Research Article

International Journal of Indigenous Herbs and Drugs
Content Available at www.saap.org.in ISSN: 2456-7345

A review on niosomes as novel drug delivery system

Badri Sireesha[1*], P. Sailaja[2], Annagowni Naga Rekha[2], Lunjala Raja Sekhar[2], B. Bala Nagaraju[2], B.Seshi Kumar Reddy[2], D. Seshu[2]

[*1] Assistant professor, Sankar Reddy Institute of Pharmaceutical Sciences, Salakalaveedu(V), Bestavaripeta (M), Prakasam (D), Pincode-523370

[2] B.Pharmacy, Sankar Reddy Institute of Pharmaceutical Sciences, Salakalaveedu(V), Bestavaripeta (M), Prakasam (D), Pincode-523370

Article Info :

Article History
Received on: 09-08-2022
Revised on: 22-08-2022
Accepted on: 26-09-2022

Abstract

Niosomes are a novel drug delivery system, in which the medication is encapsulated in a vesicle. Vesicle is composed of a bilayer of non-ionic surface active agents and hence the name niosomes. It can be used as carrier of amphiphilic and lipophilic drug. Niosomes are biodegradable, biocompatible nonimmunogenic and exhibit flexibility in their structural characterization. Niosomes have great drug delivery potential for targeted delivery of anti-cancer, anti-infective agents and various diseases. Technologies modify drug release profile, absorption, distribution and elimination for the benefit of: Improving product efficacy and safety, Patient convenience and compliance.

Keywords: Uni-lamellar, Multi-lamellar, Niosomes, compositions**,**bilayer , surfactant, drug entrapment**.**

***Corresponding Author**
Badri Sireesha

DOI: https://doi.org/10.46956/ijihd.v7i5.352

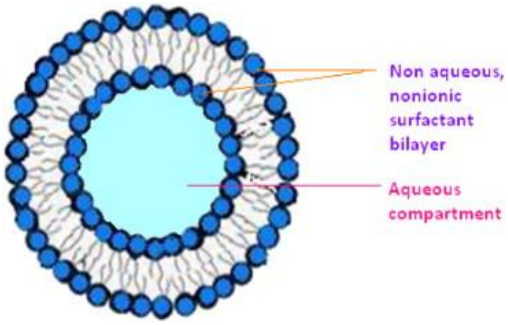
Production and Hosted By

Saap.org.in

Introduction

Niosomes are a novel drug delivery system, in which the medication is encapsulated in a vesicle. The vesicle is the niosomes are very small, and microscopic in size. Their size lies in the nanometric scale. Although structurally similar to liposomes, composed of a bilayer of non-ionic surface active agents and hence the name niosomes, which entrapped the hydrophilic drug in the core cavity and hydrophobic drugs in the non-polar region present within the bilayer hence both hydrophilic and hydrophobic drugs can be incorporated into niosomes [1]. In niosomes, the vesicles forming amphiphilic is a non-ionic surfactant such as Span – 60 which is usually stabilized by addition of cholesterol and small amount of anionic surfactant such as dicetyl phosphate. Niosomes also serve better aid in diagnostic imaging and as a vaccine adjuvant. Thus these areas need further exploration and research so as to bring out or to make for commercially available niosomal preparation [2]. Drug delivery potential of niosome can enhances by using novel drug delivery concepts like proniosomes, discomes and aspasome. Niosomes also serve better aid in diagnostic imaging and as a vaccine adjuvant. Thus these areas need further exploration and research so as to bring out or to make for commercially available niosomal preparation.

Structure



Niosomes structure

• Rate of drug and administer normal vesicle in external non aqueous phase.

SOUTH ASIAN ACADEMIC PUBLICATIONS

• They are osmotically active and stable, as well as they increase the stability of entrapped drug.
• Handling and storage of surfactants requires no special conditions.
• They improve oral bioavailability of poorly absorbed drugs and enhance skin penetration of drugs.
• They can be made to reach the site of action by oral, parenteral as well as topical routes.

Niosomes may be unilamellar or multilamellar depending on the method used to prepare them. The niosome is made of a surfactant bilayer with its hydrophilic ends exposed on the outside and inside of the vesicle, while the hydrophobic chains face each other within the bilayer [3].

Composition of Niosomes

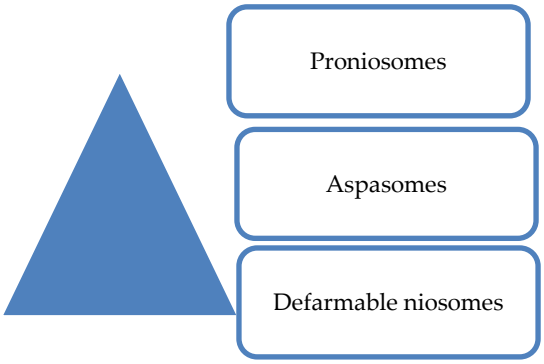
Cholesterol and Non ionic surfactants are the two major components used for the preparation of niosomes. Cholesterol provides rigidity and proper shape. The surfactants play a major role in the formation of niosomes. Few other surfactants that are reported to form niosomes are as follows:

- Di-alkyl chain surfactant
- Ester linked
- Sorbitan Esters
- Poly-sorbates [4].

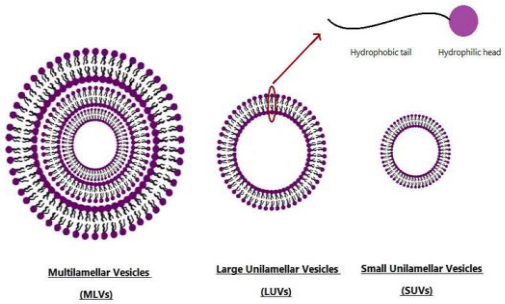
Salient features of niosomes:

- Niosomes can entrap solutes.
- Niosomes are osmotically active and stable.
- Niosomes exhibits flexibility in their structural characteristics (composition, fluidity and size) and can be designed according to the desired situation [5].
- Niosomes can improve the performance of the drug molecules.
- Better availability to the particular site, just by protecting the drug from biological environment.
- Niosomes surfactants are biodegradable, biocompatible and non-immunogenic.
- They improve the solubility and oral bioavailability of poorly soluble drugs and also enhance the skin permeability of drugs when applied topically.
- Niosomes increase the stability of the entrapped drug [6].

Types of niosomes



1. **Proniosomes**
   Proniosomes is made from the carrier and surfactant mixture. After the hydration of proniosomes, Niosomes are produced.
2. **Aspasomes**
   Aspasomes is produced using the mixture of acorbylpalmitate, cholesterol and exceptionally charged lipid diacetyl phosphate prompts the arrangement of vesicles [7]. Aspasomes are first hydrated with water/fluid arrangement and afterwards it is subjected to sonication to get the niosomes.
3. **Deformable niosomes**
   The mixture of non-ionic surfactants, ethanol and water forms the deformable niosomes [8]. These are smaller vesicles and easily pass through the pores of stratum corneum, which leads to increase penetration efficiency. It can be used in topical preparation.



1. **Multi lamellar vesicles** (MLV)
   It consists of a number of bilayer surrounding the aqueous lipid compartment separately. The approximate size of these vesicles is 0.5-10 µm diameter [9].
2. **Large unilamellar vesicles** (LUV)
   Niosomes of this type have a high aqueous/lipid compartment ratio, so that larger volumes of bio-active materials can be entrapped with a very economical use of membrane lipids.
3. **Small Unilamellar Vesicles** (SUV)
   The small unilamellar vesicles are mostly prepared from multilamellar vesicles by sonication method, French press and extrusion method [10].

Method of preparation

A. Passive Trapping Techniques

sonication method

A typical method of production of the vesicles is by sonication of solution. In this method an aliquot of drug solution in buffer is added to the surfactant/cholesterol mixture in a 10 ml glass vial. The mixture is probe sonicated at 60°C for 3 minutes using a sonicator with a titanium probe to yield niosomes [11].

Ether injection method

The ether injection method is essentially based on slowly introducing a solution of surfactant dissolved in diethyl ether

SOUTH ASIAN ACADEMIC PUBLICATIONS

into warm water maintained at 60°C. The surfactant mixture in ether is injected through 14-gauge needle into an aqueous solution of material. Vaporization of ether leads to formation of single layered vesicles. The particle size of the niosomes formed depend on the conditions used. The diameter of the vesicle range from 50 to 1000 nm.

Bubble method

It is novel technique for the one step preparation of liposomes and niosomes without the use of organic solvents. It consists of round bottomed flask with three necks placed in water bath to control the temperature [12]. Water-cooled reflux and thermometer is positioned in the first and second neck and nitrogen supply through the third neck. Cholesterol and surfactant are dispersed together in this buffer (pH 7.4) at 70° c. A continuous stream of nitrogen gas bubbles is generated and introduced through the dispersion and produce niosomes.

Multiple Membrane Extrusion Method

Mixing surfactant, cholesterol and dicetyl phosphate in chloroform by rotary evaporator forms thin film. The film hydrates with membranes of aqueous polycarbonate material. Solution and subsequent suspension extrude through polycarbonate membrane for up to 8 passages in row. It is a good way to control the number of niosomes [13].

Hand shaking method: In this method, surfactant: cholesterol (150micro.mol.) mixture was dissolved in 10ml diethyl ether in RBF. The ether is evaporated under vacuum at room temperature in rotary evaporated. Upon hydration the surfactant swells and is peeled off the support into a film. Swollen amphiphiles eventually fold to form vesicles. The liquid volume entrapped in vesicles appears to be small, which is 5-10%

B. Active Trapping Techniques

It involves the drug loading during niosome development. The niosomes are primed and the drug is then filled with a pH gradient or gradient of ions to promote drug penetration into niosomes. Various benefits of noisome shape include 100% entrapment, high drug lipid levels, lack of leakage, cost-effectiveness, and labile drug suitability. Trans membrane pH Gradient Drug Uptake ProcessIng remote loading process [14]. Surfactants and cholesterol are dissolved in organic solvent (chloroform). Solvent evaporates to produce a thin film on the surface of the round bottom flask under reduced pressure Film hydrates with 300 mM citric acid (pH4.0) by vortex mixing Multilamellar vesicles are frozen and thawed three times and later on. Aqueous solution containing 10 mg / ml of medication is added for niosomal suspension and vortex. Sample pH is raises to 7.0-7.2 with 1M disodium phosphate. The mixture is later heated at 60°C for 10 minutes to yield niosomes.

C . Miscellaneous Methods

1. Heating Method

This approach is one-step, modular and non-toxic as well as patent-based. A suitable aqueous solution such as purified water, buffer, etc. where mixtures of non-ionic surfactants, cholesterol and/or load-inducing compounds are applied to glycerol in the presence of polyol. The mixture is heated until the vesicles have formed (at low shear forces).

2. Formation of Niosomes from Proniosomes

Proniosome is a dry solution in which a thin film of dried surfactant coats single water-soluble molecule. The niosomes are identified with brief agitation by the introduction of aqueous phase at T > Tm. T is the temperature and Tm is the mean temperature of the phase transition. 25 Carrier + surfactant = proniosomes, Proniosomes + water = niosomes [15].

Characterisation of Niosomes

1. Bilayer Rigidity and Homogeneity: Niosomes ' biodistribution and biodegradation are determined by the bilayer's rigidity. In homogeneity, dispersion can occur within niosome frameworks as well as between niosomes and can be defined by PNMR, Differential Calorimetry Scanning (DSC) and Fourier Red Spectroscopy Transform-Infra (FT-IR) techniques.

2**. Size and Shape**

Different methods are used to calculate the mean diameter, such as the process of laser light scattering, as well as electron microscopy, molecular sieve chromatography, photon correlation microscopy, optical microscopy.

3. Optical Microscopy: The niosomes were mounted on glass slides and viewed under a microscope (Medilux-207RII, Kyowa Getner, Ambala, India) with a magnification of 1200X for morphological observation after suitable dilution. The photomicrograph of the preparation also obtained from the microscope by using a digital SLR camera.

4. Osmotic shock

The change in the vesicle size can be determined by osmotic studies. Niosomes formulations are incubated with hypotonic, isotonic, hypertonic solutions for 3 hours. Then the changes in the size of vesicles in the formulations are viewed under optical microscopy [17].

5. Niosomal Drug Loading and Encapsulation Efficiency: The niosomal aqueous suspension was ultra centric, supernatant was removed and sediment washed twice with distilled water to remove the adsorbent material to assess drug loading and encapsulation capacity.

The entrapment efficiency (EE) was then calculated using formula:

Entrapment efficiency (EF) = (Amount entrapped / total amount) x 100

In vitro Release Study

Dialysis: With the help of dialysis tubing in vitro release rate study can be done. A dialysis sac was washed and soaked in distilled water. The suspension of vesicle was pipette into a bag made up of the tubing and then sealed and placed in 200 ml buffer solution in a 250 ml beaker with constant shaking at 25°C or 37°C. The buffer was analysed at various time intervals, for the drug content by an appropriate assay method.

Reverse dialysis

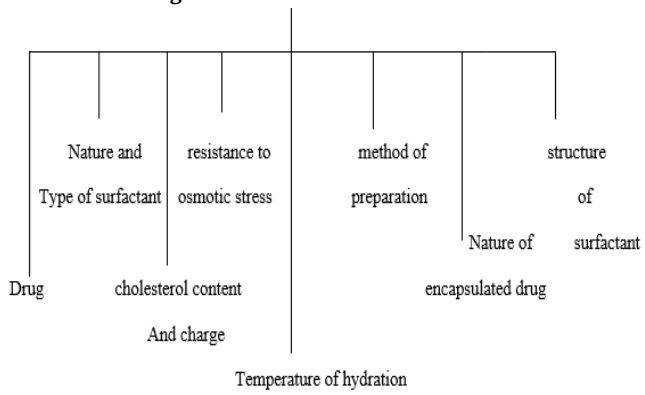
In this technique, niosomes are placed in a number of small dialysis tubes containing 1 ml of dissolution medium and the niosomes are then displaced from the dissolution medium35. Franz diffusion cell: In a Franz diffusion cell, the cellophane membrane is used as the dialysis membrane [17]. The niosomes are dialyzed through a cellophane membrane against suitable dissolution medium at room temperature. The

samples are withdrawn at suitable time intervals and analyzed for drug content.

In vivo Release Study

For in vivo study niosomal suspension was injected intravenously (through tail vein) to the albino rats using appropriate disposal syringe. These rats were subdivided into group

Factors effecting on Noisome



Drug

Entrapment of drug in niosomes influence charge and rigidity of the noisome bilayer. The hydrophilic lipophilic balance of the drug affects degree of entrapment. Vesicle size increases by interaction of solute with surfactant head groups. But some drug is entrapped in the long PEG chains In case of entrapment is affected by hydrophilic lipophilic balance of the drug.

Nature and type of surfactant

A surfactant utilized for readiness of niosomes must have a hydrophilic head and hydrophobic tail. The hydrophobic tail may comprise of maybe a couple alkyl or per fluoro alkyl gatherings or now and again a solitary steroidal gathering. The hydrophobic tail of ether sort surfactants with single chain alkyl is more poisonous than comparing dialkylether chain. The surfactants with alkyl chain length from C12-C18 are suitable for preparation of niosomes. Surfactants such as C16EO5 (poly-oxyethylenecetyl ether) or C18EO5 (polyoxy ethylenesteryl ether) are used for preparation of polyhedral vesicles. Span series surfactants having HLB number of between 4 and 8 can form vesicles [19].

The bilayers of the vesicles are either in the supposed fluid state or in gel state, contingent upon the temperature, the kind of lipid or surfactant and the nearness of different segments, for example, cholesterol. The surfactants and lipids are portrayed by the gel-fluid stage change temperature (TC). Phase transition temperature (TC) of surfactant also effects entrapment efficiency i.e. Span 60 having higher TC, provides better entrapment.

Cholesterol content and charge

Cholesterol incorporation improves the efficiency of trapping and the hydro-dynamic diameter of niosomes. In two cases, cholesterol acts:

• Increases the liquid state bilayer chain order.

• Decreases the order of the chain of bilayer gel state.

An increase in concentration of cholesterol results in an improvement in the rigidity of the bilayers and a decrease in the rate of release of encapsulated content. Medicine .The presence of charge leads to an increase in inter-lamellar distance in multi-lamellar vesicle structure between successive bilayers and greater overall trapped volume.

Resistance to osmotic stress

Addition of a hypertonic salt solution to a suspension of niosomes brings about reduction in diameter. In hypotonic salt solution, there is initial slow release with slight swelling of vesicles probably due to inhibition of eluting fluid from vesicles, followed by faster release, which may be due to mechanical loosening of vesicles structure under osmotic stress.

Temperature of hydration

Hydration temperature influences the shape and size of noisome, temperature, change of niosomal system affects assembly of surfactants into vesicles by which induces vesicle shape transformation. Ideally the hydration temperature for noisome formation should be above the gel to liquid phase transition temperature of system.

Method of preparation

Ether injection method (50-1,000 nm) forms vesicles with small diameter than vesicles formed by Hand shaking method (0.35-13 nm). By Reverse Phase Evaporation (REV) method small-sized niosomes can be produced by micro fluidisation greater uniformity and small sized vesicles are obtained.

Nature of encapsulated drug: The niosomal bilayer's charge and rigidity are strongly influenced by the encapsulated drug's physical and chemical properties [19]. Drug capture occurs by communicating with the surfactant head groups resulting in increased charge and causing mutual repulsion of the surfactant bilayer, thus increasing the vesicle size. The drug's HLB determines the degree of trapping.

Structure of surfactants

The geometry of vesicle to be shaped from surfactants is influenced by surfactant's structure, which can be characterized by basic pressing parameters. Geometry of vesicle to be shaped can be predicated on the premise of basic pressing parameters of surfactants.

Critical packing parameters can be defined using following equation:

CPP (Critical Packing Parameters) =V/lc × a0

Where,

V = hydrophobic group volume,

lc = the critical hydrophobic group length,

a0= the area of hydrophilic head group

Critical packing parameter value type of miceller structure formed can be ascertained as given below,

If CPP < ½ formation of spherical micelles,

If ½ < CPP < 1 formation of bilayer micelles,

If CPP > 1 formation inverted micelles.

Merits and Demerits

Merits	Demerits
Controlled and targeted drug delivery	May exhibit fusion, leaching, or hydrolysis of entrapped drug which limits the shelf life
Stable and osmotically active	Insufficient drug loading capacity
Increased derma penetration	Specialized equipment

and oral bioavailability	required for manufacture
Niosomes are non immunogenic, nontoxic, biocompatible , and bio degradable.	Leakage of entrapped drug
Used for parenteral and oral as well as topical routes	Physically instable
No special conditions required for handling and storage of surfactants	Time consuming techniques required for formulation
Improved therapeutic performance of drug	Aggregation
Niosomes have water base , thus having great patent compliance over oily dosage forms	Expensive

Applications of Niosomes

Niosomal drug delivery for their action against various diseases is potentially applicable to many pharmacological agents. Few of its treatment applications are as follows:

Targeting of bioactive agents

1. **To reticulo-endothelial system (RES)**

   Preferentially the vesicles occupy RES cells. It is known as opsonins due to circulating serum factors, which mark them for clearance. However, such localized accumulation of drugs has been exploited in the treatment of animal tumors known to metastasize the liver and spleen and in parasitic hepatic infestation.

2. **To organs other than reticulo-endothelial system (RES)**

   The carrier mechanism can be guided to specific sites in the body by the use of antibodies. Immuno globulins tend to have lipid surface affection and thus provide a convenient means of targeting the drug carrier. Many cells have the intrinsic ability to recognize and bind specific carbohydrate determinants and this property can be used to direct the carrier system to specific cells.

Neoplasia

The anthracyclic antibiotic Doxorubicin, with broad spectrum anti tumor activity, shows a dose dependant irreversible cardio toxic effect. The half-life of the drug increased by its niosomal entrapment of the drug and also prolonged its circulation and its metabolism altered [20]. If the mice bearing S-180 tumor is treated with niosomal delivery of this drug it was observed that their life Methotrexate entrapped in niosomes if administered intravenously to S-180 tumor bearing mice results in total regression of tumor and also higher plasma level and slower elimination.

Niosome as a carrier for haemoglobin

Niosomal suspension shows a visible spectrum super imposable onto that of free hemoglobin so can be used as a carrier for hemoglobin. Vesicles are also permeable to oxygen and hemoglobin dissociation curve can be modified similarly to non-encapsulated hemoglobin.

Ophthalmic drug delivery

It is difficult to achieve excellent bioavailability of drug from ocular dosage form like ophthalmic solution, suspension and ointment due to tear production, impermeability of corneal epithelium, nonproductive absorption and transient residence time. But to achieve good bioavailability of drug niosomal vesicular systems have been proposed. Carter et al reported that multiple dosing with sodium stibo gluconate loaded niosomes was found to be effective against parasites in the liver, spleen and bone marrow as compared to simple solution of sodium stibo gluconate.

Use in studying immune response

Because of their immunological selectivity, low danger and more noteworthy solidness; niosomes are being utilized to ponder the idea of the insusceptible reaction incited by antigens. Nonionic surfactant vesicles have plainly exhibited their capacity to work as adjuvant after parenteral organization with various distinctive antigens and peptides.

Delivery of peptide drugs

In an in-vitro intestinal loop model, niosomal trapped oral delivery of 9-desglycinamide, 8arginine vasopressin was examined and reported significantly increased peptide stability.

Anti-neoplastic Treatment

Most antineoplastic drugs cause severe side effects. Niosomes can alter the metabolism; prolong circulation and half-life of the drug, thus decreasing the side effects of the drugs. Niosomes is decreased rate of proliferation of tumors and higher plasma levels accompanied by slower elimination [21].

Transdermal delivery of drugs by niosomes

Transdermal drug delivery integrated in niosomes has achieved an improvement in penetration rate, as sluggish drug penetration through skin is the major drawback of transdermal delivery route for other dosage forms. The topical delivery of erythromycin from different formulations like niosomes has been tested on hairless mouse and tests, and confocal microscopy has found that non-ionic vesicles can be designed to target pilosebaceous glands.

Other Applications

a) Sustained Release By niosomal encapsulation, drugs with low therapeutic index and higher water solubility may be retained in circulation, and continuous release action can be achieved by niosomes. Suggested function of liver as a methotrexate depot after the liver cells take up niosomes.

b) Localized Drug Action Niosomal dosage form is one of the approaches to achieving localized drug action due to the size of niosomes and their low penetrability via epithelium and connective tissue, the drug located at the site of administration. It results in an increase in the drug's efficacy and potency, and also decreases its systemic toxic effects, e.g. Mononuclear cells consume antimonials encapsulated inside niosomes, resulting in product localization, increased potency and therefore decreased in both dose and toxicity.

Evaluation

Entrapment efficiency

After preparing niosomal dispersion, unentrapped drug is separated by dialysis centrifugation and gel filtration. The drug remains entrapped in niosomes s determined by complete vesicle disruption using 50% n-propanol or 0.1% Triton X-100 and analyzed resultant solution by appropriate assay method using the following equation.

Entrapment efficiency = (Amount entrapped / total amount) x 100

Bilayer Formation: Assembly of non-ionic surfactants to form a bilayer vesicle is characterized by an X-cross formation under light polarization microscopy.

Size: Shape of niosomal vesicles is assumed to be spherical, and their mean diameter can be determined by using laser light scattering method. Also, diameter of these vesicles can be determined by using electron microscopy, molecular sieve chromatography, ultracentrifugation, photon correlation microscopy, optical microscopy and freeze fracture electron microscopy [22].

Numbers of lamellae

This is determined by using Nuclear Magnetic Resonance (NMR) spectroscopy, small angle X-ray scattering and electron microscopy.

Membrane rigidity

Membrane rigidity can be measured by means of mobility of fluorescence probe as a function of temperature.

In-vitro release: A method of in-vitro release rate study includes the use of dialysis tubing. A dialysis sac is washed and soaked in distilled water. The vesicle suspension is pipetted into a bag made up of the tubing and sealed [23]. The bag containing the vesicles is placed in 200ml of buffer solution in a 250ml beaker with constant shaking at 25° C or 37° C. At various time intervals, the buffer is analyzed for the drug content by an appropriate assay method.

Microscopic evaluation

Transmission electron microscopy was used for microscopic evaluation of niosomal dispersions. TEM used for determination of size and used for identified whether it is spherical or not.

Conclusion

Niosomal drug delivery system is one of the best examples of great evolution in drug delivery technology. The concept of drug incorporation in the niosomes and to target the niosomes to the specific site is widely accepted by researchers and academicians. Niosomes appears to be a well preferred drug delivery system over other dosage form as noisome mostly stable in nature and economic. There is lost of scope to encapsulate toxic anti-cancer drugs, anti-viral drugs, anti-infective drugs. Anti-AIDS drugs, anti-inflammatory drugs ,etc in niosomes. They achieve better bioavailability and targeting properties and for reducing the toxicity and side effects of the drugs. Niosomes present a structure similar to the liposomes and hence they can represent alternative vesicular systems with respect to liposomes. Niosomes represent various type of drug deliveries can be possible using niosomes like targeting, ophthalmic, topical, parenteral, etc. various type of drug deliveries can be possible using niosomes like targeting, ophthalmic, topical, parenteral, etc.

References

1. Biju SS., Talegaonkar S., Misra PR., Khar RK., Vesicular systems: An overview. Indian J. Pharm. Sci. 2006, 68: 141-153.
2. Lieoma F., Uchegbu., Suresh P., Vyas., Non-ionic surfactant based vesicles (niosomes) in drug delivery. Int. J. Pharm. 1998; 172: 33–70.
3. Malhotra M., Jain N.K., Niosomes as Drug Carriers. Indian Drugs. 1994, 31(3): 81-866.
4. Alsarra A., Bosela A,, Ahmed S.M,, Mahrous G.M., Proniosomes as a drug carrier for transdermal delivery of ketorolac. Eur. J. Pharm. And Biopharm. 2004; 2(1): 1-6.
5. Hu C., Rhodes D.G., Proniosomes: a novel drug carrier preparation. Int. J. Pharm. 1999, 185: 23-35.
6. Breimer DD and Speiser R. Topics in Pharmaceutical Sciences. Elsevier Science Publishers, New York, USA. 1985;291.
7. Khandare JN, Madhavi G, Tamhankar BM: Niosomes Novel Drug Delivery System. The Eastern Pharmacist, 1994, (37), 61-64.
8. Mayer LD, Bally MB, Hope MJ, Cullis PR: Uptake of antineoplastic agents into large unilamellar vesicles in response to a membrane potential. Biochem Biophys Acta, 1985, (816), 294-302.
9. Kazi Masud Karim, Asim Sattwa Mandal, Nikhil Biswas, Arijit Guha, Sugata Chatterjee, Mamatha Behera: Niosome: A future of targeted drug delivery systems. J Adv Pharm Tech Res, 2011, (62), 122.
10. Raja Naresh RA, Chandra shekhar G, Pillai GK, Udupa N: Anti inflammatory activity of Niosome encapsulated diclofenac sodium with Tween -85 in Arthitic rats. Ind J Pharmacol, 1994, (26), 46-48.
11. Uppugalla S, Male U, Srinivasan P. Design and synthesis of heteroatoms doped carbon/polyaniline hybrid material for high performance electrode in supercapacitor application. Electrochimica Acta. 2014 Nov 10;146:242-8.
12. Male U, Uppugalla S, Srinivasan P. Effect of reduced graphene oxide–silica composite in polyaniline: electrode material for high-performance supercapacitor. Journal of Solid State Electrochemistry. 2015 Nov;19(11):3381-8.
13. Uppugalla S, Srinivasan P. High-performance supercapacitor coin cell: polyaniline and nitrogen, sulfur-doped activated carbon electrodes in aqueous electrolyte. Journal of Solid State Electrochemistry. 2019 Jan;23(1):295-306.

14. Uppugalla S, Srinivasan P. Polyaniline nanofibers and porous Ni [OH] 2 sheets coated carbon fabric for high performance super capacitor. Journal of Applied Polymer Science. 2019 Nov 5;136(41):48042.
15. Uppugalla S, Boddula R, Srinivasan P. Methyl triphenylphosphonium permanganate as a novel oxidant for aniline to polyaniline-manganese (II, IV) oxide: material for high performance pseudocapacitor. Journal of Solid State Electrochemistry. 2018 Feb;22(2):407-15.
16. http//en.wikipedia.org/wiki/Niosomes, structure of niosomes.
17. Rogerson A., Cummings J., Willmott N., Florence AT., The distribution of doxorubicin in mice following administration in niosomes. J. Pharm. harmacol. 1988, 40: 337-342.
18. Tabbakhian M, Tavakoli N, Jaafari M, Daneshamouz S. Enhancement of follicular delivery of finasteride by liposomes and niosomes. Int. J. Pharm. 2006; 323: 1-10.
19. Namdeo A, Jain N. Niosomes as drug carriers. Indian Journal of Pharm. Sci. 1996; 58: 41-46.
20. Rai A. Niosomes: An approach to current drug delivery-A Review. International Journal of Advances in Pharmaceutics. 2017; 06: 41-48.
21. Srivastav A, Das P. To Study the Formulation of Niosome of Ofloxacin and Its Evaluation for Efficacy of Anti-Microbial. International Journal of Innovative Research in Science, Engineering and Technology. 2014; 3: 17958-17965.
22. Mishra N, Srivastava V, Kaushik A, Chauhan V, Srivastava G. Formulation and in vitro-evaluation of Niosomes of Aceclofenac. JSIR. 2014; 3: 337-341.
23. Bayindir Z, Yuksel N. Characterization of niosomes prepared with various nonionic surfactants for pacitaxel oral delivery. Journal of Pharmaceutical Sciences. 2010; 99: 2049-2060.