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Review Article

Nanotechnology Integration in Proniosomal Drug Delivery System

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ABSTRACT

The scientific revolution that nanotechnology has sparked has resulted in the development of novel dosage forms like liposomes, proniosomes, and niosomes. Proniosomes are the formulation of dry surfactant-coated particles that form niosomal dispersion in a hot aqueous medium immediately upon agitation. This article offers a detailed analysis of proniosomes. They simplify transport, delivery, dosage, and storage while also reducing issues in the vesicular system caused by aggregation, fusion, and pharmaceutical leakage. Stability issues plague conventional vesicular structures like liposomes and proniosomes. This novel method showed promise in improving oral bioavailability to direct medication to a specific site by prolonging the drug's half-life in the bloodstream. This prevents harmful side effects. Proniosomes are investigated and discussed as potentially useful drug delivery systems for a range of medicinal and cosmetic uses. The use of nanotechnology in drug delivery is becoming increasingly important in the creation of novel dosage forms. Nanotechnology has focused a lot of attention on vesicular drug delivery systems like liposomes, proniosomes, and niosomes. Proniosomes are the best type of vesicular carrier. These are dry formulations because proniosomes are surfactant-coated, water-soluble carrier particles. In just a few minutes, they are rehydrated and ready for use on agitation in heated aqueous media to form niosomal dispersion right away. Drugs that are lipophilic or hydrophilic can be added to these proniosomes. Proniosomes reduce the physical stability issues associated with niosomes, such as aggregation, fusion, and leakage. These routes include oral, parenteral, dermal and transdermal, ocular, oral mucosal, vaginal, pulmonary, and intranasal

Keywords: Multilammeller, Provesicles, Surfactant, Vesicular drug delivery.

INTRODUCTION

In the field of nanotechnology, innovative vesicular drug delivery systems have advanced significantly. Due to their versatility and ability to transport a wide range of medications, these systems are frequently employed for pharmacological targeting, controlled release, and drug penetration enhancement.[1] The disadvantages of traditional dosage forms, such as low aqueous solubility, poor bioavailability, poor membrane permeability, variable plasma concentration, undesirable effects, poor patient compliance, and ultimately poor patient efficacy, can be avoided with the help of this system.[2] These systems are also valuable in evading various drawbacks associated with conventional dosage forms like low aqueous solubility, poor bioavailability, poor membrane permeability, variable plasma concentration, undesirable effects, poor patient compliance, and, finally, poor patient efficacy.[3]

Proniosomes

Proniosomes are a free-flowing, dry preparation that has been surfactant-coated. Proniosomes are directly rehydrated by brief agitation within minutes to form a multi-lamellar noisome. Dry, free-flowing pro-vesicles with a liquid crystalline consistency that easily transform into niosomes upon hydration are known as proniosomes. Phospholipids and non-ionic surfactants, two components of proniosomes, Proniosomes are thought to prevent a number of formulation-related problems with liposomes, such as chemical and physical instability, sterilizable issues, phospholipid purity problems, and large-scale production processes. Proniosomes have the added advantage of being dry niosomes, which can be used for shipping, storage, dosing, and industrial scale-up. They may also hasten the skin's recovery rate from barrier function impairment. Niosomal vesicle's amphiphilic nature allows them to accommodate. Niosome suspension is suitable for administering drugs via various methods. Their ease of transportation, distribution, storing, and processing makes them attractive options for industrial use. Thus, proniosomes may offer an additional option for the entrapment of both polar and non-polar drugs in place of liposomal and other vesicular drug delivery systems.[4] A unit dose of the medication can be administered with better drug stability and solubility when using dry phosphorosomal powder. Both hydrophilic and lipophilic medications can be administered *via* this formulation in a variety of ways, including oral, topical, transdermal, vaginal, etc.

Structure

Proniosomes are tiny structures that resemble lamellae. They mix cholesterol with a non-ionic surfactant of the dialkyl or alkyl polyglycerol ether class, and then they hydrate in an aqueous medium. A surfactant molecule arranges itself so that, in order to form a bilayer, the hydrophilic ends of the non-ionic surfactant point outward and the hydrophobic ends point in the opposite direction. Like liposomes, proniosomes are composed of a bilayer. In proniosomes, non-ionic surface active agents form the bilayer. Proniosomes can be classified as unilamellar or multi-lamellar, depending on how they were prepared.[5]

Proniosomes as drug carriers

Given their numerous disadvantages over liposomes and their increased chemical stability, proniosomes are a promising alternative for drug delivery. Proniosomes are dehydrated versions of surfactant-coated carrier vesicles that can be rehydrated when needed. The resulting niosomes are quite similar to regular, uniformly sized niosomes. Proniosomes are a dry, freely flowing product that reduces issues with stability during storage and sterilization. Additionally, they demonstrate the advantages of proniosomes' simplicity in transfer, distribution, measurement, and storage, making them an incredibly adaptable delivery system.[6]

Advantages of proniosomes

- Keeping away from physical stability issues like fusion, leaking, and aggregation.
- Preventing hydration in medications that are encapsulated reduces the dispersion's shelf life.
- Proniosomes are surfactant-coated, water-soluble carrier particles that can be hydrated to create a niosomal dispersion right before using a quick agitation with the heated aqueous medium. It offers improved distribution, storage, and transportation convenience. Dry niosomes, a promising industrial product, would be designed.
- Additionally, inappropriate solvents were steered clear of in proniosomal formulations. Without requiring the dispersion of vesicles into the polymeric matrix, the systems can be directly formulated into transdermal patches.
- Proniosomes are a versatile delivery system that have the potential to contain a wide range of active compounds due to their storage.[7]
- Enhancement of the medication's penetration and bioavailability.
- Boosts skin penetration and creates a transdermal therapy system.
- Simple manufacturing and scaling up procedures.
- Steer clear of problems with stability like sedimentation, fusion, and aggregation.
- Less adverse drug reactions.
- Used for targeted drug delivery.[8]

Disadvantages

One of the disadvantages of niosomes over proniosomes

- Aggregation,
- Fusion,
- Leakage of the drug that was trapped.
- Deposition

Types of proniosomes

- Dry granular proniosomes
- Sorbitol based
- Maltodextrin based
- Liqiud crystalline proniosomes

Dry granular proniosome

According to the type of carrier, they again divided as sorbitol based proniosomes.

Sorbitol-based proniosomes

Proniosomes serve as the carrier in orbital base proniosomes, a dry formulation that is further coated with a non-ionic surfactant and used as niosomes in just a minute by adding hot water and stirring. Typically, this is created by spraying the sorbitol powder with a surfactant mixture made in an organic solvent and then letting the solvent evaporate. Since the sorbitol carrier dissolves in organic solvents, repeating the procedure is necessary to obtain the appropriate active ingredient is hydrolyzable, it is helpful. The residual sorbitol reduces entrapment efficiency to less than half of what is seen when sorbitol is used. This calls for a decrease in the carrier proportion in the finished niosome suspension. As sorbitol dissolves in chloroform and other organic solvents, testing sorbitol particles presents a challenge. The method is sprayed slowly to prepare it.[4]

Maltodextrin-based pronisomes

It is made using the quick slurry method. The amount of time needed to create proniosomes using the slurry method is not dependent on the surfactant solution ratio. High surface-to-carrier ratio promethiosomes can be used. It is possible to prepare a ratio. It is quite easy to extract niosomes for drug delivery from these proniosomes. Sorbital is used in an analogous process that yields a solid surfactant/sorbitol cake. Hollow-blown maltodextrin particles can be used to achieve a significant increase in surface area because the morphology of the material is preserved. The rehydration process is more effective because of the thinner surface coating produced by the larger surface area. This preparation may be used to deliver amphiphilic and hydrophobic medicinal molecules.[9]

Liquid Crystalline proniosomes

There are three ways that lipophilic surfactant chains can change into a disordered, liquid state known as the lipophilic liquid crystalline state (neat phase) when the surfactant molecule is kept in contact with water. The three methods include raising the Kraft temperature (Tc), adding a solvent that dissolves lipids, and combining the use of solvent and temperature. A bilayer of molecules layered on top of one another in an intervening aqueous layer is found in the neat phase, also referred to as the lamellar phase. Under a polarized microscope, this kind of structure exhibits thread-like birefrigerant structure and typical x-ray diffraction. Higher concentrations of the lamellar crystalline phase transform into niosomes. Proniosomal gel and liquid crystalline promethosomes serve as reservoirs for transdermal medication delivery.[10]

Components needed to prepare proniosomes

Surfactant

Surfactants, especially non-ionic surfactants, are the key structural

components in the preparation of proniosomes. These surfactants do not have any charge as they possess a polar head and non-polar tail. So, their stability, toxicity and compatibility is higher than other surfactants. The non-ionic surfactants have wet and emulsifying effects by which they improve the solubility and permeability of drugs. The hydrophilic-lipophilic balance (HLB) value is critical for selecting surfactants and the HLB value between 4 and 8 is compatible with vesicle formation by proniosomes. It is difficult for hydrophilic surfactants to achieve a high concentration because of the high liquid solubility of hydrophilic surfactants. Therefore, aggregation and conglutination to form a proniosomal lamellar structure would be absent.[11]

Cholesterol

Cholesterol controls the structural and physical characteristics of periosomes and interacts with non-ionic surfactants.[12] It enhances the phosphorosomal membrane's stiffness and stability and regulates drug penetration through the membrane. The quantity of cholesterol needed to prepare protonosomes is determined by the HLB value of the surfactants. To account for the larger groups, the amount of cholesterol should be increased when the HLB value is higher than 10.[13]

However, above a certain level of cholesterol, the prepared formulation's entrapment efficiency (EE) decreases10, perhaps as a result of a drop in volume diameter.[14]

Hydration medium

Phosphate buffer is typically utilized in periosome hydration. The pH of the buffer is chosen in accordance with the drug's solubility after being capsuled.[15] They found that while drug leakage increased as the volume of the hydration medium increased, EE increased when the hydration time was extended from 20 to 45 minutes.[16]

Lecithin

Lecithin is a phospholipid that acts as a membrane stabilizer in the formulation of proniosomes. The most common lecithins that are used in the formulation are soya and egg lecithin and it has been reported that hydrogenated-type lecithins have advantages over not hydrogenated lecithins, give increased rigidity of the cholesterol and help in the formation of tight vesicles. Double bonds in non-hydrogenated lecithin allow the molecular chains to bend (conformational rotation), which prevents tight contact with the adjacent molecules on forming the niosomal membrane. This results in low rigidity and high permeability of the membrane.

Organic solvent

The solvent has the ability to improve penetration. It also has a significant impact on how big the formed vesicles are. The kind of alcohol affects the vesicle's size and the drug's rate of penetration in a proniosomal formulation. Alcohols are arranged in the following order to form different-sized vesicles: isopropanol, butanol, propanol, and ethanol.[17]

Transport media

In proniosomal formulations, the drug is accommodated by carrier materials. Carriers ought to be free-flowing, non-toxic, and safe. For ease of hydration, they should have good solubility in water but low solubility in the loaded solution. They provide the proniosomes more flexibility and surface area. Sorbitol, mannitol, glucose monohydrate, spray-dried lactose, sucrose stearate, and lactose monohydrate are the commonly used carrier materials.[12,13]

Methods of Preparation

Proniosomes can be prepared by following methods: -

- Slurry method
- Coacervation phase separation method
- The slow spray coating method.[5]

Slurry Method

Proniosomes were made by adding the carrier and the whole surfactant solution to a flask with a circular bottom that was attached to a rotating flash evaporator. A vacuum was then used to create a powder that was dry and fluid. Lastly, the formulation needs to be refrigerated and kept in light in a tightly sealed container. The amount of time needed to produce proniosomes appears to be stable and is not affected by the ratio of the surfactant solution to the carrier material. After forming, the proniosomal powder is gathered, sealed in containers, and kept cold at 4°C. Using maltodextrin as a carrier, a novel slurry method was used to create the proteosomes. A 100 ml round-bottom flask containing the carrier (maltodextrin) should be filled with the solvent and the necessary volume of surfactant and cholesterol stock solution per gram of maltodextrin and drug. If there is less surfactant loading, more chloroform can be added to create a slurry. To evaporator solvent, the flask must be attached to a rotary flash evaporator that rotates at 50 to 60 rpm, 45–2°C, with a reduced pressure of 600 mm Hg, until the mass inside the flask becomes a container under refrigeration in light.[18]

Coacervation phase separation method

This method, which involves placing a drug, lipid, and surfactant in a wide-mouthed glass vial with a tiny amount of alcohol inside, can be used to create proniosomal gels. The mixture is heated in a water bath at 60 to 70℃ for 5 minutes or until the surfactant mixture dissolves entirely. After that, a small amount of aqueous phase is added to the vial above and heated further. A clear solution forms, which cools to become proniosomal gel. Following hydration, proniosomes transformed into niosomes with consistent size.[18]

Slow spray coating method

Using this technique, an organic solvent is mixed with the surfactant before being sprayed onto the carrier. Subsequently, the solvent evaporates. Because the carrier is soluble in the organic solvent, this process was repeated until the appropriate surfactant loading was obtained. Hydration of this coating permits the formation of a multi-lamellar vesicle as the carrier dissolves. These niosomes resemble those made using conventional techniques and have a uniform size distribution. You can connect a 100 mL round-bottom flask with the required amount of carrier to a rotary flash evaporator. Using a rotary evaporator, prepare a mixture of cholesterol and surfactant and add it to a round-bottom flask by spraying aliquots onto the carrier's surface one after the other. The rotating flask can be rotated in a water bath under vacuum at 65 to 70℃ for 15 to 20 minutes after the evaporator has been emptied. It is necessary to prepare this procedure until all of the surfactant solutions have been used. Continue the evaporation process until the powder dries completely.[19]

Characterization of Proniosomes

Vesicle morphology

The measurement of proniosomal vesicles' size and shape is known as vesicle morphology. The dynamic light scattering method can be used to measure the size of promiosomal vesicles in two different conditions: without agitation and with agitation. The largest vesicle size is achieved through hydration without agitation. The size and shape of vesicles can also be measured using scanning electron microscopy, or SEM. When applying vesicles topically, it's critical to ascertain their size.[20]

Surface morphology:

Surface morphology includes aggregation formation, smoothness, and roundness. It was investigated using optical, transmission electron, and scanning electron microscopy.[21]

Encapsulation efficiency

The encapsulation efficiency of proniosomes is determined after the separation of the unentrapped drug.

Separation of unentrapped drug is done by the following techniques

Dialysis

The aqueous niosomal dispersion is dialyzed tubing against an appropriate dissolving medium at room temperature. Samples are then removed from the medium at an appropriate interval and centrifuged, and UV spectroscopy is used to determine the drug content.

Gel filtration

By gel filtration of niosomal dispersion through a sephadex G50 column, the free drug is eliminated. An appropriate mobile phase is then used to separate the mixture, and analytical techniques are used to analyze the results.

Centrifugation

After centrifuging the niosomal suspension, the surfactant is extracted. In order to obtain a niosomal suspension free of unentrapped drugs, the pellet is first rinsed and then resuspended.

Determination of entrapment efficiency of proniosomes

After the unentrapped drug is removed by dialysis, the vesicles are resuspended in 30% v/v PEG 200. To solubilize the vesicles, 1-mL of 0.1% v/v triton x-100 solution is added. The clear solution that forms is then filtered and its drug content is examined. To determine the percentage of drug entrapped, apply the formula below:

[Percent Entrapment = Amount of drug entrapped/total amount of drug × 100]

In-vitro release study by dialysis tubing method

Via the dialysis method, the in-vitro drug release from proniosomes can be estimated. Proniosomes were inserted into dialysis tubing that had been previously cleaned and sealed hermetically. Subsequently, the dialysis sac is dialyzed at room temperature using an appropriate dissolution medium. The samples are taken out of the medium at appropriate intervals and centrifuged, and their drug content is examined using appropriate analytical techniques, such as UV spectroscopy and HPLC.

By reverse dialysis

Several tiny dialyses, each containing one milliliter of dissolving medium, are inserted into proniosomes using this technique. Next, the periosomes are moved into the dissolving medium. This method allows for the direct dilution of the proniosomes, but it is unable to quantify the rapid release.

Franz diffusion cell

Franz diffusion cells can also be used for in-vitro research. Proniosomes are inserted into the cellophane-covered donor chamber of a Franz diffusion cell. After dialyzing the proniosomes against an appropriate dissolving medium at room temperature, the samples are taken out of the medium at appropriate intervals and their drug content is examined using an appropriate technique, such as UV spectroscopy or HPLC, while maintaining appropriate sink conditions.[22]

In-vitro permeation study

The drug content can be ascertained by an appropriate analytical method, and the rate of drug permeation from proniosomal formulations can be determined using the Franz diffusion cell and the Keshary Chin diffusion cell. Transdermal drug delivery has improved in part because of the interaction between proniosomes and the skin. A plausible mechanism for augmenting niosomal permeability involves the structural alteration of the stratum corneum. Proniosomes' non-ionic surfactants and phospholipids both function as penetration enhancers, boosting the numerous medications' rate of permeation. Haloperidol's penetration from proniosomal formulations was assessed using a diffusion cell flow test.It is necessary for vesicles to adhere to the skin's surface in order for the medication to permeate and divide between the stratum corneum and formulation.

Zeta potential analysis

Zeta potential analysis is used to ascertain the prepared formulations' colloidal characteristics. At a temperature of 25°C, the noisome dispersion of suitably diluted promiosomes was ascertained using a zeta potential analyzer that was based on electrophoretic light scattering and laser dopplervelocimetery method.

Stability studies on proniosomes:

A physical stability study was done to look into how the drug broke down in the proniosome while it was being stored. The prepared promiosomes are stored for a duration of one to three months at different temperatures, including room temperature (25 ± 0.5°C), refrigerator temperature (2–8°C), and elevated temperature (45 ± 0.5°C), in order to conduct stability studies. Monitoring is done on a regular basis for drug content and variations in the average vesicle diameter. According to international climate zones and climatic conditions, stability studies for dry proniosome powder intended for reconstitution should be conducted for accelerated stability at 75% relative humidity (Table 1).[23]

Table 1: Evaluation parameters of proniosomes

S.no	*Parameter*	*Techniques and instrument*
1.	Angle of repose	Funnel method [24] Cylinder method[25]
2.	Aerodynamic behavior	Twin –stage impiring[26]
3.	Sieve fractionation	Fritsch analysis sieve shaker[27]
4.	Separation of unentrapped	Exhaustive dialysis [28] Centrifugation (9below 7000xg)
5.	Shape and surface morphology	EM (scanning electron microscopy) TEM (transmission electron microscopy) Optical microscopy [29]
6.	Spontaneity (rate of hydration)	Neubaucer chamber[30]
7.	*In-vitro* drug release studies	Franz diffusion cell Keshary-chein diffusion cell45 Cellophane dialyzing membrane Spectarpor molecular porous membrane USP dissolution apparatus [31]

Application of Proniosomes

In studying immune response

Proniosomes are utilized in immunological response research because of their increased stability, immunological selectivity, and low toxicity. Niosomes are used to investigate the nature of the immune response triggered by antigens**.**

In delivery of peptide drugs

oral peptide drug delivery has long been faced with the challenge of bypassing an enzyme that breaks down the peptide. The use of proniosomes is intended to protect the breakdown of the peptides successfully from the gastrointestinal tract. In the study, the oral delivery of the vasopressin derivative entrapped in the proniosomes showed the highest entrapment of a drug & significant increase in the stability of the peptide which are incorporated.[32]

In antineoplastic treatment

The majority of antitumor drugs have serious adverse effects. Niosomes can change a drug's metabolism, prolong its half-life, and increase its circulation, all of which reduce the drug's adverse effects. In two distinct studies, the niosome entrapment of methotrexate and doxorubicin demonstrated advantages over the entrapped drugs, including a slower rate of tumor proliferation and higher levels of the drug in the plasma that were accompanied by a slower rate of elimination. For the purpose of enhancing PPT-DPPC stability, dipalmitoylphosphatidyl choline proliposomes [PPT-DPPC-PL] contain podophyllotoxin.[33]

In NSAIDs application

For the short-term treatment of postoperative pain, NSAIDs (non-steroidal anti-inflammatory drugs) such as ketorolac tromethamine can be given intramuscularly and orally in divided doses. In order to maintain the drug's blood levels of ketorolac tromethamine for an extended amount of time, a different, noninvasive method of delivery is therefore required, making the transdermal route of administration an unquestionably appealing method of administration. In hormonal therapy levonorgestrel's proniosome-based transdermal drug delivery system was created and extensively studied in both in vitro and in vivo settings. The inhibition and endometrial assay with corpora lutea formation comprised the biological assay for the progestational activity.[34]

The proniosomes as carriers for hemoglobin:

Through the use of photoinitiators like visible light and eosin. Since these hydrogels form slowly after being injected into the body, they are limited to surgical sites close to light sources. Ion-mediated gelation has been reported for a variety of polymers, such as alginates/calcium ions or chitosan/phosphate ions. The concentrations of the counter ion that are normally present in physiological conditions are insufficient for the cross-linking of the aforementioned polymers. There are two key elements that restrict the application of calcium alginate which are listed below:

- Immunogenicity potential
- Extended duration in vivo degradation [35]

Used in cardiac disorders

Proniosomal carrier system that effectively delivers the entrapped medication over an extended period of time for the treatment of hypertension (high blood pressure). The liver functions as a methotrexate depot following the liver cells' uptake of niosomes. Niosomes' prolonged-release action can be used with medications that have low water solubility and low therapeutic potency.[36]

Table 2: Some marketed formulation of proniosomes

Route	*Drug*	*Composition*	*In-vitro/in-vivo effects*
oral	vinpocetine	Span60/sorbitol/chlosterol	Improve oral bioavailability and GI absorption [37]
Oral	Candesartan cilexetil	Span60/maltodextrin/chlosterol	Improve oral bioavailability [38]
oral	Diphenyldimethylbicarbonate	Tween 80/sorbitol/stearylamine	Enhance dissolution and hepatocurative activity [39]
Parental	flurbiprofen	Span80:span20/cholesterol/sorbitol	Sustained anti-inflammatory activity and reduce dosing frequency [40]
Transdermal	Tenoxicam	Tween20 /cholesterol	Improve patient compliance and drug safety [41]
transdermal	Mefanamic acid	Span80/cholesterol/soya lecithin	Improve transdermal delivery and anti-inflammatory [42]
Ocular	LomefloxacinHcl	Span60:tween60/chloestrol	Improve ocular bioavailability and prolong corneal retention [43]
Vaginal	Terconazole	Span60:brij76/chlosterol/lecithin	Enhance mucoadhesive properties [44]
Pulmonary	Cromolyn sodium	Sucrose/stearate/cholesterol/ stearylamine	Controlled drug release and improve aerosolization[45]

Drug targeting

The proniosome's capacity to target medications is one of its most advantageous features. By employing a ligand attached to the surface of niosomes that could be actively taken up, active targeting for tumor therapy can further increase the effectiveness and specificity of niosomal drug delivery systems' cellular targeting. Drugs can be targeted to the reticuloendothelial system using promethiosomes. Proniosome vesicles are preferentially absorbed by the reticuloendothelial system (RES). Proteosomes can also direct drugs to organs other than the RES. Since immunoglobulins bind to the lipid surface of proniosomes easily, a carrier system, such as antibodies, can be added to proniosomes to direct them toward particular organs (Table 2).

CONCLUSION

Proniosomes a type of vesicular system, offer fantastic and innovative drug delivery. for a topical, anti-infective, and anti-cancer route of administration, generally. Proniosomes hold great promise as drug carriers in the future due to their increased chemical and physical stability and potential for scalability for commercial viability. Proniosome-based niosomes can be used for a variety of drug delivery applications, including topical, ophthalmic, oral vaccine, parenteral, and targeting. Niosomes derived from proniosomes is a promising drug delivery system. They are generally known to avoid a number of issues related to leakage, aggregation, and fusion, as well as issues with physical stability related to an aqueous niosome dispersion. They offer more dosing, distribution, storage, and transportation convenience. Progress in scientific research has led to the use of proniosomes as drug carriers for more precise drug delivery to targeted tissues. This is because proniosomes are composed of non-ionic surfactants, which makes them less toxic and allows for the loading of hydrophilic, lipophilic, or both types of drugs simultaneously. Proniosomes enhance the stability of the drug entrapped, lower the dosage, and allow for targeted delivery to a particular type of tissue, according to pertinent studies.

CHANCES FOR ADVANCEMENT/FUTURE PERSPECTIVES

The novel idea of pioniosomes provides new avenues for pharmaceutical research. It is possible to conduct analyses on various novel carrier materials in order to produce proniosomes that are suitable for proniosomes and biocompatible in the future. Furthermore, among vesicular systems, proniosomes are emerging as a promising drug delivery vehicle; however, further research is needed in the fields of cosmetics, herbal compounds, and nutraceuticals. They are also appropriate for peptide delivery because, in an acidic environment and with the presence of enzymes, peptides taken orally are subjected to enzymatic degradation.

Peptide stability could be increased through the use of proniosomal technology. They may also work more effectively in presenting the antigens to antigen identification cells and are convenient for the delivery of vaccines and antigens. Because pioniosomes are oxygen-permeable and can therefore be used as an efficient hemoglobin carrier in the treatment of anemia, they may also be used to deliver hemoglobin within the blood. As a result, in-depth research is needed to investigate them in an industrial setting by creating pilot plant scale-up studies. However, a number of issues with the industrial system must be evaluated in order to demonstrate their suitability for the delivery of a variety of medications and natural products.

CONFLICT OF INTEREST

None declared

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