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Solid Lipid Nanoparticles: A Novel Method to Drug Delivery Formulation

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Abstract

Solid lipid nanoparticles, which have numerous powerful advantages for clinical therapy, drug transportation, investigation, and an extensive array of many other fields of science, are at the forefront of a quickly developing field of nanotechnology. Lipid nanoparticles also have the potential to contribute to the creation of novel therapeutics because of their unique size-dependent properties. Opioids can now be added to nanocarriers, creating an unknown drug delivery prototype that could be used for therapeutic targeting at the secondary and tertiary levels. So, because solid lipid nanoparticles have great potential for attaining the goal of controlled and site-specific drug delivery, researchers are particularly interested in them. This paper examines a variety of solid lipid nanoparticles and discusses their advantages, disadvantages, and potential remedies. The various lipid-based stable nanocarriers, including lipid drug conjugates, solid lipid nanoparticles, and nanostructured lipid carriers, are presented along with their structural variations. Solid lipid nanoparticles can be produced in various ways and for multiple purposes on a large scale. The appropriate analytical techniques for characterizing stable lipid nanoparticles are highlighted, such as scanning electron microscopy, photon correlation spectroscopy, and differential scanning calorimetry. Additionally taken into account are the solid lipid nanoparticle delivery strategy and biodistribution. Stable lipid nanoparticles could completely alter how complex diseases are treated if thoroughly investigated.

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INTRODUCTION

Nanotechnology was colloid nanoparticles with a size between 10 and 1000 nm. These evolved into a versatile alternative to liposomes for drug delivery carriers. Nanoparticles should be capable of crossing various anatomical barriers, have a sustained release of their contents, and be stable inside the nanometer range for medication delivery. They are excellent for enhancing drug distribution and reducing toxic effects and can be produced with natural or synthetic materials. Furthermore, their widespread usage of nanoparticles through treatment has been

constrained by the lack of safe polymers with regulatory permission and their high price [1].

For lipophilic medications, lipids have been suggested as an alternative carrier to get around these polymeric nanoparticle limitations. These lipid nanoparticles are called solid lipid nanoparticles (SLNs), attracting many formulators' interest worldwide [2] . In the last ten years, SLNs, a new class of colloidal carriers, have been developed as an alternative to currently used conventional carriers (emulsions, liposomes, and polymeric nanoparticles). They fall under a novel class of submicron-sized lipid emulsions where the liquid lipid has been swapped out for a solid lipid (oil). The performance of drugs, neutraceuticals, and other materials can be improved by SLN, making them appealing [3] . Small size, huge surface area, high drug loading, and interface phase interaction are only a few of these unique characteristics.

SLNs are receiving much attention as cutting-edge colloidal drug carriers for intravenous applications. The physiological lipid-based SLNs, or sub-micron colloidal carriers, are dispersed in water or an aqueous surfactant solution. Therefore, if they are well-investigated, SLNs may present fresh opportunities for research and treatment [4] .

SLNs and other nanoparticles: successes and problems

Table 1 [5] demonstrates how SLNs combine the advantages of many colloidal carriers while avoiding their drawbacks. Potential downsides have included low Opioid ejection at polymeric transformation while storing, drug loading capacity, and the relatively high amount of water of dispersions (70-99.9%) also factors. A drug's solubility inside the lipid melt, its composition of a lipid matrix, and the liposome's polymerization state all impact the capacity to load drugs in conventional SLN. A perfect crystal with few faults (such as tristearin or tripalmitin) will form if remarkably similar molecules are present in the lipid matrix. Although integration medications were current, a highly complex crystalline structure cannot exist among fatty-acid chains, phospholipid layer, and crystal flaws might store the considerable quantity of drugs. Accordingly, using highly complex triglycerides for more medication loading makes more sense [6] .

Nanostructured lipid carriers (NLC)

NLCs were created to address potential SLN issues [7] . The goals were to increase medication loading and prevent drug ejection. There are three different ways you could picture this. The first idea entails combining lipids (such as glycerides) composed of numerous spatially distinct fatty acids. Due to various crystallographic faults and the use of spatially different lipids, the heavy acid chains of the glycerides are spaced farther apart, giving guest molecules more room to stay. The most significant drug load would be produced by combining modest amounts of liquid lipids with solid lipids (oils). This model is known as incomplete type NLC. Drugs can dissolve in oils that are more soluble than in solid lipids while yet being protected from deterioration by the solid lipids around them. These varieties of NLC, also known as numerous types of NLC and comparable to w/o/w emulsions, are an oil-in-solid-lipid-in-water dispersion.

The solid lipid's ongoing transformation into crystals or other forms leads to drug ejection; consequently, creating a third type of NLC—the amorphous—can halt this. The combination of specific lipids such as hydroxyl octacosanyl, hydroxyl stearate, and isopropyl myristate prevents cooling-induced crystallization despite the firmness of the particles. For the administration of ascorbyl palmitate, ketoconazole, other antifungal imidazoles, clotrimazole, and other antifungal imidazoles, the NLCs have primarily been explored in topical and dermatological preparations [8] .

Lipid drug conjugates (LDC)

Only extremely potent low-dose hydrophilic medications can efficiently integrate the solid matrix of lipids. These matrices may be helpful for hydrophilic drug targeting in the brain during severe protozoal infections [9] . The significant problem is that SLNs are restricted to loading hydrophilic medications due to partitioning effects during manufacturing. As such LDC nanomaterials containing drug-loading capabilities of up to 33% have now been developed to overcome this restriction. The initial step in producing an insoluble drug-lipid conjugate mass is covalent bonding or salt formation (using, for instance, an acid fatty) (e.g., to ester or ethers). To formulate a nanoparticle composition, this resulting LDC is then treated utilizing highly pressurized homogenization and an aqueous surfactant mixture (such as Tweens) (HPH) [10] .

SLN Preparation

SLNs contain a surfactant, water/solvent, and solid lipid (Table 2). An undeniable advantage of SLN is that the lipid matrix comprises physiological lipids, lowering the risk of acute and long-term toxicity. Lipids (tri-stearin), partially glycerides (Imwitor), essential fats (tartaric acid, linoleic acid), steroids (cholesterol), as well as paraffin are a few of the triglycerides that may be used (cetyl palmitate). To consolidate its lipids dispersal, numerous emulsi-

Table 1: Benefits of solid lipid nanoparticles

Solid lipid nanoparticle benefits
Organize and plan drug release.
Increase the drugs' stability.
Increased and higher drug content (compared to other carriers).
The ability to transport drugs that are both hydrophilic as well as lipophilic.
SLNs are highly biocompatible since the majority of triglycerides are biodegradable.
A technology based on water (avoid organic solvents).
Simple to sterilize and scale up.
More reasonably priced (cheaper than carriers based on polymers or surfactants).
Validation and regulatory approval are simpler to obtain.

Table 2: Ingredients Used in Nanoparticles Creation [11]

Name of the Ingredient	Concentration
Tego Care 450 (surfactant)	1.2%w/w
Pluronic F 68	40%
PEG 2000	0.25%
PEG 4500	0.5%
PEG 400	5%
Isopropyl myristate	3.60%
Lipid	3.33%w/v
Phospholipids	0.6-1.5%
Cetyl palmitate	10%w/w
Poloxamer 188	1.2-5%w/w
Compritol	10%
Ethyl oleate	30%
Na alginate	70%
Tristearin glyceride	95%
Ethanol/butanol	2%
Soy phosphatidylcholine	95%
Glycerol	2-4%
Tween 85	0.5%
Tween 80	50%

fiers as well as their mixtures (Pluronic F 68, F 127) have now been utilised. Emulsifiers can be added to avoid particle agglomeration more successfully [12] . The emulsifier selection is influenced by the mode of delivery, with a respectable number of emulsifiers suitable for parenteral administration. Many methods are listed in Table 3 for establishing SLNs.

SLN preparation method

Homogenization at high shear

High-shear homogenization techniques were initially used to produce solid lipid nanodispersions. Both strategies are shared and practicable. However, the presence of minute particles frequently diminishes the dispersion quality. The high-speed homogenization technique produces SLN utilizing melt emulsification and investigated the impact of various process variables on particle size and zeta potential, including cooling conditions, emulsification time, and stirring rate. The lipids used in this experiment included trimyristin, tripalmitin, and a mixture of mono, di, and triglycerides (Witepsol W35, Witepsol H35) [13] . As steric stabilizers, glycerol behenate and poloxamer 188 were utilized (0.5% w/w). After stirring at 20,000 rpm for 8 minutes, letting the mixture cool for 10 minutes, and starting at 5000 rpm at room temperature, the ideal SLN quality for Witepsol W35 dispersions was attained. The ideal emulsification and chilling times for Dynasan 116 dispersions were 10 minutes at 25,000 rpm for emulsification and 5 minutes at 5,000 rpm in cool water ($\approx 16^0$) for chilling. Faster stirring did not significantly change the particle size, although it slightly raised the polydispersity index.

Table 3: SLN Preparation Methods

Different preparation methods of SLNs
Homogenization at high shear:
Homogenization in heat
Freezing and homogenizing
High-speed homogenization using ultrasound: probe ultrasound
Ultrasonic bathing
Evaporation and emulsification of solvents
SLN preparations based on microemulsions
Supercritical fluid preparation for SLN
Using a sprayer to dry
Using a double emulsion

Intense or HOI homogenization

At a temperature above the melting temperature of a lipid, heated homogenization was done, very similar to the homogenization of such emulsification. The drug-loaded triglyceride melts the aqueous emulsifier phase and forms a pre-emulsion utilizing high-shear mixing apparatus (such as a silk version-type homogenizer) at the same temperature. The ideal droplet size is since the quality of the pre-quality emulsion seems to substantially affect the final product, with a region of just a few micrometers. High pressure is applied to homogenize a pre-emulsion just above triglyceride melting temperature. Most frequently, small particle sizes are produced because the lipid phase is less viscous at higher processing temperatures, albeit this could also speed the breakdown of medicament and its carrier. Several passing it through a strong homogenizer are followed by, typically, 3-5 passes and only commodities are generated. A sample's temperature increases (roughly 10° at 500 bar) throughout high-pressure processing [14] . Among 500 and 1500 bar, 3-5 homogenization cycles were generally sufficient. Particle crystallization was produced either by particles' high kinetic energies. Which increases particle size as homogeneity increases.

Homogenizing cold

The cold homogenization process is akin to the high-pressure grinding of a solution since it utilizes the solid lipid. To ensure Following homogenization, a lipid is solid; efficient temp control is necessary. The creation of cold homogenization addressed the following problems with the heat homogenization method: divided drug payloads as well as subsequent aqueous phase following homogeneity, causing a loss, temperature-mediated fast drug degradation, Unknown triglyceride polymorphism transition brought on by the challenging crystallization process of the nano-emulsion, which may lead to several alterations or supercooled melts [15] .

As in the heat homogenization procedure, the first preliminary stage solubilizes or disperses the medication in the lipid melt. But the succeeding steps are distinct. The quick chilling facilitates the uniform dispersion of the drug in the lipid matrix from the Opioid melting utilizing liquid nitrogen relatively than dry ice. Solid lipids of a medication content are efficiently reduced to microparticles using ball/mortar milling. The usual range of particle sizes is 50–100 microns. The increased lipid fragility caused by cold processing made particle milling much simpler. A cooled emulsifier solution is combined with the SLNs. High-pressure homogenization of dispersal is conducted with appropriate temperature regulation, either at or below the room temp and consideration for the expected temperature rise during high-pressure processing. In comparison to hot homogenized samples, cold homogenized samples frequently show a wider size dispersion and larger particle sizes [16] . The cold homogenization method lessens but does not eliminate a molecule's presence to heat as either a result of a lipid/drug interaction first melts.

High-speed homogenization or ultrasonication

These two procedures were also used to construct SLN. One of the main advantages is that every piece of equipment employed in this facility is very standard. This approach's broader particle size distribution, which can reach the micrometer range, is harmful. Particle growth during storage was one of the physical instability effects of this. This method's potential metal contamination caused by A significant issue is ultrasonication. To produce a consistent formula, fast mixing, and ultrasonication in conjunction with high temperatures are required, according to studies undertaken by

numerous research organizations [17] .

SLN produced by solvent evaporation/emulsification

To produce the dispersal of nanoparticles, A lipophilic substance was dispersed in a water-impermeable organic liquid (cyclohexane) emulsified inside an aqueous solution by precipitating into o/w emulsions. When the water evaporated, a nanoparticle dispersal was generated, and the triglyceride was poured into an aqueous medium. While cholesterol acetate functioned as a model drug and a lecithin/sodium glycocholate mixture was provided as an emulsion, the generated nanoparticles had an average diameter of around 25 nm. Siekmann and Westesen, who produced cholesterol acetate nanoparticles with a mean size of 29 nm, demonstrated its repeatability of an outcome.

SLN preparations based on microemulsions

By diluting microemulsions, Gasco and coworkers created SLN preparation techniques [18] . The optically clear mixture comprises such a co-emulsifier (sodium mono octyl phosphate), the lower melting point lipids (stearic acid), an emulsifier (polysorbate 20, polysorbate 60, soy phosphatidylcholine, as well as sodium taurodeoxycholate), but also water. A mixture has been stirred between 65-70^0 degrees Fahrenheit. The hot microemulsion dissolves in the cold water while being mixed (2–30). A ratio of hot microemulsion over ice water usually falls within 1:2 as well as 1:50. A makeup of the microemulsion significantly impacts the dilution process.

According to the literature, since the microemulsion already has the droplet structure, no energy is required to generate particles of submicron dimensions. Given the similarities between other processes and the polymer nanoparticle formation method described by French researchers, several mechanisms might be considered. Fessi created polymeric particulates by diluting polymer solutions using water indicating that the speed of its dispersion processes is critical in defining particle size. Only the relatively fast-diffusing solvent acetone can produce nanoparticles; other, more lipophilic solvents have larger particle sizes. Microemulsion's hydrophilic co-solvents may contribute to forming lipid nanoparticles like how acetone generates polymer nanoparticles [19] .

Supercritical fluid preparation for SLN

This SLN synthesis method is relatively new due to the benefit of processes without solvents. Such platform technologies exist in various formats for producing powder and nanoparticles. SLN can be created using the rapid expansion of the supercritical carbon dioxide solutions (RESS) technique. Research has shown that carbon dioxide (99.99%) was the most effective solvent for this process [20] .

Spray-drying technique

The method of turning an aqueous SLN dispersion into a pharmaceutical product is distinct from lyophilization. The cost is less than lyophilization. This method results in particle aggregation because of the high temperature, shear pressures, and a portion of the particle melting. Mullera and Freitas [21] recommend using lipids with a melting point greater than 700 for spray drying. The best outcomes were shown as 20% in ethanol-water mixes but 1% in such trehalose through liquid solution whenever it concerns SLN concentration (10/90 v/v).

Double emulsion technique

A novel technique based on solvent emulsification-evaporation named hydrophilic loaded SLN has been invented and adopted. The medication is enclosed with a stabilizer to prevent drug partitioning to the outside water phase of the w/o/w double emulsion during solvent evaporation.

Characterization of SLN structure and quality

To guarantee the quality of the SLNs, it is necessary to characterize them appropriately and correctly. Representing SLN is such a substantial challenge, nevertheless, because the delivery system is intricate and dynamic, and the particles are colloidal in size. Size of the particles, size distribution kinetics (zeta potential), degree of triglyceride modifications (polymorphism), the convergence of different colloidal systems (micelles, liposomes, supercooled, melts, drug nanoparticles), the time scale of distribution processes, drug content, in vitro drug release, as well as surface morphology a few of the essential factors that must be evaluated for SLNs. Numerous various methods can be utilized to examine the size of the particles as well as Size-distribution technologies comprise freeze-fracture electron microscopy (FFEM), atomic force microscopy, scanning tunnelling microscopy, photon correlation spectroscopy (PCS), transmission electron microscopy (TEM), scanning electron microscopy (SEM), as well as atomic force microscopy (AFM).

Zeta potential and particle size measurements [22]

The best techniques of photon correlation spectroscopy (PCS) and laser diffract (LD) are applied to determine particle sizes routinely. This is unusual for estimating the SLN size of the particles using the Coulter technique, so it is difficult to assess small

nanoparticles and requires electrolytes, which could make colloidal dispersions unstable. PCS, often called dynamic light scattering, estimates variations in the scattered light's intensity brought on by particle mobility. Sizes between a few nanometers and about three microns can be handled by this method. In light of this, PCS is an effective method for characterizing nanoparticles, but it cannot detect larger microparticles. They can be observed by using LD measurements. This strategy is based on the relationship between particle radius and the diffraction angle (Fraunhofer spectra). Smaller particles show stronger scattering at high angles compared to larger ones. It is undoubtedly advantageous that LD spans a broad size range, from the nanoscale to the lower millimetre range [23] .

The development of polarisation intensity differential scattering (PIDS) technology has dramatically increased LD's sensitivity to minute particles. Nevertheless, it is strongly encouraged to use PCS and LD together despite this advancement. Remember that neither method "measures" particle size. Instead, they search for light scattering effects that are used to estimate particle size. Non-spherical particle shapes, for instance, may result in uncertainties. Platelet forms are typically seen during lipid crystallization in the SLN as well.

Furthermore, it might be challenging to quantify PCS and LD for samples with numerous populations of different sizes. Therefore, alternative approaches might be helpful too. For instance, light microscopy is suggested even if it is not sensitive to the nanoscale size range.

Electron microscopy provides exact information on particle shape compared to PCS and LD. It is commonly measured using the zeta meter. It offers an immediate indication of the existence and characteristics of microparticles, both those that exist as individual particles and those composed of aggregates of smaller particles. However, the investigator must pay close attention to any artefacts the material preparation process may have introduced. For instance, changes that influence the particle's shape can result from removing the solvent. A key component of SLNs is their high zeta potential, likely leading to particulate disaggregation without additional problematic elements like hydrophilic surface expansions with steric stabilizers [24] .

DLS or dynamic light scattering

DLS is often termed quasi-elastic light scattering, but PCS (QELS) measures variations in the strength of scattered light at such an instant. This variation, caused by interference of light scattered by individual particles due to Brownian motion, is detected by assembling an autocorrelation function. This function has fitted a combination or modification of such an exponentially via the connection between the related decay constant(s) and the diffusion coefficient(s) [25] . Under the typical circumstances of spherical size, low concentration, and known suspending medium viscosity, particle size is ascertained from this coefficient. The approach has several advantages, including a short analysis time and no need for sensitivities to submicrometer particulates and calibrating.

Fraunhofer diffraction and static light scattering

The ensemble method known as static light scattering collects and fits the pattern of light scattered from a particle solution to the fundamental electromagnetic equations, where size is the primary variable (SLS). The procedure is quick and reliable but calls for higher particle purity than DLS and prior knowledge of the particles' optical characteristics.

Acoustic techniques

Another ensemble method is acoustic spectroscopy, which fits physical-meaningful equations to measurements of the attenuation of sound waves to determine size. The surface charge can also be studied by measuring the oscillating electric field generated as charged particles move under the influence of acoustic energy [26] .

NMR: Nuclear magnetic resonance

NMR can be used to evaluate nanoparticles' size and qualitative makeup. Their sensitivities towards molecular mobility and the specificity offered through the chemical shift combined to provide information on the physicochemical condition of components inside the nanoparticle.

Atomic imaging [27]

Nanoparticle physical characterization 113 SEM and TEM are methods for visualizing nanoparticles up close, with SEM being more useful for morphological examination. Along with the fact that TEM provides structural information, Has a smaller detection threshold for size, and is such a valuable One should be aware of the statistically small sample size and the impact that vacuum can have on the particles when validating alternative approaches.

AFM (atomic force microscopy)

By rastering a probe tip with an atomically sharp edge of the sample, this technique produces a topological map of the model based on the forces operating between the information and the surface. The differences between the sub-techniques are based on the applied force's characteristics. In contact mode, the probe can be moved across the sample or

left hovering just above (noncontact mode). AFM is a helpful technology because it allows for mapping samples according to characteristics other than size, such as colloid connection rather than deformed resistance.

Both differential scanning calorimetry (DSC) and powder X-ray diffraction:

By identifying whether or not crystal planes are present in a solid through the geometric scattering of radiation from those planes, one can determine the degree of crystallinity of that solid. By measuring the temperatures at which glass and melting points are reached and the enthalpies that go along with those temperatures, DSC is a different technique from that used with bulk materials that can also be used to identify the type and speciation of crystallinity present in nanoparticles [28] .

SLN sterilization

For distribution via intravenous and ocular routes, SLN must be sterile. The hot nanodroplets' size will likely alter due to the hot o/w microemulsion that develops in the autoclave due to the maximum temperature at which autoclaving attained sterilization. After a subsequent progressive cooling, the SLN was reconstructed; nevertheless, certain nanodroplets may mix to form more significantly than the original SLN. Because SLN were rinsed before sterilization, there may be less. In the hot system, surfactants and co-surfactants could improperly stabilize the nanodroplets.

Formulations based on oral lipid [29]

Among the advantages that Using lipid-based oral compositions offers are the following,

The capacity of poorly water-soluble, lipophilic medications to be absorbed through the GI tract is improved, and its variability is reduced. It may be possible to minimize or do away with several stages of creation and processing, such as salt selection, drug crystalline form discovery, coating, flavour-decreased confinement, masking, and cleanup requirements during the design of very potent or cytotoxic therapeutic products. Diminution or elimination of eating's positive benefits. Fabrication with relatively simple, readily available tools. Different oral lipid-based formulations include Self-emulsifying compositions, single-component lipoprotein formulations, solid dispersion formulations, and pelletizing melt.

The most widely used To create oral lipid-based compositions, excipients were found to be moderate- but rather lengthy triglyceride-based nutritional oil, such as coconut or palm seed oil, as well as lipophilic solvents, such as propylene, alcohol, as well as polyethylene glycol 400, and glycerin, as well as a variety of pharmaceutically acceptable surfactants like Cremophor® EL and RH40. When Standard techniques (solid dry or wet granulated, either water-miscible solutions in such capsules) did not produce enough bioavailability or when the medication was an oil, these formulations were used (dronabinol, ethyl icosapentate, indometacin farnesol, teprenone, and tocopherol nicotinate). These formulations were available as liquid-filled hard or soft capsules, bulk oral solutions, or both. These formulations range in complexity from straightforward drug strategies for multi-excipient, self-emulsifying pharmaceutical delivery systems using nutritive oils, with total daily medication dosages ranging from less than 0.25 g to more than 2000 mg (SEDDS).

The medication content of unit-dose capsule products ranges from 0.25 μg to 500 mg, whereas that of oral solution solutions ranges from 1 μg/ml to 100 mg/ml. In a capsule formulation, the total amount of lipid excipient delivered in a single dose ranges from 0.5 to 5 g. In contrast, the amount for oral solution solutions might range from 0.1 to 20 ml. Several of these goods can only be kept at room temperature briefly. It must be held at 2-8° for lengthy periods due to chemical and physical stability concerns.

Administrative strategies and their biodistribution

SLN comprises lipids or waxes that are significant to or associated with biology. A solid lipid nanoparticle's in vivo course will be determined through significantly influenced based on the administration and distribution routes mechanism (biological material adsorbs onto nanoparticle surface whereas SLN components deabsorb through into the physical environment). As a result, the carrier's in vivo fate may be significantly influenced by the body's metabolic and transport routes. The most critical SLN breakdown enzymes are probably the lipases in several organs and tissues. Lipases break the ester bond to produce free fatty acids, glycerol, and partial linoleic acid. Most lipases require an oil/water contact to activate their catalytic core (lid opening). An in vitro experiment revealed that the properties of solid lipid nanoparticles (lipid matrix, stabilizing surfactant) influence how quickly pancreatic lipase breaks them down.

Per-oral administration: Two possibilities for SLN that can be consumed orally are aqueous dispersions and conventional dosage forms like tablets, pellets, or capsules filled with SLN. The high ionic strength and acidity of the stomach promote particle aggregation. Although, To our knowledge, no experi-

mental findings have been published on the subject; food will probably significantly impact SLN performance. Another unanswered problem is how stomach and pancreatic lipases affect the in vivo breakdown of SLN. Sadly, there haven't been many in vivo studies conducted yet.

Parenteral administration: SLN has been injected directly into animals. Doxorubicin incorporated into SLN produced higher blood levels after intravenous injection in rats than in a commercial medication solution. It has been found that SLN had higher drug concentrations in the brain, spleen, and lung, whereas the solution boosted the medication's diffusion to the kidneys as well as the liver. Camptothecin's pharmacokinetics and bodily distributions were discussed following intravenous injection into mice. Among the investigated, The brain showed the most excellent AUC ratio of SLN to drug solution among all the organs. Particularly in organs containing reticuloendothelial cells such as the brain, heart, and heart muscle, mean residence durations (MRT) and AUC/dose of SLN were significantly larger than those of a drug solution.

Using a transdermal patch: The most petite particle sizes are found in SLN dispersions with low lipid contents (up to 5%). The disseminated lipid has a low concentration and poor viscosity, challenging cutaneous distribution. An ointment or gel formulation containing the SLN dispersion is typically required to produce a product that may be applied topically. The inclusion stage is anticipated to decrease the SLN dispersion's lipid content further, resulting in semisolid, gel-like solutions that would be appropriate for direct application to the skin.

Applications [30]

Compared to liposomes, stable lipid nanoparticles are more durable and easier to scale up for manufacture. This trait might be essential for several targeted strategies. SLNs are the fundamental components of a biodegradable, at least a year-long colloidal drug delivery system. In the body and a lab setting, drugs can be administered to liver cells that are phagocytic in motion. Potential uses of SLNs have included the following, which are only a few of them:

As a gene vector, SLNs: The gene vector's makeup may include SLN. In one study, to improve gene transfer, an SLN gene vector contained a diametric HIV-1 HAT peptide (TAT 2). Recent reports of the production of SL-acid nanoparticles are abundant (70-100 nm). It's referred to as nanospheres. It is precisely targeted by the inclusion of an antibody-lipo polymer conjugate in the particle. Carrying genetic/peptide materials, including Nucleic acids including DNA, plasmid DNA, and others. These nanoparticles of liposome acids are produced from a water-miscible organic solvent and liquid nanophase in which the lipid and DNA were separately dissolved before the organic solvent was removed.

SLNs used topically: Numerous drugs have been topically administered using SLNs and NLCs, including triptolide, imidazole antifungals, anticancer, vitamin A, isotretinoin, ketoconazole, DNA, flurbiprofen, and glucocorticoids. Podophyllotoxin-penetration SLNs of the stratum corneum and skin surface were the cause of the epidermal targeting. Glyceryl behenate can be used to make nanoparticles loaded with vitamin A. With the continual release, the strategies aid in increasing penetration. The lipid nanoparticles containing isotretinoin were created to administer medications topically. For this, soybean lecithin, Tween 80, and the heat homogenization method are used. The technique works well because the cumulative skin absorption of isotretinoin has increased. It may be advantageous to administer the drug directly to the site of action with the topical flurbiprofen-loaded SLN gel, leading to higher tissue concentrations. Utilizing polyacrylamide, glycerol, and water, this type of SLN gel was produced.

As cosmeceuticals SLNs

The SLNs have been applied to create molecular sunscreens and UV blockers as active carriers. An in vivo investigation found that 4% SLN added to a regular cream after four weeks increased skin hydration by 31%. Topicals with a novel regulated release, including SLN and NLCs, have been demonstrated. Glyceryl behenate SLNs showed enhanced vitamin A localization in the deeper layers of skin compared to standard formulations.

SLNs as a targeted anticancer medication delivery system to solid tumours

SLNs may be employed as drug delivery systems to treat neoplasms, according to findings. To boost permeability and retention effects, prolong drug release after intravenous injection, and treat breast cancer patients, tamoxifen, an anticancer medicine, is added to SLN. Tumour targeting has been achieved using SLNs infused with drugs like methotrexate and camptothecin.

SLNs in lymph node metastases and breast cancer

To increase the medication's safety and absorption while reducing its toxicity, mitoxantrone-loaded SLN local injections were created. Integration in SLNs is

reported to boost the efficacy of doxorubicin (Dox).

CONCLUSION

Paul Ehrlich developed his "magic bullet" theory in the early 20th century. According to this theory, medications should only be administered when they are at the appropriate concentration, at the correct spot in the body, and at the right time. It shouldn't cause any adverse effects while being transported to the therapeutic target, once there, or while being used. These overarching goals may be attained, at least in part, through the SLNs. Aside from these, SLNs effectively accomplish the common goal of regulated drug delivery. These were comparatively novel drug delivery techniques that have gained popularity since the early 1990s, and the possibilities for their thorough investigation and use appear promising. Future SLNs are inclined to be used for many patentable dosage forms.

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