.

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## INTRODUCTION:

Aiming to optimize therapeutic efficacy while minimizing side effects, the pharmaceutical industry has been relentlessly pursuing improved drug delivery systems for decades. This pursuit is driven by the recognition that traditional dosage forms, though widely used due to high patient compliance, often fall short of delivering optimal therapeutic outcomes [1]. Common forms such as tablets, capsules, ointments, liquids, and injectable, despite their widespread use and patient familiarity, frequently require multiple daily dosages to maintain effective therapeutic drug levels [2-4]. This can lead to fluctuating drug concentrations in the body, potential toxicity, and reduced overall efficacy of the treatment [5].

The limitations of conventional drug delivery systems have spurred the development of advanced delivery mechanisms like niosomes, liposomes, nanoparticles, and microemulsions. These novel systems, particularly niosomes and liposomes, have shown great promise in revolutionizing drug delivery by enabling targeted transport of drugs directly to affected tissues via the bloodstream. This targeted approach is not only more efficient but also significantly reduces the adverse side effects often associated with traditional drug therapies [6].

Niosomes, spherical vesicular structures formed from non-ionic surfactants, have emerged as a particularly promising tool in targeted drug delivery. Their unique composition and structure allow them to encapsulate various therapeutic agents, from small-molecule drugs to larger biological molecules like proteins and nucleic acids. This versatility, combined with their relative stability and low toxicity, makes niosomes an attractive option for drug delivery in various medical applications.

Recent studies have highlighted the potential of niosomes in diverse therapeutic areas. For instance, a study by Shah et al. (2021) explored the use of niosomes for the targeted delivery of chemotherapeutic agents in cancer therapy, demonstrating enhanced tumor targeting and reduced systemic side effects. This research underscores the potential of niosomes to revolutionize cancer treatment, offering a more effective and less toxic alternative to conventional chemotherapy [7].

In addition to cancer therapy, niosomes have shown potential in the field of vaccine delivery. A study by Singh et al. (2020) revealed that niosomes could significantly enhance the immune response to vaccines [8]. This finding opens new possibilities for vaccine

development, particularly in the context of infectious diseases where effective and robust immune responses are crucial [8].

The utility of niosomes extends beyond systemic applications to localized treatments as well. Recent research in transdermal drug delivery has demonstrated that niosomes can effectively enhance the skin penetration of various drugs. A study by Joshi et al. (2018) highlighted the increased efficacy of anti-inflammatory drugs when delivered through niosomes, suggesting their potential in treating a range of dermatological conditions [9].

Niosomes are also being explored for ocular drug delivery. Given their ability to encapsulate both hydrophilic and hydrophobic drugs, niosomes offer an exciting avenue for treating eye diseases. A study by Chang et al. (2019) found that niosomes could increase drug retention time and bioavailability in the eye, pointing to their potential to improve treatments for conditions like glaucoma [9].

Moreover, the potential of niosomes in neurology is being investigated, particularly in crossing the blood-brain barrier (BBB) – a significant challenge in treating neurological disorders. Gupta et al. (2020) conducted a study focusing on the use of niosomes for delivering drugs across the BBB, showing promise in treating conditions like Alzheimer's and Parkinson's disease [10].

Despite these promising developments, the field of niosomal drug delivery is not without its challenges. Issues such as large-scale production, ensuring uniformity and reproducibility in large batches, and navigating regulatory hurdles remain significant obstacles to the widespread adoption of niosomal therapies. Furthermore, as with any novel drug delivery system, the long-term safety and efficacy of niosomes need to be thoroughly evaluated through clinical trials [11-15].

The future of niosome research is poised to address these challenges, with ongoing studies focusing on optimizing niosome formulations for specific applications, enhancing their biocompatibility, and exploring their potential in personalized medicine. As the field continues to evolve, niosomes will likely play an increasingly prominent role in the next generation of drug delivery systems.

In conclusion, niosomes represent a significant advancement in the field of drug delivery, offering a versatile, efficient, and potentially safer alternative to traditional drug delivery methods. The ongoing research and development in this area holds great promise for the

future of pharmaceutical therapies, with the potential to significantly improve patient outcomes across a wide range of medical conditions.

**1-Structure and Composition of Niosomes:[11]**

Niosomes are an advanced form of vesicular drug delivery systems, primarily composed of non-ionic surfactants and cholesterol. These components come together to form a bilayer structure that can encapsulate a wide range of therapeutic agents, from small molecules to larger biomolecules like proteins and nucleic acids.

The bilayer structure of niosomes is akin to that of cell membranes, but instead of phospholipids, niosomes utilize non-ionic surfactants. These surfactants are amphiphilic, meaning they have both hydrophilic (water-attracting) and hydrophobic (water-repelling) parts. When these surfactants are hydrated, they spontaneously arrange themselves into a bilayer, with the hydrophobic tails facing inward and the hydrophilic heads facing outward. This arrangement creates an aqueous core within the vesicle, ideal for encapsulating hydrophilic drugs, while the hydrophobic region can accommodate lipophilic drugs.

Cholesterol is an essential component in the niosome structure. It intercalates among the surfactant molecules, providing rigidity and stability to the bilayer. Cholesterol's presence reduces the bilayer's permeability, effectively controlling the release of the encapsulated drug and minimizing leakage. A recent study by Khan et al. (2011) demonstrated that including cholesterol in niosome formulations significantly enhanced the stability of the vesicles, particularly at varying temperatures and pH levels [16].

Impact of Charge-Inducing Agents

The surface charge of niosomes, imparted by charge-inducing agents, plays a critical role in their interaction with biological membranes and cells. The surface charge can be manipulated by adding specific charge-inducing agents, such as diacetyl phosphate or stearyl amine, to the formulation. This modification influences the niosomes' ability to fuse with cell membranes and release their payload. A study by Patel et al. (2022) illustrated how altering the surface charge of niosomes can affect cell uptake, which is vital for targeted drug delivery applications [17].

Recent advancements in niosome technology have focused on exploring novel surfactants and cholesterol analogs to enhance the efficacy and stability of niosome formulations. For instance, a study by Sharma et al. investigated ethylated surfactants, which showed improved solubility and drug encapsulation efficiency. Additionally, research by Moreno et al. (2020) explored the use of plant sterols as alternatives to cholesterol, finding that they could provide similar stabilizing effects with potentially reduced toxicity.

Looking forward, the field of niosome research is moving toward the development of more sophisticated and specialized niosomal systems. Efforts are being made to create stimulus-responsive niosomes that can release their payload in response to specific triggers like pH changes, temperature shifts, or enzymatic activity. Such advancements could open new doors in the targeted and controlled release of drugs, making niosomes an even more versatile tool in the arsenal of drug delivery systems.

Niosomes, with their unique structure and composition, offer a versatile and promising platform for drug delivery. The ongoing research and recent studies in this field continue to uncover new possibilities and improvements, paving the way for more effective and targeted therapies in the pharmaceutical landscape [1].

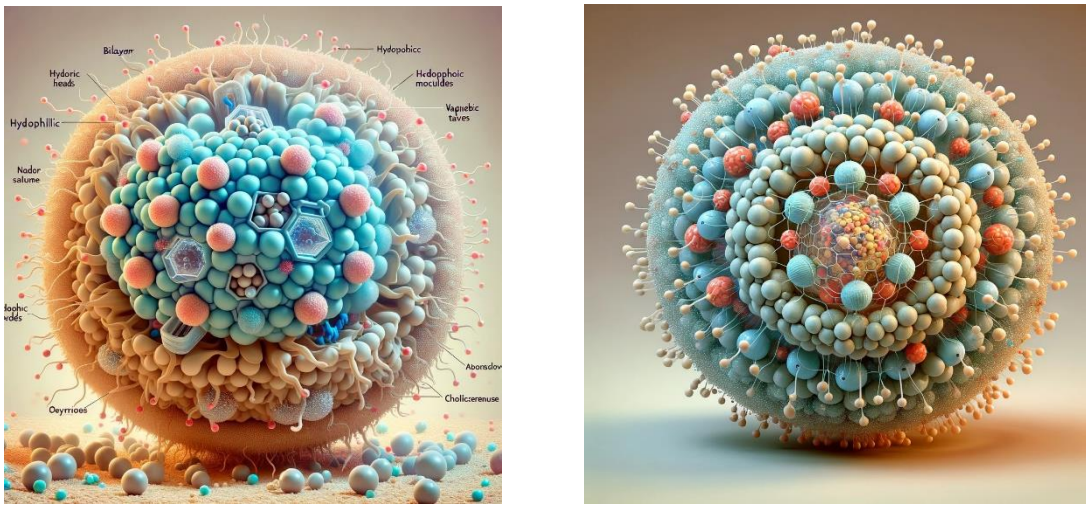


**Figure 1.** Two illustrations depicting the structure of a niosome. These images show the spherical vesicle formed by a bilayer of non-ionic surfactants with hydrophilic heads and hydrophobic tails, including cholesterol molecules for stability, and the aqueous core in the center.

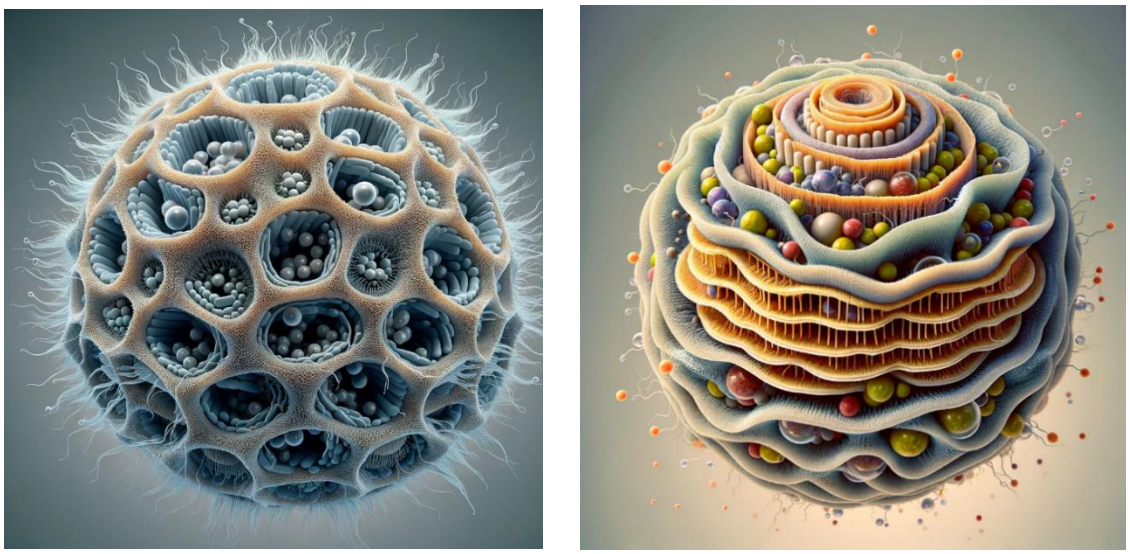

**Figure 2**. Major types of niosomes, MLV, LUV, and SLV [18]

Niosomes are round spheres made up of tiny lamellar structures, which can be single or multilamellar (Figure 1). The bilayer is composed of nonionic surfactants, which may or may not include cholesterol and a charge inducer [19, 20]. Niosomes are formed using various surfactants such as alkyl ethers, alkyl glycerol ethers, sorbitan fatty acid esters, and polyoxyethylene fatty acid esters, in different combinations and molar ratios [21] . The choice of surfactant for niosomes preparation is determined by the Hydrophilic Lipophilic Balance (HLB) value and critical packing parameter (CPP) values. These factors are crucial in selecting surfactant molecules, as the HLB value indicates the ability of a surfactant to form vesicles. Surfactants with HLB numbers ranging from 4 to 8 are suitable for vesicle preparation [22].

The symmetry of the surfactant plays a crucial role in determining the morphology of nanostructures through the self-assembly process of amphiphilic molecules, guided by the critical packing parameter (CPP). The CPP value is instrumental in predicting the resultant nanostructure shape. When the CPP is 1/3 or below, it signifies a surfactant with a large head group, leading to the formation of spherical micelles characterized by small hydrophobic tails. Should the CPP range from 1/3 to 1/2, the resulting structures are non-spherical micelles. Bilayer vesicles are typically formed when the CPP lies between 1/2 and 1, indicative of a balance between hydrophilic and hydrophobic components. Conversely, an inverted micelle structure emerges when the CPP exceeds 1, highlighting a surfactant with a substantial hydrophilic head and a compact hydrophobic tail [23]. CPP can be regarded as a

tool for achieving, understanding, and forecasting the self-assembled structure and its morphological transition in solutions including both hydrophilic and hydrophobic components [24]. Cholesterol is added to the bilayer to enhance its stiffness, hence reducing the permeability of niosomes. Charge inducers, in the meantime, supply electric charge to the vehicles and enhance the size of the vesicles, hence improving the efficacy of drug entrapment. The stabilization of vesicles is facilitated by negative charge inducers such as diacetyl phosphate, dihexadecyl phosphate, and lipo-amino acid, as well as positive charge inducers such stearyl amine and cetylpyridinium chloride [25]. Niosomes containing nonionic surfactants exhibit a tendency for the hydrophilic end to face outward towards the aqueous phase, while the hydrophobic end faces inward towards each other, resulting in the formation of a closed bilayer structure. This structure effectively encloses solutes in an aqueous solution. The closed bilayer structure of niosomes consists of hydrophilic inner and outer surfaces, with a lipophilic region sandwiched in between [26, 27]. Forming a closed bilayer structure necessitates energy input, such as heat or physical agitation. Various forces, including van der Waals and repulsive forces between the surfactant molecules maintain the vesicular structure. Modifying the components (such as type, content, and concentration), size, surface charge, or volume of the vesicles is expected to alter the characteristics of the resulting niosomes [20, 28]. Niosomes can be classified into three classes according to their vesicle size: small unilamellar vesicles (0.025–0.05 mm), multilamellar vesicles (>0.05 mm), and giant unilamellar vesicles (>0.10 mm) [28].

**2. Preparation of Niosomes:**

Various techniques are available for synthesizing niosomes, tailored according to specific needs such as the intended size and distribution of the vesicles, the number of bilayers, the efficiency of encapsulating the aqueous phase, and the desired permeability of the vesicle membranes. Typically, the production of niosomes involves hydrating a blend of surfactant and lipid at a temperature above 60°C in an aqueous solution. This step may be followed by an optional procedure to reduce the size of the vesicles, culminating in the creation of a colloidal dispersion [29].

**Preparation of small unilamellar vesicles**

A-Sonication:

Sonication stands as a traditional technique for crafting niosomes, where the process begins with the dissolution of the drug in a buffer solution. Following this, the buffer containing the drug is integrated with a non-ionic surfactant in a precisely optimized ratio. The subsequent step involves sonication of this mixture at a designated frequency, temperature, and duration to yield the desired niosomes. This method offers a straightforward approach to modulating the particle size of the niosomes, enabling the production of niosomes with reduced diameters and a narrow size distribution. While probe Sonicator are an option, their use is marked by high energy consumption, which can cause rapid temperature rises and potential titanium release [30].

**B-Micro fluidization:**

Micro fluidization employs submerged jets within the narrow passageways of the interaction chamber, where drug and surfactant streams collide at exceptionally high velocities. This method leverages the intense impact and energy to form niosomes that are uniform, smaller, and predominantly unilamellar, enhancing the consistency of the results [31].

**Preparation of multilamellar vesicles**:

**Hand shaking method:**

Referred to as the thin-film hydration technique, this approach involves dissolving a combination of surfactants and cholesterol in volatile organic solvents such as ether, chloroform, and methanol within a round-bottom flask. The removal of the organic solvent is accomplished using a rotary evaporator at ambient temperature, resulting in a thin film of the solid mixture adhering to the flask's interior. This procedure leads to the creation of multilamellar niosomes. Upon drying, the surfactant film undergoes rehydration with an aqueous solution at 60°C, accompanied by mild stirring, facilitating the niosomes' formation [32].

**Ether injection method**:

This technique involves creating niosomes by injecting a surfactant solution, dissolved in diethyl ether (a volatile organic solvent), into warm water kept at 60°C. The surfactant and

ether mixture is introduced into the water via a 14-gauge needle, leading to the formation of single-layered vesicles as the ether evaporates [33].

**The reverse-phase evaporation technique**

In this method, cholesterol and surfactant in a 1:1 ratio are dissolved together in a combination of ether and chloroform. To this, an aqueous phase containing the drug is added. The mixture is then sonicated at temperatures between 4-5°C. Following sonication, a clear gel forms, which is further sonicated upon the addition of a small volume of phosphate buffered saline (PBS). The organic solvents are removed under reduced pressure at 40°C, leaving behind a viscous niosome suspension. This suspension is then diluted with PBS and heated in a water bath at 60°C for 10 minutes to produce niosomes [34].

**Miscellaneous Methods:**

**1- Multiple Membrane Extrusion Method:**

A film composed of surfactant, cholesterol, and diacetyl phosphate dissolved in chloroform is formed through evaporation. This film is hydrated with an aqueous drug solution, and the resulting mixture is passed through polycarbonate membranes up to eight times in a series. This process is efficient for achieving precise control over niosome size [35].

**2-The bubble method**

This innovative, one-step niosome preparation technique does not require organic solvents. Utilizing a three-neck round-bottom flask within a temperature-controlled water bath, this method involves dispersing cholesterol and surfactant in a buffer solution at pH 7.4 and 70°C. Mixing is performed for 15 seconds using a high-shear homogenizer, followed immediately by nitrogen gas bubbling at 70°C to form niosomes.

**3-Characterization of Niosomes**

**1) Entrapment Efficiency**:

The definition of entrapment efficiency (EE) for vesicular systems relates to the quantity of active agents encapsulated within the structure of niosomes. The calculation of EE is represented as follows:

$$EE = \frac{amount\ entrapped}{total\ amount} \times 100 \qquad (1)$$

Here, the "Total Amount" signifies the aggregate quantity of the pharmaceutical agent present in the niosomal formulation. The determination of EE is achieved through spectrophotometric analysis, utilizing a UV-visible spectrophotometer. For genetic materials, the process involves gel electrophoresis and subsequent UV densitometry assessment. Additionally, EE may be assessed fluorometrically with the aid of a hydrophilic fluorescent marker [23].

**2) Vesicle size and shape:**

Niosomal vesicles are presumed spherical in shape, with their average diameter ascertainable via laser light scattering techniques. Additionally, the vesicle diameter can be gauged through methods such as electron microscopy, molecular sieve chromatography, ultracentrifugation, photon microscopy, optical microscopy, and freeze-fracture electron microscopy. It is noted that freeze-thaw cycles can increase vesicle diameter, potentially causing vesicle fusion [28].

**3) Zeta potential**:

The surface zeta potential of niosomes is measurable using zetasizers and Dynamic Light Scattering (DLS) devices. The surface charge significantly influences niosomal behavior, with uncharged niosomes exhibiting a higher propensity for aggregation compared to their charged counterparts. In studies conducted by Bayindir and Yuksel, niosomes encapsulating paclitaxel demonstrated a stabilization effect within a range of -41.7 to -584 mV due to their negative potential [36].

**4) In-vitro release**:

In vitro release rate studies has been performed by many researchers with the help of the The study of in vitro release rates has been a focus for numerous researchers, employing techniques such as:

- **Dialysis:** Utilizing dialysis tubing, where a dialysis sac is prepared, filled with the vesicle suspension, and then incubated in a buffer solution at controlled temperatures (25°C or 37°C) with constant agitation. Drug content in the buffer is periodically measured via suitable assay methods [37].

**Reverse dialysis**: This method involves placing niosomes within several small dialysis tubes filled with a dissolution medium, thereby separating the niosomes from the medium [38].

**Franz diffusion cell**: Within the Franz diffusion cell framework, a cellophane layer serves as the dialysis barrier. The process involves the dialysis of niosomes across this cellophane membrane against an appropriate dissolution medium maintained at ambient temperature. Drug concentration in the samples is determined at predetermined intervals through analytical methods [39].

**5) *In vivo* Release Study**

For the in vivo experiments, a niosomal suspension was administered intravenously to albino rats via the caudal vein using a sterile syringe. The animals were organized into distinct groups for observational purposes [38].

**6) Bilayer formation:**

The aggregation of non-ionic surfactant molecules to create bilayer vesicles manifests as X-shaped formations when observed under polarized light microscopy, indicating the vesicular bilayer structur [33].

**7) Stability study:**

The long-term stability of niosomal formulations is assessed by monitoring the mean vesicle size, size distribution, and the efficiency of drug entrapment over several months. This involves storing the niosomal suspension under varied temperature conditions, with periodic sampling to evaluate the proportion of the drug retained within the niosomes using UV spectroscopy or High-Performance Liquid Chromatography (HPLC) techniques [34, 35].

**4-Applications of Niosomes**

Niosome-based drug delivery systems via transdermal, parenteral, and ocular routes have been extensively researched [28, 40, 41]. The slow penetration rate of conventional transdermal techniques can be overcome via niosomal administration via transdermal channels. Drugs like diclofenac, flurbiprofen, and nimesulide are enhanced in bioavailability and therapeutic effectiveness when they are included in niosomal formulations [41]. When it comes to ophthalmic medication delivery, a niosomal formulation of timololmaleate coated with chitosan has less cardiovascular side effects and a stronger impact on decreasing intraocular pressure compared to commercially available formulations. Various more therapeutic uses involving niosomal formulations have been explored in the following sections, because to their numerous beneficial features [5].

**Niosome as a carrier for Hemoglobin**

Hemoglobin can be transported by niosomes. A visible spectrum that can be superimposed upon free hemoglobin is exhibited by niosomal suspension. Like non-encapsulated hemoglobin, oxygen can pass through vesicles, and the hemoglobin dissociation curve can be adjusted [42].

**Protein and peptide delivery**:

Taking oral proteins and peptides faces several challenges, such as degradation by digestive enzymes, varying pH levels, and the low permeability of the intestinal wall. However, encapsulating insulin within the layers of niosomes has demonstrated protection from the degrading effects of enzymes like chymotrypsin, trypsin, and pepsin during in vitro studies. Similarly, attempts to use vasoactive intestinal peptide (VIP) for treating Alzheimer's disease encountered obstacles due to its inability to penetrate the blood-brain barrier (BBB) and rapid clearance from the body when administered intravenously. Dufes and colleagues introduced glucose-coated niosomes carrying VIP aimed at targeted delivery to specific regions of the brain, suggesting that these glucose-coated vesicles offer an innovative approach for transporting medications across the BBB [43, 44].

**Ophthalmic drug delivery**

- Eye disorders are managed by administering medication directly into the eye, which can be in the form of a suspension, solution, or in-situ gel. Niosomal carriers designed for eye drug delivery have been shown to extend the release of the drug, as illustrated by the following examples:

- Compared to conventional formulations, niosomal encapsulation of Timolol maleate with chitosan has shown improved outcomes in lowering intraocular pressure with fewer cardiovascular side effects [45].

- For sustained drug release in ocular applications, gentamicin-loaded niosomes composed of Tween 60, cholesterol, and dicetyl phosphate (DCP) were found to be more effective than solutions of gentamicin, as determined through in-vitro studies [46, 47].

- Niosomes coated with bioadhesive substances and formulated with acetazolamide using span 60, cholesterol, stearylamine, or dicetyl phosphate demonstrated a greater ability to reduce intraocular pressure than the commercially available Dorzolamide. Similarly, a

chitosan-coated niosomal formulation of 0.25% Timolol maleate showed superior efficacy in reducing intraocular pressure with a reduced risk of cardiovascular side effects when compared to its marketed counterpart [48].

**Transdermal delivery**:

The primary limitation of transdermal drug delivery is its slow absorption rate through the skin. However, incorporating drugs into niosomes has not only enhanced their penetration rates but also increased their absorption efficiency, while simultaneously reducing skin irritation without disrupting the outermost layer of skin, known as the stratum corneum. This improvement was observed as follows:

Through the application of Franz diffusion cells, the permeation of ketorolac, a potent non-steroidal anti-inflammatory drug (NSAID), was assessed across excised rabbit skin from various proniosome gel formulations. These formulations significantly decreased the initial delay (lag time) in drug penetration, thus facilitating faster delivery of the medication [19].

Furthermore, in vivo experiments conducted on hairless mice with different topical erythromycin formulations demonstrated that niosome-based erythromycin formulations were superior in delivering the drug effectively to the intended pilosebaceous units, compared to other formulations [38].

**Tumour targeting**:

Chemotherapy remains the primary effective treatment against tumor cells, yet its penetration into the affected tissues and adverse effects on healthy cells often reduce the effectiveness of many cancer-fighting drugs. To mitigate these adverse effects, a variety of research groups have explored the use of niosomes to enhance the delivery of anticancer agents directly to the local lymphatic system. In an effort to create cytarabine hydrochloride niosomes with finer vesicles, a method involving lipid hydration was employed, deliberately omitting dicetyl phosphate. The resulting vesicles were sized between 600 and 1000 nm. Among the surfactants tested (Tween 20, Tween 80, Span 60, Span 80), the formulation containing Span 60 exhibited the most prolonged release rate, characterized by an immediate release phase lasting 2–6 hours, followed by a consistent release extending beyond 16 hours [49].

**Leshmaniasis Treatment**:

In addressing Leishmaniasis, a condition caused by the parasitic invasion of Leishmania species into liver and spleen cells, antimonials are often chosen above alternative treatments. Research involving mice has demonstrated that a niosomal formulation containing sodium stibogluconate, a type of antimonial, is capable of efficiently crossing cellular barriers to accurately target the infected cells. Similarly, niosomes, which are vesicles encapsulating drugs much like liposomes, have proven to be effective in the experimental treatment of leishmaniasis [50].

**5-Advantages and disadvantages of niosomal carriers**

Advantages of niosomes

Surfactants utilized in niosome preparation are recognized for their biodegradability, compatibility with biological systems, and lack of immunogenic response. The structural integrity of niosomes lends them a chemical stability that negates the need for specialized storage or handling conditions. Adjustments in the composition and production techniques of niosomes allow for precise control over their physicochemical characteristics, including shape, size, and fluidity. These vesicles are capable of encapsulating a substantial volume of substances within their compact structure.

Niosomes offer protection to delicate and labile pharmaceuticals, shielding them from various external and internal factors, thus preserving the integrity of the drug molecules. They enhance the efficacy of medications by prolonging their presence in the bloodstream and directing their action towards specific cells. Versatile in administration, niosomes can be delivered through multiple pathways including oral (e.g., cefdinir, Lornoxicam), parenteral, topical, ocular (e.g., tacrolimus, naltrexone HCl), transdermal (e.g., gallidermin, clomipramine), pulmonary (e.g., glucocorticoid), and across the brain barrier (e.g., temozolomide). They are compatible with various dosage forms, such as powders, suspensions, and semi-solids, enhancing the solubility and permeability of poorly soluble drugs and facilitating skin penetration when applied topically.

Niosomes improve patient compliance by offering an aqueous vehicle-based suspension that is preferable to oily formulations. Additionally, their aqueous nature allows for emulsification in non-aqueous phases to control drug release rates. Capable of delivering multiple drugs simultaneously, such as the anticancer agents doxorubicin and curcumin, niosomes serve as

micro-reservoirs for controlled drug release, enhancing bioavailability and allowing for the modification of vesicle composition, additive concentration, and surface charge for tailored drug delivery [51]. Extensively researched for their potential in sustained and targeted delivery, niosomes can be chemically modified to increase their versatility and affinity towards targeted sites, making them invaluable in the realm of drug delivery technology [52].

Disadvantages of niosomes

Niosomes encounter several limitations that might undermine their longevity, including physical and chemical instability, a propensity for aggregation, and the fusion of vesicles which may lead to the leaking or hydrolysis of encapsulated drugs. Furthermore, the preparation of multilamellar vesicles through processes such as extrusion or sonication is not only time-consuming but also demands specific, specialized equipment, adding to the complexity of their production [16].

**6-Comparison between niosomes and liposomes drug delivery system:**

Niosomes and liposomes exhibit comparable functionality, as they possess analogous physicochemical characteristics that are contingent upon the bilayer composition and the employed manufacturing techniques.Nevertheless, the substances employed in the formulation of niosomes enhance their stability [20]. Niosomes are formed by combining nonionic monomeric surfactants with cholesterol. In contrast, liposomes are derived from phospholipids with double chains that can be either neutral or charged. On the other hand, niosomes exhibit enhanced stability and lack various mechanisms such as active, passive, and magnetic targeting. This makes niosomes more advanced and specific as carriers for macromolecular drugs. Liposomes exhibit a greater concentration of cholesterol compared to niosomes. Consequently, the drug entrapment effectiveness of liposomes is lower compared to that of niosomes. Both of them function as amphiphilic vesicles and can be utilized for precise and prolonged drug administration.Multiple publications have documented that the in vivo functionality of niosomes closely resembles that of liposomes [53, 54]. Niosomal and liposomal vesicular systems exhibit comparable utility in the medicinal and cosmetic domains.The liposome preparation is expensive due to the presence of unstable chemical constituents (phospholipids) that are prone to oxidative destruction. Liposomes necessitate certain handling techniques [28]. Encapsulated medications are extended in their circulation and metabolic stability is enhanced when they are in an emulsified state. However, liposomes have a restricted shelf life due to the rancidification of their lipid components [55-57].

**Table 1 : Niosomes versus liposomes: a summary[54, 58]**

| Itmes | Niosomes | Liposomes |
|---|---|---|
| Type of surfactant | Non- ionic surfactant | phospholipids |
| Size of vesicles | Ranges from 10-100nm | Ranges from10-3000nm |
| cost | Inexpensive | High expensive |
| Cheimical stability | Stable | More suspestable to chemical breakdown and oxidation |
| toxicity | Less toxic | Comparatively more toxic |
| Preparation and storage | No special condition required | Special requirments like an inert atmosphere and low temprature |
| Component purity | Good | variable |
| Percentage of EE of the drug | Lower | Higher dute to the higher conc. of cholesterol. |
| Haif life | Long | Limited because of rancidification of their lipid components |

**7-Future Prospects and Ongoing Reasearch**

In recent times, there has been a significant amount of research conducted on niosomes for a wide range of purposes, including topical, transdermal, oral, and brain-targeted drug delivery [59]. Niosomes have the capacity to be optimized through the utilization of innovative techniques for preparation, loading, and modification. This optimization would allow for targeted distribution and improved efficiency in trapping drugs within the niosomes. In addition, certain niosomes can be integrated with carrier gels that respond to stimuli and/or eutectic/ionic liquids in order to enhance their duration at targeted locations. Additional investigation and study are required in these specific domains to facilitate the production of commercially viable niosomal preparations. Researchers must be vigilant regarding the necessity of carefully choosing adequate surfactants for the creation of niosomes. The type of surfactant utilized is the primary factor that determines the effective synthesis of these vesicles, as well as their toxicity, stability, and prospective applications.

**Conclusion:**

Advancements in research have led to the recognition of tiny molecules, such as proteins and vaccines, as a significant class of medicinal agents. The niosomal drug delivery system

represents a significant advancement in drug delivery methods.This strategy to drug distribution is both innovative and effective. It impacts the formulation and characteristics of the medication, including cholesterol levels, structure, kind, and surfactant quantities. Non-ionic surfactant vesicles modify the rate at which the drug is removed from the bloodstream, the way it is distributed in tissues, its metabolism, and its interaction with cells. Furthermore, niosomes exhibit improved stability and less harmful drug effects, while also providing sustained release of the enclosed medication. In addition, niosomes do not require any specific conditions for their handling and storage, unlike other drug-delivery methods like liposomes. To summarize, niosomes are a very effective method for delivering drugs in the treatment of various diseases and have the potential to offer more effective treatment than traditional drug delivery systems.

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