Review of Solid-Lipid Nanoparticle based Topical Gel

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Abstract:

Solid lipid nanoparticles are at the forefront of the rapidly developing of nanotechnology with several potential applications in drug delivery, clinical medicine, and research, as well as in other varied sciences.

The present study aims at formulating Nano sized extract, to formulate nano gel the selected formulation of green tea extract nanoparticles has been integrated into a gelling agent. The objective of present investigation was to prepare and evaluate solid lipid nanoparticles based topical gel of NSAID etoricoxib for treatment of topical diseases. SLN formulated by melt emulsification and solidification at low temperature method using tween and stearic acid. All the formulation were subjected to particle size, there distribution, zeta potential, scanning electron microscopy, crystallinity study by in vitro release studies

It has been observed that, the high lipid concentration containing formulation have higher entrapment as compare to other two formulation. It represents a broad treatment of solid lipid nanoparticles discussing classification, structure, application with merits and demerits. It was concluded that the nanoparticle based gel formulation; Etoricoxib containing Carbopol was suitable for topical application and shows much better results of anti-inflammatory activity. Nanoparticles in there technology advancement is due to their adaptable

charachteristics and there enhanced performance over there parent material. There are frequently synthesised by reducing metal ions into uncharged nanoparticles using hazardous reducing agents.

Keywords: Nanoparticles, Technology, SLN, Topical Application.

Introduction:

In 1991, solid lipid nanoparticles (SLN) were introduced. serve as a substitute for the conventional colloidal carrier system. emulsions, liposomes, and micro- and nanoparticles made of polymers.(*Zheng Zhang's Research Works*, n.d.)

Over the past ten years, there has been a lot of interest in the use of nano-sized drug carriers in topical treatment formulations. Micelles, solid lipid nanoparticles, micellar, like nanoparticles, and nanospheres are examples of nanoparticles.(Yang et al., 2015) The article discusses nanoparticles composed of nondegradable polymers like polyacrylates and synthetic biodegradable polymers like poly(lactide-co-glycolide) and poly(ε-caprolactone). as well as natural polymers like chitosan.(Borse et al., 2020)

Nanotechnology is an emerging field, and numerous nanoscale materials are used in biomedical applications for preventing various diseases. Nanotechnology is a branch of technology that manipulates matter that ranges from 1 to 100 nm. When combined with active medications, nanoparticles made of polymers, polysaccharides, metals, and bioactive chemicals produced from plants can successfully combat human pathogens like bacteria and viruses and effectively cure a variety of clinical disorders.(Lingayat et al., n.d.)

The most common method for enhancing skin penetration is nanoparticulate medication administration, Solid lipid nanoparticles (SLNs) seem to have a promising approach compared to all other nanoparticulate carriers since the stratum corneum contains substantial concentrations of epidermal lipi(*Banner on Brown m j Sharma p Clinical Pharmacology 11th Edn Edinburgh Elsevier 2012. - Google Search*, n.d.)ds, The lipid particles' tiny size validates their intimate relationship with the stratum corneum and enhances drug penetration,

occlusion, and accumulation in the dermis region, making them an excellent choice for a topical drug delivery system. SLN dispersion can be mixed with popular dermal carriers such as gels and creams to create a topical dose form with the required consistency.(Shrotriya et al., 2018)

Gels are typically chosen due to their ability to regulate swelling level easily, better targeting to the viable epidermis, controlled release nature.

Solid biodegradable lipids make up the matrix of solid lipid nanoparticles (SLN), which are aqueous colloidal dispersions. The advantages of a few colloidal carriers of its class are combined by SLNs, who strategically avoid their drawbacks. These advantages include physical stability, the guarantee that fused labile medications will be protected from degradation, the assurance that incorporated labile drugs will be released under controlled release, and excellent tolerability. In-vitro and in-vivo characterizations of SLN formulations for different application routes (parenteral, oral, dermal, ocular, pulmonary, and rectal) have been completed.(*Nanoparticles: Properties, Applications and Toxicities - ScienceDirect*, n.d.-a)

As a carrier system for correcting dynamic medication and successfully water dissolvable medication, solid lipid nanoparticles (SLNs) are presented. Nanoparticles are colloidal particles with sizes between 10 and 1000 nm They are made from synthetic distinctive polymers and can improve the delivery of medications and reduce lethality.(*Nanoparticles: Properties, Applications and Toxicities - ScienceDirect*, n.d.-b)

One of the new potential colloidal transporter systems, solid lipid nanoparticles are an alternative material to polymers that can be distinguished from oil in water emulsion for parenteral nutrition.

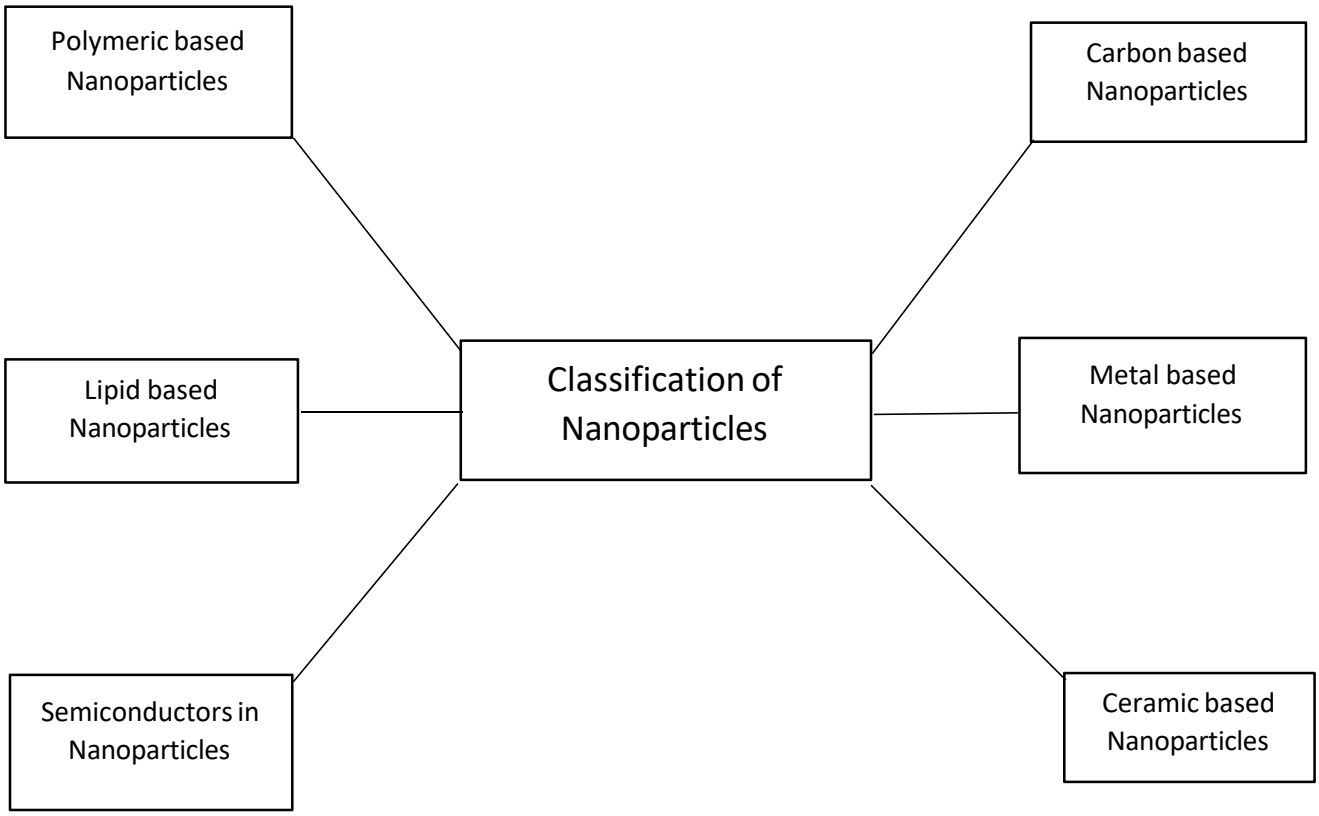
The selective inhibition of isoform 2 of the cyclooxygenase (COX-2) enzyme by etoricoxib, a COX-2 selective inhibitor, lowers the production of prostaglandins (PGs) according to Takemoto et al. (2008), from arachidonic acid. It has powerful antipyretic, anti-inflammatory, and analgesic drug has been authorized for greatly reducing discomfort and inflammation in joints level and duration of stiffness in the morning and improved handgrip

power.(*Frontiers | A Review on Nanoparticles: Characteristics, Synthesis, Applications, and Challenges*, n.d.)

The drug must stay encapsulated until the particle binds to the target in order to prevent nonspecific toxicity. It cannot diffuse out the particles while they are still in the circulatory system. Nanoparticles have a great potential for targeted drug delivery at the site of disease, which has several important implications, including:

1. The use of nanoparticles can increase drug bioavailability.
2. Medication directed at a particular location.
3. To increase poorly soluble drug absorption.
4. The successful formulation of chemotherapy drugs, including dexamethasone, doxorubicin 5-fluro-uracil, and paclitaxce, has been achieved through the use of nanomaterials.
5. Cell specificity.(Borse et al., 2020)

Classification of Nanoparticles:



1. Carbon-based NPs:

The two main subtypes of carbon-based NPs are fullerenes and carbon nanotubes (CNTs). Fullerenes contain NPs of spherical hollow cages, which resemble allotropic forms of carbon. They have generated a great deal of economic interest because of their structure, electron affinity, electrical conductivity, high strength, and adaptability. The carbon units in these compounds are arranged into pentagonal and hexagonal shapes and are all sp2 hybridized. However, CNTs are elongated and create tubular structures with a diameter of 1-2 nm. These basically look like sheets of graphite stacked on top of one other. Hence, depending on how many walls are present in the rolled sheets, they are referred to as single-walled (SWNTs), double-walled (DWNTs), or multi-walled carbon nanotubes (MWNTs).("Davis, M. E., Chen, Z. G. & Shin, D. M. Nanoparticle Therapeutics," 2024)

2. Metal NPs:

Metal NPs consist only of metals. Because of their well-known localized surface Plasmon resonance (LSPR) qualities, these NPs have unique electrical properties. A wide absorption band is seen by Cu, Ag, and Au nanoparticles in the visible portion of the solar electromagnetic spectrum. Because of their improved properties, such as facet, size, and shape-controlled manufacturing of metal NPs, metal nanoparticles (NPs) are exploited in a variety of scientific domains.(*Science Diagram Maker | Scientific Drawing Software | EdrawMax Online*, n.d.)

3. Ceramics NPs:

These are minuscule particles consisting of non-metallic, inorganic materials that undergo certain cooling and heating processes to confer unique characteristics. They have a variety of forms, such as amorphous, polycrystalline, dense, porous, and hollow, and they are renowned for their long-lasting qualities and resistance to heat. Applications for ceramic nanoparticles include coatings, batteries, and catalysts.(*(PDF) A Review on the*

Classification, Characterisation, Synthesis of Nanoparticles and Their Application, n.d.)

4. Lipid based NPs:

Due to the lipid moieties they contain, these NPs are useful in a variety of biological applications[23] Lipid nanoparticles (NPs) are spherical and usually have a diameter of 10–1,000 nm. Polymeric NPs, also known as lipid NPs, are composed of soluble lipophilic molecules in a matrix surrounding a solid lipid core.(*Science Diagram Maker | Scientific Drawing Software | EdrawMax Online*, n.d.)

5. Semiconductors in NPs:

Semiconductor NPs share characteristics with both non-metals and metals. Because of this, semiconductor NPs have special chemical and physical characteristics that enable a wide range of applications. To create more effective solar cells or brighter light-emitting diodes (LEDs), for instance, semiconductor nanoparticles (NPs) have the ability to both absorb and emit light. They can produce transistors, which are faster and smaller electrical devices that are employed in cancer therapy and bioimaging.(*Nanostructuring Solar Cells Using Metallic Nanoparticles - ScienceDirect*, n.d.)

6. Polymeric NPs:

Active chemicals may be entrapped inside the polymeric body of polymeric NPs or surface-adsorbed onto the polymeric core of polymeric NPs that range in size from 1 to 1,000 nm. The term polymer nanoparticle (PNP) is frequently used in the literature to refer to these NPs, which are frequently organic. Most of the time, they resemble nanoparticles or nanocapsules.(*Nanoparticles: Properties, Applications and Toxicities - ScienceDirect*, n.d.-a)

Structure of Nanoparticles:

Nanoparticles (NPs) have complicated structure. They are comprised of two or three layers:

(i) A surface layer that is functionalized by metal ions, a range of tiny molecules, polymers or surfactants.

(ii) The external layer can be done intentionally supplemented and differs chemically from the core.

(iii) The primary component of NPs, or core substance ,The distinctive qualities of NPs are often caused by the central substance. Thus, NPs are frequently

simply identified by their essential content

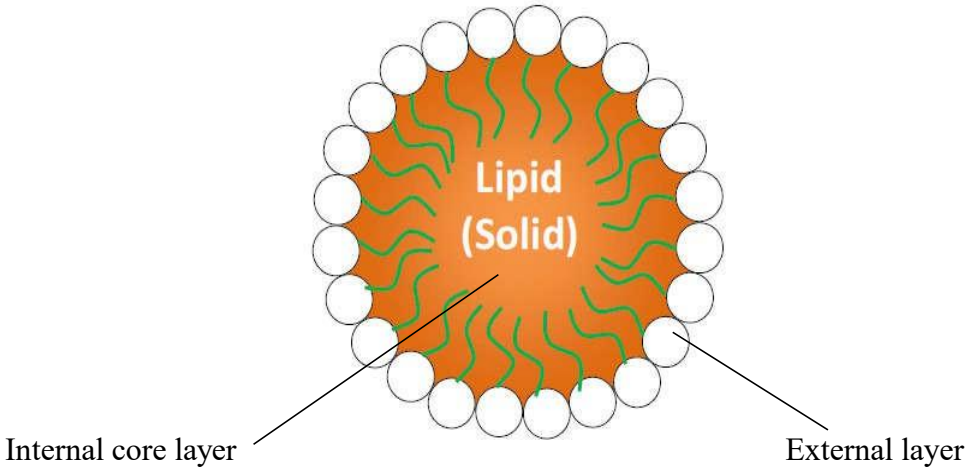


Fig: Structure of Nanoparticles.(*Science Diagram Maker | Scientific Drawing Software | EdrawMax Online*, n.d.)

Advantages:

1. Small estimate and typically contract measure distribution that provides SLNs with natural opportunities for site-specific medicine delivery.
2. Conventional emulsion producing techniques pertinent.
3. Can be stop dried to shape powdered detailing.
4. Controlled arrival of dynamic medication over a long stretch can be achieved.
5. Excellent biocompatibility.
6. Improve stability of pharmaceuticals.

7. Excellent reproducibility with a savvy high-weight homogenization technique as the readiness methodology.

8. High and enhanced drug content.

9. The achievability of consolidating both hydrophilic and hydrophobicmedications.

10. The transporter lipids are biodegradable and consequently protected.

11. Avoidance of natural solvents. Enhanced bioavailability of inadequately water dissolvable atoms.

12. Avoidance of natural solvents underway strategies.

13. Feasible huge scale generation and cleansing.(*Frontiers | Analysis of Engineered Tobacco Mosaic Virus and Potato Virus X Nanoparticles as Carriers for Biocatalysts*, n.d.)

Disadvantages:

1. Poor sedate stacking limit.

2. Drug ejection after polymeric move amid capacity.

3. Unpredictable gelation propensity.

4. The low ability to stack hydrophilic medications because of apportioning impacts amid the generation procedure.(*Nanoparticles: Properties, Applications and Toxicities - ScienceDirect*, n.d.-b)

Applications of Nanoparticles:

Specific physical and chemical characteristics, including mechanical, magnetic, optical, and thermal characteristics, are displayed by nanoparticles. This distinctiveness has resulted in its use in various contexts. Several of the noteworthy Applications of NPs are covered in the following:

1. Medicines:

Clinical medicine has greatly benefited from the use of nanoparticles in the fields of medication and gene delivery and medical imaging. Particles of iron oxide like magnetite (Fe3O4) or its Hametite (Fe2O3) in its oxidized state is most frequently used for use in biological sciences. The use of Ag NPs is

growing in catheters, wound bandages, and other home goodsgoods because of their capacity to fight microbes.(*Europe PMC*, n.d.)

2. Environmental Remediation:

Since nanoparticles can be applied both in situ and ex situ in aquatic environments, they are frequently utilized for environmental cleanup. AgNPs, or silver nanoparticles, have been widely employed as water disinfectants because of their antiviral, antifungal, and antibacterial properties. Due to its well-characterized low cost, non-toxicity, semiconducting, photocatalytic, electronic, gas sensing, and energy conversion capabilities, TiO2 NPs have been the subject of increased research for waste treatment, air purification, and photocatalysis in water treatment applications(Wang et al., 2024)

3. Mechanical industry:

Because of their superior young modulus, stress, and strain characteristics, NPs are used in the mechanical industries. Particularly in lubricants and coatings were discussed. and the creation of nanodevices with increased mechanical strength.(Shrotriya et al., 2018)

4. Electronics:

One-dimensional semiconductors and metals have special structural, optical, and electrical characteristics that make them the building blocks of the next generation of electronic, sensor, and photonic materials.(Dvir et al., 2011)

5. Food:

In order to regulate the surrounding atmosphere and keep food fresh and free from microbial contamination, nanoparticles have been used to food packaging more and more. These days, the food packaging industry uses a lot of inorganic and metal nanoparticles (NPs) as substitutes for petroleum-based polymers because they can incorporate antimicrobial compounds directly onto the coated film surface.(Borse et al., 2020)

6. Energy harvesting:

Scientists' research interests have shifted toward the creation of various methods that can assist in producing renewable energies from readily available resources at a low cost as a result of the scarcity of fossil fuels. NPs' huge surface area, optical characteristics, and catalytic nature make them an excellent choice for this application.(Anusiya & Jaiganesh, 2022) NPs are frequently utilized in the production of energy by electrochemical and photoelectrochemical (PEC) water splitting. Additional cutting-edge methods for producing energy include solar cells, piezoelectric generators, and the electrochemical conversion of CO2 to fuel precursors. Graphene has been claimed to be used in next-generation smart energy storage devices and as a source of energy.(Borse et al., 2020)

Summary:

The creative fusion of hydrogels and nanoparticles, two completely distinct kinds of biomaterials, has produced unique NP-gels with improved drug delivery capabilities and more structural variety. These hybrid biomaterials have demonstrated exceptional ability in site-specific drug targeting, remotely regulated and "on-demand" drug release, altering drug release kinetics, and supporting detoxification based on nanoparticles. Together, these uses have shown that NP-gels are a novel and resilient class of biomaterials with great promise for increasing the effectiveness of drug delivery. More complex drug delivery systems have been created by combining nanoparticles with various biomaterial platforms and devices, including nanofibers, microneedle patches, and nanomotors,in addition to the development of NP-gels.(Lingayat et al., n.d.)

Despite tremendous advancements in the creation and refinement of NP-gel formulations, obstacles still need to be overcome to increase their clinical suitability for drug delivery. One issue is foreign-body reactions, which might possibly limit the performance of implanted NP-gels and often result in the creation of collagenous capsules, particularly for in vivo applications. New material designs that are better at preventing capsule formation are being

developed to address this issue. In particular, ultra-low-fouling zwitterionic hydrogels have just been created to prevent capsule formation in mice for at least three months following subcutaneous implantation.(Lingayat et al., n.d.)

Enhancing the NP-gel formulation's clinical usability presents another set of significant issues. In this regard, the risk of premature gelation inside the needle during injection would be decreased by mechanisms that encourage gelation at lower polymer concentrations and narrower gelation temperatures.(Altammar, 2023)

Conclusion:

In conclusion, solid lipid nanoparticles based topical gels represents a promising advancements in drug delievery system their unique structure combining solid, lipid and biocompatible stabilizer enhancing the drug stability, bioavailability and control release.

SLN gels are particularly effective in improving the drug penetration through skin barrier ,making them suitable for localize treatment of dermatological and systemic condition furthermore ,their ability to encapsulate both hydrophilic and lipophilic drug broadens their application range .However challenges such as large scale production, stability issue and potential cytotoxicity need to be address .

Future aspects of SLN Gel:

It improves solubility and stability of poorly water soluble drugs,potentially increases their therapeutic efficacy. Functionalization with lignads can enables targeted delievery to specific tissues or cell. It improves skin penetration of active ingredients making them valuable for antiaging, depigmentation formulation. It also enhances healing SLN gel loaded with antimicrobial afents or growth factors could accelerate wound healing.

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