**The Novel Techniques for Enhancing Poorly Soluble Drugs – Nanosuspension, Vesicular drug delivery system (Transfersomes, Invasomes & Niosomes)**

**Abstract:** The conventional drug delivery system has several limitations, like poor solubility and the inability to achieve sustained and prolonged drug release. To overcome these limitations of conventional drug delivery systems, novel techniques have come into the existance. Solubility is the major issue seen in poorly soluble drugs, which leads to low efficiency. This book chapter explains the various solubility enhancement techniques, including nanosuspension and vesicular drug delivery systems (Transferosomes, Invasomes, and niosomes).

**Keywords:** Nanouspension, Transferosomes, Invasomes, entrapment efficiency, drug content.

**Conventional Drug Delivery System:**

Conventional drug delivery system as various limitation such as poor bioavailability and these cannot achieve sustained and prolonged release of drug. In conventional dosage form only small amount of drug reaches to target site and rest will distribute throughout body and effect the healthy tissues (40). These conventional dosage form have many limitations such as:

1. lacking a target specificity.
2. Low Bioavailability of drug.
3. Drugs with a short half-life has a greater probability of missing the dosage.
4. Frequent administration is required.
5. Unavoidable drug concentration changes might cause under or overmedication.
6. Drug level fluctuations could cause the occurrence of adverse effects.

Therefore, to reduce this limitation and increase pharmaceutical activity and decrease the toxicity a drug delivery system should be developed.

**Controlled drug delivery system(41,42):**

Controlled drug delivery systems can maintain drug levels within a particular range, require fewer administrations, use the drug in issue as effectively as possible, and promote patient compliance.

 Controlled drug delivery system has several advantages compared to conventional drug delivery system they are:

1. Release the drug in a sustained and controlled manner at a specific site and reduce patient compliance.
2. It is convenient to the patient and decreases the frequency of dosing.
3. Overdosing or Under dosing can be reduced and decrease in side effects.
4. A steady amount of drug remains in the blood and tissue over an extended duration of time with this drug delivery method.
5. For some drugs improves its bioavailability.
6. Reduction in the cost of healthcare through better therapy, a shorter course of treatment, and less time spent by the patient's provider dispensing, administering, and monitoring medication.

**Disadvantages:**

1. A delay in the drug's action
2. If a formulation technique is unacceptable there may be a chance of dosage dumping.
3. Enhanced potential for first pass metabolism.
4. Greater dependence on GI residence duration and dosage form.
5. In some circumstances, it's possible to alter the dose less accurately.
6. When compared with conventional dosages, the cost per unit dose is greater.

**These are some Novel techniques for enhancing solubility for poor soluble drugs.**

1. **Nanosuspension**

The drug discovery process by technology such as screening, computer-aided drug design, and combinatorial chemistry is leading to a vast number of drug candidates that have good efficacy, but unfortunately, many of these drugs will exhibit poor aqueous and non-aqueous solubility, hence the need to develop an innovative formulation. Also, poorly soluble drugs are challenging as they cannot achieve dissolution; hence, they have difficulty passing through the dissolving fluid to absorb through the mucosa or to be completely absorbed if the dissolution process is slow due to the formulation factor and physiochemical property of drug, which is the rate-limiting step in absorption. And it will also influence bioavailability. In the case of BCS class 2 and 4 drugs. For these drugs an alternative approach is required for better efficacy. The nanosuspension consists of the stabilizing agent and a liquid dispersion medium. The major merit of the nanosuspension is that it is applicable to the majority of the drug and it will not only increase the solubility of the drug but also alter the pharmacokinetics of the drug and hence improve its safety and efficacy. The low bioavailability of the drug can be rescued by formulating it into a nanosuspension. The main aim is to maximize bioavailability and boost dissolution rates. The formulation of poorly water-soluble drugs has become a challenging problem that is faced by pharmaceutical scientists. The problem became more intense when it came to class 2 and class 4 drugs. Nanosuspension is the nanosized, heterogeneous dispersion of insoluble drug particles that is stabilized by surfactant. The nanosuspension technique is available for a drug that has disadvantages such as the inability to form salt, a large molecular weight, and a dose that has a high log P. Nanosuspension, due to its unique properties, has shown the potential to fill this lacuna and solve the drug delivery-related problem that is associated with the drug. Nanosuspension is a dispersed system containing a drug particle of submicron size, which is known as a drug nanoparticle or nanocrystal, where the dispersed phase is an aqueous phase. The size ranges from 200-600nm.There are various methods for the preparation of nanosuspension, but the most commonly used are bottom-up and bottom-down methods. Again, with the subclassification of nanosuspension, which is shown in Figure 2.(1-6)

**Merit**

1. Nanosuspension is applicable for poorly water soluble as well as poorly lipid soluble.
2. It will increase the bioavailability.
3. It cause increase in the saturation solubility due to larger surface area.
4. It will increase dissolution rate.
5. It can be given in various route of administration.
6. Useful in passive targeting.
7. Nanosuspension will decrease the dose.
8. It is Suitable for hydrophilic drugs.
9. High drug loading capacity can be achieved by nanuspension.
10. It will Enhance the physical and chemical stability of drugs.
11. It will Provides a passive drug targeting. (1-3)

**Demerit**

1. Sedimentation may lead due to the smaller particle size.
2. Stability issues can be seen freeze and spray drying
3. Dose accuracy can be a challenging part.
4. Sufficient care must be taken while handling.
5. Smaller particle and lager surface area leads to the particle aggregation.
6. Toxic metabolic may form. (1-5)

**Fig.1:** Different types of formulation for Nanosuspension



**Need of Nanosuspension**

More than 40 percent of drug are poorly soluble in water, so they may show problem in formulating them into conventional dosage form and also for the class 2 drugs which is poorly soluble in aqueous and organic media the situation is worse. Preparation of nanosuspension is more preferred for these compounds which is insoluble in water. Nanosuspension is the one of the unique techniques for enhancing solubility and bioavailability for the poorly soluble drug in aqoues and organic media. There is need to develop a nanosuspension to overcome the solubility issues related issues and,

1. Nanosuspension will improve the solubility of poorly water-soluble drug.
2. Poor bioavailability.
3. Use of harsh excipient that is use of excessive cosolvent and other excipients.
4. Lack of dose response proportionality.
5. Having inability to optimize the lead molecule compound selection based on efficacy and safety.
6. Fed/fasted variation in the bioavailability.
7. Suboptimal dosing.
8. Use of extreme basic and acidic condition to enhance solubilization.
9. Nanosuspension is the only approach for the universally applicable to overcome the issues related to enhance the solubility of the drug in aqueous media and lipid media.
10. Suitable for the compound having high log P and high melting point.

Although all these marketed products, are currently produced by the top-down techniques, in which nanoparticle is obtained by size reduction into submicron range, precipitation method and bottom down method are the method of interest for the nanonization of the poorly soluble drugs. In this method only with simple equipment one can reduce the particle size into nanometre range. Therefore, a proper care must be taken for the type and concentration of the stabilizer in the production of the nanosuspension. The main key difference between the conventional dosage form to nanosuspension is that particle size distribution. The particle size usually in nanosuspension ranges less than 1 micrometre (14-17).

**Formulation**

**STABALIZER**

Stabilizer performs a vital function in the composition of nanosuspensions. Agglomeration can induce in the absence of appropriate stabilizer as high surface energy of nanosized particle which leads to aggregation of drug crystal. The main function of a stabilizer is to moist the drug particles very well. In a few instances, a combination of stabilizers is needed to obtain a stable nanosuspension. The drug-to stabilizer ratio within the method may additionally vary from 1:20 to 20:1 and should be investigated for a specific case e.g., Cellulosic, Poloxamers, Polysorbates, Lecithin and Povidones (14-15).

**ORGANIC SOLVENT**

Organic solvents may be required in the method of preparation of nanosuspensions if they're to be organized the use of an emulsion or microemulsion as a template. While formulating nanosuspension the acceptability of organic solvent inside a pharmaceutical area can have a toxicity ability so their elimination and less usage must be considered using emulsions or microemulsions as templates(13-16)

**SURFACTANT**

Surfactants are integrated to improve the dispersion with the aid of reducing the interfacial stress. In addition, they act as wetting or deflocculating agents e.g. Tweens and Spans extensively used surfactants (14-17).

**CO-SURFACTANT**

The selection of co-surfactant is critical when the usage of microemulsions to formulate nanosuspensions. Because co-surfactants can substantially have an effect on phase behavior, the impact of co-surfactant on drug loading should be investigated e.g., Transcutol, glycofurol, ethanol and iso-propanol thoroughly used as co-surfactants. Additionally, bile salts and Dipotassium glycyrrhizinate can be used as co-surfactants(13-18).

**OTHER ADDITIVES**

Nanosuspensions can also incorporate additives together with buffers, salts, polyols, osmogent and cryoprotectant, depending on both the route of management or the type of the drug moiety (15-17).

**PROPERTIES OF NANOSUSPENSION**

**Long term physical stability**

A few different unique features of nanosuspensions include the absence of Ostwald ripening, which is suggestive for their long-term physical stability. Ostwald ripening is responsible for crystal growth and, sooner or later, the formation of microparticles. Ostwald ripening is due to the variations in dissolution pressure and saturation solubility among small and large particle. Molecules diffuse from small particles (better saturation solubility) to areas around large particle. This ends in the formation of a supersaturated solution across the large particle and, consequently, drug crystallization and the increase of large particles The diffusion technique of the drug from the small particles to the large particles leaves a place around the small particles that is not saturated any more, therefore leading to the dissolution of the drug from the small particle and, sooner or later, the complete disappearance of the small particle (10-18).

**INNER SRUCTURE OF NANOSUSPENSION**

The high-energy will causes structural changes in the drug particles. The change in nature depends upon the hardness of the drug, the quantity of homogenization cycles, the chemical nature of the drug, and the energy density carried out by the homogenizer (16-18).

**Adhesiveness**

There is a distinct boom in the adhesiveness of extremely excellent powders as compared to coarse powders. This adhesiveness of small drug nanoparticles may be exploited for stepped-forward oral delivery of poorly soluble drugs. There is a drastic increase in the bioavailability of danazol from 5% [macrosuspension] to 80% [nanosuspension] (16-19).

**Crystalline state and morphology**

A potential alternate within the crystalline shape of nanosuspensions of growing the amorphous fraction inside the particle or maybe creating completely amorphous particles is a characteristic of attention. The application of high pressures throughout the manufacturing of nanosuspensions will promote the amorphous phase (6-18).

**Increase in dissolution velocity and saturation solubility**

The dissolution of drugs is multiplied due to the growth in the surface area of the drug particle from micrometre to nanometre. In step with the Noyes-Whitney equation, the dissolution phase increases because of the increase in surface area from micron to nanometre range (15-19).

**Method of preparation**

* Homogenization in water
* Media milling.
* Homogenization in non-aqueous media
* Combined precipitation
* Nanojet technology
* Emulsification-solvent evaporation technique.
* Hydrosol method
* Supercritical fluid method.
* Dry co-grinding
* Emulsion as template
* Microemulsion as template
* Lyophilization and Probe sonication method

There are mainly two categories for the preparation:

1. **Bottom-up method**

It is the technique by which the nano range is acquired by increasing the size of particle from the molecular range to the nano range. The traditional methods of precipitation (hydrosol) are referred to as bottom-up technology. Using a precipitation method, the drug is dissolved in an organic solvent, and this solution is blended with a miscible anti-solvent. In the water-solvent combination, the solubility is low, and the drug precipitates. The primary task is that in the precipitation system, the development of the crystals needs to be controlled by the addition of surfactant to prevent the formation of microparticles (16-19).

**Advantage**

• simple and low-cost equipment.

 **Limitations**

 • The drug needs to be soluble in of the one solvent and the solvent needs to be soluble with non-solvent.

 •It is not applicable for the drugs which is poorly soluble in both aqueous and non-aqueous solvent.

**2.** **Top-down method**

The method in which nano size particles is obtained by reduction in size of larger particles. In top- down method there are various method of preparation they are:

1. **High pressure homogenization (DissoCubes**)

DissoCubes are engineered using piston-hole-type excessive-pressure homogenizers. High-pressure homogenization has been used to put together nanosuspensions of many poorly water-soluble drugs. Homogenization includes forcing the suspension under stress through a valve with a narrow aperture. The device can be operated at stress ranging from 100 to 1500 bars (2800–21300 psi) and as much as 2000 bars, with an extent capability of forty ml (for laboratory scale) (12-19).

**Principal**

In a piston-hole homogenizer, particle size reduction is primarily based on the cavitation principle. Piston-hole homogenizers like the APV Gaulin kind have been proven. Particles are also reduced because of excessive shear forces and the collision of the particle with each other. The dispersion contained in a 3cm-diameter cylinder passes through a completely narrow hole of 25 m. The reduction in diameter from 3cm to 25 m leads to an increase in dynamic stress and a decrease in static stress below the boiling point of water at room temperature. Because of this, water begins boiling at room temperature and makes gasoline bubbles, which implode while the suspension leaves the distance (called cavitation) and everyday air pressure. The size of the drug nanocrystals that can be completed depends on elements like temperature, variety of homogenization cycles, power density of the homogenizer, and homogenization pressure. The DissoCubes are an example of this technology advanced by R.H. Muller in 1999, e.g.Omeprazole(15-20).

**Fig.2:** Method of preparation of nanosuspension

**Microemulsion as Template**

**Nanoedge**

**Method of Preparation**

**Bottom up Technology**

**Nanopure**

**DissoCubes**

**Nanocrystals**

**Top Down Technology**

**Emulsions as Template**

**Advantages**

* It does not motivate the erosion process.
* Nanosuspension, which is highly diluted and concentrated, can be prepared.
* It's very applicable to the medicine, which might be poorly soluble in both aqueous and organic media.

**Limitations**

* Pre-processing, like micronization of the drug, is required.
* High-priced devices are required, which will increase the price of the dosage form.
1. **Media milling (NanoCrystals)**

This technology was developed in 1992. Formerly, the generation was owned by Nanosystems, but currently it has been acquired by Élan Drug Transport. In this method, the nanosuspensions are produced using excessive-shear media generators or pearl mills. The media mill includes a milling chamber, a milling shaft, and a recirculation chamber. The milling chamber charged with polymeric media is the energetic aspect of the mill. The mill may be operated in batch or recirculation modes. The milling process is performed at controlled temperatures. The standard residence time generated for a nanometre-sized dispersion with an average diameter of less than 200 nanometres is 30–60 minutes (16-20).

**Principal**

The high power and shear forces generated because of the impaction of the milling media with the drug offer the energy input to interrupt the microparticulate drug into nano-sized particles. The milling medium consists of glass, zirconium oxide, or a noticeably cross-related polystyrene resin. The method can be performed in batch or recirculation mode. In batch mode, the time required to obtain dispersion is 30-60 minutes which is less than 600 nm. The media milling technique can effectively process micronized and non-micronized drug crystals(16).

**Advantage**

* Drugs which are less soluble in both aqueous and organic media may be easily formulated into nanosuspensions.
* Ease of scale-up.
* Flexibility in managing the drug quantity, starting from 1 to 400mg/mL.

**Limitation**

The fundamental scenario is the technology of milling media residues, which can be brought into the final product as a result of erosion. This can be complicated while nanosuspensions are prepared to be administered for continual treatment. The severity of this can be reduced to a first-rate level with the arrival of polystyrene resin-based milling mediums. For this medium residual monomer are typically 50 ppb, and the residuals generated for the duration of the milling processing are not more than 0.5% w/w of the final product or the resulting solid dosage form.

1. **Homogenization in non-aqueous media (Nanopure)**

Nanopure is suspensions homogenized in unfastened media or water combinations, i.e., suspensions in the aqueous media will be homogenized at zero degrees centigrade, which is referred to as a deep freeze homogenizer. The drug with nanocrystals will disperse into the liquid polyethylene glycol or gelatin(16).

 **Advantages**

The dispersion medium should be eliminated: -

* Evaporation is quicker in milder situations (while water and water-miscible solvents are used).
* That is useful for temperature-sensitive drugs.
* For isotonic nanosuspension, IV injections are obtained by homogenizing a water-glycerol mixture.
1. **Combined precipitation and homogenizing [Nanoedge]**

Mixed precipitation and homogenization (Nanoedge) in this drug are dissolved in a solvent and blended into an anti-solvent agent for precipitation. The Nanoedge is same of precipitation and homogenization. Within the water-solvent aggregate, the solubility is low, and the drug precipitates. Precipitation has additionally been coupled with high-shear processing. An aggregate of those strategies results in smaller particles and better balance in a shorter time. The most important drawback of the precipitation approach, together with the crystal increase and long time period balance, may be resolved by the use of the Nanoedge generation (15-19).

1. **Nano jet Technology**

This method, known as ‘contrary flow or nano jet technology’, uses a chamber wherein a movement of suspension is split into or greater factors, which colloid with each other at excessive pressure up to 4000 bar at an immoderate pace of a thousand m/s. The organized nanosuspensions of atovaquone had been prepared using micro fluidization. The most problematic aspect of this technique is the wide variety of passes via the microfluidizer (up to 75 passes) and the fact that the product acquired includes a substitute mixture of rapid precipitation and moderate strain homogenization. The Nanoedge using Baxter depends on the precipitation of friable materials for fragmentation below conditions of excessive shear and/or thermal electricity. The fast addition of a drug method to an antisolvent results in the unexpected generation of extraordinary crystalline or amorphous solids(16).

1. **Emulsification-solvent evaporation technique**

This method entails getting a drug ready, followed by its emulsification in some other liquid that is not a solvent for the drug. Evaporation of the solvent results in the precipitation of the drug. Crystal and particle aggregation can be managed with the aid of growing shear forces and the use of an excessive-pace stirrer (16-20).

1. **Supercritical fluid technology**

It can be used to provide nanoparticles from a drug solution. The various techniques attempted are rapid expansion of the supercritical system (RESS), supercritical anti-solvent technique, and precipitation with a compressed anti-solvent process (PCA). The RESS entails the enlargement of the drug solution in supercritical fluid through a nozzle, which leads to a loss of solvent strength in the supercritical fluid, resulting in the precipitation of the drug. The drug solution is atomized right into a chamber containing compressed CO2. Because the solvent is removed, the solution becomes supersaturated and, as a consequence, precipitates are obtained. The supercritical anti-solvent system makes use of a supercritical fluid in which a drug is poorly soluble and a solvent for the drug that is miscible with the supercritical fluid. The drug is then presented as pleasant crystals(16).

**Limitation**
Use of risky solvents and high proportions of surfactants, and compared with different strategies. Particle nucleation overgrowth due to temporary high supersaturation, which might also result in the development of an amorphous form or every other undesired polymorph.

1. **Dry co-grinding**

Nanosuspensions prepared by high-pressure homogenization and media milling using a pearl ball mill are moist-grinding strategies. These days, nanosuspensions can be obtained through dry milling techniques. The formation of colloidal particles in many poorly water-soluble tablets, including Griseofulvin, Glipalamide, and Nifedipine, by way of grinding with polyvinyl pyrrolidone (PVP) and Sodium dodecyl sulphate (SDS), Many soluble polymers and co-polymers, including PVP, Polyethylene glycol (PEG), Hydroxypropyl methylcellulose (HPMC), and cyclodextrin derivatives, have been used. The physicochemical properties and dissolution of poorly water-soluble capsules had been advanced via co-grinding because of the development of surface polarity and the transformation from a crystalline to an amorphous drug. Recently, nanosuspensions have been received through dry milling techniques. Dry co-grinding may be finished without problems and economically, and it may be performed without natural solvents(18).

1. **Emulsion as template**

Emulsion as a template that is applicable for drugs that are soluble in both organic and partially water-miscible solvents There are two approaches to fabricating drug nanosuspensions by way of the emulsification approach. In the first approach, a natural solvent or mixture of solvents loaded with the drug is dispersed within the aqueous section containing appropriate surfactants to shape an emulsion. Optimizing the surfactant composition increases the consumption of the natural phase and, ultimately, the drug loading inside the emulsion. At the beginning, natural solvents, together with methylene chloride and chloroform, were used. However, environmental dangers and human safety issues associated with approximately residual solvents have restricted their use in routine production methods. Its composition, consisting of ethyl acetate and ethyl formate, can nevertheless be taken into consideration for use. Some other approaches make use of water-miscible solvents, including butyl lactate, benzyl alcohol, and triacetin, as the dispersed phase in preference to unsafe solvents. The emulsion is prepared through the traditional approach, and the drug nanosuspension is acquired by simply diluting the emulsion. As a consequence, the nanosuspension must be made free of the internal phase and surfactants by di-ultrafiltration with the intention of making it appropriate for administration. But if all of the elements that are used for the manufacturing of the nanosuspension are found in a state perfect for the preferred direction of administration, then simple centrifugation sufficient to separate the nanosuspension(17)

**Benefits**

* A specialized system is not always essential.
* Particle size can be effortlessly controlled by controlling the size of the emulsion droplet.
* Ease of scale-up if the system is optimized well

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**Limitations**

* Drugs that might be poorly soluble in both aqueous and organic media can't be formulated via this technique.
* Safety worries because of the use of hazardous solvents inside the formulation.
* A high quantity of surfactant or stabilizer is required in comparison to the manufacturing techniques defined earlier.
* The drug nanosuspension from an emulsion template that is essentially applied to poorly water-soluble and poor bioavailability cancer drugs, mitotane, results in a large improvement in the dissolution of the drug (5-fold increase) in comparison to the commercial product(1-18).
1. **Microemulsion as template/Lipid emulsion**

Microemulsions are thermodynamically stable, which includes oil and water, stabilized through an interfacial film of surfactant and co-surfactant. Their advantages, along with excessive drug solubilization, long shelf-life and simplicity of manufacture, lead them to better drug delivery. Microemulsion structure taking benefit, Due to use of microemulsion during the manufacturing of nanosuspension. Oil-in-water microemulsions are preferred for this purpose. The inner phase of these microemulsions may be both a partially miscible liquid or an organic solvent. The drug may be each loaded inside the internal segment. The influence of the quantity and ratio of surfactant to co-surfactant at the uptake of inner segment and on the globule length of the microemulsion have to be investigated and optimized so that it will obtain the favored drug loading. The simple centrifugation or ultracentrifugation is enough to split the nanosuspension. The advantages and boundaries are similar to for emulsion templates. Additionally, the trouble will include large amounts of surfactant or stabilizers are required. e.g. Griseofulvin nanosuspension which is ready via using water, butyl lactate, lecithin and the sodium salt of tauro-deoxycholate, in which a great improvement within the dissolution phase of the drug (3-fold growth) in comparison to the industrial product (15-16).

1. **Lyophilization**

Lyophilization is a technique for formulating nanosuspension and many other formulations. It is valuable to the safety of substances that require low moisture content (less than 1%) so as to ensure balance and require a sterile and gentle maintenance manner. Lyophilization produces brilliantly pleasant products, both nutrients and prescription drugs, due to the moderate temperatures at which the process takes place, contributing to the formation of distinctly porous solids that preserve aroma, color, and flavor. Lyophilization is a technique or method through which a product is frozen (converting all matter to solid matter), after which water is removed via sublimation (primary drying) of the frozen water molecule (solid debris), i.e., ice. The whole system of freeze drying requires steps: freezing of the molecule in which water is present by using nucleation and lots of other methods; after that, the 2nd step is an important step for drying via sublimation of ice; secondarily, on this step, desorption of water occurs for stable particles; and within the remaining packing, packing should be accomplished in the vails or packing containers to restrict reabsorption of water and/or oxygen from the environment. With the aid of freeze-drying, a product that is risky, much less solid, decomposable, or degradative in the presence of moisture is converted into a dried and stable product. Improvement of this method to comply with the four needs of the Rinsed product: Its quantity should remain within the frozen kingdom, the shape and the organic activity of the dried stable and the unique substance must be identical in as many ways as feasible, and the dried product should remain strong during storage at room temperature(1-6).

**A] Sublimation**

Sublimation is when a stable (ice) substance changes without delay to a vapor without first going through a liquid (water) phase. Low pressure is required for sublimation to take place. Sublimation is a section change, and heat energy ought to be added to the frozen product for it to occur. Sublimation within the freeze-drying technique may be defined honestly as:

* Freeze: The product is completely frozen, commonly in a vial, flask, or tray.
* Vacuum: The product is then positioned beneath a deep vacuum, well below the triple point of water.
* DRY: Warmth Electricity is then brought to the product, causing the ice to sublime. The batch should be lyophilized first with pre-remedy freezing (Thermal remedy) at atmospheric pressure.
* Number one Drying (Sublimation) under vacuum.
* Secondary Drying (Desorption) below the vacuum.
* Backfill and Stoppering (for product in vials) below partial vacuum.

 **Benefits**

* It will increase shelf life of the dosage form.
* Enhancing the steadiness of a dry powder as well as the product stability in a dry state.
* It will increase the physical stability of the drug.

**Disadvantages**

* Coping with and processing time increases.
* Sterile diluents are needed upon reconstitution.
* High-priced (19).
1. **Probe sonication**

Sonication is the act of making use of sound energy to agitate particles in a sample for various functions. In laboratory science applications, Sonication is usually used in nanotechnology for dispersing nanoparticles in liquids. Sonication is applicable for the nano emulsion and nanosuspension formulations. The favoured effects from the ultrasonication of liquids, which include homogenization, dispersing, deagglomeration, milling, emulsification, extraction, lysis, disintegration, and sonochemical effects, are due to cavitation, a transducer, and a probe. The generator transforms the input electric power into an electrical signal that drives the transducer. This vibration is amplified as a longitudinal vibration inside the probe tip, causing the pattern to cavitate. Cavitation creates the ultrasound electricity, which causes the sample to disrupt and break down into smaller particles in the sonicator.

The main function involved in the probe sonication is that it will work in pulse on/off mode, in which for one second it will be on and the next second it will be off (14).

**Characterization of Nanosuspension**

Nanosuspensions are characterized by appearance, color, and nanosuspensions are characterized for appearance, color, smell, assay, related impurities, particle length, zeta potential, crystalline fame, dissolution studies and in vivo studies Amongst this, the most vital characterization strategies were mentioned: smell, assay, related impurities, particle length, zeta potential, crystalline fame, dissolution studies and in vivo studies Amongst this, the most vital characterization Strategies were mentioned..

**In Vitro Evaluation**

**Mean particle size and size distribution**

Numerous parameters of nanosuspensions like saturation solubility, dissolution velocity, bodily balance, dissolution velocity, physical stability, and organic performance rely upon the mean particle size and particle length distribution. Implying particle length and particle width (polydispersity index) can be determined through Photon Correlation spectroscopy, laser diffraction, and Coulter's present-day multi-sizer. The polydispersity index (PI) must be low for the long-term stability of the nanosuspensions. With the measuring ranges (3nm to 3 m) of PCS, determination of the contamination of the nanosuspension (by drugs having particle sizes greater than 3 m) is difficult. Particles ranging from 0.05–80 m and, in certain instruments, particle sizes up to 2000 m can be measured by using LD. It quantifies the contamination of nanosuspensions by microparticulate drugs (19).

**Particle charge (Zeta Potential**)

Zeta potential determines the stability of the nanosuspension. A zeta potential of minimum ±30mV is required for electrostatically stabilized nanosuspension (18).

**Crystalline state and particle morphology**

It's vital to recognize the crystal morphology of the drug within the nanosuspension. Polymorphic or morphological modifications in drugs that occur throughout nanosizing may be determined by the crystalline phase and particle morphology. The amorphous nature of the drug fashioned throughout the nanosuspension is determined via X-ray diffraction evaluation. It gives data about the changes in the physical type of the drug particles as well as the volume of the amorphous fraction. Differential scanning calorimetry can also be used. Scanning electron microscopy is also used to get specific statistics about particle morphology. The impact of excessive strain homogenization on the crystalline structure of the drug is envisioned by using X-ray diffraction analysis in aggregate with differential scanning calorimetry. Strategies like scanning electron microscopy (SEM), atomic pressure microscopy (AFM), or transmission electron microscopy (TEM) are preferred for figuring out the exact length and morphology of nanoparticles in suspension(11-16).

**Saturation solubility and dissolution velocity**

The dissolution and saturation solubility are more desirable with the method of nanosuspensions. Less particle size results in an expanded dissolution strain and, therefore, solubility. Surface tension takes place because the solubility increases (due to particle size reduction), which causes elevated saturation solubility. Specific physiological answers at distinctive pH and one-of-a-kind temperatures are used to perform the dedication of saturation solubility and dissolution speed in line with the strategies reported in the pharmacopoeia. The in vivo performance (blood profiles, plasma peaks, and bioavailability) of the formula is classified by these parameters. Growth in saturation solubility may be explained by using the Ostwald-Freundlich equation. The determination of the dissolution speed of nanosuspensions presents statistics about the blessings of nanosuspension over conventional formulations, especially in sustained-launch dosage bureaucracy. The Ostwald-Freundlich equation is: C(r) = C() exp (2M / rRT) ------ Equation [1], where C(r) and C() are the solubilities of a particle of radius r and of countless size. γ, M, and ρ are interfacial anxiety at the particle surface, the molecular weight of the solute, and the density of the particle, respectively(18).

**Stability**

Nanosuspensions are balanced by particle size. Lowering the particle size to the nanorange will increase the surface charge, and the tendency of the particle to agglomerate will increase. Therefore, the stabilizers are used to decrease the chances of Ostwald ripening and to improve the stability of the suspension by imparting a steric or ionic barrier .Poloxamer ,cellulosic, polysorbate, lecithin, and povidone are the various stabilizers normally used in the preparation of nanosuspension. Lecithin is desired for the improvement of parenteral nanosuspensions (1-18).

**PH**

The pH of the nanosuspension may be without difficulty measured by using the use of pH meter (16).
**Osmolarity**Practically, Osmolarity of nanosuspension can be measured via the usage of Osmometer (12).
**Drug content**

Drug content material of nanosuspension method can be completed by extracting the nanosuspension in suitable solvent mixture, like Methanol : THF (1:1) combination, shaken properly, after which centrifuged. The supernatants can be separated and diluted with same solvent mixture and the absorbance may be measured at appropriate λmax. The drug content material then can be calculated using the calibration curve (12-18).

**Diffusion study**

The diffusion study is done by using two compartment one is donor and another one is receptor.

The sample was placed on the donor compartment while in receptor consist of 7.4 PH buffer.

For every half an hour interval the sample was collected and check under UV spectroscopy (16).

**Fig.3:** Franz diffusion Cell



**In Vivo Evaluation**

The route of administration and unique form of drug Unique require specific in vivo evaluation of the nanosuspensions. Normally, the formulations are administered by the required route, and the plasma drug concentrations are determined with the aid of HPLC-UV visible spectrophotometry. Surface hydrophilicity or hydrophobicity (which determines interplay with cells prior to phagocytosis), adhesion properties, and the interplay with frame proteins are typically evaluated by in vivo parameters. The in-vivo organ distribution conductivity of the nanosuspension is low due to hydrophilicity or hydrophobicity and interactions of particles with plasma proteins. The hydrophobicity is determined through hydrophobic interaction chromatography, and the absorption of protein is determined through 2-D page quantitatively and qualitatively after intravenous injection of nanosuspensions of drug in animals (1-18).

**Evaluation of the Surface Modified of Particles**

 **Surface Hydrophilicity**

For intravenously injected nanosuspensions, extra parameters need to be determined that have an effect on the in vivo destiny of the drug nanoparticles. Hydrophilicity, or hydrophobicity, is considered one of the essential parameters affecting in vivo organ distribution after intravenous injection. The surface hydrophobicity determines the interaction with cells prior to phagocytosis, and further, it's a far more applicable parameter for the adsorption of plasma proteins, the key issue for organ distribution. The surface hydrophobicity desires to be determined in the unique environment of the drug nanoparticles, which means in an aqueous dispersion medium. A suitable approach is hydrophobic interaction chromatography (HIC), previously employed to determine the surface hydrophobicity of microorganisms and then transferred to the characterization of nanoparticulate drug providers (16).

**Adhesion properties**

In vivo bioadhesive examination is achieved when Male Wistar rats can be used. In widespread use, each animal gets a single oral dose of 1 ml of aqueous suspension containing 10 mg of the nanoparticles loaded with the drug (approximately 45 mg debris per kg body Weight). The animal is sacrificed with the aid of cervical dislocation at 1- and 3-hours post-administration. The stomach hollow space is opened, and the belly, small intestine, and cecum are removed, opened lengthwise alongside the mesentery, and rinsed with phosphate saline buffer (pH 7.4). Similarly, the stomach, small intestine, and cecum are cut into segments of two cm in length and digested in an appropriate alkali for 24 h. The drug is extracted from the digested samples with the aid of 2 ml of methanol, vortexed for 1 min, and centrifuged. An aliquot (1 ml) of the supernatants is to be assayed for the drug through spectrofluorimetry to estimate the fraction of adhered nanoparticles to the mucosa. For calculations, well-known curves of the drug can also be prepared (1-10).

**Entrapment efficiency**

The entrapment efficiency is done using ultracentrifugation technique in which it kept for 40 minutes at 14,000 rpm speed. In this specified amount of nanosuspension kept under the ultracentrifugation after specified time the supernatant liquid is collected and check under UV spectrometer (12).

**Application**

**Oral drug delivery**

The oral course is the preferred course for drug delivery due to its various advantages. The efficacy or performance of the orally administered drug normally depends on its solubility and absorption via the GIT. Hence, a drug candidate that is well-known to show poor aqueous solubility and/or dissolution-price-constrained absorption is believed to have low and/or extraordinarily variable oral bioavailability. Nano-sizing such drugs can cause a dramatic increase in their oral absorption and, in the end, bioavailability. The increase in oral bioavailability may be attributed to the adhesiveness of the drug nanosuspension, multiplied surface area (due to a discount in particle length via 10–50 fold), multiplied saturation solubility, leading to a multiplied awareness gradient among the gastrointestinal tract lumen and blood, and improved dissolution speed. This enhancement in bioavailability will lead to a subsequent reduction in drug dose, rendering the remedy cost-effective and obliterating any undue drug dumping inside the body. e.g., Danazol, a poorly bioavailable gonadotropin inhibitor, showed a drastic increase in bioavailability while administered as a nanosuspension as compared to the industrial Danazol macrosuspension. Danazol, a poorly bioavailable gonadotropin inhibitor, confirmed a drastic increase in bioavailability whilst administered as a nanosuspension in comparison to the economic Danazol macrosuspension. Danazol nanosuspension precipitated an absolute bioavailability of 82.3%, even as the marketed Danazol became 5.2% bioavailable. Nanosuspensions also have a rapid onset of action for poorly soluble drugs, i.e., those with excessive tmax values. Aside from improving oral absorption, nanosuspensions provide the following advantages:

* Progressed dose proportionality.
* Decreased inter-issue variability.

improved dose proportionality reduced fed/fasted state variability (discern 12) Many poorly water-soluble molecules whose bioavailability is dissolution-restrained aren't dose-proportional. Atovaquone, when formulated as a suspension, shows 10-15% bioavailability in high dose (750 mg t.i.d.), while its nanosuspension shows a 2.5-fold growth in bioavailability. Another essential benefit of oral drug transport is the quick onset of movement, as seen in the case of naproxen, an NSAID (12-20).

**Parenteral drug delivery**

Parenteral administration is used when a fast onset of action is required and the drug has a great first-pass metabolism or is not absorbed by the gastrointestinal tract. Parenteral management of the drug with a solubilized shape or the drug with a particle length less than five micrometers so that blockage of capillaries no longer occurs As Nanosuspensions have smaller particles in the nano variety, they may be appropriate candidates for parenteral drug transport. Various routes of parenteral management like intra-articular, intraperitoneal, and intravenous injection permit the management of the drug via nanosuspensions, certainly. Nanosuspensions will overcome the problems of solubilization ability, parenteral acceptability, bodily instability, high production costs, and difficulties in scale-up as in other parenteral formulations. Because of the direct nano-sizing of the drug particles, almost all drugs can be effortlessly processed for parenteral management. They display the increased efficacy of the drug. Nanosuspensions reduce the price of remedies and enhance the healing performance of drugs by improving the parenterally tolerable dose of drugs. An enhancement in the balance of drugs has been observed in Nanosuspensions. e.g., Clofazimine nanosuspension suggests stepped-forward balance and efficacy when compared to liposomal Clofazimine in M. avium-infected female mice. The pharmacokinetic profile and biodistribution of the drug in nanosuspension after parenteral management are inspired by a range of factors, like the physical residences of the drug particle, dose of the drug, the infusion time, the intrinsic solubility of the drug in blood, the interplay of the drug with plasma proteins, a sample of the plasma protein interaction, and the phenomenon of natural concentration (18-20).

**Pulmonary drug delivery**

Drugs that might be poorly soluble in pulmonary secretions may be administered by using the formula of the nanosuspensions. These drugs are taken as suspension aerosols or as dry powders with the aid of dry powder inhalers. The nebulized form of the aqueous nanosuspensions is used for the delivery of medicine to the lungs. Nebulization is commonly completed by means of mechanical or ultrasonic nebulizers. Nanosuspensions can be used in all kinds of nebulizers. Nanosuspensions provide the following advantages over traditional pulmonary formulations:

* Speedy diffusion and dissolution of the drug on the site of movement (which will increase the bioavailability of the drug).
* Expanded adhesiveness of the drug to mucosal surfaces
* Prolonged residence time of the medication at the absorption website online, which prolongs the impact of the drug
* A preliminary short onset of movement, after which the energetic moiety is released (which is required by most pulmonary diseases).
* Reduced nearby and systemic side effects of the drug due to the prevention of undesirable particle deposition inside the mouth and pharynx
* Even distribution of the drug within the lungs in comparison to the microparticulate shape of the drug, as all droplets of aerosol incorporate drug nanoparticles (being smaller in size). Due to the microparticulate nature and huge particle length distribution of the drug moiety present in suspension aerosols and dry powder inhalers, the following negative aspects are encountered:
Constrained diffusion and dissolution of the drug at the site of action because of its terrible solubility and microparticulate nature, which may affect the bioavailability of the drug.
Speedy clearance of the drug from the lungs because of ciliary actions
Less residence time for the medicine, leading to an absence of prolonged impact
Deposition of unwanted drug particles in the pharynx and mouth Lung infections may be dealt with by means of nanosuspensions. e.g., Buparvaquones nanosuspensions formulated via nebulization. Nanosuspension of Budesonide has additionally been organized efficaciously for pulmonary shipping. It indicates a terrific relationship between the drug concentration inside the components and the wide variety of micrograms of drug introduced per actuation (14-20).

**Ocular drug delivery**

Nanosuspensions may be explored for the drugs that show off negative solubility in lachrymal fluids. Nanosuspensions provide the subsequent blessings for ocular drug delivery.
• Extended residence time of drug within the cul-de-sac (desired for maximum ocular sicknesses for effective treatment).

• Avoidance of excessive tonicity created through water soluble drugs.

• Sustained launch of the drug may be received by means of incorporation of nanosuspension in a suitable hydrogel base or mucoadhesive base the efficacy of the nanosuspensions is based upon on the intrinsic solubility of the drug in lachrymal fluids. Therefore, the discharge and ocular bioavailability of the nanosuspension is ruled via intrinsic dissolution charge of the drug in lacrimal fluids Nanosuspensions may be formulated the usage of various varieties of polymers e.g. polymeric nanosuspension of Ibuprofen for ophthalmic controlled delivery which has been organized the usage of Eudragit RS100 with the aid of a quasi-emulsion and solvent diffusion method. Nanosuspensions of glucocorticoid pills; hydrocortisone, prednisolone and dexamethasone show progressed shelf-life and the bioavailability after ophthalmic software because of better charge of drug absorption (20).

**Drug targeting**

Nanoparticulate systems have shown great potential in the targeting of drugs, especially in the brain. As the surface properties and in-vivo behaviour of nanosuspensions can be altered easily by changing the stabilizer, they are good candidates for targeted delivery. Commercially viable nanosuspensions for targeted delivery are being developed due to the versatility of the nanosuspension, easy scale-up, and commercial production of the nanosuspensions. Targeting can be achieved by modifying the surface of nanoparticles using suitable polymers. e.g., Brain targeting of the peptide has been done successfully by the modification of the nanoparticle surface using poly-isobutyl cyanoacrylate. Various types of targeting have been achieved successfully, like targeting Cryptosporidium parvum (the organism responsible for cryptosporidiosis) by using surface-modified mucoadhesive nanosuspensions of buparvaquone, and pulmonary aspergillosis can easily be targeted by amphotericin B in the form of pulmonary nanosuspensions instead of using stealth liposomes. Gastrointestinal bacteria and parasitic infections can be targeted due to enhanced adhesion properties (15-20).

**Mucoadhesion of the nanoparticles**

When nanoparticles are obtained orally in the form of nanosuspension, they will diffuse the liquid across the mucosal surface. After adhesion, the concentrated suspension acts as a reservoir for particles and allows rapid adsorption. Step one before particle absorption is the direct contact of the particles with the intestinal cells through a bioadhesive segment. The adhesiveness of the nanosuspensions improves bioavailability as well as the concentration of parasites persisting inside the GIT (20).

**Bioavailability enhancement**

Difficult solubility, poor permeability, or terrible balance of a drug in the gastrointestinal tract (GIT) renders the drug's oral bioavailability poor. Nanosuspensions enhance bioavailability by increasing the solubility and permeability of the drug throughout the membrane. e.g., the bioavailability of oleanolic acid (a poorly soluble drug), a hepatoprotective agent, has been stepped forward by way of formulating a nanosuspension, which turned out to have a considerably superior therapeutic effect. The improved bioavailability was determined because of the faster dissolution (90% in 20 min) of the lyophilized nanosuspension powder in comparison with the dissolution of a coarse powder (15% in 20 min) (16-20).

1. **Vesicular drug delivery systems**

Vesicular drug delivery systems are a class of advanced drug delivery systems that utilize vesicles as carriers to transport drugs to specific target sites within the body. These vesicles, also known as liposomes, are small spherical structures composed of lipid bilayers, which closely resemble the structure of cell membranes.

The main advantage of vesicular drug delivery systems is their ability to encapsulate a wide range of drugs, including hydrophilic and hydrophobic compounds, within their aqueous core or lipid bilayers. This versatility allows for the effective delivery of various therapeutic agents, such as small molecules, proteins, peptides, and nucleic acids.

vesicular drug delivery systems offer significant potential for the targeted and controlled delivery of a wide range of drugs. Their ability to encapsulate diverse therapeutic agents, modify their surface for active targeting, and control drug release makes them promising candidates for improving drug efficacy, reducing side effects, and advancing personalized medicine. Ongoing research and advancements in this field hold great promise for the development of more efficient and specific drug delivery systems in the future(21).

**The objective of vesicular drug delivery systems**:

1. Enhanced Drug Stability
2. Improved Drug Solubility and Bioavailability
3. Targeted Drug Delivery
4. Controlled and Sustained Drug Release
5. Minimized Systemic Toxicity and Side Effects
6. Personalized Medicine(21,22).

**Advantages of vesicular drug delivery system:**

1. Enhanced Drug Stability.
2. Increased Drug Solubility and Bioavailability
3. Targeted Drug Delivery
4. Controlled and Sustained Drug Release
5. Reduced Systemic Toxicity and Side Effects
6. Versatility in Drug Encapsulation(21,22 ).

**Disadvantages of vesicular drug delivery system:**

1. Manufacturing Complexity
2. Stability Challenges
3. Limited Drug Loading Capacity
4. Lack of Long-Term Stability
5. Clearance by the Immune System
6. Cost (21,22)

**Classification for vesicular drug delivery system(43):**

Vesicular drug delivery system is classified according to their composition. They are two types that are lipoidal biocarriers and non-lipoidal biocarriers.

**Table.1:** Types of Vesicular drug delivery system

|  |  |
| --- | --- |
| Lipoidal Biocarriers | Non-lipoidal Biocarriers |
| Liposomes  | Niosomes  |
| Emulsomes  |  Bilosomes  |
| Enzymosomes  | Aquasomes |
| Ethosomes  |  |
| Sphingosomes  |  |
| Transferosomes  |  |
| Pharmacosomes  |  |
| Virosomes |  |

1. **Transferosomes**

Transferosomes are a type of lipid-based drug delivery system that are designed to enhance the delivery of drugs through the skin or other biological barriers. They are composed of phospholipids, surfactants, and sometimes cholesterol, which form a bilayer structure that encapsulates the drug.

Transferosomes were first introduced in the 1990s as a novel drug delivery system, and they have since been studied extensively for their potential therapeutic applications. One of the key advantages of transferosomes is their ability to improve the bioavailability of drugs that have poor water solubility, which can limit their effectiveness when administered by traditional methods.

Additionally, transferosomes can be tailored to target specific tissues or cells, which can increase the efficacy of drugs while reducing the risk of side effects. For example, transferosomes can be designed to deliver drugs to cancer cells, allowing for targeted cancer therapy with fewer side effects than traditional chemotherapy.

Overall, transferosomes are a promising drug delivery system with potential applications in a wide range of therapeutic areas. Ongoing research is focused on improving the stability, efficacy, and safety of transferosomes, as well as exploring new ways to use them in clinical practice(23)

**Advantages of Transferosomes:**

* Enhanced Penetration: Transferosomes possess high deformability and elasticity, allowing them to squeeze through narrow pores and penetrate deep into the skin or mucosal tissues. This property facilitates the efficient delivery of drugs to target sites that are otherwise difficult to reach, including deeper skin layers or systemic circulation.
* Increased Drug Bioavailability: The deformability of transferosomes enhances the bioavailability of drugs by promoting their absorption through the skin or mucosal membranes. This is particularly beneficial for drugs with poor oral bioavailability or those that require localized delivery.
* Improved Stability: Transferosomes provide improved stability to encapsulated drugs by shielding them from enzymatic degradation, pH variations, and other environmental factors. This helps maintain the integrity and activity of the drug during storage and transportation.
* Targeted Drug Delivery: Similar to invasomes, transferosomes can be surface-modified with targeting ligands to achieve targeted drug delivery. These ligands can recognize specific receptors or molecules on the target cells, allowing for precise and localized drug delivery while minimizing off-target effects.
* Versatile Formulation: Transferosomes can encapsulate a wide range of drugs, including both hydrophilic and hydrophobic compounds. This versatility makes them suitable for various types of drugs, allowing for flexibility in drug formulation and delivery(24).

**Disadvantages of Transferosomes:**

* Complex Manufacturing Process: The preparation of transferosomes requires specialized techniques and equipment, which can increase the complexity and cost of manufacturing. This can limit their widespread use and availability, especially for small-scale production or in resource-limited settings.
* Stability Challenges: Transferosomes may face stability issues during storage, such as aggregation, leakage of encapsulated drugs, or changes in their physical properties. These challenges need to be addressed to ensure consistent and reliable performance of transferosomes.
* Variable Performance: The performance of transferosomes can be influenced by various factors, including the physicochemical properties of the drug, formulation parameters, and the site of application. Achieving consistent and predictable performance across different drug molecules and conditions may require optimization and customization for each specific application.
* Regulatory Considerations: Like other novel drug delivery systems, transferosomes may require specific regulatory considerations for approval and commercialization. Compliance with regulatory standards, safety assessments, and demonstrating the efficacy of transferosomes may add complexity and time to the development process.
* Limited Drug Loading Capacity: Transferosomes may have a limited drug-loading capacity due to their vesicular structure. This can be a drawback when delivering drugs with high dosage requirements or large molecular sizes, potentially requiring higher doses or more frequent administration(25).

**Methods to prepare transferosomes**:

1. Ethanol Injection Method
2. Thin Film Hydration Method
3. Reverse Phase Evaporation
4. Ether Injection
5. Solvent Injection Method(26).

There are several methods used to prepare transferosomes. Here are some commonly employed techniques:

1. **Thin Film Hydration Method:** This technique has 3 steps:

The process begins by dissolving phospholipids and surfactants in an organic solvent (chloroform-methanol) to create a thin film of vesicles. This mixture is then heated above the lipid's transition temperature using a rotary evaporator to remove the organic solvents. Any remaining traces of the solvent are eliminated by placing the film in a vacuum overnight.

Next, the formed film is hydrated by adding an appropriate buffer and agitating it at a speed of sixty revolutions per minute for 60 hours. The vesicles formed are left at room temperature to swell.

To create smaller vesicles, the prepared vesicles are subjected to sonication using a bathtub sonicator for 60 minutes at either room temperature or 50°C. In the case of a probe sonicator, the vesicles are sonicated by manually extruding them 200 times through a sandwich layer of two 100 nm polycarbonate membranes(27).

1. **Modified hand shaking method**:

Lecithin together with the edge activator (surfactant) and drug are dissolved in a mixture of chloroform and ethyl alcohol in the magnitude relation 1:1. The mixture is subjected to evaporation to get rid of the organic solvent using temperature higherthan the transiktion temperature of lipid by hand shaking. The thin lipid film is left long to make sure complete removal of organic solvent.

The film that is formed is then hydrated with buffer of choices in conjuction with gentle shaking for quarter- hour. The suspension formed is further hydrated at 43oC for 1-2 hr

Variables that have an effect on the method of preparation are:

Lecithin: Surface -active agent

Solvent used

Surfactant used

Hydration medium.

1. **Reverse Phase Evaporation Method**: In this method, a water-in-oil (W/O) emulsion is formed by dissolving lipids and the drug in an organic solvent and then adding an aqueous phase. The resulting W/O emulsion is subjected to high-speed homogenization, leading to the formation of a water-rich vesicle system, which is subsequently converted into transferosomes.
2. **Ether Injection Method:** Lipids and the drug are dissolved in an organic solvent mixture containing ether. The organic phase is then rapidly injected into an aqueous medium under high-speed homogenization or sonication, resulting in the formation of transferosomes.
3. **Ethanol Injection Method**: Similar to the ether injection method, lipids and the drug are dissolved in an organic solvent mixture containing ethanol. The organic phase is rapidly injected into an aqueous medium under high-speed homogenization or sonication, leading to transferosome formation.
4. **Dehydration-Rehydration Vesicle Method**: This method involves the dehydration of preformed liposomes or multilamellar vesicles (MLVs) followed by rehydration with an aqueous medium containing the drug. The dehydration process can be achieved using freeze-drying, spray-drying, or other techniques, and the resulting dehydrated vesicles are subsequently rehydrated to form transferosomes.
5. **Lipid Film and Remote Loading Method**: This method combines the lipid film hydration technique with remote loading of the drug. Lipids are dissolved in an organic solvent to form a lipid film, which is then hydrated with an aqueous medium containing a pH gradient or an ion gradient. The pH or ion gradient drives the active ingredient into the vesicles during hydration, resulting in remote loading of the drug(26,27,28).

**SILENT FEATURES OF TRANSFERSOMES**

Transfersomes possess several distinctive features that make them a promising option for drug delivery. These features include:

1. Transfersomes exhibit high deformability, enabling them to effectively penetrate narrow constrictions and maintain the integrity of the vesicles.
2. Wide Range of Drug Solubility: The infrastructure of transfersomes consists of hydrophobic and hydrophilic moieties, enabling them to accommodate drug molecules with varying solubilities. They can effectively carry both hydrophilic and lipophilic drugs.
3. Transfersomes are a versatile drug carrier capable of delivering drugs with varying molecular weights. They have been successfully employed to transport a diverse range of substances such as analgesics, anesthetics, corticosteroids, sex hormones, anticancer agents, insulin, gap junction proteins, and albumin. This broad applicability highlights the potential of transfersomes as an effective delivery system for various therapeutic compounds.
4. Biocompatibility and Biodegradability: Transfersomes are composed of natural phospholipids, similar to liposomes, making them biocompatible and biodegradable. This enhances their safety profile and minimizes potential adverse effects.
5. High Entrapment Efficiency: Transfersomes exhibit high entrapment efficiency, particularly for lipophilic drugs, with rates reaching close to 90%. This ensures that a significant amount of the encapsulated drug is retained within the vesicles
6. Protection from Metabolic Degradation: Encapsulating drugs within transfersomes provides protection against metabolic degradation. The vesicles shield the drug molecules from enzymatic degradation, thereby maintaining their stability and potency.
7. Controlled Release: Transfersomes can act as depots, releasing their contents in a slow and gradual manner. This controlled release mechanism allows for sustained drug delivery, prolonging the therapeutic effect and reducing the frequency of dosing.
8. Easy Scalability: The manufacturing process of transfersomes is relatively simple, without the need for lengthy procedures or the addition of pharmaceutically unacceptable additives. This makes it easier to scale up production for commercial purposes.
9. Systemic and Topical Delivery: Transfersomes can be utilized for both systemic and topical delivery of drugs. They have the potential to transport drugs across the skin barrier for transdermal delivery or to target specific tissues and organs for systemic effects(29).

**LIMITATIONS OF TRANSFERSOMES**

1. **Stability: Transfersomes may have stability issues, particularly during long-term storage. Factors such as vesicle leakage, aggregation, and fusion can impact their stability and potentially affect the efficacy of the encapsulated drugs.**
2. **Complexity of Formulation: Formulating transfersomes requires careful optimization of various components, including lipids, surfactants, and edge activators. Achieving the desired vesicle characteristics and drug-loading capacity can be challenging and time-consuming.**
3. **Scalability: While transfersome preparation methods are relatively straightforward, scaling up the production process for commercial purposes may pose challenges. Ensuring consistent quality, batch-to-batch reproducibility, and large-scale manufacturing feasibility need to be addressed.**
4. **Skin Irritation: Transfersomes, when used for transdermal drug delivery, can cause skin irritation or sensitization in some individuals. The components of transfersomes or the drugs themselves may trigger adverse reactions on the skin.**
5. **Limited Penetration Depth: Despite their deformability, transfersomes have a certain limit to their penetration depth through the skin. They may not be able to reach deeper layers or specific target sites, which could limit their effectiveness for certain applications.**
6. **Cost: The production of transfersomes can be relatively expensive due to the cost of high-quality phospholipids and other components involved. This cost factor may influence their practicality and accessibility for widespread use.**
7. **Regulatory Considerations: Transfersomes are still a relatively new technology, and their regulatory approval for specific drug formulations may require additional studies and evidence of safety and efficacy(30).**

**Table 2:** Composition of transferosomes

|  |  |  |
| --- | --- | --- |
| Class  | Example  | Uses  |
| **Phospholipids** | Soya phosphatidyl choline, Dipalmitoyl phosphatidyl choline, Distearoyl phoshatidyl choline | Vesicles forming component |
| **Surfactant** | Sod. Cholate, Sod.deoxycholate, tween-80, Span-80 | For providing flexibility |
| **Alcohol** | Ethanol, methanol | As a solvent |
| **Buffering agent** | Saline phosphate buffer (pH 6.4) | As a hydrating medium |
| **Drug**  | Fluconazole  | A.P.I |

**Mechanism of transport:**

The mechanism of transport involves the generation of an "osmotic gradient" resulting from water evaporation when a lipid suspension, known as transferosomes, is applied to the skin surface. The transport of these elastic vesicles is not dependent on concentration. The process relies on trans-epidermal hydration as the driving force for vesicle transport. Due to their elasticity, the vesicles can pass through the pores in the corneum, although these pores are smaller in diameter compared to the vesicles. When transferosomes are applied to an open biological surface, such as non-occluded skin, they tend to penetrate the barrier and migrate into the water-rich deeper layers to maintain sufficient hydration.

During penetration through the corneum, reversible deformation of the bilayer occurs. However, it is crucial to ensure that vesicle integrity, gradient, and barrier properties for underlying hydration affinity are not compromised during this deformation.

Since transferosomes are too large to diffuse through the skin, they need to identify and establish their own pathway through the organ. The effectiveness of transferosomes in drug delivery relies on their ability to expand and overcome hydrophilic pores within the skin. Intracellular drug transportation may involve diffusion of the vesicle lipid bilayer with the skin, similar to normal endocytosis involving the diffusion of vesicles through cytomembrane. The mechanism is intricate and incorporates advanced principles of elasto-mechanics, combined with material transport and hydration/osmotic forces(28).

**Characterization of Transferosomes:**

1. Entrapment Efficiency: The entrapment efficiency of transferosomes is determined by separating the unentrapped drug from the vesicles. After centrifugation to separate the untrapped drug, the vesicles are ruptured, and an appropriate analytical technique is employed to quantify the amount of entrapped drug.
2. Vesicular Diameter: The size of vesicles is determined by employing techniques such as photon correlation spectroscopy or dynamic light scattering (DLS). These techniques provide information about the vesicular diameter and size distribution.
3. In vitro Drug Release: In vitro drug release studies are conducted by incubating the transferosomes suspension at a specific temperature. Samples are withdrawn at different time intervals, and the amount of released drug is detected using techniques such as UV spectrophotometry, high-performance liquid chromatography (HPLC), or high-performance thin-layer chromatography (HPTLC). The quantity of free drug is separated and measured to calculate the drug release profile.
4. Vesicular Shape and Type: The shape and type of transferosomes vesicles can be visualized using techniques like transmission electron microscopy (TEM) or phase contrast microscopy. The stability of the vesicles can be assessed by monitoring the size and structure of the vesicles over time. Mean size measurements can be obtained using DLS, while TEM allows observation of structural changes.
5. Surface Charge and Charge Density: The surface charge and charge density of transferosomes are determined using a zetasizer instrument. This technique provides information about the electrostatic properties of the vesicles.
6. Drug Content:The drug content in transferosomes is quantified using a modified HPLC method, which involves utilizing specific equipment and analytical parameters. This method involves employing a UV detector, column oven, autosampler, pump, and a computerized analysis program to quantify the amount of drug present in the vesicles(31).

**Application of Transfersomes:**

1. The use of transfersomes for delivering insulin offers a successful method of administering large molecular weight medications through the skin. Traditional subcutaneous administration of insulin can be inconvenient for patients. By encapsulating insulin in transfersomes (referred to as transfersulin), all the challenges associated with conventional insulin delivery can be overcome. Therapeutic effects can be observed within 90-180 minutes after the application of transfersulin on intact skin, depending on the composition of the carrier.
2. Transfersomes also provide a solution for the delivery of corticosteroids. By incorporating corticosteroids into transferosomes, the issues associated with their delivery can be addressed. Transfersome encapsulation enables site-specific and safe delivery of corticosteroids into the skin through epicutaneous administration. The use of transfersomes technology also reduces the required dosage for achieving the biological activity of corticosteroids.
3. Transfersomes have been widely employed as carriers for the transportation of proteins and peptides, allowing for their safe administration through transfersome technology. Proteins and peptides face challenges in transferring into the body due to their large molecular size and susceptibility to degradation in the gastrointestinal tract when administered orally. Therefore, injectables have been the preferred method of administration. Various approaches have been developed to overcome this limitation. Transfersomes demonstrate bioavailability comparable to subcutaneous injection when used for protein suspension. Additionally, repeated epicutaneous application of transfersome preparations of proteins can elicit a strong immune response, demonstrating their potential in immunotherapy.
4. Transfersomes can be utilized as carriers for delivering antiviral drugs such as INF (interferon). For example, leukocyte-derived INF-a, a naturally occurring protein with antiviral, antiproliferative, and immunomodulatory effects, can be delivered using transfersomes as drug delivery systems. Transfersomes enable controlled release of the administered drug and enhance the stability of labile drugs. Studies have shown promising delivery of IL-2 (interleukin-2) and INF-a through transfersomes for potential transcutaneous applications.
5. Transfersomes offer a new approach for the transcutaneous delivery of anti-cancer drugs, particularly for skin cancer treatment. Methotrexate, when delivered using transfersomes technology, has shown favorable results.
6. Transfersome applications extend to the delivery of anesthetics. The use of transfersomes containing anesthetics can induce topical anesthesia within approximately 10 minutes under appropriate conditions. The impact of transfersomal anesthetics is comparable to a subcutaneous bolus injection, with nearly 80% effectiveness, but the transfersome preparation provides a longer-lasting effect.
7. Transfersomes can also be employed for the transdermal delivery of non-steroidal anti-inflammatory drugs (NSAIDs) to overcome the gastrointestinal adverse effects associated with most NSAIDs. Studies have been conducted on diclofenac and ketoprofen. In 2007, the Swiss regulatory agency (Swissmedic) granted regulatory approval to a transfersome formulation containing ketoprofen. This formulation is anticipated to be marketed under the brand name "Diractin." Furthermore, IDEA AG has ongoing clinical development plans for additional therapeutic products utilizing transfersome technology.
8. Transfersome technology can also be utilized for the delivery of herbal drugs. Xiao-Ying et al. demonstrated higher topical absorption of transfersomes containing capsaicin compared to pure capsaicin(32,33,34).
9. **Invasomes**

Invasomes represent a new type of vesicular system that exhibits superior transdermal penetration compared to traditional liposomes. These vesicles consist of phospholipids, ethanol, and terpenes, which contribute to their enhanced transdermal properties. The key advantage of these nanovesicles lies in their ability to enhance drug permeability into the skin while minimizing systemic absorption, thus restricting drug activity within the skin layer.

Similar to liposomes, invasomes share the same structural components but incorporate terpenes. Terpenes are hydrocarbon molecules commonly found in plant essential oils. The inclusion of terpenes facilitates the formation of flexible vesicles, thereby improving the fluidity of the skin's lipid bilayers. This increased capacity to penetrate the epidermal layers enhances the effectiveness of invasomes. They achieve this by disrupting lipid and intracellular protein connections, thereby fluidizing the bilayer structure of the stratum corneum lipids.

Invasomes possess various characteristics that contribute to their efficacy, including size, surface shape, zeta potential, and stability(35).

**Advantages of invasomes:**

1. Enhanced Transdermal Penetration:
2. Controlled Drug Release
3. Increased Drug Bioavailability
4. Deformable Vesicles
5. Targeted Delivery
6. Improved Stability
7. Versatility.

**Disadvantages of invasomes:**

1. Complexity of Formulation
2. Potential Skin Irritation
3. Limited Long-Term Stability
4. Need for Specialized Manufacturing Techniques
5. Limited Scalability
6. Regulatory Considerations
7. Cost(36)

**Penetration mechanism of invasomes:**

The enhancing effects of invasomes can be attributed to a combination of processes. At normal body temperatures, the lipid layer of the stratum corneum, which is the outermost layer of the skin, is tightly packed and highly organized in terms of its conformation. Ethanol, when incorporated into the invasome membrane, disrupts the structure of the skin's lipid bilayer. This disruption allows the invasomes to penetrate the stratum corneum.

Additionally, the presence of ethanol in invasomes leads to a less densely packed lipid membrane compared to conventional vesicles. Despite this, invasomes maintain their stability. This characteristic makes the invasome membrane more malleable, enabling it to squeeze through small spaces, such as the gaps formed by the disruption of the stratum corneum lipids.

In summary, invasomes' ability to enhance penetration is facilitated by the incorporation of ethanol, which disrupts the lipid bilayer structure of the skin and allows invasomes to enter the stratum corneum. The presence of ethanol also contributes to the deformability of invasomes, enabling them to navigate through narrow spaces within the skin barrier(37).

**Method of preparation:**

1. **Mechanical Dispersion Method:** In the mechanical dispersion method, the invasomal formulation is prepared as follows: The drug and terpene or terpene mixtures are dissolved in an ethanolic phospholipid solution. The mixture is then subjected to vortexing for 5 minutes, followed by sonication for 5 minutes to achieve a clear solution. Phosphate buffer saline (PBS) with a pH of 7.4 is added to the solution using a syringe while constant vortexing is maintained for an additional 5 minutes. This process results in the final invasomal preparation.
2. **Thin Film Hydration Method:** Another approach to prepare invasomes is the thin film hydration method, which involves the following steps: Phospholipids dissolved in ethanol are mixed with methanol:chloroform (2:1) solution. The mixture is then dried to form a thin film by gradually reducing the pressure from 500 to 1 mbar at 50°C using a rotary flash evaporator. The film is placed under vacuum (1 mbar) for 2 hours at room temperature and subsequently flushed with nitrogen gas. In order to generate invasomes, the thin film is hydrated through one of two methods. The first method involves hydrating the thin film for a duration of 30 minutes at the temperature corresponding to the lipid phase transition. This hydration process is accomplished using a mixture consisting of phosphate buffer (pH 7.4, PBS), ethanol, and terpenes. Alternatively, invasomes can also be formed by hydrating the thin film using PBS (pH 7.4) alone. Both methods result in the formation of invasomes, allowing for flexibility in selecting the appropriate hydration approach based on specific formulation requirements.Once the mixture has cooled down to room temperature, ethanol and either a single terpene or a mixture of terpenes are introduced into the formulation. This addition further enhances the properties and characteristics of the invasomes(38).

**Characterization of invasome:**

1. Vesicle Shape: The shape of Inavasomes can be easily observed through techniques such as transmission electron microscopy (TEM) and scanning electron microscopy.
2. Drug Content: The drug content in Inavasomes can be determined using an ultraviolet spectrophotometer. Additionally, a modified high-performance liquid chromatographic method can be utilized to quantify the drug content.
3. Entrapment Efficiency: The entrapment efficiency of Inavasomes can be studied using the ultracentrifugation method. To separate any untrapped drug, a 5 ml invasomal formulation undergoes centrifugation at 15000 rpm for 15 minutes in two cycles.
4. The particle size of Inavasomes can be determined using techniques like dynamic light scattering and photon correlation spectroscopy. These methods allow for the measurement of vesicle size and zeta potential.
5. Furthermore, the zeta potential of the formulation can be measured using a zetasizer.
6. Stability Studies: The stability of Inavasomes can be assessed by monitoring changes in the size and structure of the vesicles over time. The mean size of the vesicles can be measured using dynamic light scattering, while structural changes can be observed using TEM(37,38).

**APPLICATION OF INVASOMES:**

* Improving Bioavailability: Asenapine Maleate (ASPM) is a second-generation antipsychotic utilized for treating schizophrenia. However, its oral bioavailability is limited due to extensive first-pass metabolism. Fatma Saeed EI Tokhy et al. explored the use of nanocarriers, specifically invasomes, as an alternative method for administering ASPM. This approach exhibited enhanced bioavailability and sustained action. Invasomes containing limonene demonstrated superior transdermal permeation compared to other carriers. The bioavailability of Asenapine increased from 3.5% to 54.5%.
* Hyperpigmentation Disorder: Hyperpigmentation disorder arises from excessive melanin production, resulting in abnormal melanin distribution on specific skin areas. Controlling tyrosinase activity is crucial in regulating melanin production. Phenylethyl resorcinol, a novel skin whitening agent, effectively inhibits tyrosinase activity. However, phenylethyl resorcinol-loaded invasomes and transfersomes face challenges related to stability and water solubility. A comparative study involving conventional liposomes showed that invasomes and transfersomes demonstrated better reduction in melanin content and tyrosinase inhibition activity.
* Acne Treatment: Acne is a common chronic inflammatory skin infection that adversely affects young adults, causing emotional stress, discomfort, and scarring. Dapsone, a sulfone compound, effectively treats acne when administered topically. El-Nabarawi et al. prepared dapsone-loaded invasomes using different terpenes to evaluate their skin delivery capability. The study revealed that invasomes significantly improved the deposition of dapsone in the skin.
* Photodynamic Therapy: Photodynamic therapy is an intriguing approach that involves the use of photosensitizing compounds. These compounds accumulate in target cells and, upon exposure to visible light, induce local irritation. This leads to apoptosis or necrosis of the target cells. Dragicevicuric et al. developed an invasomal formulation of temoporfin, a lipophilic compound, using a blend of terpenes and ethanol.The research findings indicated that invasomes containing a 1% blend of terpenes showed increased temoporfin deposition in the stratum corneum compared to liposomes.
* Transdermal Delivery for Benign Prostatic Hyperplasia: Benign prostatic hyperplasia is a common condition in elderly men that causes pathological changes in urine flow and kidney function. Prasanthi and Lakshmi et al. investigated the transdermal delivery of finasteride, a model drug for treating this condition, using invasomes and the iontophoretic technique. The invasomes formulation, optimized using Taguchi's robust design method, included terpenes such as nerolidiol, carvone, and limonene. The study revealed that a sample containing 0.5% limonene exhibited 21-fold better penetration than the controls. Additionally, the optimized formulation proved effective in transdermal delivery of finasteride when combined with iontophoretic techniques.
* Efficiency of Invasomes in Hydrophilic Drug Delivery: Invasomes have proven to be successful drug delivery systems for hydrophilic drugs. Badran et al. conducted an in vitro study and found that invasomes containing a 1% mixture of terpenes outperformed aqueous solutions in dermal delivery of hydrophilic compounds. Furthermore, when combined with a Dermaroller, a microneedle device, the vesicles demonstrated improved drug permeation and penetration(39).
1. **Niosomes:**

Whether this control is of a temporal, spatial, or combined form, the goal of novel drug delivery systems is to offer some control amount of drug release in the body. The goal of novel drug delivery is to either maintain drug activity at a predetermined rate or to keep the body's effective drug level roughly constant while minimizing any adverse effects. It is also possible to target drug action by utilizing carriers or chemical derivatization to deliver the drug to a specific target cell type, or it is possible to localize drug activity by the spatial placement of controlled release systems adjacent to or within the diseased tissue or organ(44). When Paul Ehrlich envisioned a drug delivery system that would target specifically damaged cells, he launched the period of development for targeted delivery in 1909 (Magic bullet). Drug targeting is the ability of a therapeutic substance to be directed directly to intended site of action with little or no interaction with non-target tissue(45). In these various carriers are used to deliver the drug to target site.

Pharmaceutical carriers come in a variety of forms, including particulate, polymeric, macromolecular, and cellular. Lipid particles, microspheres, nanoparticles, polymeric micelles, and other small particles are examples of the particulate type carrier, often known as the colloidal carrier system, and vesicular structures like liposomes, sphingosomes, niosomes, transferosomes, pharmacosomes, and virosomes. Certain amphiphilic building blocks are exposed to water, resulting in the formation of vesicular systems, which are highly organised assemblies of one or more concentric lipid bilayers. Many different types of amphiphilic building blocks can be used to create vesicles. The Bingham bodies were initially described as having a biological origin by Bingham in 1965 (Bangham et al., 1965). Due to the limited drugs penetration into cells, conventional chemotherapy is ineffective for treating intracellular infections. Vesicular drug delivery devices can be used to bypass this(46).

Niosomes are non-ionic surfactant vesicles that were initially developed in 1985 by Ballie et al. Niosomes are concentric bilayered vesicles that completely encapsulate an aqueous volume with a membranous lipid bilayer composed primarily of cholesterol and non-ionic surfactants. These are similar to liposomes which can entrap both hydrophilic and hydrophobic drugs(47).

Niosomes were first addressed in the cosmetic industry by Vanlerbeghe et al. in 1972. According to Handjanivila et al., a combination of cholesterol and a single alkyl chain non-ionic and non-toxic surfactant formed vesicles when it was hydrated. Since then, a variety of non-ionic surfactants, including polyglycerol alkyl ethers, glucosyl dialkyl ethers, crown ethers, polyoxyethylene alkyl ethers, ester-linked surfactants, steroid-linked surfactants, brij, and a number of spans and tweens, have been utilised to produce vesicles. Niosomes are the vesicles that result(43) and size vary from 10nm to 100nm.

Numerous mechanisms have suggested numerous ways for how niosomes might improve the transport of medicines through membranes. These include (i) Niosomes as transdermal drug delivery system reversible alteration of lipid organisation, which affect the stratum corneum's barrier function, (ii) increasing stratum corneum hydration by preventing transepidermal water loss, which causes the cellular structure of the stratum corneum to loosen, and (iii) niosome adsorption and/or fusion on the skin's surface, which creates a high thermodynamic activity. The binding of ligands on the niosomal membrane to particular receptors on the cell surfaces, which results in the direct transfer of the drug from the vesicles to the skin, may cause niosomes to adsorb onto the skin cell surfaces through the action of physical forces. On the other hand, total mixing of the niosomal contents with the cytoplasm can occur when niosomes fuse with the cell membrane. The entrapped niosomal material may potentially be released into the cell cytoplasm as a result of endocytosis of niosomes by skin cells and lysosomal breakdown(48).

**Advantages (43, 49):**

1. Similar to liposomes, entrap the solute.
2. Increases the stability of the drugs that is entrapped and is osmotically active and stable.
3. There are no additional requirements for handling or storing surfactants.
4. Take into consideration drug substances with a variety of solubilities.
5. Increase the oral bioavailability of drugs that are not well absorbed and can also increase drug penetration via the skin.
6. Can be administered orally, parenterally, or topically to deliver the drug to the site of action.
7. Niosomal surfactants are non-immunogenic, non-toxic, biodegradable, and biocompatible.
8. By delaying the clearance of drug molecules from the bloodstream, shielding them from the biological environment, and limiting their effects to target cells, niosomes enhance the therapeutic effectiveness of drug molecules.
9. They might increase how long the drug is trapped in circulation.
10. Can be utilised to transport drugs that are hydrophilic, lipophilic, and amphiphilic, as well as pharmaceuticals with a wide range of solubility.
11. Niosomes decrease the systemic toxicity of drugs including anti-infectives and anti-cancer medicines.

**Disadvantages:**

1. Physically unstable and it may form aggregation.
2. Entrapped drug leakage may occur.
3. Rarely, non-ionic surfactants interact with other components of the system and cause the formulation to become homogeneous or to precipitate.

**Types of Niosomes (50,51):**

The classification of niosomes depends on several factors, including the number of bilayers (MLV, SUV), size (LUV, SUV), and manufacturing process (REV, DRV). The following is a description of the many niosome types:

i) Multi lamellar vesicles (MLV) 1-5 um size.

ii) large uni-lamellar vesicles (LUV) 0.1- 1 μm size.

iii) small uni-lamellar vesicles (SUV) 25-500 nm size.

1. **Multi lamellar vesicles (MLV):** It comprises many bilayers that each individually enclose the aqueous lipid compartment. These vesicles have a diameter that ranges from 0.5 to 10 micrometres. The most common niosomes are multilamellar vesicles. It is simple to produce and mechanically stable when kept in storage for an extended period of time. These vesicles are suitable for use as lipophilic compound drug carriers.
2. **Large Uni-lamellar vesicles (LUV):** These niosomes feature a high aqueous/lipid compartment ratio, allowing for more bioactive molecules to be entrapped while using membrane lipids much more sparingly.
3. **Small Uni-lamellar vesicles (SUV):** The majority of these tiny unilamellar vesicles are made from multilamellar vesicles by sonication, French press extrusion, and electrostatic stabilisation, which is accomplished by adding dicetyl phosphate to CF-loaded, Span 60-based niosomes with 5(6)-carboxyfluorescein (CF) loads.

**Composition of Niosomes (52,53,54):**

For preparing niosomes, the main components are non-ionic surfactant, cholesterol and other additives.

1. **Non-ionic surfactant:** Unlike liposomes, which are mostly made of phospholipids, niosomes are primarily made of non-ionic surfactants. Non-ionic surface-active molecules are amphiphilic molecules having a polar head and a non-polar tail. Since surfactants don't carry any charge, they are more stable, compatible, and safe than anionic, cationic, and amphoteric surfactants. Non-ionic surfactants have the important property of inhibiting p- glycoprotein, in which the immersion can enhance and targeting of anticancer medicines, such as Doxorubicin, Daunorubicin, Curcumin, and Morusin, steroids such as hydrocortisone, HIV protease inhibitors such as Ritonavir, and cardiovascular medicines such as aspirin. The HLB of the surfactant affects the efficiency of niosome entrapment. The length of the alkyl chain and the size of the vesicle both grow when the HLB score increases. For the production of niosomes, surfactants with HLB in the range of 14–17 are unacceptable. Span (span 20, 60, 40,80,85) and tween (tween 20,40,60,80) and brij (Brij 30,35,52,58,72,76) are generally used for the preparation of niosomes.

**Table 1.2:** Different types of Non-ionic surfactants (54)

|  |  |
| --- | --- |
| **Type of Non-ionic surfactant** | **Examples** |
| Fatty alcohol | Cetyl alcohol, Steryl alcohol, Cetosteryl alcohol, oleyl alcohol |
| Ethers | Brij, Decyl glucoside, Lauryl glucoside, Octyl glucoside, Triton X-100, Nonoxynol-9 |
| Esters | Glyceryl laurate, polysorbates, spans |
| Block copolymers | Polaxamers |

1. **Cholesterol:** In the bilayer structure of niosomes, the hydrophilic head of a surfactant forms hydrogen bonds with cholesterol. The concentration of cholesterol in the niosome and how effectively it can enclose and sustain its loaded state have an impact on these physical and structural characteristics. Cholesterol influences the system's gel/liquid phase transition temperature and has an impact on membrane fluidity through interactions with nonionic surfactants (55). Due to its effect on niosome stability and rigidity, cholesterol is effective in preventing leakage and may change the efficiency of drug entrapment in niosomal formulations by altering the cholesterol content. The amount of cholesterol that must be added depends on the HLB value of the surfactants. The cholesterol concentration must be raised when the HLB value rises in order to offset the effect of the larger head groups on the critical packing parameter (CPP) (53).
2. **Other additives:** Niosomes' capacity to change their structure and physicochemical characteristics by adding various additives is one of their advantages. As a result, since vesicle features rather than the physicochemical qualities of the drug play a more significant part in determining pharmacokinetics and the drug delivery process, both processes may be further enhanced. To impart desired properties, several additives may be added to the niosomal composition (55).

**Factors Affecting the formation of Niosomes:**

1. **Selection of surfactants and additives:** To make niosomes, a surfactant has to have a hydrophilic head and a hydrophobic tail. One, two, or perhaps one or more alkyl, perfluoroalkyl, or in certain situations, steroidal groups may make up the hydrophobic tail. The single-chain alkyl tail of ether-type surfactants makes them more hazardous than their dialkyl corresponding bodies. Since ester-linked surfactants are in vivo degraded by Esterases to triglycerides and fatty acids, they are chemically less stable than ether-type surfactants and less hazardous than the latter. For the creation of niosome, surfactants with alkyl chains ranging from C12 to C18 are appropriate. Surfactants from the Span series with an HLB number of 4 to 8 can generate vesicles (55).
2. **Drug:** The interaction of the solute with surfactant head groups, which raises the charge and mutual repulsion of the surfactant bilayers, increases the vesicle size when the drug is trapped in niosomes. Some drugs get trapped in the lengthy PEG chains in polyoxyethylene glycol (PEG) coated vesicles, which lessens the tendency for them to expand in size. The degree of entrapment is influenced by the drug's hydrophilic-lipophilic balance (56).
3. **Charge and cholesterol content:** Cholesterol increases niosome hydrodynamic diameter and trapping efficiency. In general, cholesterol acts in two ways: on the one hand, it boosts the chain order of bilayers in the liquid state, and on the other, it lowers the chain order of bilayers in the gel state. The gel state changes into a liquid-ordered phase at high cholesterol concentrations. A decrease in the release rate of the material that was encapsulated and an increase in the stiffness of the resulting bilayers were caused by an increase in the cholesterol content of the bilayers. In a multilamellar vesicle structure, the presence of charge tends to increase the interlamellar distance between succeeding bilayers and results in a greater total entrapped volume.
4. **Resistance to osmatic stress:** When a hypertonic solution is introduced to a Niosomal suspension, the size of the Niosome reduces. In a hypotonic salt solution, where niosomes are kept, the drug is initially slowly released, resulting in swelling. The slower release might be due to vesicle fluid eluting being inhibited. A quicker releasing phase was later seen. The breakdown of the niosome's mechanical structure as a result of mechanical stress may be what leads to this quicker release phase (53,56).
5. **Critical Packing Parameter:** The critical packing parameter affects the shape of the vesicle during niosomal formation. The shape of nanostructures produced by the self-assembly of amphiphilic molecules may be anticipated based on the CPP of a surfactant. The following Equation may be used to define the critical packing parameter, which relies on the symmetry of the surfactant:

 Where, v = area of the hydrophilic head group,

 lc= crucial hydrophobic group length, and

ao= hydrophobic group volume.

Small hydrophobic tail spherical micelles may develop if CPP ≤ 1/3, for instance, correlating to a bulky head group. Bilayer vesicles can form if 1/2 ≤ CPP ≤ 1 and non-spherical micelles can form if 1/3 ≤ CPP ≤ 1/2. When the surfactant is made up of a large hydrophilic tail and a short hydrophobic tail, inverted micelles develop if CPP ≥ 1. The self-assembled structure and its morphological transition in amphiphilic liquids may be realised, explained, and predicted using CPP.

**Methods of Preparations (57,58,59):** By hydrating nonionic surfactants with hydration medium, niosomes are usually prepared. But there are so many methods to formulate the niosomes they are:

1. Transmembrane pH gradient method,
2. Thin Film Hydration technique,
3. Reversed-phase evaporation,
4. Ether injection Method,
5. Bubbling of nitrogen,
6. Sonication,
7. Enzymatic method,
8. Single-pass technique and
9. Microfluidization
10. Formation of Niosomes from proniosomes
11. **Transmembrane PH gradient method:** This theory states that the inside of the niosome has an acidic pH, which is lower than the outside. The niosome membrane is crossed by the additional unionised basic drug, but once inside, it becomes ionised in an acidic medium and is unable to exit the niosome, increasing the effectiveness of entrapment for such medications. Surfactant and cholesterol were dissolved in chloroform, and under low pressure, these will evaporate and form a thin film. By vortex mixing, this film is hydrated with an acidic chemical solution (often citric acid), and the result is kept freeze-thawed to produce niosomes. The aqueous solution containing the drug is added to the niosomal suspension. Phosphate buffer is added to increase the PH, and the interior of the niosomes becomes more acidic than the exterior medium. This will make the unionised form of the drug pass the bilayers of niosomes, and after the drug enters the niosomes, it ionises in an acidic medium and makes successful entrapment.
12. **Thin Film Hydration Technique:** Thin-film hydration is a common technique used for preparing niosomes. Cholesterol and surfactant are dissolved in organic solvents (Chloroform: Ethanol) in a round bottom flask (fig 1) and kept for rotary evaporator along with speed, temperature and pressure. The thin film will be formed on the walls of the flask, and this was hydrated with preheated buffer and again kept for rotary evaporator for stirring. After sometimes the vesicles will be formed.

**Fig.4:** Rotary Evaporator



1. **Reversed Phase Evaporation:** Surfactant and cholesterol are dissolved in organic solvent (ethanol, chloroform), and an aqueous solution containing the drug was added and sonicated with a temperature of 4oc – 50c. Further, after adding phosphate buffer saline (PBS), keep for sonication resulting in the formation of gel and temperature is increased, and pressure is reduced to 40oc to evaporate the solvent. The PBS has added again and kept for the bath sonicator at 60oc for 10min, and niosomes were formed.
2. **Ether Injection Method:** Ether injection method is prepared by dissolving non-ionic surfactant and cholesterol in diethyl ether and taking the entire solution into a syringe. This solution is slowly introduced 1ml/min into a preheated buffer and kept for stirring until vesicles form. The gradual vaporisation of the solvent causes an ether gradient to extend towards the aqueous non-aqueous interface, which is likely what causes the development of bigger unilamellar vesicles. The creation of the bilayer structure may be due to the former. The vesicle's diameter ranges from 50 to 1000 nm, depending on the parameters used. This method's drawback is that it's challenging to get rid of the trace amounts of ether that are commonly present in the vesicles suspension.
3. **Bubbling of nitrogen:** Organic solvents are not used in this procedure. Phosphate buffer saline (PBS), additives, and surfactants were put into a glass reactor with three necks. The reactor is set in a water bath to regulate the temperature. The thermometer is placed in the second neck, nitrogen gas enters the first neck, and water refluxes into the third neck. After 15 seconds of high-shear homogenizer mixing, these components are combined. Niosomes were produced when nitrogen gas was bubbled at 70 °C.
4. **Sonication:** The surfactant-cholesterol combination is initially distributed in the aqueous phase using this approach. Multilamellar vesicles (MLV) are created when this dispersion is probe sonicated for 10 min at 60°C. Unilamellar vesicles are created after additional ultrasonication of these MLVs, either by a probe sonicator or a bath sonicator.
5. **Enzymatic method:** In this method, niosomes are generated from a mixed micellar solution via an enzymatic approach. Esterases degrade molecules such as polyoxyethylene and cholesterol, which when coupled with diacetyl phosphate and other lipids form multilamellar niosomes. The surfactants used in this process include polyoxyethylene cholesteryl sebacetate diacetate and polyoxyethylene stearyl derivatives.
6. **Single-pass technique:** It is a patented approach that involves the continuous extrusion of a lipid solution or suspension through a nozzle after passing through a porous device. It combines homogenization and high-pressure extrusion to provide niosomes a limited supply of sizes between 50 and 500 nm.
7. **Microfluidization:** To create unilamellar vesicles with a certain size distribution, a new approach has been developed. This approach is based on the submerged jet concept, in which two fluidized streams contact precisely designed microchannels inside an interaction chamber at extremely high speeds. It is designed such that the energy provided to the system stays in the region of niosomes production when thin liquid sheets impact along a common front. The niosomes that are produced as a result are smaller, more consistent, and more repeatable (60).
8. **Formation of niosomes from proniosomes:** A water-soluble carrier, such as sorbitol or mannitol, is coated with surfactant when using the proniosome approach. A dry formulation is created as a result of the coating process. This substance is known as "Proniosomes" and has to be hydrated before usage. The inclusion of the aqueous phase results in the formation of the niosomes. This approach provides ease in dosing and storage while decreasing physical stability issues including the aggregation, leakage, and fusion problem. It also produces better outcomes than conventional niosomes.

**Characterization of Niosomes (61,62,63):**

There are many physicochemical methods for characterization of niosomes they are as follow:

1. Study of drug excipient-interaction
2. Size, Morphology and size distribution
3. Zeta potential
4. Optical microscopy
5. Drug Content
6. Entrapment efficiency
7. In-vitro drug release studies
8. Stability studies
9. **Study of drug excipient-interaction:** Drug-excipient interactions can be determined using a variety of techniques. The most used methods are: FTIR, Differential scanning calorimetry (DSC) and X-ray diffraction technique (XRD).

These methods can identify the physicochemical states and interactions between drugs and excipients in nanotechnology and pharmaceuticals.

To evaluate the thermal and crystallinity properties of niosomes and excipients, DSC and XRD analyses were carried out. DSC often detects phase changes like the glass transition and crystallisation. The drug molecules' crystalline and amorphous states are identified using XRD methods.

To determine or evaluate drug-excipient interactions and search for any incompatibilities between the formulation's constituents, Fourier transform infrared spectroscopy (FTIR) was utilised. The incompatibility between the drug and the excipients was predicted by observing changes in the drug's distinctive peaks after mixing with the excipients. This method involves subjecting the sample to infrared radiation from an infrared source, which is then absorbed by the sample and deposits energy quanta into vibrational modes, stimulating vibrational movements. As a result, a molecule only absorbs radiation at frequencies that correspond to its molecular modes of vibration in the area of the electromagnetic spectrum between visible and short waves when it is subjected to radiation caused by the thermal emission of a hot source. Bands in the vibrational spectrum are created by these variations in vibrational motion, and each spectral band is identified by its frequency and amplitude.

1. **Size, Morphology and Size distribution:** The size of niosomes and their morphology can be determined using a variety of methods, including light microscopy, photon correlation spectroscopy, electron microscopic analysis, SEM (scanning electron microscope) and TEM (transmission electron microscope), freeze-fracture replicators, light scattering, zeta sizer and meta sizer. Due to the differing measurement theories employed by the two, the transmission electron microscopy (TEM) approach yields lower particle sizes than the dynamic light scattering (DLS) method.
2. **Zeta potential:** The charge on niosomes causes them to repel one another. Additionally, this electrostatic repulsion maintains them stable by avoiding fusion and aggregation. Zeta potential is used to measure the niosome charge. The zeta potential is measured using a zeta potential analyzer, master size, microelectrophoresis, pH-sensitive fluorophores, high-performance capillary electrophoresis, and DLS equipment. Henry's equation is used to determine zeta potential.

Where, £ = Zeta potential.

μE = Electrophoretic mobility

 η = Viscosity of medium

Σ = Dielectric constant

1. **Optical Microscopy:** A drop of prepared sample was placed on glass slide and covered with a slip and these were viewed under optical microscope with magnification of 1200X. The obtained vesicles were taken by using digital SLR camera.
2. **Drug Content:** The drugs that are still in niosomes are identified by completely disrupting the vesicles with 50% n-propanol or 0.1% Triton X-100 or methanol and analysing the resulting solution using an appropriate assay method for the drug.
3. **Entrapment efficiency:** Unentrapped drugs are separated by dialysis, centrifugation, or gel filtration after niosomal dispersion has been prepared. This was kept for ultracentrifugation at 17000rpm for 40 minutes and temperature at 4oC. In this the supernatant layer was collected and analyzed by using UV spectrophotometer.
4. **In-vitro drug release studies:** The Invitro drug release studies were done by using Franz diffusion cells. In this it contains two chambers one is donor chamber and the other is receptor. The dialysis membrane was soaked before and placed in between the chambers. The niosomal suspension was kept in donor chamber and in receptor chamber phosphate buffer was kept with continuous stirring at 100rpm in magnetic stirrer and the sample was withdrawn at specific time interval and analyzed under UV spectrophotometer.
5. **Stability studies:** The optimised batch was placed in airtight, sealed vials and kept there at various temperatures to test the stability of niosomes. Because drug leakage and decrease would result from formulation instability, surface characteristics and the proportion of drug maintained in niosomes and niosomes formed from proniosomes were chosen as metrics for assessing stability in terms of drug retention rate. The niosomes were sampled at regular intervals (0,1,2, and 3 months), observed for colour changes and surface properties, and tested for the percentage of drug retained after being hydrated to form niosomes and analysed using appropriate analytical methods (UV spectroscopy, HPLC methods, and so on) (64).

**Applications of Niosomes (65,66,67):**

1. **To Increase Oral Bioavailability:** As compared to the drug alone, it has been shown that the formulation of niosomes increased the oral bioavailability of acyclovir and griseofulvin. Similar to this, when provided as micellar solution together with the POE-24- cholesteryl ester in the bile duct of rats, poorly absorbed peptide and ergot alkaloid absorption can be boosted (63).
2. **Anticancer Drug Delivery:** In order to increase the therapeutic index of the anticancer drugs by localising the cytotoxic effects to target cells, methotrexate-loaded niosomes were initially used as a more reliable and cost-effective alternative drug delivery technology to liposomes. When vincristine was enclosed in niosomes, its anti-tumour action was also enhanced in mice having Ehrlich ascites and S-180 sarcoma. Additionally, in the two tumour types indicated above, Span 60 bleomycin niosomes enhanced bleomycin's anti-tumour effects. Doxorubicin's cytotoxic side effects were lessened when it was enclosed in C16G2 niosomes. The dosages chosen for usage in vivo did not cause hemolysis in vitro when doxorubicin copolymer-loaded niosomes were used. On the liver and spleen, C16G2 niosomes likewise had localised, long-lasting effects. In addition, niosomal delivery systems for 5-flurouracil based on Span 40 and Span 60 demonstrated a sustained and increased local concentration of the drugs in the liver and kidney of the rats when compared to the injectable drug solution. Recently, drug release has been effectively regulated using niosomes for the magnetic targeting of doxorubicin to a particular organ with no further toxicity.
3. **NSAIDS:** The preparation of NSAID-loaded niosomes has been done by a number of different companies. Adverse reactions including mucosal irritation are possible with these drugs. Topically applied NSAID-loaded niosomes can considerably improve drugs penetration. Marianecci et al. developed ammonium glycyrrhizinate (AG) loaded niosomes with various surfactants and cholesterol concentrations to investigate the potential use of niosomes for anti-inflammatory drug delivery. Drug entrapment efficacy, anisotropy, cytotoxicity, skin tolerability, and other parameters were explored for characterization. The AG- loaded niosomes demonstrated great skin tolerability, non toxin, and the capability to ameliorate anti-inflammatory exertion in mice. Additionally, when applied to chemically produced human skin erythema, the anti-inflammatory effect of the medication supplied through niosomes was shown to be enhanced.
4. **Antiviral Drugs:** The capacity of niosomes to distribute different antiviral drugs has also been established. Zidovudine, the first anti-HIV drug licensed for clinical use, was developed by Ruckman and Sankar. They then entrapped niosomes and evaluated the effectiveness of their entrapment as well as the sustainability of release. The ratios of Tween, Span, and cholesterol were combined to create niosomes. Tween 80 niosomes caught a large amount of zidovudine, and the addition of diacetyl phosphate extended the duration of drug release. Compared to niosomes maintained at 4°C for 90 days, the drug leakage from Tween 80 formulations held at room temperature was substantial. Further evidence that Tween 80 formulations containing diacetyl phosphate were eliminated from circulation after five hours came from the results of a pharmacokinetic research conducted on rabbits.
5. **Leishmaniasis:** Drugs that target the niosome can be utilised to treat illnesses when the reticuloendothelial system's organ is the site of the infecting organism. A parasite infects the liver and spleen cells to cause leishmaniasis. Antimonials, which are routinely prescribed medications and are related to arsenic, harm the heart, liver, and kidney at high amounts. After administering sodium stibogluconate in the free, liposomal, and niosomal forms, the quantities of antimony in the mouse's liver and serum were measured. Both vesicular formulations resulted in high liver and low serum levels. The ability of niosomal sodium stibogluconate to treat experimental murine visceral leishmaniasis to be more effective than free drug appears to be contingent on maintaining high drug levels in the infected reticuloendothelial system.
6. **Cosmetics:** The cosmetic products developed by L'Oreal were the source of the first report of non-ionic surfactant vesicles. In the 1970s and 1980s, L'Oréal invented and patent niosomes. Lancôme debuted "Niosome," the first product, in 1987. The benefits of employing niosomes in cosmetic and skin care products include their capacity to improve the bioavailability of chemicals that are difficult to absorb as well as skin penetration.
7. **Peptide drug delivery:** It has long been difficult to avoid the enzymes that would break down peptides used in drug administration. Investigations are being done on the potential use of niosomes to successfully shield peptides from peptide breakdown in the gut. An in vitro study utilising a vasopressin derivative trapped in niosomes indicated that drug entrapment significantly increased peptide stability (68).
8. **Antibiotics:** Antibiotic and anti-inflammatory drug delivery can be accomplished using niosomal carriers. These carriers have been employed often to increase drugs retention in the skin and to improve ineffective skin penetration. Rifampicin, a niosomal delivery system-encapsulated wide range antibiotic, was developed by Begum and her colleagues. This work demonstrated that the niosomal formulation of rifampicin is capable of providing constant and sustained release of the medication. They studied the activity of this system in in vitro environments.
9. **Antifungal agents:** When compared to other carriers, the use of niosome as a drug carrier, particularly for antifungal drugs, produces better results. The capacity to encapsulate both hydrophilic and hydrophobic drugs, as well as their prolonged stability in circulation, are all major characteristics of niosomes. They also considerably improve drug penetration through the skin. They may make suitable candidates for the treatment of fungi-related disorders since the cost of the raw ingredients (mainly surfactants) is lower than that of liposomes (69).

**Conclusion:** Solubility is seen as a major concern in the formulation of dosage forms. The conventional drug delivery system has limitations, which lead to poor solubility and bioavailability. A novel technique showed a major contribution to improving the solubility effects of various poorly soluble drugs. By developing nanosuspension and vesicular drug delivery systems (Transferosomes, invasomes, and Niosomes), Solubility issues will improve and the drug will show its effect on the target site.

**References**

1. [PatravaleVetal.Nanosuspensions:apromising drug delivery strategy.](https://www.slideshare.net/rahildalal9/nanosuspensions-39136262#40) Journal of Pharmacy and Pharmacology 2004;56:827-40
2. L.Wuetal.Physical and chemical stability of drug nanoparticles .Advanced Drug Delivery Reviews.2011;63:456-69
3. Mulleretal.Nanpsuspensions:A formulation approach for poorly soluble and poorly bioavailable drugs.Handbook of pharmaceutical controlled release technology,1stEdition(2005) ,published by MarcelDekker,pg345- 356
4. Das Setal .Nanosuspension: a new vehicle for the improvement of the delivery of drugs to the ocular surface. Application to amphotericinB. Nanomedicine: Nanotechnology, Biology and Medicine.2011;7:242-47
5. Gargetal .Formulation and pharmacokinetic evaluation of a nasulacrine nanocrystalline suspension for intravenous delivery.InternatoinalJournalofPharmaceutics.2009;367:179-86
6. Singh Ketal .Surface modified nevirapine nanosuspensions for viral reservoir targeting:Invitro and invivo evaluation.InternatoinalJournalofPharmaceutics.2011;421:341-51
7. Patel VR, Agrawal YK. Nanosuspension: An approach to enhance solubility of drugs. J Adv Pharm Technol Res. 2011 Apr;2(2):81-7. doi: 10.4103/2231-4040.82950. PMID: 22171298; PMCID: PMC3217698.
8. Singh SK, Vaidya Y, Gulati M, Bhattacharya S, Garg V, Pandey NK. Nanosuspension: Principles, Perspectives and Practices. Curr Drug Deliv. 2016;13(8):1222-1246. doi: 10.2174/1567201813666160101120452. PMID: 26721266.
9. Yarraguntla, Srinivasa Rao & Kamala Kumari, Paravastu. . Nanosuspensions: A Review international journal of pharmacy 2011 vol 7. 77-89.
10. Sachin S.Pawar, BajiraoR.Dahifale, SandipP.Nagargoje, RajanS.Shendge. Nanosuspension Technologies for Delivery of Drugs. Nanoscience and Nanotechnology Research. 2017 Vol. 4, No. 2, , page no 59-66.doi <http://pubs.sciepub.com/nnr/4/2/4>
11. Jacob, S., Nair, A.B. & Shah, J. Emerging role of nanosuspensions in drug delivery systems. Biomater Res  2020 vol 24, 3 . <https://doi.org/10.1186/s40824-020-0184-8>
12. Sarika V. Khandbahale. A Review- Nanosuspension Technology in Drug Delivery System. Asian J. Pharm. Res. 2019; 9(2): 130-138. doi: 10.5958/2231-5691.2019.00021.2
13. Jacob S, Nair AB, Shah J. Emerging role of nanosuspensions in drug delivery systems. Biomater Res. 2020 Jan 15;24:3. doi: 10.1186/s40824-020-0184-8. PMID: 31969986; PMCID: PMC6964012.
14. Patel, Vishal & Agrawal, Yadvendra. (2011]. Nanosuspension: An approach to enhance solubility of drugs. Journal of advanced pharmaceutical technology & research. 2. 81-7. 10.4103/2231-4040.82950.
15. Geeta Vikram Yadav\* and Sushma R. Singh NANOSUSPENSION: A PROMISING DRUG DELIVERY SYSTEM Pharmacophore (An International Research Journal) , 2012 Vol. 3 (5)
16. Dhiman, S Dharmila and Thakur, GS “Nanosuspension: A recent approach for nano drug delivery system”, Int J Curr Pharm Res, Vol 3, Issue 4, 96-101.
17. Jagdale, DM; Kamble, VA and Kadam, VJ (2010), “Nanosuspension a novel drug delivery system”, International Journal of Pharma and Bio Sciences, Vol.1, Issue-4, 352-360.
18. Prabhakar, Ch. (2011), “A review on nanosuspensions in drug delivery”, International Journal of Pharma and Bio Sciences, Vol 2, Issue 1
19. Bhargavi, R (2001), “A technical review of nanosuspensions”, International Journal of Pharmacy &Technology, Vol. 3, Issue No.3, 1503-1511.
20. Bucolo, C; Maltese, A; Pignatello, R and Spedalieri, G et. al. (2002), “Flurbiprofen loaded acrylate polymer nanosuspensions for ophthalmic application”, Biomaterials, 23, 3247-3255
21. Chavan Vaishnavi, Miss. Pooja Bhonde, Dr. Gajanan Sanap. Vesicular Drug Delivery System. Journal of Emerging Technologies and Innovative Research ( JETIR) , 2014, March 2023, Volume 10, Issue 3 .
22. [Reshmi Rajan](https://pubmed.ncbi.nlm.nih.gov/?term=Rajan%20R%5BAuthor%5D), [Shoma Jose](https://pubmed.ncbi.nlm.nih.gov/?term=Jose%20S%5BAuthor%5D), [V. P. Biju Mukund](https://pubmed.ncbi.nlm.nih.gov/?term=Mukund%20VP%5BAuthor%5D), and [Deepa T. Vasudevan](https://pubmed.ncbi.nlm.nih.gov/?term=Vasudevan%20DT%5BAuthor%5D) . Transferosomes - A vesicular transdermal delivery system for enhanced drug permeation, Journal of Advanced pharmaceutical technology and research, 2011 Jul-Sep; 2(3): 138–143.
23. Fernández-García, Raquel, Aikaterini Lalatsa, Larry Statts, Francisco Bolás-Fernández, M. Paloma Ballesteros, and Dolores R. Serrano. "Transferosomes as nanocarriers for drugs across the skin: Quality by design from lab to industrial scale." International journal of pharmaceutics 573 (2020): 118817.
24. Shaik Sajid Ali, Madhu Gudipati\* , Ramarao Nadendla, Current Status and Future Prospects of Transfersomal Drug Delivery, Scholars Research Library, Der Pharmacia Lettre, 2023, 15(1): 01-09.
25. Merin P. Eldhose\*, Flowerlet Mathew, Neethusha J. Mathew, Merin P. Eldhose\*, Transfersomes – A Review, Human Journals Review Article July 2016 Vol.:6, Issue:4
26. Nirlep kaur, Transdermal Drug Delivery through Carriers: Transfersomes,Rx Pharmatutor Pharmacy Infopedia , ISSN: 2347-7881.
27. Shaik Sajid Ali, Madhu Gudipati\* , Ramarao Nadendla, Current Status and Future Prospects of Transfersomal Drug Delivery, Scholars Research Library Der Pharmacia Lettre, 2023, 15(1): 01-09.
28. [Dharmendra Solanki](https://www.researchgate.net/profile/Dharmendra-Solanki), [Lalit Kushwah](https://www.researchgate.net/scientific-contributions/Lalit-Kushwah-2166232879), [icky Chouhan](https://www.researchgate.net/scientific-contributions/Vicky-Chouhan-2166229238) [Mohit Motiwale](https://www.researchgate.net/profile/Mohit-Motiwale), TRANSFEROSOMES-A REVIEW, October 2016 [WORLD JOURNAL OF PHARMACY AND PHARMACEUTICAL SCIENCES](https://www.researchgate.net/journal/WORLD-JOURNAL-OF-PHARMACY-AND-PHARMACEUTICAL-SCIENCES-2278-4357) 5(10):435-449.
29. Nirlep kaur, Transdermal Drug Delivery through Carriers: Transfersomes,Rx Pharmatutor Pharmacy Infopedia , ISSN: 2347-7881.
30. [Reshmy Rajan](https://pubmed.ncbi.nlm.nih.gov/?term=Rajan%20R%5BAuthor%5D), [Shoma Jose](https://pubmed.ncbi.nlm.nih.gov/?term=Jose%20S%5BAuthor%5D), [V. P. Biju Mukund](https://pubmed.ncbi.nlm.nih.gov/?term=Mukund%20VP%5BAuthor%5D), and [Deepa T. Vasudevan](https://pubmed.ncbi.nlm.nih.gov/?term=Vasudevan%20DT%5BAuthor%5D), Transferosomes - A vesicular transdermal delivery system for enhanced drug permeation, [J Adv Pharm Technol Res.](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3217704/) 2011 Jul-Sep; 2(3): 138–143.
31. Kalyani.V & M.Kishore Babu, Transferosomes: An emerging tool for effective transdermal drug delivery, Journal of Chemical and Pharmaceutical Sciences, ISSN: 0974-2115
32. Soraya Babaie , Azizeh Rahmani Del Bakhsayesh, Ji Won Ha, Ki Hyun Kim, Invasome: A Novel Nanocarrier for Transdermal Drug Delivery, Feb 2020
33. [PK Lakshmi](https://www.researchgate.net/scientific-contributions/PK-Lakshmi-2162727153) , [B Kalpana](https://www.researchgate.net/scientific-contributions/B-Kalpana-2061338332) , [Prasanthi Domaraju](https://www.researchgate.net/profile/Prasanthi-Domaraju) , [Invasomes-novel Vesicular Carriers for Enhanced Skin Permeation](https://www.researchgate.net/publication/269967529_Invasomes-novel_Vesicular_Carriers_for_Enhanced_Skin_Permeation), Jan 2013
34. [PK Lakshmi](https://www.researchgate.net/scientific-contributions/PK-Lakshmi-2162727153) , [B Kalpana](https://www.researchgate.net/scientific-contributions/B-Kalpana-2061338332) , [Prasanthi Domaraju](https://www.researchgate.net/profile/Prasanthi-Domaraju) , [Invasomes-novel Vesicular Carriers for Enhanced Skin Permeation](https://www.researchgate.net/publication/269967529_Invasomes-novel_Vesicular_Carriers_for_Enhanced_Skin_Permeation), Jan 2013
35. A Krishna Sailajaand T Meghana, Applications of Invasomal Drug Delivery System, Archieves of Pharmacy & Pharmacology Research ( APPR) , October 22,2021.
36. G. Pavan Kumar\*, Dr. P. Veera Lakshmi, S. Bhargavi, B. SudhaRani, A REVIEW ON INVASOMES: NOVEL VESICLES FOR TRANSDERMAL DRUG DELIVERY, 2022 JETIR December 2022, Volume 9, Issue 12.
37. [Soraya Babaie](https://pubmed.ncbi.nlm.nih.gov/?term=Babaie%20S%5BAuthor%5D), [Azizeh Rahmani Del Bakhshayesh](https://pubmed.ncbi.nlm.nih.gov/?term=Del%20Bakhshayesh%20AR%5BAuthor%5D), [Ji Won Ha](https://pubmed.ncbi.nlm.nih.gov/?term=Ha%20JW%5BAuthor%5D), [Hamed Hamishehkar](https://pubmed.ncbi.nlm.nih.gov/?term=Hamishehkar%20H%5BAuthor%5D),,\* and [Ki Hyun Kim](https://pubmed.ncbi.nlm.nih.gov/?term=Kim%20KH%5BAuthor%5D) , Invasome: A Novel Nanocarrier for Transdermal Drug Delivery, [Nanomaterials (Basel).](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7075144/) 2020 Feb; 10(2): 341.
38. [Thanaporn Amnuaikit](https://pubmed.ncbi.nlm.nih.gov/?term=Amnuaikit+T&cauthor_id=32104421), [Tunyaluk Limsuwan](https://pubmed.ncbi.nlm.nih.gov/?term=Limsuwan+T&cauthor_id=32104421), [Pasarat Khongkow](https://pubmed.ncbi.nlm.nih.gov/?term=Khongkow+P&cauthor_id=32104421), [Prapaporn Boonme](https://pubmed.ncbi.nlm.nih.gov/?term=Boonme+P&cauthor_id=32104421)Vesicular carriers containing phenylethyl resorcinol for topical delivery system; liposomes, transfersomes and invasomes,Pubmed , Asian J Pharm Sci  2018 Sep;13(5):472-484.
39. [Soraya Babaie](https://sciprofiles.com/profile/964493) , [Azizeh Rahmani Del Bakhshayesh](https://sciprofiles.com/profile/642932) , [Ji Won Ha](https://sciprofiles.com/profile/author/ZW43MDhHeE1wWEZmWm5INm10YW5JZWY4NTFnalhwK25jbmlMRkorK0dvQT0%3D) , [Hamed Hamishehkar](https://sciprofiles.com/profile/799086) , [Ki Hyun Kim](https://sciprofiles.com/profile/280876) , Invasome: A Novel Nanocarrier for Transdermal Drug Delivery, Nanomaterials 2020, 10(2), 341
40. Wilczewska AZ, Niemirowicz K, Markiewicz KH, Car H. Nanoparticles as drug delivery systems. Pharmacological reports. 2012 Sep 1;64(5):1020-37.
41. Bhowmik D, Gopinath H, Kumar BP, Duraivel S, Kumar KS. Controlled release drug delivery systems. The Pharma Innovation. 2012 Dec 1;1(10).
42. Adepu S, Ramakrishna S. Controlled drug delivery systems: current status and future directions. Molecules. 2021 Sep 29;26(19):5905.
43. Kamboj S, Saini V, Magon N, Bala S, Jhawat V. Vesicular drug delivery systems: a novel approach for drug targeting. brain. 2013;1(11).
44. Biju S, Talegaonkar S, Mishra P, Khar R. Vesicular systems: an overview. Indian journal of pharmaceutical sciences. 2006 Mar 1;68(2).
45. Tewabe A, Abate A, Tamrie M, Seyfu A, Abdela Siraj E. Targeted drug delivery—from magic bullet to nanomedicine: principles, challenges, and future perspectives. Journal of Multidisciplinary Healthcare. 2021 Jul 5:1711-24.
46. Jadhav SM, Morey P, Karpe MM, Kadam V. Novel vesicular system: an overview. Journal of applied pharmaceutical science. 2012 Jan 30(Issue):193-202.
47. Abraham Lingan, M. "Formulation and evaluation of topical drug delivery system containing clobetasol propionate niosomes." PhD diss., Madurai Medical College, Madurai, 2008.
48. Parmar A, Brijesh S. Niosomes as Transdermal Drug Delivery System. Biomedical Research Journal. 2018 Jan 10;5(2).
49. Shaji J, Shah A. Niosomes: A novel drug delivery system. World J Pharm Res. 2015 Mar 29;4(06):853-76.
50. Shakya V, Bansal BK. Niosomes: a novel trend in drug delivery. International Journal of Research and Development in Pharmacy & Life Sciences. 2014 Jul 15;3(4):1036-41.
51. Makeshwar KB, Wasankar SR. Niosome: a novel drug delivery system. Asian journal of pharmaceutical research. 2013;3(1):16-20.
52. Ge X, Wei M, He S, Yuan WE. Advances of Non-Ionic Surfactant Vesicles (Niosomes) and Their Application in Drug Delivery. Pharmaceutics. 2019 Jan 29;11(2):55.
53. Parekh F, Patel B, Vyas K, Patani P. Recent Advances and Scopes In Niosomes. Journal of Pharmaceutical Negative Results. 2022 Nov 12:2093-102.
54. Kazi, K. M., Mandal, A. S., Biswas, N., Guha, A., Chatterjee, S., Behera, M., & Kuotsu, K. (2010). Niosome: A future of targeted drug delivery systems. Journal of advanced pharmaceutical technology & research, 1(4), 374–380.
55. Momekova DB, Gugleva VE, Petrov PD. Nanoarchitectonics of Multifunctional Niosomes for Advanced Drug Delivery. ACS Omega. 2021 Dec 6;6(49):33265-33273
56. Tangri P, Khurana S. Niosomes: Formulation and evaluation. International Journal. 2011; 2229:7499.
57. Gharbavi M, Amani J, Kheiri-Manjili H, Danafar H, Sharafi A. Niosome: a promising nanocarrier for natural drug delivery through blood-brain barrier. Advances in Pharmacological and Pharmaceutical Sciences. 2018 Dec 11;2018.
58. Thabet Y, Elsabahy M, Eissa NG. Methods for preparation of niosomes: A focus on thin-film hydration method. Methods. 2022 Mar 1; 199:9-15.
59. Khoee, S., & Yaghoobian, M. Niosomes: a novel approach in modern drug delivery systems. Nanostructures for Drug Delivery, 2017, 207–237.
60. Shirsand SB, Keshavshetti GG. Recent advances in niosomal drug delivery—A review. Res. J. Life Sci. Bioinform. Pharm. Chem. Sci. 2019; 3:514-31.
61. Sezgin-Bayindir Z, Yuksel N. Investigation of formulation variables and excipient interaction on the production of niosomes. Aaps Pharmscitech. 2012 Sep; 13:826-35.
62. Bhardwaj P, Tripathi P, Gupta R, Pandey S. Niosomes: A review on niosomal research in the last decade. Journal of Drug Delivery Science and Technology. 2020 Apr 1; 56:101581.
63. Rajera R, Nagpal K, Singh SK, Mishra DN. Niosomes: a controlled and novel drug delivery system. Biological and Pharmaceutical Bulletin. 2011 Jul 1;34(7):945-53.
64. Sharma D, Aara A, Aate J. Niosomes as Novel Drug Delivery System: Review Article. Pharma Tutor 2018; 6(3):58-65
65. Abdelkader H, Alani AW, Alany RG. Recent advances in non-ionic surfactant vesicles (niosomes): self-assembly, fabrication, characterization, drug delivery applications and limitations. Drug delivery. 2014 Mar 1;21(2):87-100.
66. Ag Seleci D, Seleci M, Walter JG, Stahl F, Scheper T. Niosomes as nanoparticular drug carriers: fundamentals and recent applications. Journal of nanomaterials. 2016 Oct;2016.
67. Nasir A, Harikumar SL, Amanpreet K. Niosomes: An excellent tool for drug delivery. international journal of research in pharmacy and chemistry. 2012;2(2):479-87.
68. Atif M, Singh SP, Kumar A. NIOSOMES: A NOVEL FORMULATION FOR ANTI-AGEING COSMECEUTICALS. European Journal of Biomedical. 2018;5(4):370-5.
69. Osanloo M, Assadpour S, Mehravaran A, Abastabar M, Akhtari J. Niosome-loaded antifungal drugs as an effective nanocarrier system: A mini review. Current medical mycology. 2018 Dec;4(4):31.