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Transferosomes: Novel Elastic Carriers for Enhanced Transdermal Drug Delivery

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ABSTRACT

Transferosomes, with their remarkable ability to penetrate the skin barrier, offer a revolutionary approach to transdermal drug delivery. Unlike traditional vesicular systems, transfersomes effortlessly traverse the stratum corneum, the skin's outermost layer, via distinct intracellular lipid pathways. This unique characteristic enables them to deliver a diverse spectrum of therapeutic agents, ranging from small molecules to large proteins and peptides, with exceptional efficiency and precision. Transferosome's controlled release mechanism provides an added layer of precision, allowing for targeted and sustained drug delivery tailored to specific therapeutic needs. Moreover, their specialized design underscores the importance of optimization for individual drug molecules to achieve the most effective formulations and desired pharmacological responses. The versatility of transfersomes extends to their ability to deliver a wide range of active compounds, including proteins, peptides, insulin, corticosteroids, interferons, anesthetics, NSAIDs, anticancer drugs, and herbal remedies. Ongoing scientific exploration of transfersomes holds immense promise for unlocking novel therapeutic strategies against a multitude of diseases. This review highlights the significant impact of transfersomes in advancing transdermal drug delivery and shaping the landscape of pharmaceutical interventions for improved therapeutic outcomes.

INTRODUCTION

TRANSFEROSOMES:

The term transfersome and the underlying concept were introduced in 1991 by **Gregor Cevc**. In the broadest sense, a transfersome is a highly adaptable and stress-responsive, complex aggregate. Its preferred form is an ultra-deformable vesicle possessing an aqueous core surrounded by a complex lipid bilayer. Interdependency of local composition and shape of the bilayer makes the vesicle both self-regulating and self-optimising. This enables the transfersome to cross various transport barriers efficiently, and then act as a drug carrier for non-invasive targeted drug delivery and sustained release of therapeutic agents.[1]

A **Transfersome** is an ultra-deformable vesicle that is a highly adaptable and stress-responsive complex aggregate. These Transfersomes tend to increase the hydrophilic pore size of the skin wide enough to be able to transport larger aggregates through the stratum corneum. The delivery of macro-molecules into and through the intact skin is due to the trans-barrier particle motion driven by the moisture gradient across the permeation barriers like the stratum corneum, thus allowing delivery of such macro-molecules of size greater than a 100kDa.[2]

The high and self-optimizing deformability of typical composite transfersomes membrane, which are adaptable to ambient tress allows the ultra-deformable transfersomes to change its membrane composition locally and reversibly, when it is pressed against or attracted into narrow pore. The transfersomes components that sustain strong membrane deformation preferentially accumulate, while the less adaptable molecules are diluted at sites of great stress. This dramatically lowers the energetic cost of membrane deformation and permits the resulting, highly flexible particles, first to enter and then to pass through the pores rapidly and efficiently. This behaviour is not limited to one type of pore and has been observed in natural barriers such as in intact skin.[3]

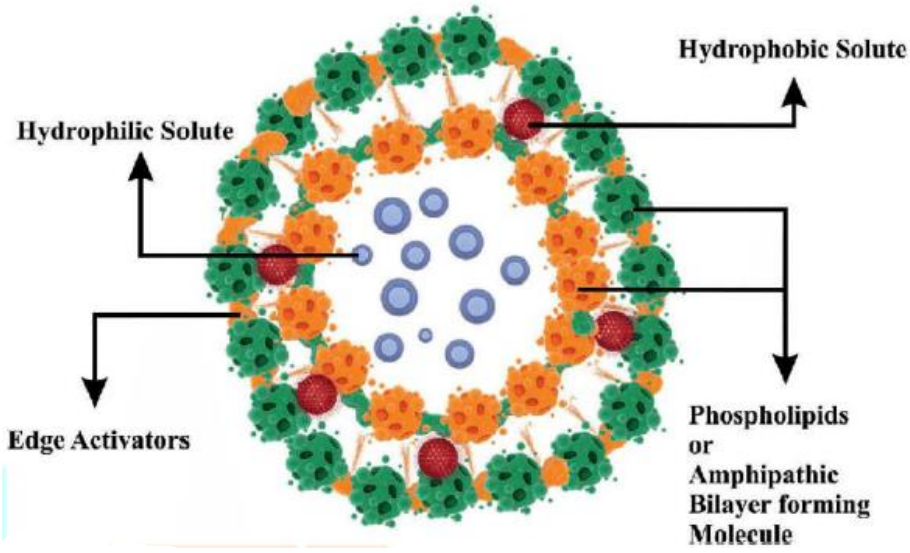

Figure 1: Structure of Transferosomes

COMPOSITION OF TRANSFEROSOMES:

The modified liposomal vesicular system (transfersomes) is composed of the phospholipid component and single-chain surfactant as an edge activator. The formulation of transfersomes includes-

i. The main ingredient, an amphipathic ingredient (e.g., soy phosphatidylcholine, egg phosphatidylcholine, etc.) that can be a mixture of lipids, which are the vesicle-forming components that create the lipid bilayer in transferosomes.

ii. 10–25% surfactants/edge activators; the most commonly used edge activators in transfer some preparations are surfactants as sodium cholates; sodium deoxycholate; Tweens and Spans (Tween 20, Tween 60, Tween 80, Span 60, Span 65, and Span 80) and dipotassium glycyrrhizinate, which are biocompatible bilayer-softening compounds that increase the vesicles' bilayer flexibility and improve the permeability.

iii. About 3–10% alcohol (ethanol or methanol), as the solvent and, finally, hydrating medium consist with either water or a saline phosphate buffer (pH 6.5–7). [4,5]

Table 1: Different additives used in formulation of transfersomes

Sr. No	Class	Example	Use
1	Phospholipids	Soya phosphatidyl choline, egg phosphatidyl choline, dipalmitoyl, phosphatidyl choline	Vesicles forming component
2	Surfactants	Sodium cholate, Sodium deoxycholate, Tween-80, Span-80, Tween 20	Vesicles forming component
3	Solvents	Ethanol, methanol, isopropyl alcohol, chloroform	As a solvent
4	Buffering agent	Saline phosphate buffer (pH 6.4), phosphate buffer pH 7.4	As a hydrating medium
5	Dye	Rhodamine-123, Rhodamine-DHPE, Fluorescein-DHPE, Nile-red	For Confocal Scanning Laser Microscopy (CSLM) study

MECHANISM OF ACTION:

Transferosomes overcome the skin penetration difficulty by squeezing themselves along the intracellular sealing lipids of the stratum corneum. At present, the mechanism of enhancing the delivery of active substances in and across the skin is not very well known. Two mechanisms of action have been proposed.

i. Transferosomes act as drug vectors, remaining intact after entering the skin.

ii. Transferosomes act as penetration enhancers, disrupting the highly organized intercellular lipids from the stratum corneum and therefore facilitating the drug molecules' penetration in and across the stratum corneum.

The transfer of vesicles usage in drug delivery consequently relies on the carrier's ability to widen and overcome the hydrophilic pores in the skin. Intracellular drug transportation may involve diffusion of a vesicle lipid bilayer with the cell membrane like normal endocytosis. The mechanism is thus complex and involves advanced principles of mechanics combined with material transport and hydration/osmotic force. Possible pathways for a penetrant to cross the skin barrier.

a) Across the intact horny layer,

b) Through the hair follicles with the associated sebaceous glands, or

c) Via the sweat glands.[6]

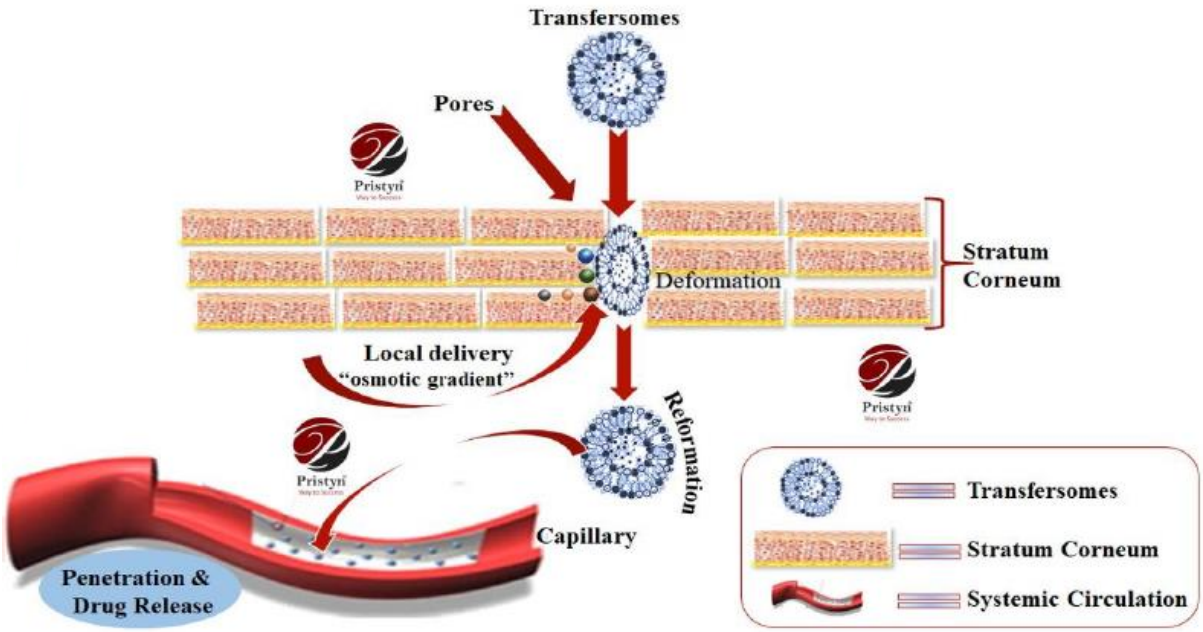

Figure 2: Mechanism of Penetration of Transferosomes

ADVANTAGES:

Transfersomes can deform and pass through a narrow constriction (from 5 to 10 times less than their own diameter) without measurable loss.

1. They have high entrapment efficiency, in the case of lipophilic drugs near to 90%.

2. This high deformability gives better penetration of intact vesicles.

3. They can act as a carrier for low as well as high molecular weight drugs e.g., analgesics, anesthetics, corticosteroids, sex hormones, anticancers, insulin, gap junction protein, and albumin.

4. Transfersomes possess an infrastructure consisting of hydrophobic and hydrophilic moieties together and as a result, can accommodate drug molecules with wide range of solubility.

5. They act as depots, releasing their contents slowly and gradually.

6. They can be used for both systemic as well as topical delivery of drugs.

7. They are biocompatible and biodegradable as they are made from natural phospholipids similar to liposomes.

8. They protect the encapsulated drug from metabolic degradation.

9. Easy to scale up, as the procedure is simple, do not involve lengthy procedure and unnecessary use or pharmaceutically unacceptable additives. [7]

DISADVANTAGES:

1. One of the drawbacks in utilizing transferases is the difficulty to achieve the phospholipids purity, thus synthetic phospholipids can also be used as an alternative.

2. Transferosomes are expensive to formulate because of the expensive equipment as well as raw materials used in lipid excipients.

3. The barrier role of the skin changes with age and is different from person to person and from one site to another site of the skin on the same person.

4. Hypersensitivity directions and skin irritation may occur. [8]

PREPARATION METHODS OF TRANSFERASES:

THIN FILM HYDRATION TECHNIQUE:

This method has three steps:

1. The first step involves the dissolution of phospholipids along with surfactants in an organic solvent (Chloroform-methanol) to get a thin film of vesicles. The mixture is then subjected to heat above the transition temperature of lipid, in a rotary evaporator to free the mixture of organic solvents. Any remaining traces of solvent are removed by placing overnight in a vacuum.

2. The formed film is then subjected to hydration with a suitable buffer at 60 rpm for 1 h. The vesicles formed are left for 2 h to swell at room temperature.

3. The small vesicles are then prepared by subjecting the prepared vesicles to sonication at room temperature or at 50°C for 30 min using a bath sonicator. In a probe sonicator, the vesicles are sonicated at 40 °C for 30 min. The desired vesicles are obtained by

homogenizing the sonicated vesicles by manual extrusion 10 times through a sandwich layer of 200 and 100nm polycarbonate membranes yields.[9]

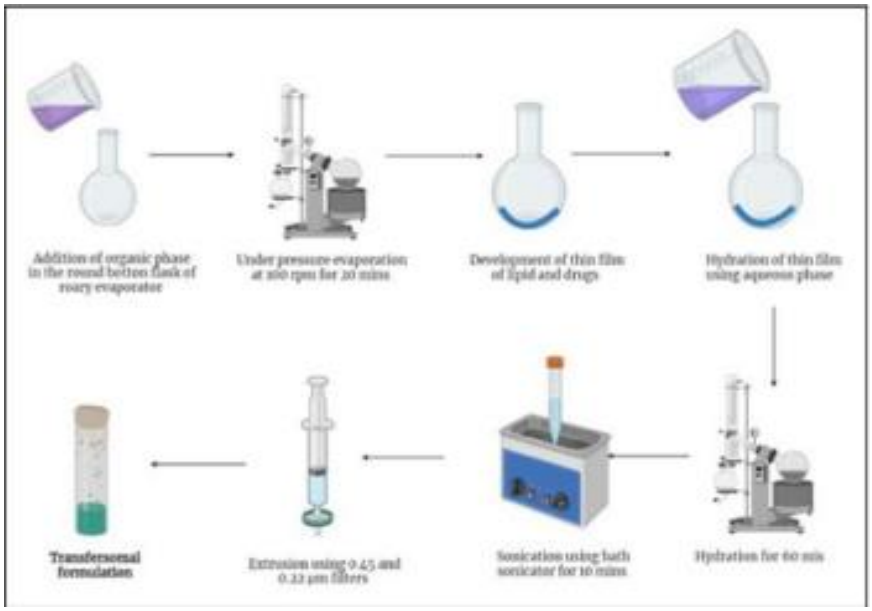

Figure 3: Thin Film Hydration Technique

MODIFIED HAND-SHAKING METHOD:

Drug, phosphatidyl choline, edge activators were dissolved in ethanol: chloroform 1:1 mixture. Organic solvent was removed by evaporation while hand shaking above lipid transition temperature (43°C) a thin film was formed inside the flask wall with rotation. The film was kept overnight for complete evaporation of solvent. Then the film is hydrated with phosphate buffer (6.4) with gentle shaking for 15 min at the corresponding temperature. The transferosomes suspension further hydrated to 1 hr at 2-8°C. [10]

ROTARY FILM EVAPORATION METHOD:

This method is also known as the hand-shaking process, which was initially invented by Bangham. In this process, the quantity needed of phospholipids and surfactants (as EAs) is essential to organize a thin film. It is largely worn for the research of multilamellar vesicles. A solution of phospholipids and EAs is organized in a crude solvent such as a combination of chloroform and methanol. The prepared solution is transferred to a round-bottomed flask which is rotated at constant temperature (above glass transition temperature of lipids) and reduced pressure. A film of lipids and EA is formed on the walls of the flask. The twisted film is then hydrated using aqueous media containing the drug. This causes lipids to swell

and form bilayer vesicles. Vesicles of the desired size can be obtained by extrusion or by sonication of the superior vesicles.

ETHANOL INJECTION METHOD:

In this process, the aqueous solution containing drug is heated with unremitting stirring at constant temperature. Ethanolic solution of phospholipids and EAs is injected into an aqueous solution dropwise. As the solution comes into contact with aqueous media the lipid molecules are precipitated and form bilayer structures. This process offers assorted advantages over other methods, which include simplicity, reproducibility, and scale-up. [11]

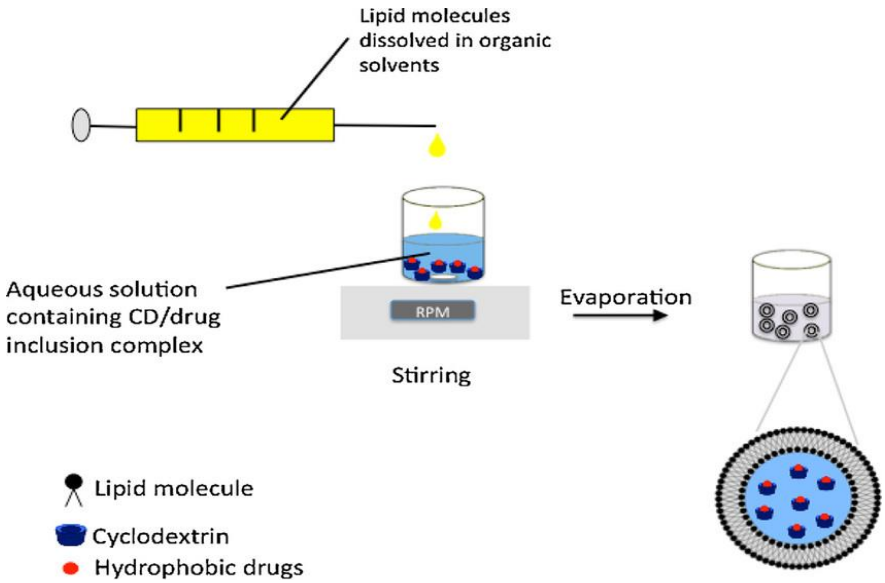

Figure 4: Ethanol Injection Method

VORTEXING-SONICATION METHOD:

In this method, mixed lipids (i.e., phosphatidylcholine, EA, and the therapeutic agent) are blended in a phosphate buffer and vortexed to attain a milky suspension. The suspension is sonicated, followed by extrusion through poly-carbonate membranes.

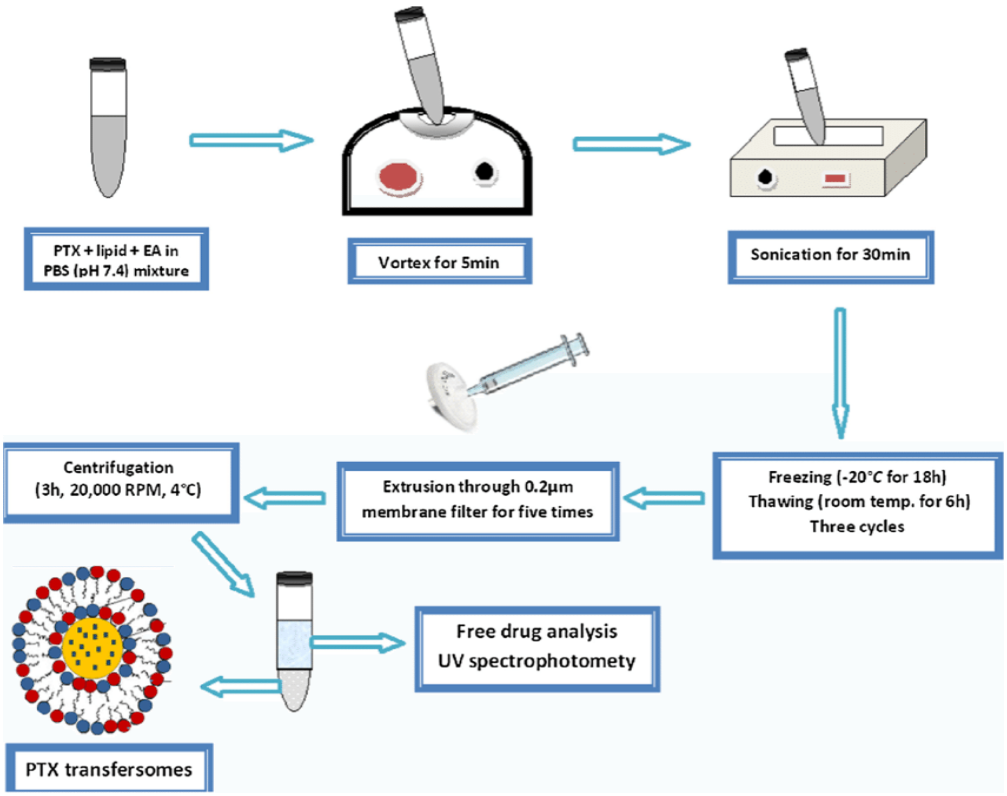

Figure 5: Vortexing-Sonication Method

SUSPENSION HOMOGENIZATION PROCESS:

In this process, transfersomes are prepared by mixing an ethanolic soybean phosphatidylcholine solution with an appropriate amount of edge-active molecule, e.g., sodium cholate. This prepared suspension is subsequently mixed with Triethanolamine-HCl buffer to yield a total lipid concentration. The resulting suspension is sonicated, frozen, and thawed for 2 to 3 times.

AQUEOUS LIPID SUSPENSION PROCESS:

In this process, the Drug-to-lipid ratio in the vehicles is fixed between 1/4 and 1/9. Depending upon the particular formulation type, the composition is preferred. This would ensure the high flexibility of the vesicle membrane in comparison to the standard phosphatidylcholine vesicles in the fluid phase. Specifically, vesicles with a size ranging from 100-200 nm are prepared by using soya phosphatidylcholine with the standard deviation of the size distribution (around 30%). This formulation could be prepared by suspending the lipids in an aqueous phase wherein the drug is dissolved. [12]

REVERSE PHASE EVAPORATION METHOD:

Firstly, Lipids are dissolved in organic solvents placed in a round bottom flask. An aqueous medium containing edge activators is introduced under nitrogen purging. The drug is added to a lipid or aqueous media based on its solubility characteristics. After which, the created system is sonicated until it becomes a homogenous dispersion, which should not be separated for at least 30 minutes. Under decreased pressure, the organic solvent is then extracted. The system will then transform into a thick gel, followed by the formation of vesicles. Centrifugation or dialysis method may be used to remove nonencapsulated material and residual solvents.

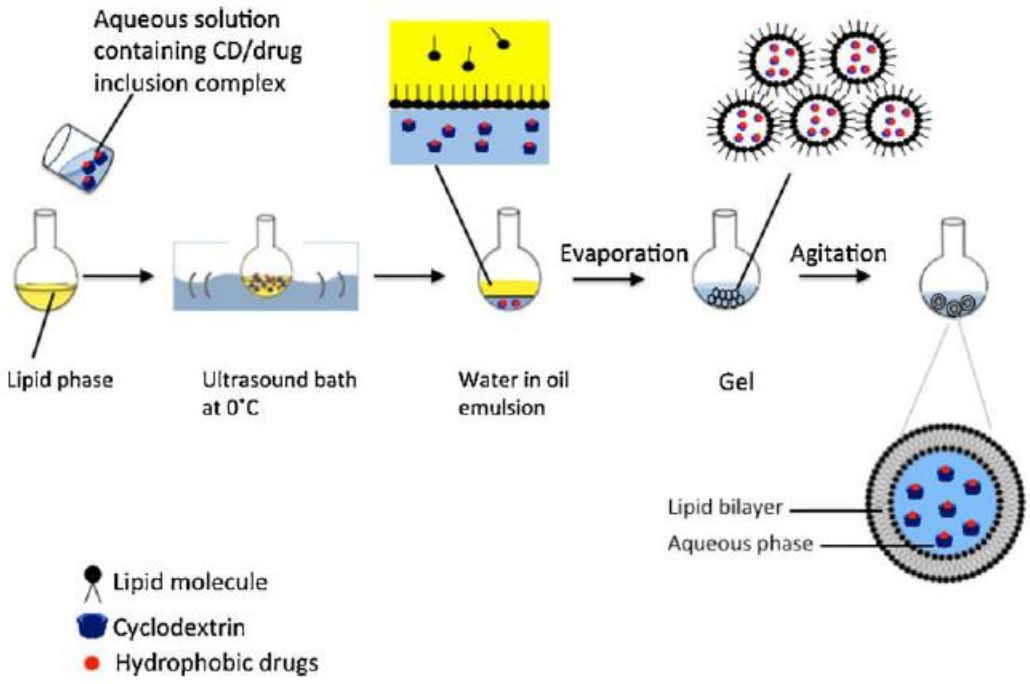

Figure 6: Reverse Phase Evaporation Method

CENTRIFUGATION PROCESS:

The phospholipids, EA and drug are dissolved in the organic solvent, below reduced pressure and respective temperature, using a rotary evaporator the solvent is removed, the leftover residues of the solvent are removed under vacuum, and the lipid film obtained is hydrated with a phosphate buffer by centrifugation at room temperature and drug incorporation is done at this stage and remaining vesicles are swollen at room temperature and resulting obtained multilamellar lipid vesicles are sonicated.

FREEZE-THAW PROCESS:

The multilamellar vesicles are frozen at notable low temperatures and then heated to very high temperatures. The prepared suspension is then transferred to a tube for 30 seconds at 30°C, followed by which the tube is immersed in a nitrogen bath. After freezing, they are subjected to high temperatures in a water bath. This process is performed eight to nine times.

HIGH PRESSURE HOMOGENIZATION TECHNIQUE:

In this process phospholipids, edge activators and drugs are dissolved in distilled water followed by ultrasonic shaking and stirred vigorously**,** the mixture is subjected to ultrasonic shaking and then subjected to high-pressure homogenization to be homogenized and finally obtained transferases should be properly stored.[13]

FACTORS AFFECTING PROPERTIES OF TRANSFERASES:

In the process of obtaining an optimized formulation of transfersomes, there are number of process variables that could affect the properties of the transfersomes. These variables basically involve the manufacturing of transpersonal formulations, which are identified as follows:

Effect of Phospholipid ratio to edge activator ratio:

Due to the fact that the phospholipid: edge activator ratio has a significant impact on entrapment efficiency, vesicle size, and penetration ability, it should be accurate. In general, it has been suggested that EE could be reduced by using a surfactant with a higher concentration. This could be due to an increase in vesicular membrane permeability caused by the arrangement of surfactant molecules inside the vesicular lipid bilayer structure, which could result in pores within the vesicular membrane, increasing fluidity and allowing the entrapped medication to leak quickly.

Effect of various solvents:

Solvents like ethanol or methanol are employed. The solubility of all formulation components in the solvent, as well as their compatibility with the solvent, influence the solvent selection. To generate a good film-forming capability and greater stability after hydration, all excipients and medicines should ideally dissolve in solvent and achieve a clear transparent solution,

Solvents employed in formulation can also act as penetration enhancers, increasing drug flux through membranes. Ethanol was employed in many experiments to increase the transit of estradiol, hydrocortisone, 5-fluorouracil, and levonorgestrel through rat skin, according to Williams and Barry.[14]

Effect of Various Edge Activators (Surfactants):

Deformability, as well as the entrapment efficiency of transfersome vesicles, are affected by the type of edge activators used in their formulations. This could be due to the difference in the chemical structure of the EA. Generally, the vesicle size decreases by increasing the surfactant concentration, the hydrophilicity of the surfactant head group, carbon chain length and the hydrophilic-lipophilic balance (HLB). The three surfactants, including tween 80, span 80 and sodium deoxycholate, were used to prepare the transfersomes, and a reduction of the vesicle size was found when the higher surfactant concentration used. A small polydispersity index (PDI) was reported with the higher surfactant concentration. A small PDI is responsible for consistent size distribution, which is thought to be an important factor for the reduction of interfacial tension and provides a homogeneous formulation. Additionally, an increased surfactant concentration may lead to an increase in charge of the vesicles, which results in a reduction of vesicle aggregation and enhances the stability of the system. In addition, surfactant properties are one of the properties that are responsible for the entrapment efficiency of the vesicles, as, for example, the entrapment of a lipophilic drug would be enhanced with the use of a surfactant with a low HLB value. However, if the amount of lipophilic drug exceeds the vesicular loading capacity, it may disrupt the vesicular membrane, leading to drug leakage, and lowering the entrapment efficiency and skin permeation ability. The optimum amount of surfactant used in the formulation depends on the packing density of the phospholipid used and the surfactant-phospholipid interaction. The presence of surfactants can have an impact on the permeation property of transfersomes.

Effect of the Hydration Medium:

The hydrating medium may consist of either water or saline phosphate buffer (pH 6.5–7). The pH level of the formulation should be suitable to achieve a balance between both the formulation properties and biological applications, as well as the route of administration. The lipid bilayer of transfersomes mimics the phospholipid layer of the cell membrane, and only unionized drugs remain membrane-bound to the phospholipid bilayer and penetrate through

the intracellular route. It is important to use the suitable pH of the hydration medium, which keeps the drug unionized to increase the entrapment and permeation of the drug.[15]

CHARACTERIZATION OF TRANSFERASES:

The characterization of transfersomes is generally similar to liposomes, Niosomes and micelles. The following characterization parameters have to be checked for transfersomes:

VESICLE SIZE DISTRIBUTION AND ZETA POTENTIAL:

Vesicle size, size distribution and zeta potential were determined by the Dynamic Light Scattering system by Malvern Zetasizer.

VESICLE MORPHOLOGY:

Vesicle diameter can be determined using photon correlation spectroscopy or Dynamic light scattering (DLS) method.

NUMBER OF VESICLES PER CUBIC MM:

This is an important parameter for optimizing the composition and other process variables. Non- sonicated transfer some formulations are diluted five times with 0.9% sodium chloride solution. Haemocytometer and optical microscope can then be used for further study. The Transfersomes in 80 small squares are counted and calculated using the following formula:

Total number of Transfersomes per cubic mm = (Total number of Transfersomes counted × dilution factor × 4000) / Total number of squares counted.

ENTRAPMENT EFFICIENCY:

The entrapment efficiency is expressed as the percentage entrapment of the drug added. Entrapment efficiency was determined by the first separation of the un-entrapped drug by use of the mini-column centrifugation method. After centrifugation, the vesicles were disrupted using 0.1% Triton X-100 or 50% n-propanol76. The entrapment efficiency is expressed as: [16]

$$\text{Entrapment efficiency} = (\text{Amount entrapped} / \text{Total amount added}) \times 100$$

TURBIDITY MEASUREMENT:

Turbidity of the drug can be measured by using nephelometer.

SURFACE CHARGE AND CHARGE DENSITY:

Surface charge and charge density of transfersomes can be determined using a zeta sizer.

PENETRATION ABILITY:

Penetration ability of Transfersomes can be evaluated by using fluorescence microscopy.

OCCLUSION EFFECT:

Occlusion of the skin is considered to be a helpful parameter for the permeation of drug in case of topical preparations. [17]

DRUG CONTENT:

The drug content can be determined using one of the instrumental analytical methods such as modified high-performance liquid chromatography method (HPLC) method using a UV detector, column oven, auto sample, pump and computerized analysis program depending upon the analytical method of the pharmacopoeial drug.

DEGREE OF DEFORMABILITY OR PERMEABILITY MEASUREMENT:

In the case of transfersomes, the permeability study is one of the important and unique parameters for characterization. The deformability study is done against the pure water as standard. Transfersomes preparation is passed through a large number of pores of known size (through a sandwich of different microporous filters, with pore diameter between 50 nm and 400 nm, depending on the starting transfersomes suspension). Particle size and size distributions are noted after each pass by dynamic light scattering (DLS) measurements.

The degree of deformability is expressed as:

$$D=J(rv/rp)$$

where D = degree of deformability, J = amount of suspension extruded during 5 min, rv = size of the vesicle and rp = pore size of the barrier. [18]

IN-VITRO DRUG RELEASE:

Franz diffusion cells are employed in the *in-vitro* drug release study.

The donor chamber is fixed to the receptor chamber by means of adhesive tape. The fluid in the receptor chamber is constantly stirred by a magnetic bar. As normal skin surface temperature is approximately 32°C, therefore, in the release study, the temperature of the receptor fluid should be kept at the in vivo skin surface temperature of 32±1°C. A mixed cellulose ester membrane of an average pore size of 0.45µm is used. The membranes are soaked in the release media (phosphate buffer) at room temperature overnight in order to allow the membrane pores to swell. The aliquots of 1 mL of the receptor medium are withdrawn at appropriate time intervals (such as 0, 0.5, 1, 2, 3, 4, 5 and 6 h), and simultaneously, the receptor medium is replaced by an equal volume of the fresh PBS to maintain the sink conditions. The obtained samples were analyzed for drug content using UV spectrophotometer at a specific wavelength. [19]

IN-VITRO SKIN PERMEATION STUDIES:

The ***in-vitro*** **permeation studies** were done using the **Franz Diffusion cell.**

The selected membranes are horizontally mounted on the receptor compartments as the side, indicating the stratum corneum facing upwards toward the donor compartments. The receptor compartments of the Franz diffusion cells are filled with phosphate buffer saline solution, which is stirred by the magnetic bar and the temperature of the receptor fluid should be kept at 37±0.5°C. An appropriate amount of the testing formulation is added into each donor compartment as it is placed on the membrane, and the top of the diffusion cell is opened to mimic non-occluded conditions. Specific volumes of aliquots of the receptor medium are withdrawn at appropriate time intervals, and simultaneously, the receptor medium is replaced by an equal volume of the fresh receptor medium to maintain the sink conditions. The obtained samples can be analyzed using a UV spectrophotometer at a specific wavelength. [20,21]

STABILITY OF TRANSFERSOMES:

The stability of the transfersomes is generally determined by TEM visualization at 4°C and 37°C. DLS size measurement can also be used at different time intervals (30,45, and 60

days), following vesicles preparation. The initial entrapment is considered as 100% and the percent drug loss is calculated. The optimized transpersonal formulations can be stored in tightly sealed amber vials at different temperature conditions. According to ICH (International Conference on Harmonization) guidelines, under the stability testing of new drug substances and products, the general case for the storage condition is described as, for the long term, 25±2°C/60% relative humidity (RH)±5% RH or 30±2°C/65% RH±5% for 12 months and, for accelerated testing, 40±2°C/75% RH±5% for six months. Drug products intended for refrigeration should be subjected to long-term storage at a condition of 5±3°C for 12 months and accelerated study for 25±2°C/60% RH±5% RH for six months. A significant change for the drug product is defined as the failure to meet its specifications. [22]

APPLICATIONS:

Delivery of insulin:

Transfersome is one of the successive ways to deliver such large molecular weight drugs on the skin. Insulin is generally administered by a subcutaneous route that is inconvenient for patient. Encapsulation of insulin in transfersome (transfersulin) overcomes all problems arises with conventional insulin delivery. After the application of transfersulin on the intact skin, therapeutic effect observed after 90-180 min, depending on the carrier composition.

Delivery of anesthetics:

Application of transfersome containing anesthetics induces topical anesthesia, under suitable conditions, within 10 min. Effect when we said in case of pain in sensitivity is nearly as strong (80%) as of a comparable subcutaneous bolus injection, but transfersomal anesthetics preparation has last longer effect.

Delivery of herbal drugs:

Herbal drugs are also delivered by transfersome approach. Xiao-Ying *et al*. who shows the better topical absorption of transfersomes of capsaicin in comparison to pure capsaicin.

Delivery of Corticosteroids:

Problems arise with corticosteroid delivery is mask by incorporating it into transfersomes. Site specificity and overall drug of corticosteroid delivery into skin by optimizing the

epicutaneously administered drug dose safety is achieved by transfersome encapsulation. Dose required for the biological activity of corticosteroids is less by use of transfersomes technology. [23]

Delivery of Proteins and Peptides:

Large molecules weight compounds can be easily transported across the skin with the help of transfersomes. For example, insulin, interferon like leukocytic derived interferon (INF) can be delivered through mammalian skin. They have been widely used as a carrier for the transport of other proteins and peptides. [24]

Delivery of Interferon (INF):

Transferosomes have also been used as a carrier for interferons, for example, INF-α is a naturally occurring protein having antiviral, anti-proliferative and some immunomodulatory effects. Transferosomes as drug delivery systems have the potential for providing controlled release of the administered drug and increase the stability of labile drugs. [25]

Delivery of anticancer drugs:

Transfersome technology provides a new approach for cancer treatment, especially skin cancer. Result found to be favorable when methotrexate was tried for transdermal delivery using transfersome technology.

Delivery of NSAIDs:

The typical problems associated with NSAIDs like GI irritation can be overcome by transdermal delivery using transfersomes. Some drugs like diclofenac and ketoprofen are already studied for their efficacy using transferosomes and the ketoprofen formulation is already approved by Swiss regulatory agency. [26]

Delivery of Anti-Inflammatory Drugs:

Diclofenac sodium, celecoxib, mefenamic acid and curcumin-loaded transfersomes were developed and studied for the purpose of topical administration by several research groups. Research findings suggested that transfersomes could improve the stability and efficacy of anti-inflammatory drugs. [27]

CONCLUSION:

Transferosomes represent a groundbreaking class of ultra-deformable vesicular carriers that revolutionize transdermal drug delivery. Unlike conventional vesicular systems, transfersomes exhibit exceptional skin penetration capabilities, effortlessly traversing the stratum corneum, the skin's outermost barrier, via two distinct intracellular lipid pathways. This unique characteristic enables transfersomes to deliver a wide spectrum of drug molecules, ranging from small molecules to large proteins and peptides, with remarkable efficiency and precision. The versatility of transfersomes extends to their ability to encapsulate a diverse array of therapeutic agents, including insulin, corticosteroids, interferons, anesthetics, NSAIDs, anticancer drugs, and herbal remedies. Moreover, transfersomes offer the advantage of controlled drug release, tailoring the delivery profile to specific therapeutic requirements. The efficacy of transfersomes stems from their meticulously designed vesicular structure, which must be meticulously optimized for each individual drug molecule to achieve the most effective formulation and maximize pharmacological outcomes. Ongoing scientific investigations into transfersomes hold immense promise for unlocking novel therapeutic strategies against a multitude of diseases. Indeed, the future of dermal and transdermal drug delivery is poised to be transformed by the advent of transfer-based products.

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