IJTI | INTERNATIONAL JOURNAL OF THERAPEUTIC INNOVATION

Review article

Solid lipid nanoparticles: a novel approach to improve the therapeutic efficacy of glimepiride in diabetes management

Harsh Jaiswal*, Mangal Singh Panwar

Gyanodaya Institute of Pharmacy, Gyanodaya University, Neemuch, Madhya Pradesh, India

Corresponding author: Harsh Jaiswal, ✉ Harshlalitjaiswal@gmail.com, **Orcid Id**: https://orcid.org/0009-0008-1628-2424

Received - 30-06-2026**, Revised** - 20-07-2026, **Accepted** - 27-08-2026 **(DD-MM-YYYY)**

Refer this article

Harsh Jaiswal, Mangal Singh Panwar, Solid lipid nanoparticles: a novel approach to improve the therapeutic efficacy of glimepiride in diabetes management. International Journal of Therapeutic Innovation, July-August 2026, V4 – I4, Pages - 10 – 16. Doi: https://doi.org/10.55522/ijti.v4i4.0166.

ABSTRACT

Glimepiride is a third-generation sulfonylurea drug widely used for the treatment of type 2 diabetes mellitus and has major formulation problems due to its poor aqueous solubility (BCS Class II drug). This review critically discusses the development and evaluation of Solid Lipid Nanoparticles (SLNs) as a promising nanocarrier system to overcome the bioavailability limitations of glimepiride. SLNs have several distinct advantages such as improved solubility, controlled release of the drug, enhanced stability and the possibility of targeted delivery. This review highlights the recent formulation approaches, characterisation methods and in vitro/in vivo performance of glimepiride-loaded SLN-based delivery systems, showing their potential to enhance the pharmacokinetic profile and therapeutic efficacy of glimepiride. These results underpin the potential of lipid nanotechnology to revolutionise the management of diabetes by overcoming the inherent limitations of conventional oral antidiabetic therapy.

Keywords: Solid lipid nanoparticles, Glimepiride, Diabetes mellitus, Nanocarrier, Bioavailability, Controlled release, BCS Class II.

INTRODUCTION

Diabetes mellitus has now become one of the major public health challenges of the 21st century. The prevalence of this metabolic disease is increasing at an alarming rate throughout the world, and it is estimated that by 2040 over 642 million people will be affected. Type 2 diabetes mellitus (T2DM) is characterised by insulin resistance and progressive beta-cell dysfunction, accounting for the majority of cases. Effective pharmacological intervention is required to achieve glycemic control and prevent debilitating complications [1].

Glimepiride, a third-generation sulfonylurea, remains a mainstay of management of T2DM. This agent stimulates insulin secretion from pancreatic beta cells and promotes glucose-stimulated insulin secretion by blocking ATP-sensitive potassium channels. Advantages of glimepiride over the older sulfonylureas include greater potency, a longer duration of action and a better cardiovascular safety profile. But the physicochemical properties of glimepiride limit its therapeutic potential considerably [2].

Glimepiride is poorly soluble in aqueous medium, and it is classified as a Biopharmaceutical Classification System (BCS) Class II drug with low solubility and high permeability. This solubility limitation results in slow dissolution in gastrointestinal fluids, which in turn results in erratic absorption, subtherapeutic plasma concentrations and unpredictable clinical responses. According to the Noyes-Whitney equation, the rate of dissolution is directly proportional to the surface area exposed for dissolution. This means that higher doses of conventional glimepiride formulations may be required to achieve therapeutic efficacy, which can lead to increased adverse effects and decreased patient compliance [3].

The problems of formulation of poorly soluble drugs have stimulated a lot of research in the area of novel systems for drug delivery. Among the different nanotechnology-based approaches, Solid Lipid Nanoparticles (SLNs) are a promising platform to improve the oral bioavailability of BCS Class II drugs. SLNs are colloidal carriers with a particle size of 10-1000 nm and are composed of physiologically well-tolerated lipids that are solid at body temperature. These nanocarriers combine the advantages of conventional colloidal systems (e.g. emulsions, liposomes, polymeric nanoparticles) and overcome their intrinsic limitations [4].

SLNs have special features which are more suitable for delivery of poorly soluble drugs like glimepiride. Firstly, the lipid matrix can dissolve lipophilic drugs thus improving their loading

capacity and stability. Second, the nanometric size offers a large surface area, which results in an increase of dissolution rates and improved absorption. Third, SLNs can protect encapsulated drugs from degradation by enzymes in the gastrointestinal tract. Fourth, they can improve lymphatic uptake, possibly bypassing the first-pass metabolism. Finally, SLNs are a safe and scalable technology as they use Generally Recognised as Safe (GRAS) lipids and do not require organic solvents for their manufacture [5].

This review seeks to provide a comprehensive review of the formulation, characterisation, and evaluation of glimepiride-loaded SLNs. We discuss recent research findings to evaluate the potential of this novel drug delivery system to overcome bioavailability limitations of glimepiride and thus enhance therapeutic outcomes in type 2 diabetic patients [6].

Physicochemical properties and therapeutic challenges of glimepiride

Physical and chemical properties

Glimepiride ($C_{24}H_{34}N_4O_5S$, molecular weight 490.62 g/mol) is a sulfonylurea derivative with a complex molecular framework that contains a sulfonylurea group, which is crucial to its hypoglycemic activity. The compound is a white to off-white crystalline powder and has a melting point of 208-213 °C. This lipophilic character is reflected in the log P value of about 3.2, indicating a considerable hydrophobicity.

The pH-dependent solubility of glimepiride in water is very low in acidic and neutral media (lower than 4 μg/mL) and slightly increased at pH > 7 (about 20 μg/mL). The pH-dependent solubility profile has important consequences for oral absorption, as the drug encounters different pH conditions in the gastrointestinal tract. Glimepiride is soluble in organic solvents, e.g. dimethyl sulfoxide (DMSO) and methylene chloride; however, its solubility in ethanol and methanol is limited [7, 8].

Pharmacokinetic constraints

Oral administration of glimepiride leads to excellent absorption with peak plasma concentrations occurring in 2-3 hours. The absolute bioavailability is reported to be complete, but the slow dissolution of the drug in gastrointestinal fluids may delay absorption, leading to variable peak concentrations and onset of action. It is highly bound to plasma protein (>99.5%), predominantly to albumin, which accounts for its long duration of action.

Glimepiride is extensively metabolised in the liver by CYP2C9 to the active cyclohexyl hydroxymethyl derivative (M1), which has approximately one-third of the pharmacological activity of the parent compound. M1 is then metabolised to the inactive carboxyl derivative (M2). The elimination half-life is about 5-8 hours and may be prolonged to 9 hours after repeated administration.

The primary pharmacokinetic issue with glimepiride is its dissolution-limited absorption. Glimepiride is a BCS Class II drug whose absorption is limited by its poor aqueous solubility and not by membrane permeability. This limitation of dissolution may lead to suboptimal absorption, especially at higher doses, and contributes to substantial inter- and intra-individual variability of therapeutic response. Food intake can also affect the absorption of the drug, making dose optimisation more complex in practice.

Clinical implications of poor solubility

There are several clinical consequences of the dissolution-limited absorption of glimepiride. Subtherapeutic plasma drug concentrations may lead to poor glycemic control, whereas excessive variability may increase the risk of hypoglycaemia. Such challenges often require careful titration of the dose and may require higher doses than are theoretically needed, possibly increasing the risk of adverse effects.

Poor dissolution and resultant slow onset of action may also affect patient compliance and therapeutic adherence. These limitations can be overcome by developing new formulations that are designed to improve glimepiride solubility and dissolution rate, which will lead to more consistent therapeutic outcomes and improved quality of life for the patients.

Solid lipid nanoparticles-reasons and advantages

Development of Lipid-Based Pharmaceutical Delivery Systems

Since the birth of liposomes in the 1960s, lipid-based delivery systems for drugs have gone a long way. Liposomes offered biocompatibility and versatility, but limitations such as poor stability, low drug loading capacity and rapid clearance by the reticuloendothelial system have spurred the search for alternative carriers. Emulsions and microemulsions showed better stability, but were limited by the presence of liquid lipids that might influence the controlled release properties.

Solid Lipid Nanoparticles (SLNs) were introduced in the early 1990s and were a paradigm shift in lipid-based drug delivery. SLNs are made up of solid lipids which are solid at room and body temperature, thus providing improved stability and controlled release compared to liquid lipid systems. Lipophilic drugs can be enclosed in the crystal lattice of the solid lipid matrix, thereby protecting them from degradation and providing a sustained release profile [10].

Structural features and composition

Most often, SLNs consist of three main components: solid lipid matrix, one or several surfactants and water. The lipid component may be triglycerides, partial glycerides, fatty acids, steroids or waxes and provides the structural framework of the nanoparticles. The choice of lipid is crucial as it determines the drug loading capacity, release kinetics and particle stability.

Surfactants play different roles in SLN formulations. These are used to improve the stability of the lipid dispersion by reducing the surface tension and providing electrostatic or steric stabilization to prevent the aggregation of particles. The choice and concentration of surfactants are of great importance for the mean particle size, the polydispersity and the overall stability of the SLN dispersion [11].

Advantages of SLNs for glimepiride delivery

SLNs possess some unique advantages which make them particularly suitable for the improvement of glimepiride delivery:

Improved solubility: Lipophilic drugs can be incorporated into the lipid matrix of SLNs, thus forming a depot from which the drug is released upon dispersion in gastrointestinal fluids. This strategy circumvents the dissolution limitations of the conventional glimepiride formulations.

Controlled release: The lipid solid matrix allows for prolonged and sustained drug release that can reduce dose frequency and maintain therapeutic plasma concentrations.

Increased stability: SLNs protect encapsulated drugs from chemical degradation in the gastrointestinal tract, for example, enzymatic degradation and pH-induced instability.

Lymphatic uptake: SLNs can be taken up by the lymphatic system, thereby avoiding first-pass metabolism and increasing the bioavailability of drugs that undergo hepatic clearance.

Biocompatibility: Safety is ensured by the use of physiologically well-tolerated lipids with GRAS status and minimization of the risk of toxicity or immunogenicity.

Scalability: SLN production techniques, in particular high-pressure homogenization, are scalable, thus allowing for the transition from laboratory studies to industrial-scale production [12].

Glimepiride-loaded SLNs formulation development

Selection of lipids and surfactants

The choice of the lipid and surfactant components is very important for the formulation of glimepiride-loaded SLNs to obtain optimum drug loading, particle size and stability. The solubility of glimepiride in different lipids has a significant impact on the formulation results as shown by research findings.

Glyceryl behenate (Compritol 888 ATO) has been a preferred lipid matrix for glimepiride SLN formulations due to its high drug solubilization capacity and favourable crystallisation properties. Also, other lipids like glyceryl monostearate (GMS), stearic acid, palmitic acid and cetyl palmitate have been studied, and the formulation parameters like particle size and entrapment efficiency vary a lot with the choice of lipid.

Equally important is the selection of surfactants and cosurfactants. Poloxamer 188 (Pluronic F 68) and polysorbate 80 (Tween 80) are commonly used because of their excellent wetting properties and ability to stabilise SLN dispersions. This combination of surfactants has been found to optimise particle size reduction and to enhance drug entrapment efficiency [13].

Methods of preparation

Among the different techniques of preparation of glimepiride-loaded SLNs, high-pressure homogenization is the most widely used technique.

Hot Homogenization: In this method, the drug and lipid are melted at a temperature above the melting point of the lipid. The aqueous surfactant phase is heated to the same temperature and poured in, and the mixture is homogenised under high pressure. The obtained nanoemulsion was then cooled to room temperature, allowing the lipid to crystallise and form solid nanoparticles.

Cold homogenization: This method involves preparation of a drug-lipid melt which is quickly cooled to form a solid matrix. The lipid-drug mixture is then solidified, ground and dispersed in a cold aqueous surfactant solution, followed by high-pressure homogenization at temperatures below the melting point of the lipid. Cold homogenization is particularly suitable for drugs that are prone to thermal degradation.

Microemulsion method: In other approaches, microemulsions are prepared containing the drug and the lipid components, and are diluted in cold water to precipitate the SLNs. The advantage of this approach is the lower energy input, but it can be more sensitive to the formulation parameters [14].

Formulation parameters optimisation

The optimisation of glimepiride SLN formulations usually consists of systematic variation of critical parameters like lipid concentration, surfactant concentration, homogenization pressure and number of homogenization cycles.

Lipid concentration: Usually, higher lipid concentration increases entrapment efficiency but also increases particle size and polydispersity. Studies on optimisation have established the optimal lipid concentrations to reconcile these competing demands.

Surfactant concentration: Higher surfactant concentrations generally lead to smaller particles and better stability by preventing aggregation. However, at high surfactant concentrations, micelles can form, and drug encapsulation can be reduced.

Homogenization parameters: Higher homogenization pressures and higher cycle numbers are usually associated with a decreased particle size, but can also lead to drug degradation or particle coalescence. To achieve the desired properties of the particles, optimisations are needed [15].

Characterisation of glimepiride-loaded SLNs

Particle size and zeta potential

Particle size is an important quality attribute of SLN formulations, influencing in a direct manner the dissolution rate, absorption and stability. The most commonly used technique to determine mean particle size and polydispersity index (PDI) is dynamic light scattering (DLS). The optimised glimepiride SLN formulations showed mean particle sizes in the range of 170 nm - 835 nm and PDIs generally below 0.3, indicating a narrow size distribution.

The surface charge of SLNs can be predicted by measuring zeta potential, which is important for physical stability. Zeta potentials greater than ±30 mV are generally considered to be stable formulations, since the electrostatic repulsion prevents aggregation of particles. The Zeta potential values of Glimepiride SLNs were in the range of -10 mV to -33 mV depending on the composition of the formulation and type of surfactant used [16].

Entrapment efficiency and drug loading

Entrapment efficiency (EE%) is the percentage of drug entrapped in the SLN matrix relative to the total drug added initially. Entrapment efficiency of glimepiride SLNs has been reported to be in the range of 61% to 94%. High encapsulation of glimepiride was observed with optimised formulations. High lipid solubility of glimepiride favours its incorporation in the lipid matrix, and the surfactant system facilitates the drug solubilization.

Another important parameter is drug loading capacity, which is defined as the amount of drug incorporated per unit mass of lipid. The loading capacities are normally 1–5% for most lipophilic drugs, but the loading of glimepiride has been optimised to obtain desirable drug-to-lipid ratios [17].

Drug-lipid compatibility studies

Compatibility between glimepiride and formulation excipients is important for product stability and performance. Fourier Transform Infrared Spectroscopy (FTIR) is widely applied for the study of potential drug-excipient interactions. FTIR spectra indicated no significant molecular interactions in glimepiride SLNs. The characteristic peaks of the drug were replaced or shifted due to encapsulation inside the lipid matrix.

Differential Scanning Calorimetry (DSC) provides complementary information on the thermal behaviour of formulations. The DSC thermograms of glimepiride showed a characteristic endothermic melting peak at about 213oC. This peak is either decreased or shifted in the SLN formulations, indicating the dispersion of the drug in the lipid matrix.

X-ray Powder Diffraction (XRPD) analysis was used to demonstrate the crystallinity of the drug in the formulation. Glimepiride is available in crystalline form, but the encapsulation in SLN often leads to loss of crystallinity, and the drug is present in an amorphous or molecularly dispersed state in the lipid matrix. The conversion from crystalline to amorphous form contributes to improved dissolution characteristics [18].

Morphological characterization

The morphology is visually confirmed by Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). The optimised glimepiride SLNs are generally spherical or slightly oval in shape with smooth surfaces and narrow size distributions. SEM images confirmed the crystallisation of the drug to spherical nanoparticles, representing the formation of SLNs. In Vitro Performance Evaluation.

Drug release profile

In vitro dissolution studies can be useful in predicting the in vivo drug release behaviour and in evaluating the potential for bioavailability enhancement. The dialysis membrane diffusion method is often used for the determination of drug release from glimepiride SLNs in dissolution media mimicking physiological environments.

The comparative release profiles showed that the SLN formulations had better dissolution characteristics than pure glimepiride. Pure glimepiride has low dissolution due to its poor aqueous solubility. However, SLN formulations have demonstrated significant enhancement in release. Optimised formulations showed up to 95 % of the encapsulated drug released within 24 h.

There are several reasons for the increased release. The nanometric size of SLNs gives a huge surface area for dissolution, and the presence of surfactants improves drug wettability and dispersion. Furthermore, the amorphous state of glimepiride in the lipid matrix may also contribute to an increased apparent solubility.

Kinetics of release

The drug release kinetics analysis provides information about the mechanism that controls the drug release from SLNs. The release of Glimepiride from SLN formulations was biphasic, with initial rapid release followed by sustained release over a prolonged period of time. The early release may be caused by drug linked on the surface of nanoparticles or quick dissolution of amorphous drug. The prolonged phase may be due to diffusion-controlled release from the lipid matrix.

Release profiles of the optimised formulations were of zero-order kinetics and were concentration-independent, which is indicative of diffusion-controlled release from a matrix system. This is a favourable behaviour because it can lead to higher and more consistent drug concentrations in plasma for a longer period of time. This may result in less frequent dosing and improved therapeutic effects [19].

Stability analysis

The stability of the SLN formulations under various storage conditions is crucial for product viability and clinical translation. The stability of glimepiride SLNs was also studied for a prolonged period of time at elevated temperature (e.g. 45°C/70% RH) in accelerated stability studies, and the optimised formulation showed good retention of its physicochemical properties. Formulations do not show any significant changes in appearance, pH, particle size, entrapment efficiency or drug release profile in a period of 3 months.

Lyophilisation (freeze-drying) is an effective method for improving the long-term stability of SLN formulations. Cryoprotectants such as mannitol and/or trehalose are added in the lyophilisation process to maintain the integrity of the nanoparticles upon reconstitution and to prevent aggregation of particles. This method enables preparation of stable, ready-to-use SLN formulations for commercial development and patient use [20].

Mechanisms of bioavailability enhancement

Solubility and dissolution enhancement

The main mechanism for the enhancement of bioavailability of glimepiride via SLNs is the improved solubility and dissolution characteristics. Nanometric particle size leads to a very large surface area and thus, as predicted by the Noyes-Whitney equation, a substantial increase in the dissolution rate. Besides, the lipid matrix may serve as a solubilising system, which renders the

drug in a dissolved or amorphous state and enhances the aqueous solubility.

The presence of surfactants in SLN formulations further facilitates dissolution improvement. Surfactants such as Tween 80 and Poloxamer lower the surface tension between the hydrophobic drug particles and the gastrointestinal fluids to improve the wetting of the drug. Increased wettability allows rapid dissolution of the drug at the site of absorption.

Absorption and permeability enhancement

Other mechanisms by which SLNs can improve absorption of glimepiride include solubility enhancement. SLNs, because of their nanometric size, can be taken up by intestinal enterocytes through endocytic pathways, avoiding the efflux transporters and increasing the overall absorption.

Moreover, the lipid character of SLNs assists in lymphatic uptake of the drug, which can provide a route for the absorbed drug to avoid the first-pass effect in the liver. Such a lymphatic route is especially beneficial for highly metabolised drugs such as glimepiride, potentially improving bioavailability.

Targeting and controlled release potential

The design of SLN formulations has the potential for targeted delivery and controlled drug release. Targeting ligands on the surface of SLNs may help in the delivery of glimepiride to specific sites such as pancreatic beta cells or hepatic tissues. Also, the controlled release characteristics of SLNs can lead to prolonged therapeutic effects, reduced frequency of administration and better patient compliance.

In vivo studies and clinical implications

Advantages for pharmacokinetics

Pharmacokinetic studies in animal models in vivo exhibited a significant increase in bioavailability of glimepiride after SLN administration. The glimepiride SLNs showed enhanced maximum plasma concentration (Cmax), area under the curve (AUC) and mean residence time compared to the conventional formulations.

The pharmacokinetic improvements indicate improved absorption of glimepiride from SLN formulations with improved and prolonged plasma drug exposure. Relative bioavailability values of 300-350%, relative to conventional preparations, have been reported for optimised SLN formulations in studies.

Pharmacodynamic benefits

Pharmacodynamic studies have confirmed that the improved pharmacokinetic properties of glimepiride SLNs result in better therapeutic efficacy. SLN formulations have shown better and longer hypoglycemic effects compared to conventional glimepiride in diabetic animal models.

The improved pharmacodynamic profile is due to the sustained release and increased bioavailability of glimepiride from SLN formulations. More stable plasma levels of the drug can lead to improved control of blood glucose and may reduce the risk of hypoglycaemic episodes associated with peak-trough fluctuations.

Comparative evaluation of formulation strategies

SLNs versus other nanoparticulate systems

Although SLNs are a promising approach for glimepiride delivery, other nanotechnology-based approaches have been explored as well. The nanosuspensions prepared by antisolvent precipitation and high-energy techniques have shown an increase in the solubility and dissolution of glimepiride. However, nanosuspensions are subject to stability problems and require further stabilisation strategies.

Self-nanoemulsifying pharmaceutical delivery systems (SNEDDS) have been reported as promising systems for delivery of glimepiride, improving its dissolution and absorption. SNEDDS offer the advantage of fast spontaneous emulsification and possibly higher loading capacity in comparison to SLNs but are prone to stability issues.

Polymeric nanoparticles, liposomes and cyclodextrin inclusion complexes have also been employed for the delivery of glimepiride. Each method has its own advantages and problems, with SLNs generally considered to be better because of their excellent stability, biocompatibility, manufacturability and cost-effectiveness [21, 22].

Comparative effectiveness

Comparative studies have been carried out on the relative efficacy of SLN and nanostructured lipid carrier (NLC) formulations for delivery of glimepiride. Both systems present high bioavailability enhancement compared to conventional formulations. However, NLCs containing liquid lipids in the solid matrix may have advantages in drug loading capacity and release profile.

The performance of different formulation approaches depends on the particular formulation parameters and the conditions of evaluation. To summarise, SLNs were the preferred system for glimepiride delivery due to their excellent stability, ease of preparation and proven bioavailability enhancement.

Future directions and challenges

Technical and production challenges

SLN formulations have huge potential, but a number of technical challenges need to be overcome for successful commercial translation. Manufacturing scalability is a concern, as the most commonly used technique, high-pressure homogenization, requires specialised equipment and careful process control. Further challenges include the optimisation of lyophilisation cycles in an effort to maintain nanoparticle stability and redispersibility.

Another concern is the batch-to-batch variability, because the properties of SLNs can be influenced by slight changes in processing parameters or characteristics of the raw materials. “Regulatory approval requires strong manufacturing processes and suitable quality control measures to ensure that the product performs consistently.

Regulatory considerations

The regulatory pathway for SLN-based drug products offers opportunities and challenges. GRAS-listed lipids and surfactants are generally more readily approved by regulatory agencies since these materials have well-established safety profiles. However, the complexity of nanoparticle characterisation and the requirement to show equivalence to conventional formulations necessitate a large amount of regulatory documentation.

The United States Food and Drug Administration (FDA) and European Medicines Agency (EMA) have developed guidance documents for nanomedicine products that provide a framework for the development and approval of SLN-based formulations. A successful regulatory submission requires compliance with these guidelines, including full physicochemical characterization and proven safety.

Directions and innovations for the future

Research on SLN technology is in progress for the development of new strategies for better glimepiride delivery and therapeutic effects. Some of the most promising cutting-edge strategies are:

Surface Modification: The surface of SLNs could be functionalized with targeting ligands for specific targeting to pancreatic beta cells, which could improve therapeutic efficacy and decrease systemic exposure and side effects.

Multi-drug delivery: Glimepiride with other antidiabetic drugs in SLN formulations may offer the possibility of combination therapy, which can give synergistic effects and better patient compliance with complex treatment protocols.

Smart Release systems: The stimuli-responsive SLN formulations, triggered by physiological signals, e.g., glucose concentration, could be designed to release drugs on demand to optimise glycemic control with minimised hypoglycemic risk.

Advanced characterisation: Further advancement in the characterisation area, such as cryo-TEM, atomic force microscopy (AFM) and advanced spectroscopic techniques, is providing a better understanding of SLN architecture, drug localisation, and stability and hence enabling rational formulation design [23].

CONCLUSION

Glimepiride Solid Lipid Nanoparticles Formulation: A Significant Breakthrough in Type 2 Diabetes Management. SLNs provide a solution to the dissolution problem of this poorly soluble drug that results in improved oral bioavailability and therapeutic efficacy as well as a reduction in the dosing frequency.

Comprehensive formulation optimisation, rigorous physicochemical characterisation, and in vitro and in vivo performance evaluation demonstrated the successful development of glimepiride-loaded SLNs. The optimised formulations showed desirable characteristics such as nanometric particle size, high entrapment efficiency, excellent stability and improved drug release profiles. A significant increase in bioavailability and antidiabetic efficacy of glimepiride has been observed in pharmacokinetic and pharmacodynamic studies. The potential advantages of SLN-based glimepiride formulations are significant, though there are hurdles to be overcome relating to manufacturing scalability, regulatory approval and clinical translation. The employed biocompatible GRAS listed materials in SLN technology further support a positive safety profile, and the demonstrated manufacturing feasibility provides a pathway to commercialisation.

To summarise, Solid Lipid Nanoparticles are a potential drug delivery system for improving the therapeutic performance of glimepiride and other poorly soluble antidiabetic drugs. Future studies in this area may allow the implementation of these advanced formulations in clinical settings, improving the quality of life of patients with type 2 diabetes.

REFERENCES

1. Müller R H, Mäder K, Gohla S, 2000. Solid lipid nanoparticles (SLN) for controlled drug delivery - a review of the state of the art. European Journal of Pharmaceutics and Biopharmaceutics. 50(1), Pages 161-177. Doi: 10.1016/S0939-6411(00)00087-4.

2. Mehnert W, Mäder K, 2001. Solid lipid nanoparticles: Production, characterization and applications. Advanced Drug Delivery Reviews. 47(2-3), Pages165-196. Doi: 10.1016/S0169-409X(01)00105-3.

3. Shinde R, Shinde P, Hosmani A, 2020. Comprehensive review on solid lipid nanoparticles. International Journal of Pharmaceutical Sciences and Research. 11(8), Pages 3650-3660. Doi: 10.13040/IJPSR.0975-8232.

4. Sastri K T, Radha G V, Pidikiti S, 2020. Solid lipid nanoparticles: Preparation techniques, their characterization, and an update on recent studies. Journal of Applied Pharmaceutical Science. 10(6), Pages 126-141. doi:10.7324/JAPS.2020.10616.

5. Gaber D A, Alhuwaymili A S, Alhawas H S, et al, 2022. Synthesized nano particles of glimepiride via spray freezing into cryogenic liquid: Characterization, antidiabetic activity, and bioavailability. Drug Delivery. 29(1), Pages 364-373. Doi: 10.1080/10717544.2021.2018524.

6. Naseri N, Valizadeh H, Zakeri-Milani P, 2015. Solid lipid nanoparticles and nanostructured lipid carriers: Structure, preparation and application. Advanced Pharmaceutical Bulletin. 5(3), Pages 305-313. Doi: 10.15171/apb.2015.043.

7. Azhar M, Alasmari M S, Zamir A, et al, 2025. The clinical pharmacokinetics and pharmacodynamics of glimepiride—a systematic review and meta-analysis. Pharmaceuticals. 18(1), Pages 122. Doi: 10.3390/ph18010122.

8. Kumar B S, Goli D, 2019. In vitro–in vivo characterisation of glimepiride lipid nanoparticulates prepared by combined approach of precipitation and complexation. International Journal of Nanoscience and Nanotechnology. 15(3), Pages 157-177. Doi: 10.22034/IJNN.2019.03.004.

9. Kumar B, Kumar N, Sisodia V K, et al, 2023. Development and optimization of solid lipid nanoparticles loaded with Glimepiride for enhancement of pharmacokinetic and therapeutic applicability. Journal of Drug Delivery Science and Technology. 85, Pages 104566. Doi: 10.1016/j.jddst.2023.104566.

10. Hu L, Tang X, Cui F, 2004. Solid lipid nanoparticles (SLNs) to improve oral bioavailability of poorly soluble drugs. Journal of Pharmacy and Pharmacology. 56(12), Pages 1527-1535. Doi: 10.1211/0022357044959.

11. Shah P, Chavda K, Vyas B, 2021. Formulation development of linagliptin solid lipid nanoparticles for oral bioavailability enhancement: Role of P-gp inhibition. Drug Delivery and Translational Research. 11, Pages 1166-1185. Doi: 10.1007/s13346-020-00842-6.

12. Darwish M K, El-Enin A S, Mohammed K H, 2022. Optimized nanoparticles for enhanced oral bioavailability of a poorly soluble drug: Solid lipid nanoparticles versus nanostructured lipid carriers. Pharmaceutical Nanotechnology. 10(1), Pages 69-87. Doi: 10.2174/2211738510666220329145743.

13. Shinkar D M, Jadhav S S, Pingale P L, 2022. Formulation, evaluation, and optimization of glimepiride nanosuspension by using antisolvent evaporation technique. Pharmacophore. 13(4), Pages 49-58. Doi:10.51847/SDnRf8lz1l.

14. Alqahtani M S, Kazi M, Alsenaidy M A, 2021. Advances in oral drug delivery. Frontiers in Pharmacology. 12, Pages618411. Doi: 10.3389/fphar.2021.618411.

15. Qushawy M, Nasr A, Swidan S, 2020. Development and characterisation of glimepiride novel solid nanodispersion for improving its oral bioavailability. Scientia Pharmaceutica. 88(4), Pages 52. Doi: 10.3390/scipharm88040052.

16. Pandey N K, Singh S K, Gulati M, et al, 2020. Overcoming the dissolution rate, gastrointestinal permeability, and oral bioavailability of glimepiride and simvastatin co-delivered in the form of nanosuspension and solid self-nanoemulsifying drug delivery system: A comparative study. Journal of Drug Delivery Science and Technology. 60, Pages 102083. Doi: 10.1016/j.jddst.2020.102083.

17. Mendoza-Muñoz N, Urbán-Morlán Z, Leyva-Gómez G, et al, 2021. Solid lipid nanoparticles: An approach to improve oral drug delivery. Journal of Pharmacy & Pharmaceutical Sciences. 24, Pages 509-532. Doi: 10.18433/jpps3152.

18. Mirchandani Y, Patravale V B, Brijesh S, 2021. Solid lipid nanoparticles for hydrophilic drugs. Journal of Controlled Release. 335, Pages457-464. Doi: 10.1016/j.jconrel.2021.05.032.

19. Lin C H, Chen C H, Lin Z C, 2017. Recent advances in oral delivery of drugs and bioactive natural products using solid lipid nanoparticles as the carriers. Journal of Food and Drug Analysis 25(2), Pages 219-234. Doi: 10.1016/j.jfda.2017.02.001.

20. Gonçalves L M, Maestrelli F, Mannelli L D, et al, 2016. Development of solid lipid nanoparticles as carriers for improving oral bioavailability of glibenclamide. European Journal of Pharmaceutics and Biopharmaceutics. 102, Pages 41-50. Doi: 10.1016/j.ejpb.2016.02.016.

21. Bhalekar M, Upadhaya P, Madgulkar A, 2017. Formulation and characterization of solid lipid nanoparticles for an anti-retroviral drug darunavir. Applied Nanoscience. 7(1-2), Pages 47-57. doi:10.1007/s13204-016-0549-5.

22. Kumar R, Singh A, Garg N, 2018. Solid lipid nanoparticles for the controlled delivery of poorly water-soluble non-steroidal anti-inflammatory drugs. Ultrasonics Sonochemistry. 40, Pages 686-696. Doi: 10.1016/j.ultsonch.2017.08.018.

23. Jawahar N, Meyyanathan S N, Reddy G, 2012. Solid lipid nanoparticles for oral delivery of poorly soluble drugs. Journal of Pharmaceutical Sciences and Research. 4(7), Pages 1848-1855. Doi: 10.13040/IJPSR.0975-8232.4(7).1848-5.