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A REVIEW ON SOLID LIPID NANOPARTICLE

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ABSTRACT

The most advanced nanotechnology formulations are solid lipid nanoparticles (SLN), which have several uses in a variety of domains, including drug delivery, clinical medicine, research, and other diverse disciplines. SLN are spherical, nanometre-sized particles that are submerged in water or an aqueous surfactant solution while being treated with hydrophilic or lipophilic drugs. Various biodegradable and bio acceptable polymers that can also circumvent the harmful effects of conventional drug carrier systems should be used to improve the solubility and bioavailability of poorly soluble medications. Lipid nanoparticles present a chance to create novel treatments because of their special size-dependent characteristics. Drug delivery presents a new concept that can be used for drug targeting through the ability to conjugate pharmaceutical to nano carriers. Solid lipid nanoparticles have therefore drawn a lot of interest from researchers due to their significant potential for achieving the goal of regulated and site-specific medication delivery. Lipids that are physiologically friendly are used to create solid lipid nanoparticles, or SLNs. They are essential for the delivery of hydrophobic medications, which make up over 40% of all authorized medications Drug delivery methods based on nanotechnology can be divided into three categories based on their structural and chemical makeup: lipid-based NPs, polymeric NPs, and inorganic NPs. Particular focus is placed on the relationship between drug incorporation and the complexity of SLN dispersions, which includes the physical state of the lipid (supercooled melts, various lipid modifications) and the presence of alternative colloidal structures (liposomes, micelles, drug nanosuspensions, mixed micelles, liquid crystals).

KEYWORD:- Solid lipid nano particle, Nano structured lipid carriers, drug delivery.

INTRODUCTION

The pharmaceutical sciences have been greatly impacted by the growing development of drug delivery methods based on nanotechnology in recent decades (Lin, Gao and Ouyang 2021) (Rastegari, et al. 2021) (van Alem, et al. 2021). They are essential for the delivery of hydrophobic medications, which make up over 40% of all authorized medications (Yang, et al. 2019).

SLNs, which were first developed in 1991, are systems of medication carriers in the nanoscale range. They mostly consist of aqueous or fluid surfactant arrangements with nanometer sized solid lipids and active pharmacological components dispersed throughout. At normal temperature or within the body, these lipids are solid. (A.Alsaad 2020) one of the main limiting factors that significantly impacts medication release and bioavailability is the hydrophobic medicines' poor water solubility, which can be addressed by nanotechnology-based drug delivery systems. Furthermore, the attachment of pharmaceuticals to nanoparticles (NPs) improves the overall efficiency and safety by increasing drug stability, decreasing enzyme degradation, extending circulation time, and improving target cell absorption (Mitchell, et al. 2021) (Patra, et al. 2018) (Le, Choi and Oh 2018).

Drug delivery methods based on nanotechnology can be divided into three categories based on their structure and chemical makeup: lipid-based NPs, polymeric NPs, and inorganic NPs. Gold, silver, iron, and silica are examples of inorganic materials that make up inorganic nanoparticles. These inorganic NPs may have unique electrical, physical, optical, or magnetic characteristics due to certain of the materials' special qualities. For example, iron oxide NPs may have superparamagnetic capabilities, or gold NPs may have photothermal effects (Hu, et al. 2020) Because of their high stability, inorganic nanoparticles (NPs) hold Promise as drug delivery methods for imaging, diagnostics, and photothermal treatments. However, they are not frequently utilized in clinical settings due to their poor water solubility and toxicity problems. Numerous natural or synthetic polymers can be used to create polymeric nanoparticles**.** (Ghosn, et al. 2019) (Caldorera-Moore, Vela Ramirez and Peppas 2019) (Valcourt, et al. 2020) Emulsions, liposomes, lipid NPs, and solid lipid are examples of lipid-based NPs.

SLNs) nanoparticles. They are perfect solutions for clinical applications since they may be made from non-toxic and biodegradable materials[16,17] (Lorente, et al. 2018) (El-Hammadi, et al. 2017). Another name for the second generation of SLNs is nanostructured lipid carriers (NLCs). Nonetheless, both SLNs and NLCs can be mentioned using SLNs.

By changing the lipid components, the drug release from SLNs can be regulated.[23,24] (Müller, Mäder and Gohla 2000) (Wissing, Kayser and Müller 2004). To improve stability and target particular tissues, the surface of SLNs can be altered (Baek and Cho 2017), Non-solvent methods including high-speed stirring and high-pressure homogenization can be used to create SLNs (Khatri, et al. 2020). The numerous uses of SLNs in oral, parenteral, transdermal, intranasal, ophthalmic, and pulmonary drug administration are made possible by these benefits (Dhiman, Awasthi, et al., Lipid nanoparticles as carriers for bioactive delivery 2021) (Scioli Montoto, Muraca and Ruiz 2020). SLN are physiological lipid-based sub-micron colloidal carriers, which have a diameter of 50–1000 nm and are distributed in water or an aqueous surfactant solution. Small size, vast surface area, high drug loading, phase interaction at the interface, and other unique qualities make SLN appealing due to their potential to enhance pharmacological performance (M. R. Mozafari 2006) (Houli Li (2009).) (Melike Uner 2007).

The reasons for the increasing interest in lipid-based system are many – Fold and Include

1. An improved ability to address the key issues of technology transfer and manufacture scaleup
2. Lipids enhance oral bioavailability and reduce plasma profile variability.
3. Better characterization of lipoid excipients

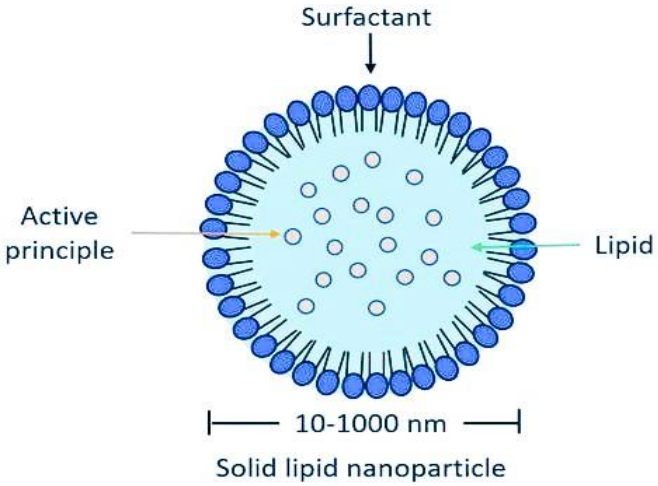

Fig. 1: Structure of solid liqud nanoparticle (SLN).

Nanoparticle

The core element of nanotechnology is nanoparticles (NPs). Particulate materials with at least one dimension less than 100 nm are called nanoparticles. They may consist of biological materials, metal, metal oxides**,** or carbon**.** (S 2015)

Nanotechnology

According to the National Nanotechnology Initiative (NNI), nanotechnology is the study and application of structures that are around 1–100 nm in size. •Nanotechnology shares the same objective as medicine: to use a controlled and targeted medication delivery technique to diagnose as precisely and early as possible and to cure as effectively as possible without causing any side effects. (Garud, singh and Garud. 2012).[3]

Solid lipid nanoparticles' objectives

(Melike Uner, SOLID LIPID NANOPARTICLES: A REVIEW 2001) (Indu Pal Kaur 2008)

1. The potential for regulated medication release (X. Z. Houli Li 2009)5.
2. High payload for drugs.
3. Lack of carrier biotoxicity
4. Combining Hydrophilic and Lipophilic medications.
5. Staying away from organic solvents.

Advantage of SLS: (S. Mukherjee, 349-358) (Mader (2001))

1. Target and/or regulate the release of drugs**.**
2. Outstanding biocompatibility
3. Elevated and improved drug content.
4. Increased pharmacological stability
5. Very high long-term stability.
6. Sterilization and scaling up are simple.
7. No particular solvent is needed.
8. Quite stable over the long run.
9. Adaptability in application.
10. S amenable to commercial sterilizing techniques.
11. Improved control over the encapsulated chemicals' release kinetics.
12. Increased bioavailability of bioactive substances that are trapped.
13. Labile integrated chemicals are protected chemically
14. The same raw components are needed for emulsions.
15. Typical emulsion production techniques that work

Disadvantage of SLN

1. During storage, drug ejection occurs following a polymeric transition
2. The dispersions have a rather high-water content (70–99.9%).
3. The limited ability to load water-soluble medications because of production-related partitioning effects (Jaiswal and Gupta 2013)[11]
4. Tendency for eccentric gelation.
5. Unexpected polymeric transition motion (Uner and Yener. 2007) (Sawant and Dodiya 2008)
6. Inadequate ability to load drugs**.**

Type of SLN

The two types of lipid nanoparticles are called nanostructured lipid carriers (NLCs), which are made of a mixture of solid and liquid at room temperature, and solid lipid nanoparticles (SLNs), which are made of solid lipids at 20 to 28◦C (Fig. 1). SLNs have drawbacks like a tendency toward gelatin, a high diffused water volume, a reduced ability to pack drugs, a high movement of polymeric transition, and polymeric variation that results in drug elimination, as well as difficulties in optimization and, in certain situations, a challenging preparation process. NLCs are beginning to overcome SLNs' limitations. SLNs are separated into three primary groups according to the location of the drug composition: 1) A model of a homogeneous matrix that evenly distributes the medication within a lipid matrix. 2) The drug concentration in the liquid steel of the outer portion identifies the drug enrich shell model. 3) The steel liquid core component contains drug aggregations in the drug-enriched core model (Prastiwi N. n.d.).

The drug's location affects how quickly it is released from SLNs. While type 2 SLNs are suitable for burst release, types 1 and 3 are suitable for controlled release. Furthermore, SLNs are designed to preserve the drug release profile, which lessens the requirement for frequent use and boosts therapeutic outcomes (N.Yadav 2013) (G.A. Shazly 2017).

In the synthesis of SLNs, factors such as size, solid state, crystalline formation of the lipid core, polydispersity, zeta potential, drug encapsulation efficiency, and loading rate are crucial (Lide Arana 2021). When it comes to antibacterial activity, the bacterial cell wall's surface charge can dictate how it interacts with SLN. he bacterial cell wall's surface charge can influence how it interacts with SLNs in the case of antibacterial activity. In order to effectively deliver medications to bacterial cells, SLNs can interact differently with various bacterial strains. It has been suggested that an effective drug delivery system with a positive surface charge can produce more effective antibacterial action since bacterial strains have negative charges (Sandeep Kumar 2016)] (Ana González-Paredes 2019). Because of the structure of their lipid core, cationic SLNs have been demonstrated to adhere to bacteria more quickly and exhibit more favorable antibacterial effects (Ana González-Paredes 2019). Furthermore, lipid cores are essential for medication delivery in the intracellular milieu. The most effective intracellular delivery appears to be a lipid core based on tripalmitin.[21] But according to other researchers, conjugating antibiotics into anionic SLNs may also increase medication efficacy (X.F. Wang 2012) (Patrícia Severino 2017). Furthermore, it has been shown that macrophage cells phagocytose negatively charged SLNs more frequently (Eleonora Maretti 2019). It's also important to remember that some published findings suggested that SLN size might improve cell uptake (S Xie 2017).

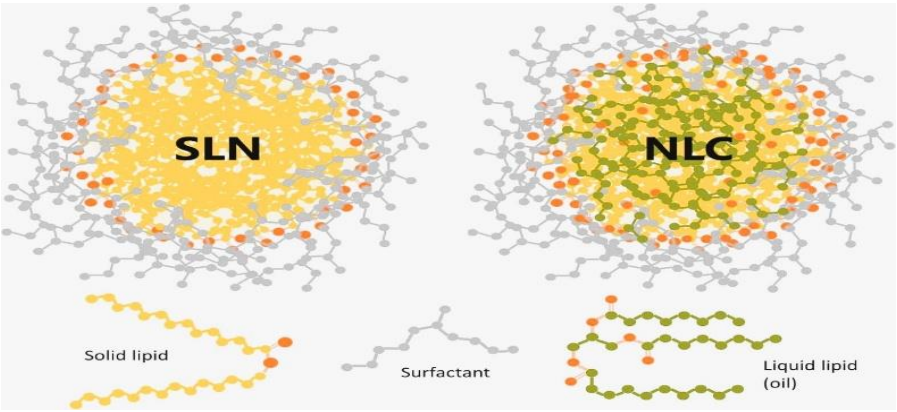

Fig. 2: Molecular Structure of SLN and NLC.

Preparation methods of SLNs

A. High-pressure homogenization
- Hot homogenization
- Cold homogenization

B. Ultra-sonication /high speed homogenization
- Probe ultra-sonication
- Bath ultra-sonication

C. Solvent emulsification-evaporation method
D. Solvent injection method
E. Spray drying method
F. Double emulsion method
G. Solvent emulsification-diffusion method
H. Microemulsion base method
I. Membrane contractor method
J. Supercritical fluid method

A. High-pressure homogenization

The first method for creating solid lipid nanodispersions was high-pressure homogenization, a widely utilized and controllable technology. The presence of microparticles, however, usually lowers the quality of the dispersion. Olbrich et al. conducted research on manufactured solid lipid nanoparticles (SLN) using the high-speed homogenization process. The impact of several process variables, such as emulsification duration, stirring rate, and cooling conditions, on particle size and zeta potential was investigated in this work. Trimyristin, tripalmitin, and glycerol behenate—a mixture of mono, di, and triglycerides—were the lipids utilized in the study. As a steric stabilizer, poloxamer 188 was also used at a 0.5% w/w concentration. Witepsol W35 dispersions were stirred for eight minutes at 20,000 rpm to get the greatest SLN quality, chill for 10 minutes and stir for 5 minutes at room temperature (Corrias F 2011).

Cold homogenization

In the cold method, the drug-lipid melt is chilled with dry ice or liquid nitrogen before being pulverized in a mortar or ball mill. Next, the powder is combined with a cold aqueous surfactant solution and homogenized using a high-pressure homogenizer at room temperature or lower. High-pressure homogenization is a simple and affordable method. The application of thermolabile drugs is, however, restricted by the hot method's need for high temperatures during homogenization. The solution to this issue is cold homogenization, a practical and successful large-scale production method that eliminates the need for organic solvents (Battaglia L 2012).

Hot homogenization

Hot homogenization is the process of processing at temperatures above the melting point of lipids. Using a high-shear mixing device, such as a Silverson-type homogenizer, the drug-loaded lipid melt and the aqueous emulsifier phase are combined at high shear and maintained at the same temperature to form a pre-emulsion. A few micrometer-sized droplets are ideal, and the quality of the pre-emulsion greatly affects the final result. The pre-emulsion goes through high-pressure homogenization above the lipid melting point. Because of the reduced viscosity of the lipid phase, higher processing temperatures typically lead to smaller particle sizes; nevertheless, they can also accelerate the breakdown of the drug and carrier. The best results are achieved when the pre-emulsion is run through the high-pressure homogenizer (HPH) several times, often three to five runs. The high-pressure procedure causes the sample's temperature to increase by about 10°C at 500 bar. Three to five homogenization cycles at pressures ranging from 500 to 1500 bar are usually adequate. It's important to keep in mind that increasing the number of homogenization cycles may lead to particle coalescence, a phenomenon that could increase particle size because of the high kinetic energy of the particles (Battaglia L 2012).

B. Ultra-sonication /high speed homogenization

The drug-lipid mixture is heated above the lipid's melting point, and it is then dispersed into an aqueous-surfactant solution that is maintained at the same temperature using a high-shear mixer. The resulting emulsion is then ultrasonically sonicated to reduce particle size after being cooled to room temperature to provide the final nanoparticles. One potential drawback of the ultrasonication process is the potential for metal contamination, which must be kept in mind (Ekambaram P 2011).

C. Solvent emulsification-evaporation method

Using the solvent emulsification-evaporation approach, this technology creates Solid Lipid Nanoparticles (SLNs) from water-immiscible organic solvents such as dichloromethane, cyclohexane, toluene, and chloroform. In order to create nanodispersions, the drug and lipids are dissolved in a particular solvent or combination of solvents, and the resulting solution is then emulsified in an aqueous phase. After that, mechanical stirring or a rotary evaporator are used to remove the organic solvent. Lipids precipitate once the solvent evaporates, forming solid lipid nanoparticles (Pooja D 216)

D. Solvent injection method

Lipids and active ingredients are dissolved using a water-miscible organic solvent, such as methanol, acetone, or isopropanol, or a mixture of water-miscible solvents. After that, the organic solution is agitated while it is injected into an emulsifier aqueous solution using an injection needle. This injection procedure results in solvent migration and nanoparticle precipitation. This method offers a number of remarkable advantages, including speedy output, ease of handling, and simple equipment (K. 2012dec).

E. Spray drying method

Lipids with a melting point greater than 70°C are used in a less expensive and non-lyophilization technique. The best results were obtained when solid lipid nanoparticles (SLN) were used at 1% concentration in a trehalose in water solution or 20% trehalose in ethanol and water mixture. A low lipid content and the inclusion of carbohydrates help to maintain the colloidal particle size during the spray-drying process. Because they form smaller, more homogeneous crystals at lower inlet temperatures, ethanol-water mixtures are preferred over pure water to lessen lipid melting. Because they form smaller, more homogeneous crystals at lower inlet temperatures, ethanol-water mixtures are preferred over pure water to minimize lipid melting (Deli G 2009).

F. Solvent emulsification-diffusion method

Trotta et al. invented the solvent emulsification-diffusion method in 2003 for creating Solid Lipid Nanoparticles (SLNs), which are primarily employed in the synthesis of polymeric nano-carriers. Organic solvents that exhibit partial miscibility with water, such as butyl lactate, methyl acetate, ethyl acetate, isopropyl acetate, and

benzyl alcohol, are commonly used in this process. Mutual saturation between the organic solvent and the water initiates the process and establishes the first thermodynamic equilibrium for both phases. The combination is then emulsified while being stirred to produce an oil-in-water (o/w) emulsion in the aqueous phase, which is composed of solvent-saturated water and a stabilizer, following the dissolution of the medications and lipids in the water-saturated solvent. o helps the solvent infiltrate into the continuous phase, the emulsion is then diluted with water (at a volume ratio of 1:5 to 1:10). Lipid precipitation produces Solid Lipid Nanoparticles (SLNs) on its own, and vacuum distillation or lyophilization are used to remove the solvent (Manjunath K 2005).

G. Microemulsion base method

Transparent, thermodynamically stable, and microheterogeneous dispersions are known as microemulsions. They are composed up of water, a surfactant, a co-surfactant, and a lipophilic phase (lipid). This technology was used by the Gasco research group to synthesize Solid Lipid Nanoparticles (SLNs). This method entails distributing the drug into a fatty acid or glyceride that has been melted first. At the same time, a solution of water, surfactant, and co-surfactant is heated to a temperature that is at least as high as the melting point of the lipid. The aqueous surfactant solution is added to the lipid melt while being gently stirred to create a transparent microemulsion. This microemulsion is then dissolved in cold water (2°C to 10°C) while being gently stirred mechanically. The volume ratios of the heated microemulsion to cold water range from 1:25 to 1:50. After being distributed in a cold aqueous medium, oil droplets rapidly recrystallize to form solid lipid nanoparticles (SLNs). Crucially, the precipitation process—rather than the stirring itself—is what produces SLNs. Following a water wash using diafiltration, the resulting lipid nanoparticle dispersion can be lyophilized. Butanol, taurodeoxycholate sodium, lecithin, and bile salts are among the surfactants and co-surfactants used in this method (Khurana S 2013).

H. Membrane contractor method

This process involves pushing a drug-lipid melt through a hydrophobic porous membrane and into an aqueous-surfactant solution that circulates inside the membrane module. Successful removal of the lipid droplets occurs when the aqueous phase cools to room temperature, ultimately resulting in the formation of nanoparticles. The ease of use and continuous production capability of this technology are its primary benefits.[35] The creation of warm w/o/w double microemulsions is done in two processes. An aqueous solution containing the drug is first added to a mixture of melted lipid, surfactant, and co-surfactant at a temperature marginally higher than the lipid's melting point to form a clear system. A w/o microemulsion is produced as a result. In the second phase, the resultant w/o microemulsion is combined with a water, surfactant, and co-surfactant solution to create a transparent w/o/w system. Solid lipid nanoparticles (SLNs) can be created by dispersing the warm double microemulsions into cold surroundings. An ultrafiltration system with a dispersion medium can then be used to clean the SLNs. Several emulsions have inherent instabilities, including the rupture of the layer on the surface of the internal droplets, the coalescence of oil droplets, and the coalescence of internal aqueous droplets within the oil phase. Stability is essential in the manufacture of SLNs because of the brief interval between the creation of the transparent double microemulsions and their quenching in a cold aqueous medium. This stability can be achieved over this period (Nabi-Meibodi M 20132).

I. Supercritical fluid methods

The notable advantage of this relatively new method is that it produces solid lipid nanoparticles (SLNs) without the need for solvents. This platform technology for preparing powders and nanoparticles comes in a number of versions. SLNs can be produced particularly using the sRapid Expansion of Supercritical Carbon Dioxide Solutions (RESS) technology. Interestingly, the process performs remarkably well when carbon dioxide (99.99%) is used as a solvent (Garud A 2012).

Characterization of SLNs

Complete and precise characterization of solid lipid nanoparticles (SLNs) is necessary for effective quality control. However, SLNs are challenging to characterize due to the dynamic and complicated nature of the delivery mechanism and the colloidal size of the particles. Key factors that must be assessed for SLNs include particle size, degree of crystallinity, lipid modification (polymorphism), presence of extra colloidal structures (such as micelles, liposomes, supercooled melts, and drug nanoparticles), distribution process timescale, drug content, in vitro drug release, and surface morphology.

Zeta potential analysis

Through the use of electroacoustic or electrophoretic mobility measurements, zeta potential values are frequently used to estimate the surface charge magnitude in aqueous dispersions. Techniques such as dynamic light scattering (DLS) and laser diffraction (LD) can be used to estimate zeta potential, which can be used as markers of the long-term physical stability of nanoparticles. It has been reported that stability is primarily ensured by electrostatic interactions, with absolute values greater than 30 mV needed to ensure stability; however, when surfactants are used to provide steric stabilization, an absolute value of 20 mV is deemed sufficient for nanoparticle stabilization (Kesharwani R 2016).

Measurement of crystallinity

Lipid crystallinity assessment must be considered in addition to particle size analysis when describing the quality of solid lipid nanoparticles (SLNs). In X-ray diffraction analysis (XRD), incident X-ray radiation is

applied to a material, and the scattering angles and intensities of the resulting X-rays are subsequently measured. This method is frequently employed to examine the phase and crystallinity of nanoparticles (NPs). But the precision and resolution of XRD can be impacted when samples are extremely amorphous with different interatomic distances or when the NPs are on a scale smaller than several hundred atoms (Titus D. Samuel EJ 2019).

Entrapment efficiency

It is crucial to measure the drug content in solid lipid nanoparticles (SLNs) because it influences the release characteristics. The proportion of the overall quantity of medication Entrapment efficiency is the amount that is added to the particle that is integrated into it. The amount of drug encapsulated per unit weight of nanoparticles can be determined by removing the free drug and solid lipids from the aqueous media. Techniques such as centrifugation, filtration, and gel permeation chromatography can be applied to this separation process (Li N 2021)

Particle size

Numerous methods, including photon-correlation spectrometry (PCS), transmission electron microscopy (TEM), and scanning electron microscopy (SEM), can be used to assess the size, shape, and surface characteristics of solid lipid nanoparticles. Scanning electron microscopy (SEM) uses electron cannon to create a controlled electron beam. The beam is then directed vertically through the microscope until it makes contact with the samples. Electrons and X-rays are released when the samples collide. A three-dimensional image of the sample can then be created by detectors gathering the scattered electrons and X-rays. SEM can be used to better understand nanoparticles (NPs) by revealing details about their size, shape, aggregation, and dispersion. In TEM, a high-energy electron beam passes through the analyte, which is often composed of minuscule particles. Certain characteristics, such as grain boundaries and dislocations, as well as elements like crystal structure, can be identified thanks to these electrons' interactions with the atoms of the analyte (Hou D 2003).

Route of administration

For a variety of drug delivery routes, including oral, parenteral, topical, intranasal, ocular, and pulmonary, solid lipid nanoparticles exhibit considerable promise (Uner M 2007).

Oral administration

Solid Lipid Nanoparticles (SLNs) are a potential oral drug delivery system due to their various advantages, which include cost effectiveness, ease of use, and patient compliance. Numerous advantages come with oral medication formulations in lipid nanoparticles, including enhanced GI tract drug solubilization, protection for labile pharmaceuticals, potential controlled release properties, extended residence periods, and the potential for selective drug delivery. Nanoparticles also absorb through lymphatic flow, which lengthens their half-life and boosts their bioavailability.

This is particularly beneficial for drugs that the liver metabolizes in the first pass. When a medication has harmful consequences, lipid nanoparticles perform effectively. Researchers have recently looked into the possibility of using Solid Lipid Nanoparticles (SLNs) to deliver various drugs and natural products orally to cure a variety of illnesses. Among these are therapies for conditions including cancer, central nervous system disorders, heart disease, infections, diabetes, and osteoporosis (Das S 2011).

Oral administration

For the delivery of bioactive pharmacological agents with limited bioavailability and narrow therapeutic index values, parenteral administration is the most effective form of administration. This is particularly true for drugs that are prescribed to unconscious individuals. Significant technological advancements in parenteral drug administration have now led to the creation of complex systems that offer drug targeting and sustained or controlled release of parenteral medications. Because proteins and peptide medications are highly susceptible to enzymatic breakdown, frequent compensation is required when administering them orally. Interestingly, Solid Lipid Nanoparticles (SLNs) that are delivered parenterally and have controlled drug release mechanisms are now effective treatment strategies. These formulations offer regulated pharmaceutical release while also addressing patient adherence concerns and the need for frequent dosing. The primary disadvantage of their intravenous administration is their rapid clearance by the reticuloendothelial system. By changing the surface with materials like polyethylene glycol or Pluronic F68, this issue can be mitigated (Wissing SA. 2004).

Topical administration

Solid Lipid Nanoparticles (SLNs) are a revolutionary medication delivery technique with numerous advantages for dermatological applications when applied topically. Lipid-based colloidal carriers, or SLNs, provide a unique platform for the controlled skin administration of pharmaceuticals. Better drug absorption and bioavailability are made possible by their huge surface area and small particle size. Moreover, lipophilic drugs dissolve more readily in lipid-rich SLNs, facilitating their effective delivery to the targeted skin layers. Additionally, SLNs are suitable for topical applications due to their stability and biocompatibility. Additionally, SLNs can be altered for extended release, which lowers the frequency of applications and enhances therapeutic outcomes. Because SLNs can contain both hydrophobic and hydrophilic medications, they can be used to treat a greater variety of dermatological issues. When everything is taken into account, topical SLN

administration has the potential to increase patient adherence to and the efficacy of dermatological therapy (Scioli Montoto S. Muraca G 2020).

Ocular administration

Solid lipid nanoparticles administered ocularly have shown promise as a solution to issues related to traditional ocular medication delivery. One of the biggest problems for ocular formulations is rapid drug elimination after injection. SLNs solve this issue because of their small particle size and lipid matrix, which provide improved corneal penetration and prolonged drug release. This innovative approach potentially improves patient adherence, lowers the need for repeated dosages, and boosts bioavailability. And the biocompatibility of SLNs lowers the risk of ocular discomfort. Solid lipid nanoparticles delivered intraocularly can improve the precision and efficacy of ocular medication administration (Bhatt R 2015).

Intranasal delivery

Intranasal administration is a practical and non-invasive method of delivering medication. This approach offers rapid absorption and commencement of pharmacological action by preventing the digestive system from breaking down sensitive drugs like peptides and proteins. It also addresses the problem of inadequate transport via epithelial cells. Medication distribution through the intranasal route is a practical and non-invasive method. Intranasal administration of solid lipid nanoparticles (SLNs) is a new and exciting advancement in drug delivery. Because solid lipid nanoparticles are composed of biocompatible lipids, they offer a stable and regulated substrate for the encapsulation of many pharmaceuticals. By utilizing the nasal mucosa's large surface area and its abundant vascular network, SLNs can swiftly and directly enter the systemic circulation when administered intranasally. This distribution strategy is particularly helpful for drugs with low bioavailability or those that are susceptible to enzymatic degradation in the gastrointestinal tract. Additionally, the nasal route offers a patient-friendly, non-invasive alternative to traditional delivery methods that could increase patient compliance. The unique physicochemical properties of solid lipid nanoparticles increase therapeutic efficacy and support medication solubility and sustained release. These features include their large surface area and small particle size. All things considered, the intra-nasal distribution of solid lipid nanoparticles holds great promise for enhancing medication delivery, allowing for greater bioavailability and provide targeted treatment for a variety of illnesses (Mitra RN 2018).

Application

1. **Cancer therapy:** By improving their therapeutic index through more accurate tumor targeting and reduced systemic toxicity, SLNs have shown promise in the delivery of anticancer drugs.
2. **Neurological disorders:** SLNs have the ability to penetrate the blood-brain barrier, enabling the targeted administration of drugs to the brain in order to treat neurological disorders.
3. **Infectious diseases:** In order to fight infectious disorders brought on by bacteria, viruses, and fungi, SLNs have been investigated for the delivery of antimicrobial drugs (Khan I 2019).
4. **Skin disorders:** In topical formulations used to treat skin problems, SLNs enhance drug penetration into the skin layers and offer controlled medication release.
5. **Gene delivery:** For gene therapy applications, SLNs can transport nucleic acids like siRNA and mRNA (Sivadasan D 2023).

CONCLUSION

Solid lipid nanoparticles (SLNs) have gained significant attention as a novel drug delivery system due to their biocompatibility, ability to encapsulate both hydrophilic and lipophilic drugs, and potential for controlled and targeted release. This review has summarized various aspects of SLNs including their preparation methods, advantages, limitations, and wide-ranging pharmaceutical applications. SLNs offer benefits such as improved drug stability, enhanced bioavailability, and scalability of production. However, challenges such as low drug loading, potential drug leakage during storage, and the need for long-term toxicity studies still limit their broader clinical use.

Advancements in formulation strategies and surface modification techniques may help overcome these challenges. Future research should focus on optimizing SLN formulations, understanding there in vivo behaviour, and ensuring regulatory compliance for safe and effective clinical translation. Overall, SLNs represent a versatile and evolving nanocarrier system with great potential in modern therapeutics.

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