



**INTERNATIONAL JOURNAL OF
PHARMACEUTICAL SCIENCES**
[ISSN: 0975-4725; CODEN(USA):IJPS00]
Journal Homepage: <https://www.ijpsjournal.com>



Review Article

Nanostructured Lipid Carrier (Nlc): A Cutting-Edge Drug Delivery System

Pavithra S., Roshini R., Nikitha G., Sathish M., Sriramcharan Pitta*

P.S.V College of pharmaceutical science and research, The Tamilnadu Dr. M.G.R Medical university Chennai-600032

ARTICLE INFO

Received: 18 Sep 2024

Accepted: 22 Sep 2024

Published: 02 Oct 2024

Keywords:

Nano, Structured, Lipid, Carrier

DOI:

10.5281/zenodo.13882362

ABSTRACT

Nanostructured Lipid Carriers (NLCs) are an advanced form of drug delivery system, particularly designed for enhancing the oral bioavailability of lipophilic (fat-loving) medications. Traditional lipid matrices have been used to deliver such drugs more effectively by increasing their absorption in the body. NLCs, the third generation of these lipid-based carriers, are composed of a blend of solid and liquid lipids that do not mix well at a molecular level, known as spatially incompatible lipids. This unique composition of NLCs remains stable at room temperature and addresses several limitations found in earlier lipid carriers like solid lipid nanoparticles (SLNs). The inclusion of liquid lipids within the solid lipid matrix creates structural imperfections, which allow for higher drug loading and prevent the drug from being expelled during storage. This structure also facilitates a more controlled and sustained release of the drug, improving its overall efficacy. NLCs are versatile, meaning they can be used for various drug delivery methods, especially oral delivery. Their benefits include enhanced drug stability, improved solubility, and a higher capacity for drug loading. Additionally, NLCs are relatively easy to manufacture on a large scale, making them a practical option for pharmaceutical companies. This review offering a promising solution for the effective and scalable delivery of lipophilic drugs.

INTRODUCTION

Oral drug delivery is the most convenient, affordable, and patient-friendly mode of pharmaceutical administration, it is also the most extensively used. Nevertheless, lipophilic medications frequently face obstacles in attaining

efficient oral bioavailability. Their quick first-pass metabolism and poor water solubility, which decrease the amount of medication available in the bloodstream after consumption, are the main causes of this. Lipid-based matrices have been the

*Corresponding Author: P. Sriram charan

Address: P.S.V College of pharmaceutical science and research, The Tamilnadu Dr. M.G.R Medical university Chennai-600032

Email ✉: sriramcharan678@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



focus of research to improve the absorption and bioavailability of lipophilic medicines in order to solve these problems. Liposomes, solid lipid nanoparticles (SLN), nanostructured lipid carriers (NLC), and lipid emulsions (LE) are a few of the lipid-based carriers that have been produced. The manufacture of lipid pellets, which was pioneered by Eldem and Speiser, set the foundation for contemporary lipid-based drug delivery methods. Gasco developed a microemulsion method in 1993 for creating solid lipid microspheres, which had advantages including room-temperature stability and simplicity of handling. Even with SLNs' effectiveness, issues with drug ejection during storage because of lipid crystallisation and poor drug loading capacity persisted. As a result, a third-generation lipid matrix known as Nanostructured Lipid Carriers (NLCs) was created (1–5). Non-polar colloidal particles (NLCs) present a viable approach to enhance the oral bioavailability of lipophilic medicines due to their enhanced stability, increased drug loading capacity, and capacity to generate highly concentrated particle dispersions.

NLC & TYPES

An incompatible mixture of solid lipids and a combination of liquid lipids is called NLC. It doesn't soften even at room temperature. Comparable to single-pass metabolism (SLN), it

offers several benefits such as the use of suitable lipids, regulated drug release from the carrier, economical large-scale production utilising existing equipment, avoiding lymphatic transport-mediated first pass metabolism, and shielding the drug moiety from biochemical deterioration. It also gets rid of all of SLN's disadvantages, such as the fact that NLC has better drug loading because liquid lipid is used, stops drug ejection during long-term storage, and lets you use lipids at higher ratios (up to 95%) than SLN, where lipids form incoherent systems at ratios higher than 30%. (6)–(8)

Three categories can be applied to NLC

- a. The imperfect type
- b. The multiple type
- c. The amorphous type

a. The imperfect type:

Drug loading is enhanced and defects are produced by mixing chemically different liquid and solid lipids.

b. The multiple type: These oil nano compartments are solid lipid-encapsulated. Dissolved or added to the oil compartments is the medicine. It was prepared using a lipid-lipid precipitation method.

c. The amorphous type: This is made by carefully combining particular kinds of liquid and solid lipids (such isopropyl myristate) to produce NLC that are in an amorphous state.

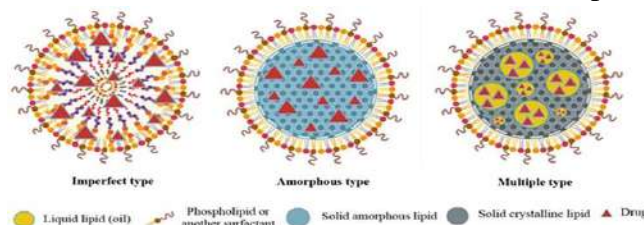


Figure 1: A Diagram Illustrating On Types Of Nlc.

COMPOSITION OF NLC (TABLE 1)

S.no	Solid lipid	Liquid lipids	Aqueous surfactants	Co-emulsifiers
1.	Triglycerides-tricaprin, trimyristin, tristearin.	Natural and synthetic oils such as mustard oil, castor oil, cod-liver oil, medium chain	Tween-80, Pluronic F-68	Soyabean lecithin, egg lecithin phosphatidyl choline.

		triglycerides, oleic acid.		
2.	Hard fat types-glyceryl monostearate, stearic acid, cetyl alcohol.			

DIFFERENT MECHANISM OF NLC FOR IMPROVE BIOAVAILABILITY.

Direct absorption: via the GI tract, or intestinal lymphatic transfer. Because NLC uses long-chain triglycerides and is lipophilic, it might cause the synthesis of chylomicron, which is then absorbed by the transcellular pathway. Via the intestinal lymphatic system, highly lipophilic compounds are transported around the hepatic first metabolism. In the GIT, lingual lipase and gastric lipase start the hydrolysis of TG, resulting in a crude TG emulsion that is released into the duodenum. This unrefined emulsion stimulates bile salts, biliary lipids, and pancreatic juice. Biliary lipids stabilise TG emulsion by binding to its surface. Pancreatic lipase forms fatty acids (FA) and monoglycerides (MG) at the outermost layer of homogenised TG droplets (9-12) These are eventually broken down by a range of organelles and arranged to produce the lipid core of the chylomicron. To stabilise the chylomicrons that are formed, phospholipids and apolipoproteins are added. These stabilised lipoproteins are then secreted with the layer of lamina mucosa and mesenteric lymphatic.

Mucoadhesion:

Mucus adheres to lipid nanoparticles, which prolongs the mucus's residence time and speeds up the medication's release from the carrier.

Mixed micelle formation:

The lipids used in NLC trigger the small intestine to release bile since they are similar to dietary lipids. Lipid digestion products are produced when lipids are broken down by enzymes and mixed with bile to form mixed micelles. This event causes the medication to become more soluble, which facilitates its passage across membranes (13).

Increased permeability:

Surfactants alter the intestinal wall's permeability in a number of ways. For instance, poloxamer is known to cause cell membrane distortion and to open the tight connection of intestinal epithelial cells, enabling the paracellular transfer of NLCs [10]. It also inhibits P-gp efflux and facilitates NLC transport over the intestinal mucosa. They also provide the required steric stabilisation.

Inhibits drug degradation:

In the hostile GI environment, several medications become unstable. NLC has the benefit of shielding the medication from enzymatic and chemical breakdown by the lipids, which delays in vivo conversion.

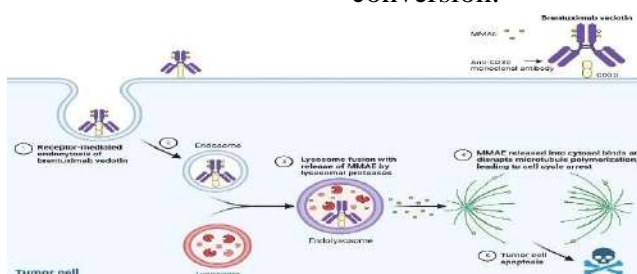


Figure 2: Mechanism Of Nlc.

PREPARATION METHODS

High pressure homogeniser: The most typical usage for it is to produce NLC. It is better than

other methods since it can be produced on a big scale without the need for organic solvents. The hot homogenisation technique and the cold homogenisation technique are the two approaches (14–17). In both procedures, the medication is first dissolved in solid liquids known as melted lipid mixtures (LM) at a temperature that is 5–10 °C over the lipid's melting point. The melt above is mixed with an emulsion in a hot aqueous surfactant solution, and both are homogenised in HPH at the same temperature to create a hot nano-emulsion. NLC is produced when the mixture cools to room temperature. The melt mentioned above (step 1) was crushed and solidified in the cold homogenisation process to produce lipid microparticles. To create resuspension, these were dispersed in a cold aqueous surfactant solution, and to create NLC, they were homogenised at reduced/RT.

Microemulsion technique:

For full solubilisation, the medication was introduced to lipids that had melting points 5–10 °C higher than those of the LM, lipophilic surfactant. The lipid melt was stirred while the aqueous surfactant solution was added at the same temperature. When the ingredients were combined in the right proportion, a transparent micro-emulsion was created. To create NLC, it was then scattered into ice-cold water and gently stirred continuously. Here, precipitation—rather than being mechanically produced by stirring—is what caused the particles to become so tiny. (18)

Solvent diffusion technique:

It is separated into two phases: the organic phase, which comprises the medicine, lipophilic surfactant, and LM, and is dissolved in organic solvents at a high temperature. The final organic solution was quickly combined with the aqueous surfactant solution at room temperature (25 °C) and physically agitated strongly for a predetermined period of time in order to produce NLC. The resultant dispersion can be kept under

vacuum in desiccators for an entire day in order to evaporate the leftover organic solvent.

Solvent emulsification technique:

The drug, surfactant, and lipid mixture were melted and uniformly mixed with room temperature heated aqueous surfactant solution to form the primary emulsion. The warm original emulsion was pulverised using a lab ultrasonic cell pulveriser to form the nano-emulsion. The beaker was then rapidly frozen by immersing it in freezing water and stirred to produce a homogenous NLC dispersion (19–21).

Solvent evaporation technique:

In this process, LM and the drug are combined with an organic solvent, and the mixture is then emulsified in an aqueous phase.

NLC is produced when the lipid precipitates after the solvent has evaporated.

CHARACTERISATION

Drug loading (DL) and drug entrapment efficiency (Ee):

The resultant NLC dispersion was spun for 15-20 minutes at high rpm (10000–20,000000) to measure the drug. The particle size was taken into consideration when choosing the rpm; the smaller the particle, the higher the rpm needed for centrifugation. To ascertain the amount of drug present in the supernatant, an appropriate HPLC method was employed for analysis. The following formulas were used to determine the drug loading (DL) and drug entrapment efficiency. (22-25)

$$E = (W1 - WS) \times 100\%$$

$$DL = (W1 - WS) / (W1 - WS + WI) \times 100$$

Particle size (PS) and zeta potential (ZP): Using Malvern Zetasizer, a device based on Mie theory, Photon Correlation Spectroscopy (PCS) was used to evaluate the particle size and zeta potential of NLC. All ZP and size measurements were performed at 25 °C following the proper dilution steps. Based on particle electrophoretic mobility in an aqueous solution, the ZP was determined. Long-term stability and surface charge



characteristics are provided by the ZP. Particle aggregation is less likely to be caused by electrostatic repulsion at greater ZP. For the NLC to be stable, the ZP of dispersion typically needs to be either less than -30 mV or larger than +30 mV(26-32)

External morphological research:

These investigations display the particle morphology. The samples are diluted appropriately, spread out on a sample holder, and vacuum-dried in order to get them ready for SEM. Once they have been covered with gold, these are examined using a SEM. The diluted substance is dried in a TEM on carbon-coated grids to form the thin-film material. After that, drying, TEM inspection, and colouring with phosphotungstic acid are carried out. The recrystallisation index (RI) was ascertained by thermal analysis of the generated NLC formulation using DSC. A carefully weighed sample (3-5 mg) was sealed and put inside an aluminium pan. To provide context, an empty aluminium pan was used (33–36).The samples were heated over a temperature range at an optimum heating rate of 5–10 °C/min.

Wide angle XRD:

This procedure involves mixing the medication and LM with an organic solvent before emulsifying the combination in an aqueous phase. When the solvent evaporates and the lipid precipitates, NLC is created.

APPLICATION

Essentially, the NLC is available for all stated SLN applications. When it comes to speedy two-market entrance and low regulatory obstacles, oral and topical delivery are the most desirable options. Zhang and colleagues have described the characterisation and evaluation of NLC as an oral delivery system for etoposide. When given orally to rats, studies on the pharmacokinetics of NLC have shown longer half-lives and improved relative bioavailability in comparison to drug solution When used as oral carriers for

Domperidone encapsulation, NLC demonstrated a higher and consistently faster release than SLN, according to similar investigations conducted by Thatipamula et al. (41-44). After 40 days in storage, the combination remained cohesive. In comparison to free solution, the investigation by Chen et al. on the impact of lipophilic solvents on the oral administration of lovastatin from NLC showed a considerable improvement in bioavailability,When compared to SPC-NLC, myverol-NLC was more stable in the stomach environment, demonstrating the emulsifier's function. The development of NLC for oral hypoglycaemic medicines was reported by Jain et al. A study on the impact of surfactant mixes on NLC showed that a formulation comprising sodium taurocholate, poloxamer 188, and lecithin had a better and more favourable release profile. Zhuang et al.'s study.When comparison to the suspension in Wistar rats given by mouth, the production and characterisation of vinpocetine-loaded NLC upon In-vivo PK investigation demonstrated enhanced relative bioavailability of NLC up to 300%. Tiwari and colleagues PK research comparing the relative bioavailability of NLC and SLN for Simvastatin showed that NLC had a better bioavailability than both suspension and SLN. A wide variety of approved excipients are readily available, including all lipids and surfactants used in creams, pills, pellets, and capsules. Particularly interesting are pharmacological life-extensions. egg: cyclosporine. (45-47) Because of the special properties of NLC, there is little to no risk of potential patent infringement. Many patents cover emulsions, micro-emulsions, and liposomes. Fewer patents cover lipid nanoparticles made of solid lipids, especially those made of mixes of solid and liquid lipids. Some specialised uses exist, like delivering nanoparticles to the eyes to prolong retention times. Many studies address the use of polymeric nanoparticles to prolong the retention of



medications in the eye; however, no product has been commercialised as of yet due to a number of factors, including the toxicity of non-accepted polymer poly alkyl-cyanoacrylate. Since that SLN showed an extended retention duration in the eye, it would be even more advantageous to use NLC with better drug accommodation qualities. Andrade et al. design and evaluate the feasibility of a topical administration technique for voriconazole eye therapy, based on cationic nanostructured lipid carriers (NLCs). Souto et al. examined comparable key issues in ocular drug management. They discussed the fascinating strategies of submicron-sized particles, or colloidal carrier systems. Nanostructured lipid carriers (NLC) and solid lipid nanoparticles (SLN) are promising replacements for well-known and often used ocular carrier systems such liposomes, polymeric nanoparticles, and nano emulsions. The reviewer was particularly focused on the available therapeutic alternatives while examining the most recently approved drugs (48–49). Nebulised aqueous NLC dispersions serve a similar purpose as nano suspensions in terms of administering medication to the lungs. A nano-drug delivery method for co-encapsulating DOX and PTX has been developed by Wang et al. This approach was expected to treat the multidrug resistance caused by a single round of treatment. Additionally, it was intended for dual-drug-loaded nanostructured lipid carriers to specifically target cancer cells with little effects on healthy cells or tissues. Treatment for targeted combinational lung cancer can be aided by the PTX-DOX NLC used in this investigation. You can use any basic mechanical nebuliser to administer these dispersions. As with SLN, the main benefit of NLC is its ability to combine a state-of-the-art encapsulation technique with a conventional dosage form that the patient is familiar with, like a tablet or pellet.(50)

CONCLUSION

Consequently, the mentioned analysis demonstrated that NLC is thought to be the most intelligent and sophisticated lipid nanoparticle production method available today, with enhanced capabilities for drug loading, control over release patterns, and stable long-term drug integration. NLC is a simple-to-use medicine carrier for oral delivery due to its many benefits. Over the past ten years, the biological field has consistently improved NLC formulation. Both modifications were necessary to ensure the results and the efficacy of the NLCs' deployment. NLCs have a profusion of possible industrial applications, and their many advantages have resulted in the issuing of multiple patents for a range of uses. Nevertheless, many of them are the result of more commercially motivated studies in addition to basic research. The production method of highly concentrated lipid particle dispersions, which was made possible by NLC technology, simplifies the conversion of aqueous dispersions into solid products including tablets, capsules, pellets, and powders for reconstitution. It is applicable to both SLN and NLC. The expanding number of preclinical and clinical examples in the paper, which eloquently demonstrate how potential nano formulations might be used to overcome the pharmaceutical industry's current technological disadvantage, can be used to explain the increasing number of patented NLC-based formulations. As a result, these benefits are fixing earlier issues. It is also one of the possible deliveries that the pharmaceutical market is anticipated to see in the near future because to its capacity for large-scale production.

CONFLICT OF INTEREST:

ACKNOWLEDGEMENT:

The authors extend their appreciation to P.S.V College of pharmaceutical science and research, for their kind support acknowledging their crucial support.

REFERENCE :



1. Tadatsugu M, Toshihiro M, Takashi Y, Hidenobu T (2000) *Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films* 18: 1584.
2. Kashiwaba Y, Sugawara K, Haggaa K, Watanabe H, Zhang BP, et al. (2002) Characteristics of c-axis oriented large grain ZnO films prepared by low-pressure MO-CVD method. *Thin Solid Films* 411(1): 87-90.
3. Fortunato E, Barquinha P, Pimentel A, Gonçalves A, Marques A, et al. (2005) Recent advances in ZnO transparent thin film transistors. *Thin Solid Films* 487(1-2): 205-211.
4. Hua Chi Cheng, Chia-Fu Chen, Cheng-Chung Lee (2006) Thin-film transistors with active layers of zinc oxide (ZnO) fabricated by lowtemperature chemical bath method. *Thin Solid Films* 498(1-2): 142- 145.
5. Ott AW, Chang RPH (1999) Atomic layer-controlled growth of transparent conducting ZnO on plastic substrates. *Materials Chemistry and Physics* 58(2): 132-138.
6. El Bekkaye Yousfi, Jacques F, Daniel L (2000) Study of atomic layer epitaxy of zinc oxide by in-situ quartz crystal microgravimetry. *Applied Surface Science* 153(4): 223-234.
7. Seong KK, Cheol SH, Sang HK, Sun JY (2005) Comparison between ZnO films grown by atomic layer deposition using H₂ O or O₃ as oxidant. *Thin Solid Films* 478(1-2): 103-108.
8. Lim SJ, Soon JK, Hyungjun K (2007) High performance thin film transistor with low temperature atomic layer deposition nitrogendoped ZnO. *Appl Phys Lett* 91: 183517.
9. Özgüra Ü, Alivov YI, Liu C, Tekeb A, Reshchikov MA (2005) A comprehensive review of ZnO materials and devices. *Journal of Applied Physics* 98: 041301.
10. Banerjee D, Lao JY, Wang DZ, Huang JY, Ren ZF (2003) Large-quantity free-standing ZnO nanowires. *Appl Phys Lett* 83: 2061.
11. Karuppasamy A, Subrahmanyam A (2007) Effect of electron bombardment on the properties of ZnO thin films. *Mater Lett* 61(4-5): 1256-1259.
12. Pearton SJ, Norton DP, Ip K, Heo YW, Steiner T (2005) Recent progress in processing and properties of ZnO. *Prog Mater Sci* 50(3): 293-340.
13. Ruffolo SA, La Russa MF, Malagodi M, Rossi CO, Palermo AM, et al. (2010) ZnO and ZnTiO₃ nanopowders for antimicrobial stone coating. *Appl Phys A* 100(3): 829-834.
14. Kääriäinen ML, Kääriäinen TO, Cameron DC (2009) Titanium dioxide thin films, their structure and its effect on their photoactivity and photocatalytic properties. *Thin Solid Films* 517(24): 6666-6670.
15. Kääriäinen ML, Cameron DC (2012) The importance of the majority carrier polarity and p-n junction in titanium dioxide films to their photoactivity and photocatalytic properties. *Surf Sci* 606(3-4): 22-25.
16. Kääriäinen ML, Cameron DC (2012) Nitrogen doping in atomic layer deposition grown titanium dioxide films by using ammonium hydroxide. *Thin Solid Films* 526: 212-217.
17. Schiller R, Weiss CK, Landfester K (2010) Phase stability and photocatalytic activity of Zr-doped anatase synthesized in miniemulsion. *Nanotechnology* 21(40): 405603.
18. Moreau JW, Weber PK, Martin MC, Gilbert B, Hutcheon ID, et al. (2007) Extracellular proteins limit the dispersal of biogenic nanoparticles. *Science* 316(5831): 1600-1603.
19. Pal S, Tak YK, Song JM (2007) Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A



- study of the Gram-negative bacterium *Escherichia coli*. *Appl Environ Microbiol* 73(6): 1712-1720.
20. Feng QL, Wu J, Chen GQ, Cui FZ, Kim TN, et al. (2000) A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Staphylococcus aureus*. *J Biomed Mater Res* 52(4): 662-668.
 21. Müller RH, Radtke M, Wissing SA (2002) Nanostructured lipid matrices for improved microencapsulation of drugs. *Int J Pharm* 242 (1-2): 121- 128.
 22. Zhang T, Chen J, Zhang Y, Shen Q, Pan W (2011) Characterization and evaluation of nanostructured lipid carrier as a vehicle for oral delivery of etoposide. *Eur J Pharm Sci* 43(3): 174-179.
 23. Thatipamula R, Palem C, Gannu R, Mudragada S, Yamsani M (2011) Formulation and in vitro characterization of domperidone loaded solid lipid nanoparticles and nanostructured lipid carriers. *DARU* 19(1): 23- 32.
 24. Chen CC, Tsai TH, Huang ZR, Fang JY (2010) Effects of lipophilic emulsifiers on the oral administration of lovastatin from nanostructured lipid carriers: Physicochemical characterization and pharmacokinetics. *Eur J Pharm Biopharm* 74(3): 474-482.
 25. Zhuang CY, Li N, Wang M, Zhang XN, Pan WS, et al. (2010) Preparation and characterization of vincetamine loaded nanostructured lipid carriers (NLC) for improved oral bioavailability. *Int J Pharm* 394(1-2): 175-185.
 26. Andrade LM, Rocha KA, De Sá FA, Marreto RN, Lima EM, et al. (2016) Voriconazole-Loaded Nanostructured Lipid Carriers for Ocular Drug Delivery. *Cornea* 35(6): 866-871.
 27. Amiri M, Jafari S, Kurd M et al (2021) Engineered solid lipid nanoparticles and nanostructured lipid carriers as new generations of blood-brain barrier transmitters. *ACS Chem Neurosci* 12:4475–4490.
 28. Sarhadi S, Gholizadeh M, Moghadasian T, Golmohamadzadeh S (2020) Moisturizing effects of solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC) using deionized and magnetized water by in vivo and in vitro methods. *Iran J Basic Med Sci* 23:337–343.
 29. Jaiswal P, Gidwani B, Vyas A (2016) Nanostructured lipid carriers and their current application in targeted drug delivery. *Artif Cells Nanomed Biotechnol* 44:27–40.
 30. Tsai M-J, Wu P-C, Huang Y-B et al (2012) Baicalein loaded in tocopherol nanostructured lipid carriers (tocopherol NLCs) for enhanced stability and brain targeting. *Int J Pharm* 423:461–470.
 31. Selvamuthukumar S, Velmurugan R (2012) Nanostructured lipid carriers: a potential drug carrier for cancer chemotherapy. *Lipids Health Dis* 11:1–8.
 32. Faheim S, Gardouh A, Nouh A, Ghorab M (2018) Review article on nanoemulsions and nanostructured lipid carriers. *Rec Pharm Biomed Sci* 2:23–31.
 33. Subramaniam B, Siddik ZH, Nagoor NH (2020) Optimization of nanostructured lipid carriers: understanding the types, designs, and parameters in the process of formulations. *J Nanoparticle Res* 22:1–29.
 34. Tamjidi F, Shahedi M, Varshosaz J, Nasirpour A (2013) Nanostructured lipid carriers (NLC): a potential delivery system for bioactive food molecules. *Innov Food Sci Emerg Technol* 19:29–43.
 35. Naseri N, Valizadeh H, Zakeri-Milani P (2015) Solid lipid nanoparticles and nanostructured lipid carriers: structure,

- preparation and application. *Adv Pharm Bull* 5:305–313.
36. Kaur S, Nautyal U, Singh R et al (2015) Nanostructure lipid carrier (NLC): the new generation of lipid nanoparticles. *Asian Pac J Health Sci* 2:76–93.
 37. Fang C-L, Al-Suwayeh AS, Fang J-Y (2012) Nanostructured lipid carriers (NLCs) for drug delivery and targeting. *Recent Pat Nanotechnol* 7:41–55.
 38. Rajalakshmi G, Dhanapal CK, Sundhararajan R (2020) an insight to nanostructured lipid carrier system. *J Drug Deliv Ther* 10:173–182.
 39. Czajkowska-Kośnik A, Szekalska M, Winnicka K (2019) Nanostructured lipid carriers: a potential use for skin drug delivery systems. *Pharmacol Reports* 71:156–166.
 40. Montenegro L, Lai F, Offerta A et al (2016) From nanoemulsions to nanostructured lipid carriers: a relevant development in dermal delivery of drugs and cosmetics. *J Drug Deliv Sci Technol* 32:100–112.
 41. Arunkumar N, Deecaraman M, Rani C (2014) Nanosuspension technology and its applications in drug delivery. *Asian J Pharm* 3:168–173.
 42. Wen J, Chen G, Chen S (2018) Nanostructured lipid carriers. In: Roohinejad S, Greiner R, Oey I, Wen J (eds) *Emulsion-based systems for delivery of food active compounds: formation, application, health and safety*. Wiley, Hoboken, pp 139–159
 43. Severino P, Andreani T, Macedo AS et al (2012) Current state-of-art and new trends on lipid nanoparticles (SLN and NLC) for oral drug delivery. *J Drug Deliv* 2012:1–10.
 44. Belouqui A, Solinís MÁ, Rodríguez-Gascón A et al (2016) Nanostructured lipid carriers: promising drug delivery systems for future clinics. *Nanomed Nanotechnol Biol Med* 12:143–161.
 45. Poonia N, Kharb R, Lather V, Pandita D (2016) Nanostructured lipid carriers: versatile oral delivery vehicle. *Futur Sci OA* 2:FSO35.
 46. Souto EB, Baldim I, Oliveira WP et al (2020) SLN and NLC for topical, dermal, and transdermal drug delivery. *Expert Opin Drug Deliv* 17:357–377.
 47. Iqbal MA, Md S, Sahni JK et al (2012) Nanostructured lipid carriers system: recent advances in drug delivery. *J Drug Target* 20:813–830.
 48. Samimi S, Maghsoudnia N, Eftekhari RB, Dorkoosh F (2019) Lipid-based nanoparticles for drug delivery systems. In: Mohapatra SS, Ranjan S, Dasgupta N et al (eds) *Characterization and biology of nanomaterials for drug delivery: nanoscience and nanotechnology in drug delivery*. Elsevier, pp 47–76
 49. Salvi VR, Pawar P (2019) Nanostructured lipid carriers (NLC) system: a novel drug targeting carrier. *J Drug Deliv Sci Technol* 51:255–267
 50. Ganesan P, Narayanasamy D (2017) Lipid nanoparticles: Different preparation techniques, characterization, hurdles, and strategies for the production of solid lipid nanoparticles and nanostructured lipid carriers for oral drug delivery. *Sustain Chem Pharm* 6:37–56.

HOW TO CITE: Pavithra S, Roshini R , Nikitha G , Sathish M. , Sriramcharan Pitta, Nanostructured Lipid Carrier (Nlc): A Cutting-Edge Drug Delivery System, *Int. J. of Pharm. Sci.*, 2024, Vol 2, Issue 10, 111-119. <https://doi.org/10.5281/zenodo.13882362>



