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DEVELOPMENT AND CHARACTERIZATION OF SOLID LIPID NANOPARTICLE (SLN)-LOADED FORMULATIONS FOR ENHANCED DRUG DELIVERY

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ABSTRACT

Solid lipid nanoparticles (SLNs) have emerged as a promising nanocarrier system in modern drug delivery due to their ability to overcome limitations associated with conventional dosage forms. SLNs are submicron-sized particles composed of physiologically compatible lipids that remain solid at body temperature, offering a unique combination of advantages such as controlled drug release, improved bioavailability, and enhanced stability of encapsulated drugs. These carriers are particularly beneficial for poorly water-soluble drugs, enabling efficient drug loading and protection from degradation. The present review focuses on the development and characterization of SLN-based formulations for enhanced drug delivery. It comprehensively discusses various preparation techniques, including high-pressure homogenization, microemulsion methods, and solvent-based approaches, along with the role of formulation components such as lipids, surfactants, and stabilizers. Detailed insights into characterization parameters like particle size, zeta potential, drug entrapment efficiency, morphology, and in-vitro drug release are also provided. Furthermore, the review highlights the wide range of applications of SLNs in oral, topical, parenteral, ocular, and targeted drug delivery systems, including their potential in brain targeting and cancer therapy. Despite several advantages, certain limitations such as drug expulsion and low loading capacity are also addressed. In conclusion, SLNs represent a versatile and efficient platform for drug delivery, with significant potential for future advancements through surface modification, hybrid systems, and targeted delivery strategies. Continued research and technological innovations are expected to further enhance their clinical applicability and commercial viability.

KEYWORDS: *Solid Lipid Nanoparticles (SLNs), Drug Delivery, Nanocarriers, Bioavailability, Controlled Release, Nanotechnology*

INTRODUCTION

Overview of Drug Delivery Challenges

The successful delivery of therapeutic agents remains a major concern in pharmaceutical development due to several inherent limitations associated with conventional dosage forms. Among these, poor solubility, low bioavailability, and extensive first-pass metabolism are the most critical challenges that significantly affect drug efficacy. One of the primary issues is **poor aqueous solubility**, particularly for a large proportion of newly developed drug molecules. Drugs with low solubility exhibit slow dissolution rates in biological fluids, which directly limits their absorption and therapeutic effectiveness. This problem is especially common in BCS Class II and IV drugs, where solubility becomes the rate-limiting step in drug absorption. Another major challenge is **low bioavailability**, which refers to the fraction of an administered drug that reaches systemic circulation in an active form. Even when a drug is adequately soluble, factors such as poor permeability across biological membranes, instability in gastrointestinal conditions, and rapid metabolism can significantly reduce its bioavailability. As a result, higher doses are often required to achieve therapeutic effects, increasing the risk of side effects. Additionally, **first-pass metabolism** plays a crucial role in reducing drug availability, particularly for orally administered drugs. After absorption from the gastrointestinal tract, drugs are transported to the liver via the portal circulation, where they undergo metabolic degradation before reaching systemic circulation. This hepatic metabolism can substantially decrease the concentration of active drug, thereby limiting its therapeutic efficacy. Collectively, these challenges highlight the need for advanced drug delivery systems that can enhance solubility, improve bioavailability, and bypass or minimize first-pass metabolism, ultimately leading to more effective and reliable therapeutic outcomes.

Introduction to Nanotechnology in Pharmaceutics

Nanotechnology has revolutionized the field of pharmaceutical sciences by offering innovative approaches to drug delivery and therapeutic effectiveness. It involves the design, development, and application of materials at the nanoscale (typically 1–1000 nm), where unique physicochemical properties such as increased surface area, enhanced reactivity, and improved interaction with biological systems are observed. In pharmaceutics, nanotechnology-based delivery systems have been widely explored to overcome limitations associated with conventional dosage forms, including poor solubility, low stability, and inadequate targeting.

Various nanocarrier systems such as liposomes, polymeric nanoparticles, dendrimers, nanoemulsions, and lipid-based nanoparticles have demonstrated significant potential in improving drug solubility, enhancing bioavailability, and enabling controlled and site-specific drug delivery. These systems can be engineered to modify drug release profiles, protect drugs from degradation, and facilitate transport across biological barriers, thereby improving overall therapeutic outcomes.

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Definition and Concept of Solid Lipid Nanoparticles (SLNs)

Solid Lipid Nanoparticles (SLNs) are a class of lipid-based nanocarriers composed of physiologically compatible lipids that remain solid at room and body temperatures. Typically ranging in size from 50 to 1000 nm, SLNs are stabilized by surfactants and dispersed in an aqueous medium. The solid lipid core serves as a matrix for drug incorporation, where the drug can be either dissolved or dispersed within the lipid structure. The concept of SLNs was developed as an alternative to traditional colloidal carriers such as emulsions, liposomes, and polymeric nanoparticles, aiming to combine their advantages while minimizing associated limitations. The solid nature of the lipid matrix provides improved stability and allows for controlled drug release. Depending on the method of preparation and composition, drugs can be incorporated into SLNs in different models, such as homogeneous matrix systems, drug-enriched shells, or drug-enriched cores.

Advantages of SLNs over Conventional Systems

Solid lipid nanoparticles offer several advantages compared to conventional drug delivery systems, making them a promising platform for enhanced drug delivery. One of the key benefits is their ability to **improve the solubility and bioavailability** of poorly water-soluble drugs by incorporating them into a lipid matrix. Additionally, SLNs provide **controlled and sustained drug release**, which helps maintain therapeutic drug levels over an extended period. SLNs are composed of **biocompatible and biodegradable lipids**, reducing the risk of toxicity and making them suitable for long-term use. They also offer **protection of labile drugs** from chemical and enzymatic degradation, thereby enhancing drug stability. Another significant advantage is their potential for **targeted drug delivery**, as surface modification techniques can be applied to direct the nanoparticles to specific tissues or cells. Furthermore, SLNs can be produced using **scalable and cost-effective manufacturing methods**, such as high-pressure homogenization, making them suitable for large-scale production. Their versatility in accommodating both hydrophilic and lipophilic drugs, along with improved patient compliance, further highlights their superiority over conventional drug delivery systems.

Rationale for Using Solid Lipid Nanoparticles

The growing need for advanced drug delivery systems has led to the development of novel nanocarrier platforms capable of overcoming the limitations of conventional dosage forms. Among these, lipid-based nanocarriers have gained significant attention due to their inherent compatibility with biological systems and their ability to enhance drug delivery performance.

Need for Lipid-Based Nanocarriers

Lipid-based nanocarriers have emerged as an effective strategy to improve the delivery of drugs, particularly those with poor aqueous solubility and low bioavailability. Lipids are physiologically acceptable materials that can enhance drug solubilization and facilitate absorption through biological membranes. Their structural similarity to biological membranes allows for better interaction with cells, thereby promoting efficient drug uptake. Additionally, lipid-based systems can bypass certain biological barriers and reduce drug degradation, making them highly suitable for both systemic and targeted drug delivery applications.

Limitations of Traditional Dosage Forms

Conventional drug delivery systems such as tablets, capsules, and injections often fail to deliver drugs at the desired rate and site of action. These systems are commonly associated with several drawbacks, including poor solubility of active pharmaceutical ingredients, rapid drug degradation, non-specific distribution, and fluctuating plasma drug concentrations. Moreover, orally administered drugs frequently undergo extensive first-pass metabolism, resulting in reduced bioavailability. Lack of controlled drug release and the need for frequent dosing further contribute to poor patient compliance and suboptimal therapeutic outcomes.

Advantages of Solid Lipid Nanoparticles

Solid lipid nanoparticles provide a promising solution to the challenges associated with traditional drug delivery systems by combining the benefits of lipid carriers with nanotechnology.

- **Controlled Drug Release:** SLNs enable controlled and sustained release of drugs by incorporating them within a solid lipid matrix. This helps maintain therapeutic drug levels over an extended period and reduces dosing frequency.
- **Improved Stability:** The solid state of lipids in SLNs enhances the physical and chemical stability of the encapsulated drug. It protects sensitive drugs from degradation caused by environmental factors such as light, heat, and enzymatic activity.
- **Biocompatibility and Biodegradability:** SLNs are composed of naturally occurring or physiologically compatible lipids, making them safe and well-tolerated. Their biodegradable nature ensures minimal toxicity and reduces the risk of accumulation in the body.
- **Targeted Drug Delivery Potential:** SLNs can be engineered for site-specific drug delivery through surface modification techniques, such as ligand attachment or PEGylation. This enables selective delivery of drugs to specific tissues or cells, thereby improving therapeutic efficacy and reducing side effects.

Composition of Solid Lipid Nanoparticles (SLNs)

The composition of solid lipid nanoparticles plays a crucial role in determining their physicochemical properties, stability, drug loading capacity, and overall performance in drug delivery. SLNs are typically composed of lipids, surfactants, co-surfactants or stabilizers, and the active pharmaceutical ingredient. Each component contributes significantly to the formation and functionality of the nanoparticulate system.

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Lipids Used

Lipids form the core matrix of SLNs and are responsible for drug encapsulation and controlled release. The selection of lipid depends on factors such as drug solubility, melting point, crystallinity, and compatibility with other formulation components.

- **Triglycerides**
  Triglycerides such as tristearin are commonly used due to their high biocompatibility and ability to form stable lipid matrices. They provide a solid framework for drug incorporation and help in achieving sustained drug release.
- **Fatty Acids:** Fatty acids like stearic acid are widely employed in SLN formulations because of their well-defined structure and favorable melting characteristics. They enhance drug entrapment and contribute to the formation of a stable lipid core.
- **Waxes:**
  Natural and synthetic waxes, such as cetyl palmitate and beeswax, are also used as lipid matrices. Waxes offer higher rigidity and can improve the stability of SLNs, although they may influence drug release profiles depending on their crystallinity.

Surfactants

Surfactants are essential for stabilizing SLNs by reducing interfacial tension between the lipid and aqueous phases. They prevent aggregation of nanoparticles and contribute to uniform particle size distribution.

- **Poloxamers**
  Poloxamers (e.g., Poloxamer 188, 407) are non-ionic surfactants widely used due to their excellent stabilizing properties and low toxicity.
- **Tween and Span:** Tweens (e.g., Tween 80) and Spans (e.g., Span 60) are commonly used surfactants that enhance emulsification and stability of SLNs. Their hydrophilic-lipophilic balance (HLB) values play a key role in formulation design.
- **Lecithin**
  Lecithin, a natural phospholipid, is frequently used due to its biocompatibility and ability to improve the stability and drug incorporation efficiency of SLNs.

Co-surfactants and Stabilizers

Co-surfactants and stabilizers are often incorporated to enhance the stability and performance of SLNs. They assist in reducing particle size, improving dispersion, and preventing particle aggregation during storage.

- **Role and Importance:** Co-surfactants help in further lowering interfacial tension and improving the flexibility of the interfacial film, leading to better nanoparticle formation. Stabilizers such as polyethylene glycol (PEG) can provide steric stabilization,preventing particle aggregation and enhancing shelf life. Additionally, they may contribute to improved drug release characteristics and bioavailability.

Drug Candidates Suitable for SLNs

The selection of drug candidates is critical for the successful formulation of SLNs. These systems are particularly advantageous for drugs with specific physicochemical limitations.

- **Lipophilic Drugs:** SLNs are highly suitable for lipophilic drugs due to their affinity for the lipid matrix, which facilitates efficient drug loading and sustained release.
- **Poorly Water-Soluble Drugs (BCS Class II & IV):** Drugs with low aqueous solubility benefit significantly from SLN formulations, as the lipid matrix enhances their solubility and dissolution rate, leading to improved bioavailability.

Methods of Preparation of Solid Lipid Nanoparticles (SLNs)

The preparation method of solid lipid nanoparticles significantly influences their particle size, drug loading efficiency, stability, and release characteristics. Various techniques have been developed to produce SLNs, each with its own advantages and limitations depending on the nature of the drug and formulation requirements.

High-Pressure Homogenization (HPH)

High-pressure homogenization is one of the most widely used and scalable techniques for SLN preparation. It involves forcing a lipid dispersion through a narrow gap at high pressure, resulting in particle size reduction due to shear stress and cavitation forces.

- **Hot Homogenization:** In this method, the lipid is melted above its melting point, and the drug is dissolved or dispersed in the molten lipid. This lipid phase is then emulsified in a hot aqueous surfactant solution to form a pre-emulsion. The pre-emulsion is subjected to high-pressure homogenization at elevated temperatures, followed by cooling, which leads to the formation of SLNs as the lipid solidifies. This method is suitable for lipophilic drugs but may not be ideal for thermolabile compounds.
- **Cold Homogenization:** Cold homogenization is developed to overcome the limitations associated with heat exposure. In this method, the drug-loaded molten lipid is rapidly cooled (e.g., using liquid nitrogen or dry ice) and then ground into microparticles. These

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particles are dispersed in a cold surfactant solution and subjected to high-pressure homogenization at or below room temperature. This technique reduces thermal degradation and minimizes drug loss during processing.

Microemulsion Technique

The microemulsion method involves the formation of a warm microemulsion consisting of melted lipid, surfactant, co-surfactant, and water. This microemulsion is then dispersed in cold water under continuous stirring, leading to the rapid crystallization of the lipid and formation of SLNs. This method is simple and reproducible, but it requires a high concentration of surfactants and careful optimization of formulation parameters.

Solvent Emulsification–Evaporation

In this method, the lipid and drug are dissolved in an organic solvent that is immiscible with water (e.g., chloroform or dichloromethane). The organic phase is emulsified into an aqueous phase containing surfactants to form an oil-in-water emulsion. The organic solvent is then evaporated under reduced pressure or continuous stirring, resulting in lipid precipitation and SLN formation. This method is suitable for thermolabile drugs but may involve concerns related to solvent toxicity and removal.

Solvent Diffusion Method

The solvent diffusion method involves dissolving the lipid and drug in a partially water-miscible solvent such as ethanol. This organic phase is then injected into an aqueous phase containing surfactants. Due to rapid solvent diffusion into the aqueous phase, the lipid precipitates, forming nanoparticles. This technique is advantageous due to its simplicity and reduced solvent toxicity compared to other solvent-based methods.

Ultrasonication / High-Speed Homogenization

This method utilizes mechanical energy to reduce particle size. The lipid phase is melted and emulsified into an aqueous surfactant solution using high-speed stirring to form a coarse emulsion. This emulsion is then subjected to ultrasonication, which breaks down the droplets into nanoparticles. Although this method is simple and cost-effective, it may result in broader particle size distribution and potential metal contamination from the probe.

Spray Drying and Lyophilization (for Stabilization)

To enhance the stability and shelf life of SLNs, drying techniques such as spray drying and lyophilization (freeze-drying) are often employed.

- **Spray Drying:** This technique converts SLN dispersions into dry powder form by rapidly evaporating the solvent using hot air. It is suitable for large-scale production but may cause particle aggregation due to thermal stress.
- **Lyophilization (Freeze-Drying):** Lyophilization involves freezing the SLN dispersion followed by sublimation of ice under vacuum conditions. Cryoprotectants such as sugars (e.g., trehalose, mannitol) are added to prevent particle aggregation during freezing and drying. This method is highly effective in preserving particle size and stability but is relatively expensive and time-consuming.

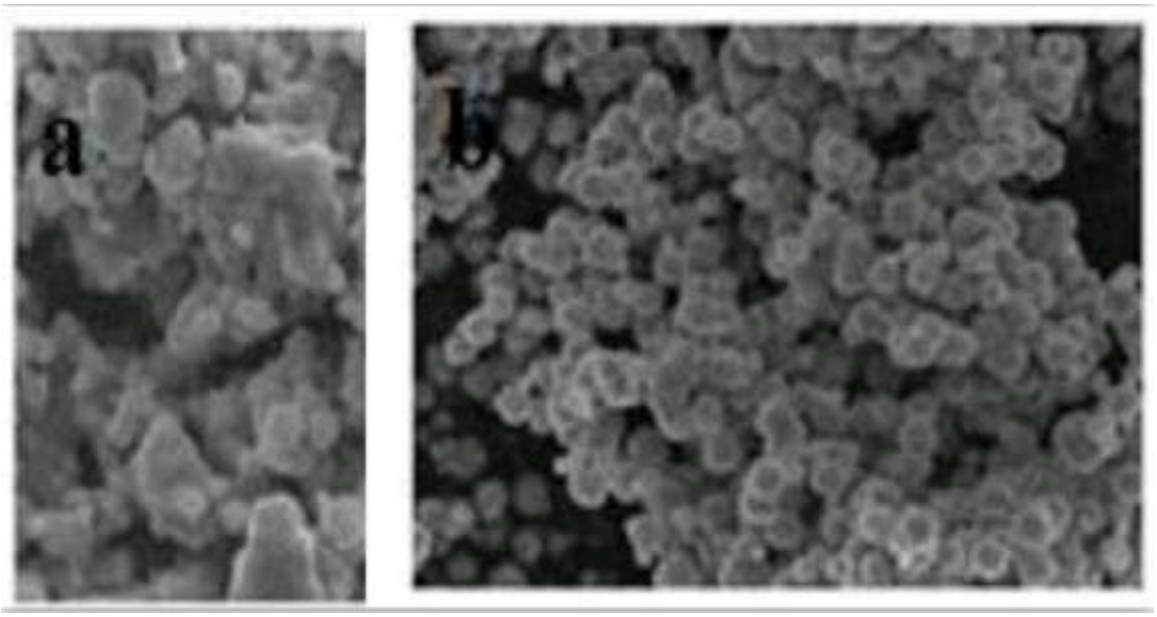
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Characterization of SLNs

Particle Size and Polydispersity Index (PDI), Zta Potential, and Entrapment Efficiency

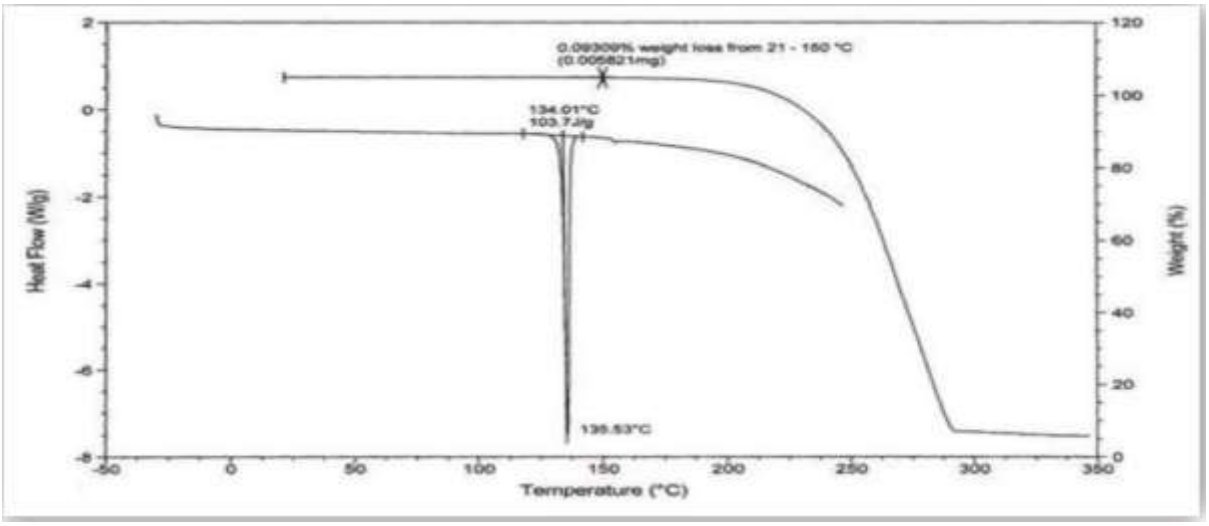
Formulations	Particle size (nm)	PDI	zeta potential (mV)	Entrapment efficiency (%)
C1	300±0.10	0.261±0.22	−19.5±0.11	87.11±0.11
C2	289±0.14	0.302±0.13	−20.3±0.15	91.02±0.14
C3	297±0.07	0.274±0.11	−20.6±0.24	89.12±0.13
C4	280±0.13	0.403±0.15	−21.3±0.15	96.05±0.12
C5	287±0.02	0.312±0.152	−23.4±0.19	92.13±0.01
C6	297±0.04	0.270±0.21	−22.4±0.27	89.02±0.05
C7	275±0.14	0.251±0.25	-19.2 ±0.11	97.15±0.25
C8	282±0.03	0.271±0.33	−21.8±0.43	93.14±0.07
C9	294±0.13	0.272±0.05	−21.4±0.73	90.15±0.11
C10	280±0.05	0.405±0.15	−21.8±0.14	95.23±0.22
C11	284±0.07	0.285±0.17	−19.9±0.54	93.12±0.03
C12	280±0.02	0.314±0.19	−22.4±0.17	96.10±0.05
C13	281±0.1.2	0.273±0.12	−23.5±0.24	95.14±0.03
C14	287±0.04	0.413±0.22	−21.6±0.15	92.05±0.13
C15	283±0.03	0.431±0.17	−24.7±0.54	94.02±0.03
C16	280±0.04	0.421±0.24	−23.4±0.74	95.24±0.13
C17	285±0.08	0.414±0.11	−24.7±0.54	93.21±0.08
C18	302±0.29	0.417±0.23	−25.5 ±0.19	85.01±0.13
C19	286±0.07	0.425±0.17	−24.9±0.64	92.13±0.14

Morphology

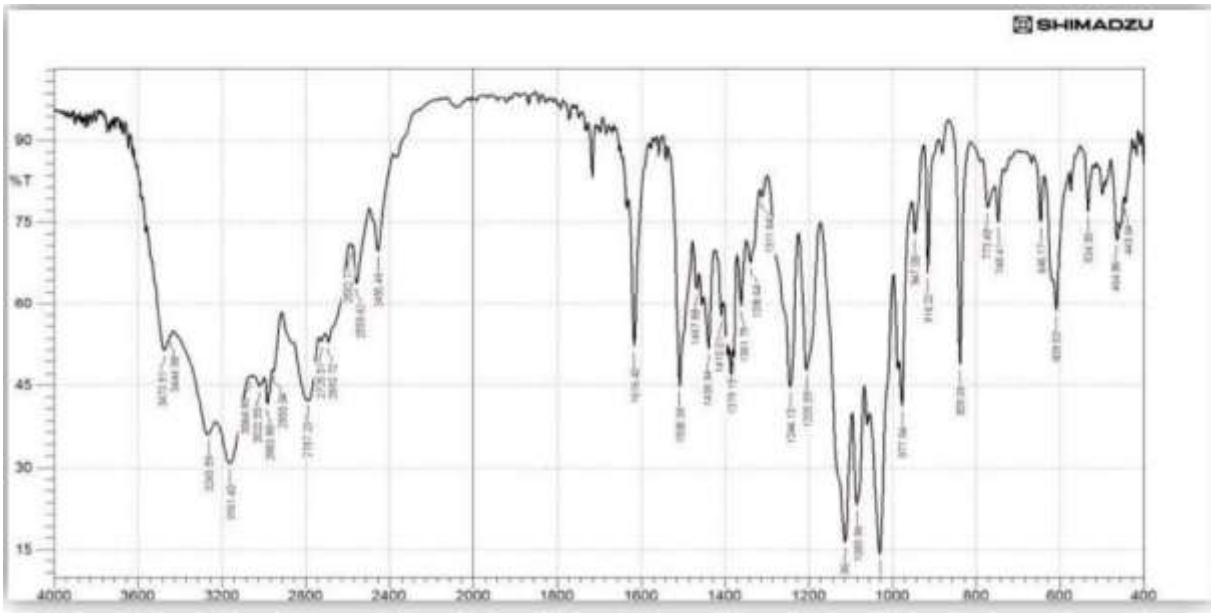


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Thermal Analysis



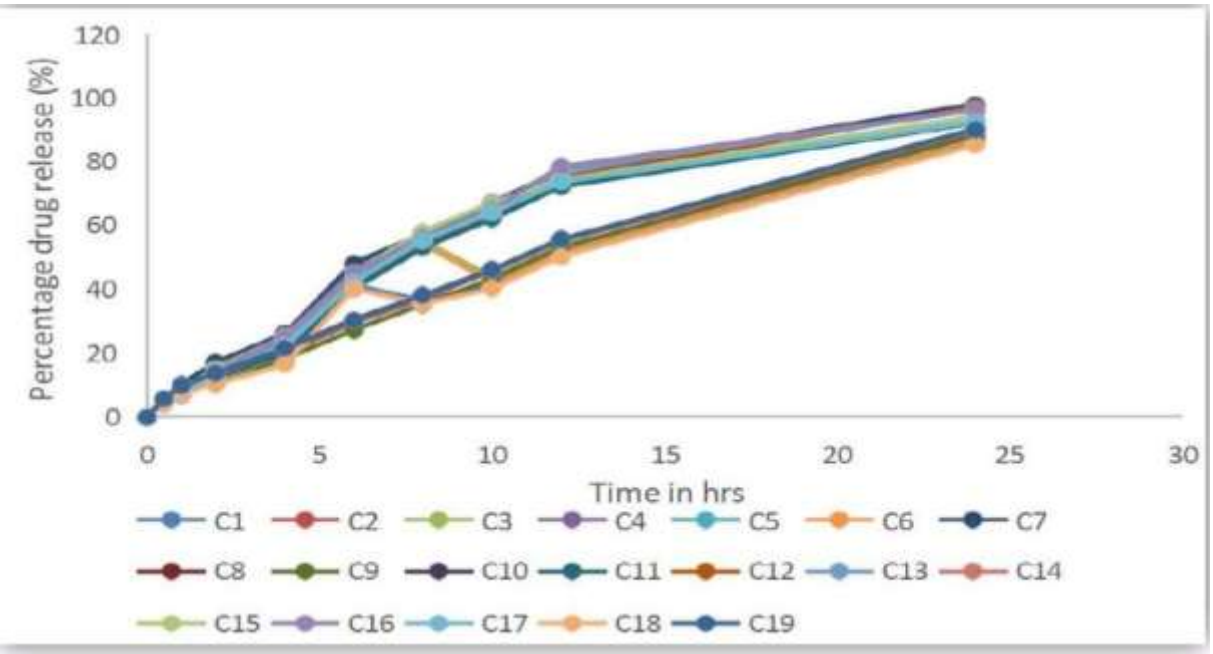
FTIR



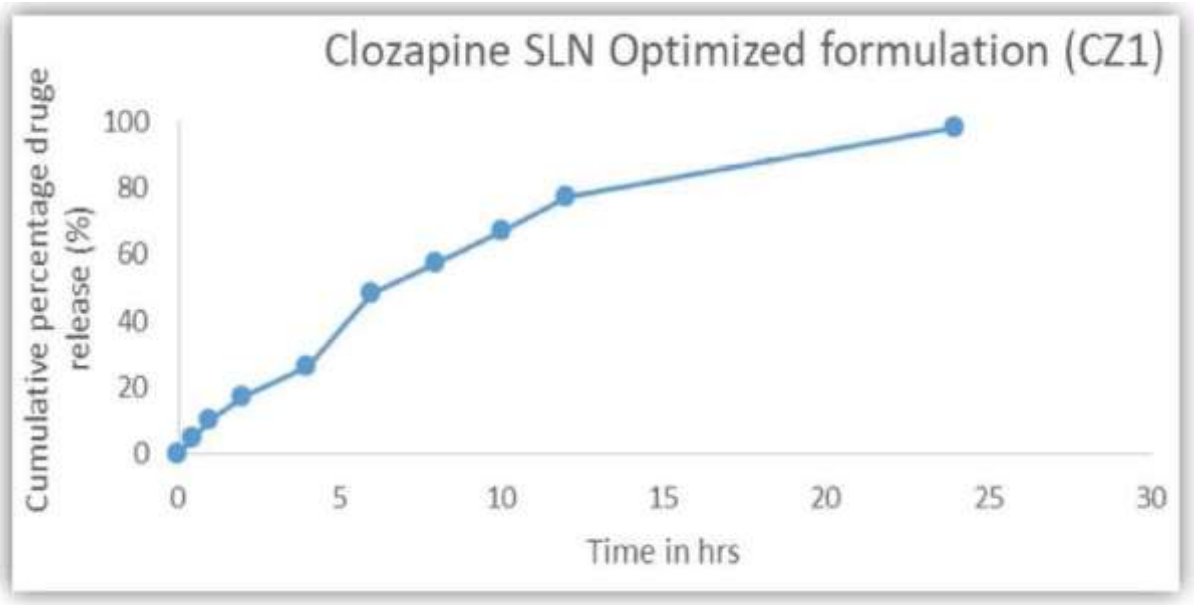
FTIR OF DAPAGLIFLOZIN SLN FORMULATION

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Drug Release Studies



INVITRO DRUG RELEASE DATA



IN VIVO DRUG RELEASE

order parameters	Zero order (k0)	First order (k1)	Higuci model (kH)	Hixon-Crowell (kHC)	Korsmeyer-Peppas (kKP)	n
Adjusted r2	0.995	0.976	0.978	0.986	0.988	
r2	0.995	0.976	0.978	0.986	0.988	
AIC	28.32	41.55	35.24	32.49	34.25	0.692
MSC	5.254	3.124	3.925	4.121	4.824	

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SUMMARY OF DRUG RELEASE KINETICS OF OPTIMIZED DAPAGLIFLOZIN

Conclusion

Solid lipid nanoparticles (SLNs) have emerged as a versatile and promising nanocarrier system that addresses many of the limitations associated with conventional drug delivery approaches. Their ability to enhance the solubility of poorly water-soluble drugs, improve bioavailability, and provide controlled and sustained drug release makes them highly valuable in modern pharmaceutics. The use of physiologically compatible lipids further ensures safety, biocompatibility, and reduced toxicity, which are essential for clinical applications.

The impact of SLNs on the drug delivery field is significant, as they offer a platform capable of improving therapeutic efficacy while minimizing adverse effects. Their adaptability for

various routes of administration—including oral, topical, parenteral, and targeted delivery—highlights their broad applicability. Furthermore, advancements in formulation strategies and surface modification techniques have expanded their potential in targeted and site-specific drug delivery, particularly in challenging areas such as brain targeting and cancer therapy.

In conclusion, SLNs represent a highly effective and innovative approach in drug delivery research. Despite certain limitations, ongoing developments such as nanostructured lipid carriers, hybrid systems, and stimuli-responsive nanoparticles are expected to overcome existing challenges. With continued research, technological advancements, and successful scale-up strategies, SLNs hold great promise for future clinical translation and commercialization, ultimately contributing to the development of safer and more efficient therapeutic systems.

REFERENCES

1. *Fleisher D. Stewart BH, Amidon GL. [28] Design of prodrugs for improved gastrointestinal absorption by intestinal enzyme targeting. Methods in enzymology on CD-ROM/Methods in enzymology. 1985 Jan 1:360-81.*
2. *Scientific Opinion on the re-evaluation of polyoxy ethylene sorbitan mono laurate (E 432), polyoxy ethylene sorbitan mono oleate (E 433), polyoxy ethylene sorbitan mono palmitate (E 434), polyoxy ethylene sorbitan mono stearate (E 435) and polyoxy ethylene sorbitan tri stearate (E 436) as food additives. EFSA Journal. 2015 Jul:13(7).*
3. *Fasinu PS, Orisakwe OF. Heavy Metal Pollution in Sub-Saharan Africa and Possible Implications in Cancer Epidemiology. Asian Pacific Journal of Cancer Prevention. 2013 Jun 30; 14(6):3393-402.*
4. *Cremers SCLM, van Hogezand R. Bänffer D. den Hartigh J. Vermeij P, Papapoulos SE, et al. Absorption of the oral bisphosphonate alendronate in osteoporotic patients with Crohn's disease. Osteoporosis International. 2005 Jun 15;16(12):1727-30.*
5. *Amidon GL, Leesman GD, Elliott RL. Improving intestinal absorption of water-insoluble compounds: A membrane metabolism strategy. Journal of Pharmaceutical Sciences. 1980 Dec:69(12):1363-8.*
6. *Fiedorowicz JG, Swartz KL. The role of monoamine oxidase inhibitors in current psychiatric practice. Journal of psychiatric practice [Internet]. 2004;10(4):239-48.*
7. *Fukuda K. Ohta T. Yasushi YAMAZOE. Grapefruit Component Interacting with Rat and Human P450 CYP3A: Possible Involvement of Non-Flavonoid Components in Drug Interaction. Biological and Pharmaceutical Bulletin. 1997 Jan 1:20(5):560-4.*
8. *Markovic M. Ben-Shabat S, Keinan S, Aponick A. Zimmermann EM, Dahan A. Lipidic prodrug approach for improved oral drug delivery and therapy. Medicinal Research Reviews. 2018 Oct 15:39(2):579-607.*
9. *Stella VJ. Prodrugs: Some Thoughts and Current Issues. Journal of Pharmaceutical Sciences. 2010 Dec:99(12):4755-65.*
10. *Salawi A. Self-emulsifying drug delivery systems: a novel approach to deliver drugs. Drug Delivery. 2022 Jun 6:29(1):1811-23.*
11. *Sekhon BS. Surfactants: Pharmaceutical and Medicinal Aspects. Journal of Pharmaceutical Technology, Research and Management [Internet]. 2013 May 2:1(1):43-68.*
12. *Liu P, Chen G, Zhang J. A Review of Liposomes as a Drug Delivery System: Current Status of Approved Products, Regulatory Environments, and Future Perspectives. Molecules [Internet]. 2022 Feb 17:27(4).*
13. *Hou D. Xie C, Huang K, Zhu C. The production and characteristics of solid lipid nanoparticles (SLNs). Biomaterials, 2003 May:24(10):1781-5.*
14. *Scioli Montoto S. Muraca G, Ruiz ME. Solid Lipid Nanoparticles for Drug Delivery: Pharmacological and Biopharmaceutical Aspects. Frontiers in Molecular Biosciences. 2020 Oct 30:7.*
15. *Mendoza-Muñoz N, Urbán-Morlán Z, Leyva-Gómez G, Zambrano-Zaragoza M de la L, Piñón-Segundo E. Quintanar-Guerrero D. Solid Lipid Nanoparticles: An Approach to Improve Oral Drug Delivery. Journal of Pharmacy & Pharmaceutical Sciences. 2021 Oct 13: 24:509- 32.*
16. *Mukherjee S. Ray S. Thakur R. Solid lipid nanoparticles: A modern formulation approach in drug delivery system. Indian Journal of Pharmaceutical Sciences [Internet]. 2009:71(4):349.*
17. *Fasinu P. Choonara YE, Khan RA, Du Toit LC, Kumar P. K. Ndesendo VM, et al. Flavonoids and Polymer Derivatives as CYP3A4 Inhibitors for Improved Oral Drug Bioavailability. Journal of Pharmaceutical Sciences. 2013 Feb;102(2):541-55.*
18. *Sabiha Enam Spriha, SM Abdur Rahman. A Review on Biological Activities of Sugars and Sugar Derivatives. Dhaka University Journal of Pharmaceutical Sciences. 2022 Jun 9:381-94.*
19. *Pratama KG, Tandarto K, Hengky A. weight loss effect of sodium-glucose cotransporter-2 (sglt2) inhibitors in patients with obesity without diabetes: a systematic review. Acta Endocrinologica (Bucharest) [Internet]. 2022;18(2):216-24.*
20. *Bunney BS. Clozapine: a hypothesised mechanism for its unique clinical profile. The British journal of psychiatry Supplement [Internet]. 2018 [cited 2024 Aug 29]; (17)*

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21. *Lieberman JA, Safferman AZ. Clinical profile of clozapine: Adverse reactions and agranulocytosis. Psychiatric Quarterly. 1992:63(1):51-70.*
22. *Merovci A, Mari A, Solis C, Xiong J, Daniele G, Chavez-Velazquez A, et al. Dapagliflozin Lowers Plasma Glucose Concentration and Improves B-Cell Function. The Journal of Clinical Endocrinology & Metabolism. 2015 May 1:100(5):1927-32.*
23. *Mante GV, Gupta KR. Hemke AT. Estimation of Dapagliflozin from its Tablet Formulation by UV-Spectrophotometry. Pharmaceutical Methods. 2017 Aug 15:8(2):102-7.*
24. *Zaibi N, Li P. Xu SZ. Protective effects of dapagliflozin against oxidative stress-induced cell injury in human proximal tubular cells. Franco R, editor. PLOS ONE, 2021 Feb 19:16(2):e0247234.*
25. *Zhu RR, Qin LL, Wang M, Wu SM, Wang SL, Zhang R, et al. Preparation, characterization, and anti-tumor property of podophyllotoxin-loaded solid lipid nanoparticles. Nanotechnology, 2009 Jan 12:20(5):055702-2.*
26. *Lalit Mohan Negi, Jaggi M. Sushama Talegaonkar. Development of protocol for screening the formulation components and the assessment of common quality problems of nano- structured lipid carriers. International Journal of Pharmaceutics. 2014 Jan 1:461(1-2):403-10.*
27. *Nanoscience N, Research. Review. Nanoscience and Nanotechnology Research [Internet]. 2017:4(2):67-72.*
28. *Sharifi H, Zabihzadeh SM, Ghorbani M. The application of response surface methodology on the synthesis of conductive polyaniline/cellulosic fiber nanocomposites. Carbohydrate Polymers. 2018 Aug; 194:384-94.*
29. *Mohammad Hadi Dehghani, Mehdi Qasemi, Alireza Mesdaghinia, Ramin Nabizadeh, Mahmood Alimohammadi, Mojtaba Afsharnia, et al. Production and application of a treated bentonite-chitosan composite for the efficient removal of humic acid from aqueous solution. 2018 Dec 1:140:102-15.*
30. *Teerana chaideekul V, Muller R, Junyaprasert V. Encapsulation of ascorbyl palmitate in nanostructured lipid carriers (NLC) Effects of formulation parameters on physicochemical stability. International Journal of Pharmaceutics. 2007 Aug 1:340(1-2):198-206.*
31. *Ince A, Glinka G. A numerical method for elasto-plastic notch-root stress strain analysis. The Journal of Strain Analysis for Engineering Design. 2013 Apr 5:48(4):229-44.*
32. *Modarres-Gheisari SMM, Gavagsaz-Ghoachani R. Malaki M, Safarpour P. Zandi M. Ultrasonic nano-emulsification A review. Ultrasonics Sonochemistry. 2019 Apr:52:88-105.*
33. *Behzad Sharif Makhmalzadeh, Haghani K. Rezaie A, Masoud Ali Karami. Superoxide dismutase-contained solid lipid nanoparticles: Formulation development and In-vivo*
34. *Behzad Sharif Makhmalzadeh, Haghani K. Rezaie A, Masoud Ali Karami. Superoxide dismutase-contained solid lipid nanoparticles: Formulation development and In-vivo evaluation for second-degree burn wound healing in rat. Burns. 2024 Jun 1*
35. *Ghosh A, Khanam N. Nath D. Solid lipid nanoparticle: A potent vehicle of the kaempferol for brain delivery through the blood-brain barrier in the focal cerebral ischemic rat. Chem Biol Interact [Internet]. 2024:397(111084):111084.*
36. *Parhi R, Suresh P. Preparation and Characterization of Solid Lipid Nanoparticles-A Review, Current Drug Discovery Technologies. 2012 Mar 1:9(1):2-16.*
37. *Parhi R, Suresh P. Preparation and Characterization of Solid Lipid Nanoparticles-A Review. Current Drug Discovery Technologies. 2012 Mar 1:9(1):2-16.*
38. *Dhillon S. Dapagliflozin: A Review in Type 2 Diabetes. Drugs [Internet]. 2019 Jun 25:79(10):1135-46.*
39. *Poovi G. Damodharan N. Lipid nanoparticles: A challenging approach for oral delivery of BCS Class-II drugs. Future Journal of Pharmaceutical Sciences [Internet]. 2018 Dec:4(2):191- 205.*
40. *Harivardhan Reddy L. Vivek K. Bakshi N, Murthy RSR. Tamoxifen Citrate Loaded Solid Lipid Nanoparticles (SLNTM): Preparation. Characterization. In Vitro Drug Release, and Pharmacokinetic Evaluation. Pharmaceutical Development and Technology. 2006 Jan:11(2):167-77.*
41. *Shizawa K. Nanosize Particle Analysis by Dynamic Light Scattering (DLS). YAKUGAKU ZASSHI. 2019 Feb 1:139(2):237-48.*
42. *Zoulikha M, Xiao Q, Boafo GF, Sallam MA, Chen Z. He W. Pulmonary delivery of siRNA against acute lung injury/acute respiratory distress syndrome. Acta Pharmaceutica Sinica B. 2022 Feb 1:12(2):600-20.*
43. *Laurindo LF, de Carvalho GM, de Oliveira Zanuso B. Figueira ME, Direito R, de Alvares Goulart R, et al. Curcumin-Based Nanomedicines in the Treatment of Inflammatory and Immunomodulated Diseases: An Evidence-Based Comprehensive Review. Pharmaceutics [Internet]. 2023 Jan 10:15(1):229.*
44. *Nahum V. Domb AJ. Recent Developments in Solid Lipid Microparticles for Food Ingredients Delivery. Foods. 2021 Feb 11:10(2):400.*
45. *Rajpoot K. Solid Lipid Nanoparticles: A Promising Nanomaterial in Drug Delivery. Current Pharmaceutical Design. 2019 Dec 17:25(37):3943-59.*
46. *chi, Li W, Wang X. Xue J. Zhao L, Song Y, et al. Thiopental sodium loaded solid lipid nano-particles attenuates obesity-induced cardiac dysfunction and cardiac hypertrophy via inactivation of inflammatory pathway. Drug Delivery. 2020 Jan 1:27(1):1188-20).*
47. *Rostamabadi H. Falsafi SR, Jafari SM. Nanoencapsulation of carotenoids within lipid- based nanocarriers, Journal of Controlled Release. 2019 Mar; 298:38-67.*
48. *Dieng SM. Anton N. Bouriat P. Thioune O, Sy PM, Massaddeq N, et al. Pickering nano emulsions stabilized by solid lipid nanoparticles as a temperature sensitive drug delivery system. Soft Matter. 2019;15(40):8164-74.*
49. *Akbari J. Saeedi M. Ahmadi F, Hashemi SMH. Babaci A, Yaddollahi S. et al. Solid lipid nanoparticles and nanostructured lipid carriers: a review of the methods of manufacture and routes of administration. Pharmaceutical Development and Technology. 2022 May 28:27(5):525-44.*
50. *Naseri N. Valizadeh H, Zakeri-Milani P. Solid Lipid Nanoparticles and Nanostructured Lipid Carriers: Structure, Preparation and Application. Advanced Pharmaceutical Bulletin. 2015 Sep 19:5(3):305-13.*
51. *Ganesan P, Narayanasamy D. Lipid nanoparticles: Different preparation techniques, characterization, hurdles, and strategies for the production of solid lipid nanoparticles and nanostructured lipid carriers for oral drug delivery. Sustainable Chemistry and Pharmacy.*

SJIF Impact Factor (2026): 8.863| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 11 | Issue: 4 | April 2026 - Peer Reviewed Journal

2017 Dec: 6:37-56.

52. *Hou D. Xie C. Huang K. Zhu C. The production and characteristics of solid lipid nanoparticles (SLNs). Biomaterials. 2003 May;24(10):1781-5.*
53. *Sandhya P. Satyendra Kumar T. Chandni P. Archna P. Encapsulation of Alendronate in Chitosan based Polymeric Nanoparticles for Effective Management of Osteoporosis Development to Release Kinetic Study. International Journal of Medical Nano Research. 2022 Jan 31:9(1).*
54. *Ezra A. Golomb G. Administration routes and delivery systems of bisphosphonates for the treatment of bone resorption. Advanced Drug Delivery Reviews. 2000 Aug:42(3):175-95.*
55. *Lenghaus K. GuangHuaQiao G, Solomon DH, Gomez C, Rodriguez-Reinoso F. Sepulveda-Escribano A. Controlling carbon microporosity: the structure of carbons obtained from different phenolic resin precursors. Carbon. 2002 Apr;40(5):743-9.*
56. *Fasinu PS, Orisakwe OE. Heavy Metal Pollution in Sub-Saharan Africa and Possible Implications in Cancer Epidemiology. Asian Pacific Journal of Cancer Prevention.2013 Jun 30:14(6):3393-402.*
57. *Nelson and coller Treatment of Canine Leukocyte Adhesion Deficiency Using a SIN Lentiviral Vector and Human CD18 Promoter Expressing Canine CD18. Molecular Therapy. 2009 May:17:$163.*
58. *Ak G, Ünal A, Karakayalı T. Özel B, SelviGünel N, HamaratŞanlıer Ş. Brain-targeted, drug-loaded solid lipid nanoparticles against glioblastoma cells in culture. Colloids and Surfaces : Biointerfaces. 2021 Oct:206:111946.*
59. *Simarjot KaurSandhu, Kumar S. Raut JS, Singh M, Kaur S. Sharma G, et al. Systematic Development and Characterization of Novel, High Drug-Loaded, Photostable, Curcumin Solid Lipid Nanoparticle Hydrogel for Wound Healing. 2021 May 5:10(5):725-5.*
60. *Nasrollahzadeh M. Ganji F, Taghizadeh SM, Vasheghani-Farahani E, Mohiti-Asli M. Drug in adhesive transdermal patch containing antibiotic-loaded solid lipid nanoparticles. Journal of Bioscience and Bioengineering. 2022 Sep 21 [cited 2022 Nov11]:Availablefrom: https://www.sciencedirect.com/science/article/pii/S1389172322002286.*
61. *Eldem T. Speiser P. Hincal A. Pharmaceutical Research. 1991:08(1):47-54,*
62. *Thase ME, Youakim JM. Skuban A. Hobart M. Augustine C. Zhang P, et al. Efficacy and safety of adjunctive brexpiprazole 2 mg in major depressive disorder: a phase 3, randomized, placebo-controlled study in patients with inadequate response to antidepressants. The Journal of Clinical Psychiatry [Internet]. 2015 Sep 1 [cited 2020 Mar8]:76(9):1224-31.Availablefrom: https://www.ncbi.nlm.nih.gov/pubmed/26301701.*
63. *Faghihi S. Awadi MR. Mousavi SE, RezayatSorkhabadi SM. Karboni M. Azarmi S. et al. Diazepam Loaded Solid Lipid Nanoparticles: In Vitro and in Vivo Evaluations. Advanced Pharmaceutical Bulletin. 2020 Sep 8*
64. *Parhi R, Suresh P. Preparation and Characterization of Solid Lipid Nanoparticles-A Review. Current Drug Discovery Technologies. 2012 Mar 1:9(1):2-16.*
65. *Kovačević AB, Müller RH,Keck CM. Formulation development of lipid nanoparticles: Improved lipid screening and development of tacrolimus loaded nanostructured lipid carriers (NLC). International Journal of Pharmaceutics. 2020 Feb;576:118918.saraLawrence MJayne, Rees GD. Microemulsion-based media as novel drug delivery systems. Advanced Drug Delivery Reviews. 2000 Dec;45(1):89-121.*
66. *Sumera, Anwar A, Ovais M. Khan A, Raza A. Docetaxel-loaded solid lipid nanoparticles: a novel drug delivery system. IET Nanobiotechnology. 2017 Sep 1:11(6):621-9*
67. *Abdelbary G., Fahmy RH. Diazepam-Loaded Solid Lipid Nanoparticles: Design and Characterization. AAPS PharmSciTech. 2009 Mar;10(1):211-9.*
68. *Tiyaboonchai W. Tungpradit W. Plianbangchang P. Formulation and characterization of curcuminoids loaded solid lipid nanoparticles. International Journal of Pharmaceutics. 2007 Jun:337(1-2):299-306.*
69. *Míao J. Du YZ, Yuan H, Zhang X. Hu FQ. Drug resistance reversal activity of anticancer drug loaded solid lipid nanoparticles in multi-drug resistant cancer cells. Colloids and Surfaces B: Biointerfaces. 2013 Oet 1:110:74-80.*
70. *https://go.drugbank.com/drugs/DB06292*
71. *https://www.drugs.com/monograph/clozapine.html.*
72. *Amol G. Jadhao*1, Pranjali G. Patil1, Priya M. Dandekar1, Mayuri G. Zore1, Manasvi S. Patil2, Pooja V. Vidhate3, 1Gawande College of Pharmacy, Sakharkherda, 2Womens college of pharmacy, Pethvadgaon, 3R.G. Sapkal Institute of Pharmacy, Nashik, Analytical Method Development, Validation and Evaluation of Synthetic Drug, Page No. :619, Journal of Technology, ISSN: 10123407.*
73. *Amol G. Jadhao, Prachi S. Mankar, Pooja B. Kharat, Vaishnavi N. Thakare, Vaishnavi Navtahle, Punam S. Narwade, Dr. Jayshri B. Sanap, Komal N. Mohite, Manisha R. Jawale, Prashant A. Patil, Department of Pharmaceutics, Gawande College of Pharmacy, Sakharkherda, Maharashtra, India, Formulation and Various Pharmacological Properties of Hibiscus Rosa Sinesis, International Journal of Trend in Scientific Research and Development (ijtsrd), Volume-5, Issue-4, E-ISSN 2456-6470.*
74. *Amol G Jadhao, Kiran Wadatkar, Sakshi Waghmare, Prashant A Patil Gawande College of Pharmacy, Sakharkherda, Maharashtra, India, Various Formulation and Pharmacological Properties of Chinese Chaste Tree, International Journal of Trend in Scientific Research and Development (IJTSRD), Volume 5 Issue 4, May-June 2021 Volume-5, Issue-4, May-June 2021 Page 965.*
75. *Mr. Amol G. Jadhao, 2. Mr. Prathmesh R. Dungu, 3. Dr. Jayshri B. Sanap, "A Cost-Benefit Analysis of Real-Time Inventory Tracking Systems for Pharmaceuticals: Balancing Efficiency and Implementation Costs", IJRTI_200076, IJRTI2412026, International Journal for Research Trends and Innovation.*
76. *Jadhao AG, Devkar M J, Shaikh S S. M., Sanap JB, Patil PA, Formulation and Evaluation of Herbal Syrup, Asian Journal of Pharmaceutical Research and Development. *Address for Correspondence: Devkar Mohan J, Gawande College of Pharmacy, Sakharkherda, Tq. Sindkhed Raja, Buldana, Maharastra, India.*
77. *1Mr Amol G. Jadhao 2Miss. Sakshi S. Ingle, 3Mr. Umesh D. Solake, 4Miss. MayuriG. Zore, 5Miss. Jayshri B. Sanap 1Assitant Professor & HOD, 2,3 Students of B. Pharm Final Year, Teratogenic Effect of Different Drugs at Different Stages of Pregnancy, © 2024 IJRTI, Volume 9, Issue 5, ISSN: 2456-3315.*

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EPRA International Journal of Research and Development (IJRD)
Volume: 11 | Issue: 4 | April 2026 - Peer Reviewed Journal

78. *Recent Advanced of Fabrication Techniques and Application of Micro-Needle AmolG. Jadhao, Vrushali S. Borey*, Saurabh. B. Ingle, Pooja V. Kotwal, Taufik R. Sheikh, Shtrughan U. Nagrik, Jayshri B. Sanap. Gawande College of Pharmacy, Sakharkherda, Dist Buldana (Maharastra), India, 2023; 11(3): 59-66.*
79. *Jadhao, A. G., Bhosale, A. G., Sitaphale, G. R., Rajguru, J. R., Sonali, S. A., & S. V. Deshmane, S. V. (2019). Magnetic And Ph Sensitive Nanoparticles For Cancer Drug Delivery. Asian Journal of Pharmaceutical Research and Development, 7(4), 60–71.*
80. *Amol G. Jadhao*1, Sakshi G. Kambe2, Shweta G. Takle3, Akanksha C. Jadhao4, Vaishnavi V. Chaudhari5 and Jayshri B. Sanap6 1Assit. Prof. & HOD of Pharmaceutics Department Gawande College of Pharmacy, Sakharkherda, Buldana, Maharashtra. 2,3,4, Vol 13, Issue 15, 2024. ISO 9001:2015 Certified Journal-362.*
81. *Amol G. Jadhao*, Vaishali B. Magar Department of Pharmaceutics, Gawande College of Pharmacy, Sakharkherda, Buldana, Maharastra, India, Various Symptoms, Prevention and Treatments of Corona-virus (Covid-19) Jadhao et al Asian Journal of Pharmaceutical Research and Development.2021;9(6):90-9*