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Review Article

A Review On Nano-Advantage: Why Nano-Niosomes Are Gaining Preference Over Traditional Niosomes

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ABSTRACT

Niosomes represent an innovative drug delivery mechanism where the therapeutic agent is enclosed within a vesicle. In terms of structure, niosomes mirror liposomes, both featuring a bilayer composition. However, niosomes diverge from liposomes in that their bilayer is constructed from non-ionic surfactants, as opposed to the phospholipids typical of liposomes. While most surfactants form micellar patterns in water, certain ones can form bilayer vesicles, termed niosomes. In the continually advancing domain of drug delivery, nanoniosomes have marked a notable progression beyond conventional niosomes. This analytical piece highlights the swift rise of nanoniosomes, underscoring their enhanced characteristics, propelling them to the forefront of contemporary therapeutic innovations. While traditional niosomes are lauded for their encapsulation potential and biocompatibility, their nano-sized counterparts, nanoniosomes, promise increased absorption, superior bioavailability, and precision targeting. Their adeptness in encapsulating a broad spectrum of drugs, be it water-soluble or lipid-based, positions nanoniosomes as a pivotal instrument in the realm of tailored medical treatments. Through an in-depth examination of their merits and practical applications, this analysis clarifies the potential of nanoniosomes to eclipse niosomes in the modern drug delivery landscape. As the demand for more effective drug delivery systems grows, nano-niosomes stand out for their potential to provide safer, more effective, and more patient-friendly therapies, signifying a major leap forward in personalized medicine and sustained drug delivery. The ongoing advancements in nanofabrication techniques are expected to further bolster the scalability and commercial viability of nano-niosomes, paving the way for their widespread adoption in clinical applications.

INTRODUCTION

Niosomes represent vesicular systems designed for the prolonged, regulated, and directed release

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of therapeutic agents. Although liposomes were the pioneering vesicular delivery mechanisms, they presented challenges such as potential toxicity, higher costs, and instability across diverse pH levels. These drawbacks led researchers to turn their attention to niosomes. Depending on their layer composition, niosomes can be singular-layered, few-layered, or multiple-layered. Comprising non-ionic surfactants, niosomes are aptly named and are deemed safe due to these non-toxic surfactants. Beyond non-ionic surfactants, niosomes might also encompass cholesterol or its variants and molecules carrying a charge. While cholesterol lends firmness to the structure, charged entities ensure the formulation's stability. Niosomes materialize when these non-ionic surfactant agents self-organize. Their unique structure allows them to be harnessed for the encapsulation and transport of both water-attracting and water-repelling drugs. Essentially, niosomes are vesicles crafted from non-ionic surfactants that envelop a water-based solution within a bilayer construct. They bear resemblance to liposomes, but with a distinction: they arise from non-ionic surfactants as opposed to phospholipids[1]

HISTORY OF NIOSOME:-

In 1909, Paul Ehrlich paved the way for targeted drug delivery, envisioning a mechanism that would specifically direct drugs to affected cells. Drug targeting can be described as the capability of channeling a medicinal agent precisely to the intended site of action, ensuring minimal interaction with off-target tissues[2]. The pioneering niosome formulations emerged and were patented by L'Oreal in 1975[3]. Niosomes first made their mark in the delivery of anticancer medications[4][5]. These crafted niosome formulations were adept at modifying the pharmacokinetic attributes, organ distribution, and metabolism of methotrexate in rodents. Owing to their adaptability in structure, form, and dimension, niosomes can encapsulate water-attracting drugs in their aqueous sections or lipid-loving drugs by allowing these compounds to integrate into the bilayer region. They can be designed as singular-layered, few-layered, or multiple-layered vesicles. Among their other virtues, niosomes offer commendable physical stability, are economically efficient, and their production, both routine and on a larger scale, is relatively uncomplicated[6] [7] [8]

STRUCTURE OF NIOSOME AS COMPARED TO LIPOSOMES:-

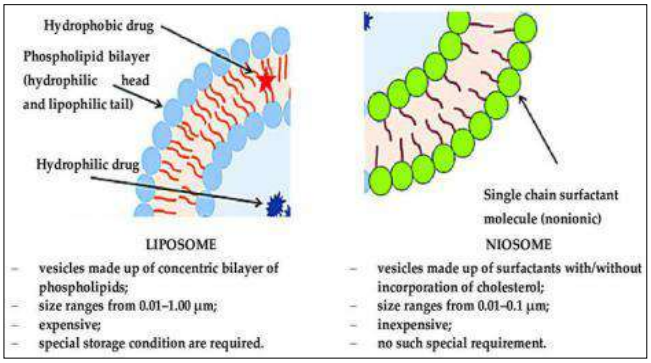

Fig no 1 Structure of Niosome as Compared to Liposomes

NIOSOME AS COMPARED TO LIPOSOME:-

Both liposomes and niosomes exhibit similarities in their nature. While the phospholipids in liposomes demonstrate instability, niosomes, composed of non-ionic surfactants, offer greater stability. Niosomes are crafted using a singular chain of non-ionic surfactant, in contrast to liposomes that are derived from dual-chain phospholipids. Niosomes typically range in size from 10-100nm, whereas liposomes span between 10-300nm. Economically, niosomes present a more cost-effective option than liposomes[9]. Both niosomes and liposomes feature a bilayered composition. However, the constituents employed in the formulation of niosomes grant them enhanced stability[10]. Niosomes are synthesized from neutral, singular chain surfactants and cholesterol, while liposomes emerge from neutral or charged dual-chain phospholipids. Liposomes

have a higher cholesterol content than niosomes, leading to reduced drug entrapment efficiency in liposomes compared to niosomes. For industrial production, niosomes are more cost-friendly and don't necessitate specialized storage prerequisites, unlike the specific conditions demanded for liposome production. The production cost of liposomes is escalated due to their volatile ingredients (phospholipids) that are prone to oxidative deterioration. Thus, liposomes necessitate specialized handling techniques[11]. In terms of longevity, niosomes outlast liposomes. They enhance the circulation duration of the encapsulated therapeutics and amplify metabolic stability in an emulsified state. Conversely, liposomes have a restricted lifespan owing to the rancidity of their lipid constituents[12].

COMPOSITION OF NIOSOME:-

Niosomes are spherical entities characterized by microscopic layered (either singular-layered or multiple-layered) formations. These layers arise from nonionic surfactants, potentially combined with cholesterol and a charge-generating agent. Diverse surfactants, in varied combinations and molar proportions, can be utilized to produce niosomes. Surfactant examples encompass alkyl ethers, alkyl glyceryl ethers, sorbitan derivatives of fatty acids, and polyoxyethylene derivatives of fatty acids. Introducing cholesterol bolsters the bilayer's rigidity, leading to niosomes that are more sealed. On the other hand, charge inducers bestow a charge upon the vesicles, augmenting their size and thereby enhancing the efficiency of drug encapsulation. Agents that introduce a negative charge, such as dicetyl phosphate, dihexadecyl phosphate, and lipoamino acid, as well as those that introduce a positive charge, like stearylamine and cetylpyridinium chloride, offer vesicle stabilization.

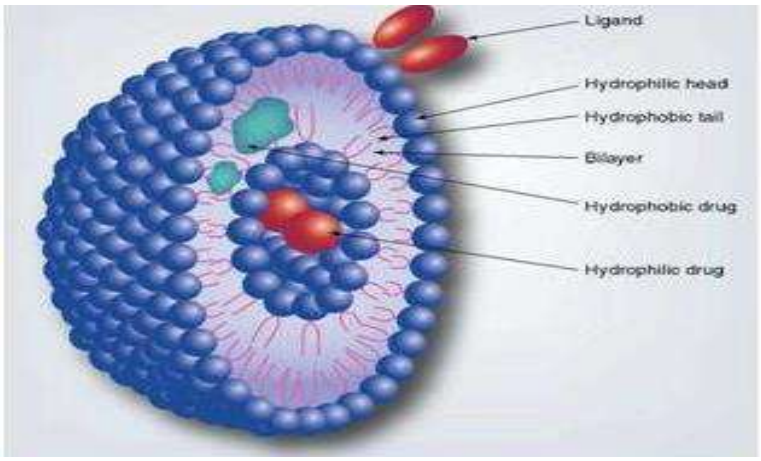

Fig No 2 Structure Of Niosome

In niosomes, nonionic surfactants align themselves such that the water-attracting end is oriented outwards (adjacent to the water phase), while the water-repelling end is oriented inwards, coming together to create a sealed bilayer structure that captures solutes in a water solution. Consequently, this bilayer configuration has water-attracting layers on both the inner and outer surfaces, with a lipid-attracting zone sandwiched in the middle. The formation of this sealed bilayer demands energy inputs such as heat or physical disturbance. Internal forces within these vesicles, like van der Waals forces and repulsion forces among the surfactant molecules, are crucial for preserving the vesicular shape. Adjustments in the vesicle's components (like their type, makeup, and amount), size, surface charge, or volume can potentially alter the attributes of the resulting niosomes. Depending on their vesicle dimensions, niosomes can be classified into three categories: small

singular-layered vesicles (0.025–0.05 mm), multiple-layered vesicles (>0.05 mm), and large singular-layered vesicles (>0.10 mm) [13].

Bilayer structure:

Core:

The niosome's central segment is a water-based section suitable for containing water-attracting medications or substances.

Surfactant Dual-Layer:

This layer encircles the central water-based section and is formed by non-ionic surfactants. The water-attracting ends of the surfactant molecules are oriented towards the central section and the external surroundings, whereas the water-repellent ends congregate in the middle of the dual-layer. This configuration is apt for housing lipid-attracting or water-repellent medications[14].

Cholesterol :

For enhancing the firmness and decreasing the permeability of the dual-layer, cholesterol is incorporated. The cholesterol entities situate themselves amidst the surfactant entities, minimizing gaps and organizing the dual-layer more systematically[15].

Shape and size:

Niosomes might be singular-layered (having one dual-layer) or multi-layered (numerous layered rings). Their dimension can span from nanoscale to microscale, contingent on the formulation approach and constituents[16].

Surface charge:

Primarily, niosomes carry a neutral electrostatic charge, a result of the non-ionic characteristic of the surfactants. However, to adapt the electrostatic charge for specific uses, charged entities can be integrated[17].

Additives:

Water-Attracting Polymers: Compounds such as polyethylene glycol (PEG) might be appended to the niosome's surface to amplify stability and duration in the circulatory system.

Preserving Agents:

Certain compounds can be infused to conserve the niosome formulation and extend its longevity[18].

Entrapment efficacy:

The proficiency of the niosome in capturing and preserving the medication is termed its encapsulation capacity. Factors like structure, makeup, and formulation technique can sway this capacity[19].

Bilayer fluidity:

The flexibility or solidity of the dual-layer can dictate the dispensation rate of the contained drug. It's steered by the category and ratio of surfactants and cholesterol[20].

TYPES OF NIOSOMES:

Multilamellar Vesicles (MLV):

Often referred to as multilamellar vesicles, MLVs are among the most prevalent forms of niosomes. Typically, their diameter spans between 0.5-10 µm. Their formation process is straightforward, and they demonstrate mechanical stability, ensuring an extended shelf life. Characteristically, they feature several bilayers enveloping an aqueous lipid section independently. Due to their structure, MLVs are particularly apt for carrying lipophilic drugs.

Large Unilamellar Vesicles (LUV):

These niosomes, distinguished by a single membrane, boast a significant aqueous to lipid ratio. This characteristic allows them to encapsulate a substantial volume of therapeutic agents, optimizing the use of membrane lipids. LUVs usually measure between 100-3000 nm in diameter.

Small Unilamellar Vesicles (SUV):

SUVs are predominantly derived from MLVs, primarily through the sonication technique. Studies indicate that their diameter typically falls between 10-100 nm[9,21,22].

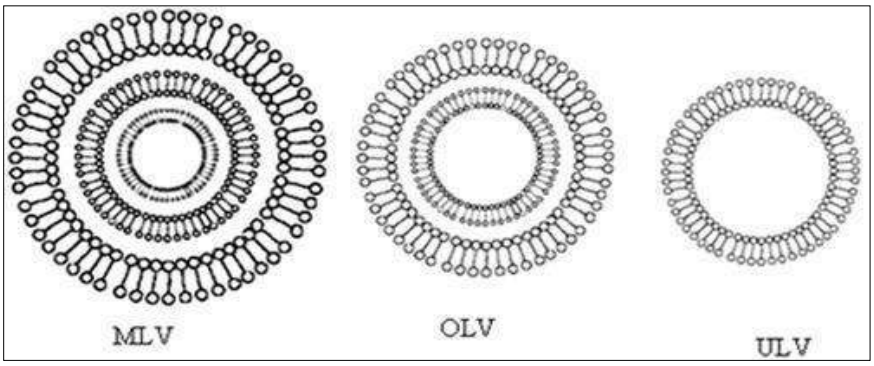

Fig no 3 Types of Niosome

ADVANTAGES OF NIOSOMES:-

1. The conventional and extensive production of niosomes doesn't necessitate the use of harmful solvents.
2. Owing to their chemically stable composition, niosomes don't demand specialized handling or storage environments.
3. By adjusting their composition and fabrication methods, the attributes of niosomes like form, suppleness, and magnitude can be finely tuned.
4. Niosomes have the capacity to house a significant quantity of substance within a limited vesicular space.
5. The niosomal architecture safeguards the drug components against adverse external and internal factors, paving the way for delivering fragile and susceptible medications.
6. Niosomes enhance the drug's therapeutic efficacy by prolonging its presence in the bloodstream and directing its action to specific cells.
7. Niosomes can be introduced through various pathways like oral, intravenous, and dermal, and in diverse forms like powders, liquids, and gels. This boosts the solubility and uptake of poorly soluble medications and also augments drug permeation through the skin upon topical application[23].

DISADVANTGES:-

1. Niosomes are physically unstable.
2. Unstability leads to aggregation.
3. Sometimes fusion is occurred.
4. Leaking of entrapped drug.
5. Hydrolysis of encapsulated drugs which limiting the shelf life of the dispersion.
6. Specialized equipment required for manufacture. The preparations costs expensive.
7. Time consuming techniques required for formulation.
8. The preparations costs expensive.[2,24]

NANO-NIOSOMES:-

INTRODUCTION

Within the progressive domain of drug transportation, vesicular mechanisms have consistently garnered interest due to their proficiency in augmenting bioavailability, resilience, and therapeutic potency of diverse medications. In this spectrum, niosomes—spherical structures formed through the organization of non-ionic surfactants in water solutions—have been acknowledged for their potential since the latter part of the previous century[25]. Nano-niosomes, by blending the inherent attributes of niosomes like biocompatibility and the capacity to house both water-loving and water-hating drugs, with the distinct advantages of nanosized carriers such as improved penetration, retention, and the possibility for targeted transportation, have paved new paths in drug transportation, signifying enhanced therapeutic results across a broad array of medical utilities[26]. This article elucidates

nanosized entities termed nanoniosomes, which fall within the realms of nanochemistry and nanomedicine. Nanochemistry, closely intertwined with nanotechnology, spans a vast territory deeply rooted in physics, engineering, biotechnology, and, of course, chemistry. This discourse provides a concise overview of nanochemistry through the lens of a supramolecular chemist keen on crafting and exploring chemical clusters at the nanoscale, leading to the evolution of nanotechnological structures termed niosomes[17]. Nanoparticles, with dimensions spanning roughly 0.1 to 100 nm, manifest unique physico-chemical properties distinct from their larger counterparts, resulting in innovative features. Historically, nanotech materials were crafted using a "top-down" approach, which revolved around fragmenting materials employing methodologies established by solid state physicists. Yet, an emergent methodology, termed the "bottom-up" technique, stands as the bedrock of nanochemistry, facilitating the birth of nanostructures and nanomaterials via the incorporation of supramolecular and biomimetic entities. These methodologies intersect with biology and biomimetic chemistry, birthing the domain of nanobiology[17]. Translating drug carriers into the nanoscale offers myriad benefits, including: enhanced drug kinetics and distribution due to an amplified surface-to-volume ratio; reduced toxicity via targeted drug accumulation; an improved intracellular delivery and retention, enhancing drug efficacy and longevity either intracellularly or in the bloodstream[27,28,17].

In the bottom-up paradigm, nanomaterials emerge from smaller foundational units, typically harnessing self-organization techniques to shape highly structured two- and three-dimensional nanoscale entities. In this mechanism, molecules smaller than a nanometer organically birth nanoscale formations like surfactant micelles or bilayers, rooted in their inherent molecular characteristics or influenced by a template, such as another molecule or pre-organized structure. Equilibrium between supramolecular interactions and external dynamics dictate the connection and orientation of potential foundational molecular units for nanoscale designs. Molecules serve as more apt foundational blocks compared to atoms, given their reduced reactivity in comparison to isolated atoms[17].

HISTORY OF NANO NIOSOMES:-

The tale of nano-niosomes has its roots in the pioneering research on niosomes. In the late 1970s and into the 1980s, niosomes, which are vesicles formed from non-ionic surfactants, surfaced as viable alternatives to the phospholipid-centric liposomes[29]. These niosomes gained traction in the realm of drug transportation, notably due to their capability to house both water-attracting and water-repelling medications. With the dawn of the 21st century, the allure of nanotechnology, especially within the medical sector, began to amplify[30]. Drug delivery mechanisms at the nanoscale started drawing attention, owing to their potential for optimized drug kinetics, precision targeting, and augmented therapeutic outcomes. Capitalizing on the foundational niosome research and acknowledging the merits of nanoscale interventions, scientists embarked on a journey to unlock the capabilities of nanometric niosomes, colloquially dubbed "nano-niosomes"[17]. These minuscule vesicles harmonized the strengths of both niosomes and nanotechnology. As the 1990s transitioned to the 2000s, there was a marked uptick in breakthroughs related to the crafting and understanding of nano-niosomes[8]. The scientific community delved into various techniques to reliably concoct nano-niosomes, while also probing their resilience, drug encapsulation efficiency, and drug dispersion characteristics. With a maturing comprehension of nano-niosomes, their applications began to span diverse

therapeutic domains, ranging from skin-level drug transportation to precision oncology treatments and further[26]

STRUCTURE OF NANO NIOSOME:-

Bilayer Membrane:

At the heart of a nano-niosome's structure is its lipidic bilayer, formed upon the hydration of non-ionic surfactants. These surfactants configure themselves so that their water-attracting "heads" are oriented towards the watery medium, both internally and externally, while their water-repelling "tails" cluster together at the core of the bilayer.

Aqueous Core:

Nested inside the nano-niosome is a watery chamber. This space serves as the repository for water-soluble drugs or active agents.

Size:

Adhering to its "nano" descriptor, the nano-niosome's dimension falls within the nanometer spectrum. Typically, their diameter spans from 10 nm up to several hundred nm.

Cholesterol and Other Lipids

The bilayer often integrates cholesterol or other fatty molecules. Cholesterol can toggle the membrane's fluid dynamics, rendering it either more supple or stiffer based on the envisaged attributes. It also plays a role in dictating vesicle permeability and overall robustness.

Charge modifiers:

Some nano-niosomes might incorporate agents that instill a specific electrical charge, affecting how they engage with biological entities. For example, the inclusion of dicetyl phosphate could bestow a negative charge onto the nano-niosome.

Surface Modifications:

In scenarios of targeted medicinal transport, the nano-niosome's exterior can undergo alterations. Elements such as ligands, antibodies, or specific peptides can be tethered to the outer layer of the nano-niosome, directing it towards designated cells or bodily regions, ensuring the sequestered medication hits its precise destination.

Additional components:

Tailored to specific uses, nano-niosomes might encompass other elements, like polyethylene glycol (PEG) strands, which prolong their presence in the bloodstream, or distinct stabilizing agents to amplify their longevity on the shelf[31,32].

TYPES OF NANO NIOSOMES:-

Based on Lamellarity:

Unilamellar Vesicles (ULVs):

These nano-niosomes consist of a single bilayer membrane.

Small Unilamellar Vesicles (SUVs):

They are less than 50 nm in diameter.

Large Unilamellar Vesicles (LUVs):

These vesicles are larger, usually over 100 nm in diameter.

Multilamellar Vesicles (MLVs):

Comprising multiple concentric bilayers[3,17].

Based on Surface Modifications:

Conventional Nano-Niosomes:

Basic vesicles without specific surface modifications.

PEGylated Nano-Niosomes:

These vesicles have polyethylene glycol (PEG) chains attached to their surface.

Targeted Nano-Niosomes:

The surface of these vesicles is modified with specific ligands or antibodies for targeted drug delivery[26,32].

Based on Charge:

Neutral Nano-Niosomes:

These vesicles don't carry any net charge.

Cationic Nano-Niosomes:

Positively charged vesicles, beneficial for certain applications like gene delivery.

Anionic Nano-Niosomes:

Negatively charged vesicles[33,34].

Based on Application:

Cosmetic Nano-Niosomes:

Specifically designed for cosmetic applications.

Therapeutic Nano-Niosomes:

Designed for drug delivery in therapeutic areas.

Diagnostic Nano-Niosomes:

Modified to carry imaging agents for diagnostic purposes[25,35]

Based on Composition:

Elastic or Flexible Nano-Niosomes:

These are formulated with edge activators to provide flexibility.

Vesicles with Special Additives:

Nano-niosomes with specific additives or co-surfactants[36,37,38].

METHOD OF PREPARATION OF NANO NIOSOMES:-

Thin film hydration method-

The combination of vesicle-forming components, including surfactants and cholesterol, were dissolved in a blend of volatile organic solvents: chloroform and ethanol in a 1:2 ratio within a round-bottomed flask. Using a rotary evaporator and maintaining a temperature above the lipid transition point, the organic solvent was evaporated, resulting in a thin film of the mixture adhering to the flask's inner surface. Subsequently, this dried film of surfactant was rehydrated with 10 mL of an aqueous solution (pH 7.4 buffer) at temperatures ranging from 0-60 °C, accompanied by mild stirring. This procedure led to the formation of characteristic multilamellar niosomes[39].

Micro fluidization method-

Microfluidization is a contemporary technique employed to produce unilamellar vesicles with a specific size distribution. This approach operates on the submerged jet concept where two fluid streams collide at extremely high speeds within meticulously defined micro-channels inside the interaction chamber. The collision of these thin liquid sheets is orchestrated to ensure that the energy provided is confined to the niosome generation zone. Consequently, the niosomes produced are more uniform, of smaller dimensions, and exhibit enhanced consistency[40].

High Pressure Homogenization Method-

An initial niosome suspension is created using conventional techniques, such as the thin-film hydration method. This mixture is then subjected to a high-pressure homogenizer, where it's propelled through a constricted space under extremely high pressures. To attain the preferred particle size reduction, several iterations through the homogenizer might be necessary[41].

APPLICATONS OF NANO NIOSOMES AS COMAPRING TO TRADITIONAL NIOSOMES:-

For ANTICANCER DRUG DELIVERY SYSTEM-

Size and Enhanced Cellular Uptake:

Nano niosomes:- due to their nanoscale size (typically ranging from 10 nm to a few hundred nm), can be more efficiently taken up by cells, including cancer cells. This enhanced cellular uptake can lead to higher intracellular drug concentrations, potentially improving therapeutic efficacy[42].

Example for Nano-niosomes:

Paclitaxel-loaded nano-niosomes demonstrated improved cellular uptake and cytotoxicity against cancer cells compared to larger niosomes[42].

Niosomes:

Larger in size, their cellular uptake might be less efficient compared to nano-niosomes, potentially leading to reduced intracellular drug delivery.

Example for Niosomes:

Doxorubicin-loaded niosomes showed enhanced cellular uptake, but the efficiency might be influenced by the vesicle size[8].

Enhanced Tumor Penetration:

Nano-niosomes:

Their nanoscale size allows for better penetration into solid tumors, reaching even the innermost

regions, which can be less accessible to larger vesicles.

Example for Nano-niosomes:

Curcumin-loaded nano-niosomes demonstrated deeper tumor penetration and improved therapeutic efficacy in breast cancer models[43].

Niosomes:

Due to their larger size, the penetration into solid tumors might be limited, potentially reducing drug delivery to inner tumor regions.

Example for Niosomes:

Niosomes encapsulating doxorubicin showed limited penetration in solid tumors, leading to suboptimal drug delivery to the tumor's core regions.

Surface Modification and Targeted Drug Delivery:

Nano-niosomes:-due to their higher surface-area-to-volume ratio. They can be more effectively surface-modified with ligands, antibodies, or peptides for targeted drug delivery, leading to increased drug accumulation in tumor tissues and reduced off-target effects.

Example for Nano-niosomes:

Folate-modified nano-niosomes encapsulating doxorubicin targeted cancer cells overexpressing folate receptors, achieving enhanced therapeutic effects[44].

Niosomes:

While they can also be surface-modified for targeting, the efficiency and extent of modification might differ due to their size and structural characteristics.

Example for Niosomes ,

Transferrin-conjugated niosomes were developed for brain tumor targeting[45].

Pharmacokinetics and Biodistribution:

Nano-niosomes:

They can alter the pharmacokinetics of anticancer drugs, leading to prolonged circulation time, reduced rapid clearance, and enhanced accumulation at the tumor site.

Example for Nano-niosomes:

Methotrexate-loaded nano-niosomes showed prolonged drug circulation times, leading to improved antitumor efficacy[46].

Niosomes:

Depending on their size and surface characteristics, they might have different pharmacokinetic profiles, potentially leading to quicker clearance and reduced tumor accumulation.

Example for Niosomes:

Traditional niosomes encapsulating 5-fluorouracil demonstrated altered pharmacokinetics, but the specific benefits might vary based on their size and composition[47]

FOR TRANSDERMAL DRUG DELIVERY SYSTEM:-

Enhanced Skin Penetration

Nano-niosomes:

Their smaller size allows for deeper penetration into the skin layers, facilitating the delivery of encapsulated drugs to deeper skin tissues or systemic circulation.

Example:

Nano-niosomes loaded with tretinoin demonstrated improved penetration into the skin and better therapeutic outcomes compared to a conventional ge.

Niosomes:

While they can facilitate drug delivery across the stratum corneum, their larger size may limit the depth of skin penetration.

Example:

Niosomal gel containing diclofenac diethylamine showed enhanced skin permeation compared to conventional gels but might not reach as deep as nano-niosomal formulations[48,49].

Sustained Drug Release:

Nano-niosomes:

Due to their structure, they can offer sustained drug release, ensuring prolonged drug exposure.

Example:

Acyclovir-loaded nano-niosomes provided sustained drug release, leading to prolonged antiviral activity.

Niosomes:

They can also offer sustained release, but the release profile might vary based on their size and composition.

Example:

Niosomes loaded with minoxidil showed sustained drug release, enhancing its therapeutic effects[50,51].

Improved Drug Stability:

Nano-niosomes:

They can protect encapsulated drugs from degradation in the challenging skin environment.

Example:

Ketoconazole-loaded nano-niosomes demonstrated enhanced stability and antifungal activity when applied topically.

Niosomes:

They can also encapsulate and protect drugs, but the extent of protection might vary based on their formulation.

Example:

Niosomal encapsulation of quercetin enhanced its stability against degradation[52,53].

FOR VACCINES AND MACROMOLECULE

Protection of Encapsulated Molecules:

Nano-niosomes:

They can efficiently protect sensitive macromolecules from degradation, especially in the challenging gastrointestinal environment when taken orally.

Example:

Nano-niosomes have been investigated for the oral delivery of insulin, where they protected the hormone from degradation in the stomach and enhanced its bioavailability.

Niosomes:

While they can also encapsulate and protect macromolecules, the level of protection might vary based on their formulation.

Example:

Hepatitis B surface antigen loaded into niosomes showed improved stability and elicited a stronger immune response when compared to free antigen[54,55].

Enhanced Cellular Uptake:

Nano-niosomes:

Their smaller size facilitates better cellular uptake, which is especially crucial for vaccines and other macromolecules targeting intracellular sites.

Example:

DNA vaccines encapsulated in nano-niosomes demonstrated enhanced cellular uptake and improved immunogenicity.

Niosomes:

They can also facilitate cellular uptake, but the efficiency might differ due to their larger size.

Example:

Niosomal encapsulation of the tuberculosis antigen Ag85B-ESAT-6 enhanced antigen uptake by dendritic cells, leading to a potent immune response[56,57].

Targeted Delivery:

Nano-niosomes:

They can be easily modified for targeted delivery, allowing for the precise delivery of vaccines and macromolecules to specific cells or tissues.

Example:

Nano-niosomes modified with mannose targeted dendritic cells,enhancing the delivery of encapsulated antigens and improving immune responses.

Niosomes:

They can be modified for targeting, but the efficiency might vary based on their size and structure.

Example:

Chitosan-coated niosomes were developed for targeted nasal delivery of the influenza virus antigen, leading to enhanced immune responses[58,59].

HOW NANO-NIOSOMES ARE BETTER THAN NIOSOMES-

Size:

As the name suggests, these vesicles are in the nanometer range, typically from 10 nm to a few hundred nm in diameter.

Enhanced Permeation and Retention (EPR) Effect:

Can exploit the EPR effect in tumor tissues more effectively due to their nanoscale size, leading to preferential accumulation in tumor sites.

Bioavailability:

Can enhance the solubility of poorly water-soluble drugs more effectively, leading to improved bioavailability.

Targeted Delivery :

Their smaller size allows for better functionalization for targeted drug delivery.

Circulation Time:

Tend to have prolonged circulation time in the bloodstream due to reduced clearance by the reticuloendothelial system (RES).

Stability:

Often exhibit enhanced stability in the bloodstream.

Cellular Uptake:

Their nanometric scale facilitates enhanced cellular uptake.

Versatility in Drug Encapsulation:

Highly versatile, capable of encapsulating both hydrophilic and lipophilic drugs.

Safety and Side Effects:

Due to targeted delivery, they can reduce off-target side effects.

Manufacturing and Scalability:

Might require more specialized techniques for consistent size and reproducibility.

FUTURE PROSPECTIVE-

Nano-niosomes, due to their nanometric scale, are poised to revolutionize drug delivery in the coming years, overshadowing traditional niosomes. Their smaller size offers enhanced tissue penetration and bioavailability, making them particularly effective for targeted drug delivery, especially in cancer therapy. Furthermore, they can be tailored for precise and efficient delivery, essential for advancements like gene therapy and personalized medicine. Nano-niosomes also hold promise in transdermal applications, diagnostic imaging, and vaccine development. As technology matures, scalable production methods will likely make nano-niosomes more commercially viable, marking them as the future cornerstone in vesicular drug delivery systems.

CONCLUSION-

In summary, nano-niosomes have emerged as a groundbreaking innovation in novel drug delivery systems, offering a suite of advantages that significantly surpass those of traditional niosomes. The diminutive size of nano-niosomes facilitates deeper tissue penetration and enhanced bioavailability, making them exceptionally effective for targeted therapies, particularly in areas such as oncology, gene therapy, and personalized medicine. These nanoscale vesicles excel in encapsulating a diverse range of therapeutic agents, both hydrophilic and lipophilic, ensuring a broad spectrum of applicability. Their stability, reduced potential for immunogenicity, and ability to provide controlled and sustained release of drugs, position them as a superior choice in drug delivery technology. Furthermore, the adaptability of nano-niosomes to be engineered for specific targeting, combined with their potential in transdermal applications and diagnostic imaging, amplifies their significance in modern pharmaceutical research and development. As we look to the future, the ongoing advancements in the synthesis and scaling of nano-niosome production are expected to enhance their feasibility and cost-effectiveness. This progression will likely establish nano-niosomes as a cornerstone in the evolving

landscape of drug delivery systems, heralding a new era in efficient, safe, and targeted therapeutic interventions.

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