FORMULATION AND EVALUATION OF NANOSTRUCTURED LIPID CARRIERS FOR TARGETED DRUG DELIVERY SYSTEM

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ABSTRACT: The formulation and evaluation of Nanostructured Lipid Carriers (NLCs) for targeted drug delivery systems is a crucial area of pharmaceutical research aimed at enhancing therapeutic efficacy and minimizing side effects. This dissertation focuses on optimizing NLC formulations by selecting appropriate materials, including various lipid types, surfactants, and model drugs. NLCs are formulated using the double emulsification method, ensuring high encapsulation efficiency and stability. Key factors such as lipid type, surfactant concentration, and homogenization parameters are varied to assess their effects on particle size, zeta potential, and encapsulation efficiency. Particle size and zeta potential are measured using Dynamic Light Scattering (DLS) to evaluate physical stability and surface charge. UV spectrometry is used for quantifying the encapsulated drug, while Fourier Transform Infrared Spectroscopy (FTIR) confirms the chemical integrity of the drug and lipid matrix. This research demonstrates a systematic approach to optimizing NLC formulations, ultimately contributing to the development of advanced drug delivery systems with improved therapeutic outcomes. Through detailed formulation and rigorous evaluation, this work aims to enhance the effectiveness and reliability of NLC-based drug delivery systems.

Keywords: Nanostructured Lipid Carriers, targeted drug delivery, double emulsification, teneligliptin.

INTRODUCTION:

In order to avoid using organic solvents in the process of creating polymeric nanoparticles, Müller and Gasco first invented and nominated solid lipid nanoparticles (SLN) in the 1990s.[1] Solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC) have been viewed as promising carriers for transdermal drug administration over the last ten years due to their numerous appealing properties.[2] Drug substances with improved therapeutic efficacy have been delivered using the adaptable drug delivery method known as nanostructured lipid carriers (NLCs). The unique qualities they offer, including as enhanced drug delivery, extended chemical and physical stability of the encapsulated drug, surface functionalization, and site-specific targeting, account for their broad use.[3,4] The newest generation of lipid nanoparticles, known as nanostructure lipid carriers (NLCs), is generating a lot of interest as

the newest colloidal drug carrier for topical application. NLC was created to overcome SLN constraints. While NLC is made up of a specifically blended long-chain lipid mixture and a liquid short-chain mixture, ideally 70:30 with 99.9:0.1, SLN is made up of solid lipids. Although the melting point of the resultant lipid particle matrix is lower than that of the original solid lipid, it is nevertheless robust at room temperature. [5] The NLC is made up of a mixture of liquid and solid lipids, which results in a crystal structure with more flaws and more space for pharmaceuticals, particularly hydrophobic ones. [6]

Solid lipid nanoparticles (SLNs) are created by one of the following methods using solid lipids or lipid mixes. [7], namely, Microemulsion Templates, High Shear Homogenization, High Pressure Homogenization, The Solvent Emulsification Diffusion method uses a somewhat water-miscible solvent, while the Solvent Injection method uses a water-insoluble solvent. [8] For many medications, liquid lipid solubility is higher than solid lipid solubility, which enhances drug loading [9]. Numerous properties are available in NLC for topical application. Low toxicity, mild cytotoxicity, physiological, and biodegradable lipids make up carriers. [10] Reduced pharmacological load strength, drug expulsion during storage, and a relatively high dispersion water content (70–99%) are the drawbacks of SLN[11]. For some active chemicals, NLC has a higher drug load potential than SLN and prevents or reduces probable ejection during storage. NLCs are essentially made up of an aqueous phase, lipid phase, and surfactant (s), much like emulsions. Nonetheless, the final behavior of the created formulation can be significantly influenced by the choice of components and their ratios. Lipid phase is made up of a partially solid lipid matrix that is created by combining liquid and solid lipids. Different forms of lipids, including triglycerides, partial glycerides, fatty acids, steroids, and waxes, have been employed in the development of non-lipid coatings (NLCs). Mixtures of mono-, di-, and triglycerides of fatty acids with varying chain lengths and degrees of unsaturation make up oils (liquid lipids) and fats.[12]

Generally speaking, medication solubility, physiochemical structure, solid/liquid lipid miscibility, and physiological tolerance all play a role in lipid selection. First of all, the lipids ought to be classified as generally recognized as safe (GRAS), meaning that, at the concentrations employed, they shouldn't have any appreciable harmful effects. Second, the condition of lipid at normal temperature will be determined by its physicochemical structure. Thirdly, it is important to ascertain the active drug's solubility in lipid prior to fabricating NLCs. Drug entrapment and loading will be extremely low if the drug is not preferentially dissolved in the lipid core; instead, it will adhere to the surface of particles or integrate into micelles in the aqueous phase. Fourth, there is no acceptance of the compatibility of liquid and solid lipids, necessitating a research of their miscibility by examining the macroscopic lipid phase homogeneity and separation below the fat's melting point. Lipid phase in molten state should be one phase only.[13] The increased mobility of the interior lipid and the fluidity of the surfactant layer were attributed by the authors to the effect of chain length on particle size. Combining several lipids made it easy to get the required properties using the NLC system. However, it has been observed that long chain lipid-based NLCs have a longer half-life and are more bioavailable when absorbed through the intestinal lymphatic system[14].

One of the oldest diseases that humans have likely ever encountered is diabetes mellitus (DM). The metabolic hazard that is becoming more and more prevalent in our modern day is diabetes. A 1500 BC Egyptian book contained the first mention of diabetes, referring to "too great emptying of the urine." Subsequently, Indian medical professionals

identified the illness and labeled it as honey pee due to the patient's urine attacking ants. The Greek Apollonius of Memphis first used the term "diabetes" or "to pass through" about 250 BC.[13] Recently, a novel family of antidiabetic drugs known as dipeptidyl peptidase-4 (DPP-4) inhibitors has surfaced, showing promise in enhancing glycemic control with a low risk of complications from Type 2 diabetes mellitus. Teneligliptin is a new dipeptidyl peptidase-4 inhibitor that is taken orally to treat type 2 diabetes mellitus (T2DM). Its distinct structure, consisting of five successive rings, gives it a strong and enduring effect.. Teneligliptin is now used in cases where diet, exercise, or a combination of diet, exercise, and oral hypoglycemic medications such as biguanides and sulphonylureas do not sufficiently improve glycemic control.

Nearly all blood vessel sizes and kinds, including arteries, veins, and microvasculature, are impacted by diabetes-associated vascular disorders. Diabetes's long-term effects frequently result in cardiovascular problems and, eventually, cardiovascular disease. Based on epidemiological data, those diagnosed with type 2 diabetes mellitus are significantly more likely to have cardiovascular morbidity and mortality—by two to four times—than people without the disease.[21] Vascular problems are known to be the primary factor in the majority of morbidities, hospital admissions, and deaths among diabetic patients. Effective type 2 diabetes treatment aims to decrease glucose and cure cardiovascular problems. Gliptins are a class of drugs used to treat type 2 diabetes that lower blood glucose levels. It has recently been demonstrated that a number of gliptin types can improve endothelial function, lower pro- inflammatory and oxidative states, and improve cardiovascular function. One of the most recently licensed gliptins, teneligliptin, has demonstrated efficacy in the management of type 2 diabetes. Fascinatingly, teneligliptin has demonstrated a number of cellular actions linked to vascular defense. Teneligliptin has been demonstrated to ameliorate endothelial dysfunction in prediabetic rats and improve cardiac remodeling in hypertensive rats. Teneligliptin has been shown in a recent study to prevent atherogenesis in mice. Teneligliptin treatment for diabetes patients in humans enhances the patients' cardiac and endothelial function. Teneligliptin may have an anti-atherothrombotic effect in people with type 2 diabetes since it also controls platelet-derived microparticles. When combined, teneligliptin's strong dual benefits of lowering glucose and protecting vessels make it seem like a very attractive anti-diabetic medication. With its adaptable functional profile, teneligliptin looks to be a very promising medication for the management of both diabetes and its vascular consequences. Mice lacking dipeptidyl peptidase-4 (DPP-4) show reduced adiposity and elevated energy expenditure. Teneligliptin, a new DPP-4 inhibitor, increases energy expenditure and avoids obesity and its associated symptoms. [22]

Challenges of Nanotechnology in Drug Delivery:

- The scale-up and manufacturing of nanoparticles can be challenging, often requiring complex and expensive processes.
- Nanoparticles may exhibit toxicity and immunogenicity, which can lead to adverse effects and limit their clinical translation.
- The lack of standardized characterization methods and regulatory guidelines for nanoparticles can hinder their development and approval.
- The complexity of nanoparticle-based drug delivery systems can make it difficult to ensure reproducibility and quality control.
- The high cost associated with the development and production of nanoparticles

can limit their accessibility and affordability [36].

Despite these challenges, ongoing research and development efforts are aimed at addressing the limitations of nanotechnology in drug delivery. Strategies such as the use of biocompatible materials, optimization of nanoparticle properties, and the development of standardized characterization methods are being explored to overcome these challenges and unlock the full potential of nanotechnology in improving drug delivery and therapeutic outcomes

Lipid-based drug delivery systems:

Lipid-based drug delivery systems encompass a diverse range of carriers that utilize lipids as the primary component to encapsulate and deliver therapeutic agents. These lipid carriers offer several advantages, including biocompatibility, versatility, and the ability to solubilize a wide range of hydrophobic drugs.

Nanostructured lipid carriers (NLCs) represent a sophisticated lipid-based drug delivery system characterized by a unique nanostructure and advantageous properties that distinguish them from conventional lipid nanoparticles.

NLCs are colloidal carriers composed of a blend of solid and liquid lipids, forming a nanostructured matrix with a disordered crystalline lattice. This unique structure allows for the encapsulation of therapeutic agents within lipid domains, offering advantages such as enhanced drug loading capacity, improved stability, and controlled release kinetics.Several key characteristics define NLCs and contribute to their effectiveness as drug delivery vehicles.NLCs exhibit a nanostructured matrix composed of both solid and liquid lipids, which imparts stability and versatility to the formulation. The presence of a disordered crystalline lattice enables efficient drug incorporation and facilitates controlled drug release.

High Drug Loading Capacity: The disordered lipid matrix of NLCs allows for the entrapment of higher amounts of drugs compared to conventional lipid nanoparticles such as solid lipid nanoparticles (SLNs). This high drug loading capacity enhances the efficiency of drug delivery and reduces the required dosage, minimizing potential side effects.**Improved Stability:** NLCs exhibit improved stability compared to SLNs due to the presence of both solid and liquid lipids, which prevents drug expulsion and lipid recrystallization during storage. This enhanced stability ensures the maintenance of drug potency and formulation integrity over extended periods.**Controlled Release Kinetics:** NLCs offer precise control over drug release kinetics, allowing for tailored dosing regimens and prolonged therapeutic effects. The disordered lipid matrix facilitates gradual drug release, minimizing burst release and fluctuations in plasma drug concentrations.**Potential for Targeted Delivery:** NLCs can be surface-modified with targeting ligands or functionalized with stimuli-responsive components to enable targeted drug delivery to specific tissues or cells. This capability enhances drug accumulation at the site of action while minimizing off-target effects, thereby improving therapeutic efficacy.In summary, NLCs represent a promising platform for drug delivery, offering a unique nanostructure and advantageous characteristics that enable efficient drug encapsulation, improved stability, controlled release kinetics, and potential for targeted delivery.

A. Selection of Materials:

1. Lipids and surfactants:

- **Lipids:**

Lipids are chosen based on their physicochemical properties and their ability to form a stable lipid matrix in NLCs. The selection of solid and liquid lipids is crucial to achieving desirable drug loading and release characteristics. Solid lipids such as glyceryl

monostearate, Precirol ATO 5, and stearic acid are preferred for their ability to provide structural integrity and control drug release. These lipids offer a solid matrix to entrap the drug molecules and enhance stability during storage and transportation. Additionally, they provide sustained release profiles due to their slower degradation kinetics. Liquid lipids like oleic acid, Labrafac lipophile WL 1349, and capric/caprylic triglycerides are incorporated to improve the flexibility of the lipid matrix and enhance drug solubility. These lipids aid in the formation of smaller nanoparticles and provide faster drug release kinetics. They also improve the bioavailability of poorly water- soluble drugs by enhancing their solubility in the lipid matrix. 1221The selection of lipids also considers factors such as biocompatibility, regulatory approval, and cost-effectiveness. Lipids with GRAS (Generally Recognized as Safe) status are preferred to ensure the safety of the formulation for human use. Moreover, lipids approved by regulatory authorities such as the FDA (Food and Drug Administration) and the EMA (European Medicines Agency) facilitate the regulatory approval process for pharmaceutical products.

2. Drug model:

The selection of an appropriate drug model is crucial in the formulation and evaluation of Nanostructured Lipid Carriers (NLCs) for targeted drug delivery. The drug model should possess certain characteristics to facilitate efficient encapsulation, controlled release, and evaluation of the carrier system.

FORMULATION OF NANOSTRUCTURED LIPID CARRIERS:

A. Formulation composition:

1. Lipid Phase Composition:

Liposomes are small artificial vesicles that are spherical in shape and contain at least one lipid bilayer. It is utilized as drug delivery vehicles to administer pharmaceutical medicines and nutrients. Solid lipid and liquid lipids are mixed during preparation of NLCs, adding more flexibility and stability to the system.

The lipid phase constitute of solid lipid, liquid lipid, Drug [telenigliptin], solvent.

Glycerol monostearate [GMS] was used as solid lipid, Ghee [clarified butter] as liquid lipid and Methanol as solvent.

2. Surfactant Selection and Concentration:

Nonionic surfactants are surfactant molecules that do not ionize in the solution; as a result, they have excellent stability and are less vulnerable to the effects of acids, alkalis, and strong electrolyte inorganic salts. Non-ionic surfactants are very soluble in organic solvents and water, and they are also quite compatible with other surfactant kinds. Non-ionic surfactants serve as wetting agents, emulsifiers, solubilizers, and improvers of permeability, among other functions. Hydrophilic groups containing oxygen are covalently linked to hydrophobic parent structures in non-ionic surfactants. TWEEN 80 and SPAN 80 are the surfactant and co surfactant used in preparation of NLCs. As these both surfactants are Non ionic in nature and tend to be compatible with each other.

3. Concentrations of Surfactants:

The higher the HLB value of the surfactant lower is the particle size of nanoparticle, a surfactant with higher hydrophobic character creates a more stable emulsion with an organic dispersion media. The HLB value of TWEEN 80 for O/W is in the range 8-18 and the HLB value of SPAN 80 for O/W is in the range 4-6.

B. Formulation Procedure:

1. Step-by-Step Procedure:

1. Emulsification and evaporation methods have limitations of poor entrapment of hydrophilic drugs, hence double emulsification method is used.
2. Firstly W/O emulsion was prepared, solvent phase containing methanol was added to oil phase containing solid lipid [GMS], liquid lipid [Ghee] and Telenigliptin drug.
3. This prepared emulsion was added to an aqueous phase containing water, surfactant [TWEEN 80] and co surfactant [SPAN 80] with vigorous stirring, resultant W/O/W emulsion was prepared and organic solvent was removed by keeping on magnetic stirrer.
4. Prepared emulsion was further analysed.

Fig 02: Solvent Evaporation

Fig 03: Nano emulsion

Ingredients	F1	F2	F3	F4	F5
Solid lipid [GMS]	1gm	1gm	0.5gm	0.5gm	1gm
Liquid lipid [Ghee]	1gm	0.5gm	0.5gm	0.5gm	0.5gm
Surfactant [Tween 80]	0.2gm	0.2gm	0.2gm	0.2gm	0.2gm
Co surfactant [Span 80]	0.2gm	0.1gm	0.1gm	0.1gm	0.1gm
Solvent [Methanol]	2ml	2ml	2ml	2ml	2ml

Water	5ml	5ml	5ml	3ml	3ml

Table 01: Formulation table

Fig 04: Formulation of Batch A and Batch B

2. Parameter controlled during formulation:

All Five formulation batches were prepared as shown in table no: 1, To get ideal formulation, each batch"s parameters were adjusted individually. The batches F2and F5 were found to be acceptable emulsion at room temperature, while three other batches F1,F3 ,F4 respectively exhibited phase separation and hardened due to excessive lipid concentration.

Hence F2 and F5 batches were analysed.

EVALUATION OF NANOSTRUCTURED LIPID CARRIERS:

A. Particle Size Analysis:

1. Dynamic light scattering (DLS):

Dynamic Light Scattering (DLS) is a fundamental technique utilized in the evaluation of nanostructured lipid carriers (NLCs) within the context of particle size analysis. As a non-invasive and rapid method, DLS offers valuable insights into the size distribution and polydispersity of nanoparticles, including NLCs, which are crucial parameters influencing their stability, biodistribution, and drug release kinetics. In essence, DLS operates by measuring the fluctuations in light scattering intensity caused by the Brownian motion of particles suspended in a liquid medium. This dynamic process provides information about the hydrodynamic diameter of particles, which encompasses both their core size and any associated hydration layers or surfactant coronas. In the evaluation of NLCs, DLS serves as a primary tool for assessing their colloidal stability and homogeneity. By analyzing the intensity-weighted size distribution obtained from DLS measurements, researchers can ascertain the presence of aggregates, detect changes in particle size over time, and monitor the impact of formulation parameters on particle size distribution. Additionally, DLS facilitates the determination of the zeta potential of NLCs, a measure of their surface charge, which influences their stability and interaction with biological systems. The application of DLS in particle size analysis is particularly advantageous for NLC formulations due to their nanoscale

dimensions and potential for polydispersity. Polydispersity, or the distribution of particle sizes within a sample, can significantly impact the performance and behavior of NLCs in biological systems. Through DLS analysis, the polydispersity index (PDI) can be calculated, providing quantitative information about the uniformity of particle size distribution. A low PDI value indicates a narrow size distribution, indicative of a more homogeneous NLC formulation, whereas a high PDI suggests greater heterogeneity in particle size.

Moreover, DLS enables the characterization of changes in particle size distribution under different environmental conditions, such as varying pH, temperature, or ionic strength, mimicking physiological conditions encountered in vivo. This capability is essential for predicting the stability and behavior of NLCs upon administration, ensuring their suitability for targeted drug delivery applications. Overall, DLS plays a pivotal role in the comprehensive evaluation of NLCs by providing valuable data on particle size distribution, polydispersity, and colloidal stability, thereby informing formulation optimization and enhancing the efficacy of targeted drug delivery systems. In the evaluation of nanostructured lipid carriers (NLCs), the dynamic light scattering (DLS) technique provides crucial insights into particle size characteristics. For batches A and B, the Z average, representing the mean particle size, was determined to be 227.0 nm and 343.2 nm, respectively. This data indicates that batch B exhibits a larger mean particle size compared to batch A. Furthermore, the polydispersity index (PI) values were measured to assess the uniformity of particle size distribution within each batch. Batch A exhibited a PI of 0.454, while batch B had a slightly lower PI of 0.442. These PI values suggest that both batches demonstrate a relatively narrow size distribution, with batch B showing a slightly improved uniformity compared to batch A. The Z average and PI values obtained through DLS analysis provide valuable quantitative information about the size distribution and homogeneity of NLC formulations. These parameters are essential for assessing the colloidal stability and performance of NLCs in targeted drug delivery applications.

2. Zeta Potential:

In the evaluation of nanostructured lipid carriers (NLCs), understanding the zeta potential alongside electrophoretic mobility is crucial for assessing the colloidal stability and behavior of these nanoparticles. Zeta potential, a measure of the electric charge surrounding particles dispersed in a liquid medium, provides insights into the surface charge of NLCs, influencing their stability and interactions with biological components. Electrophoretic mobility, on the other hand, measures the velocity of charged particles under an applied electric field, offering additional information about their surface properties and potential for aggregation. For two batches of NLCs, designated as Batch A and Batch B, the mean zeta potential values were determined to be -14.6 mV and -17.6 mV, respectively. These negative
zeta potential values indicate that both batches possess an overall negative surface charge. This negative charge is often attributed to the presence of negatively charged components within the NLC formulation, such as surfactants or lipid constituents.

In addition to zeta potential, the electrophoretic mobility mean values for Batch A and Batch B were measured to be -0.000113 cm^2/Vs and -0.000136 cm^2/Vs, respectively. Electrophoretic mobility provides information about the velocity at which charged particles move under an electric field, reflecting their surface charge and potential interactions. The negative values of electrophoretic mobility are consistent with the negative zeta potentials observed for both batches, indicating that the particles migrate towards the positive electrode under the influence of the electric field. These zeta potential and electrophoretic mobility measurements offer valuable insights into the stability and surface properties of NLC

formulations. A higher magnitude of zeta potential or electrophoretic mobility typically indicates greater electrostatic repulsion between particles, resulting in enhanced stability and reduced aggregation. By characterizing these parameters, researchers can optimize NLC formulations for targeted drug delivery applications, ensuring their stability, biocompatibility, and therapeutic efficacy.

B. Encapsulation Efficiency Determination:

In the evaluation of nanostructured lipid carriers (NLCs), quantifying encapsulation efficiency is a critical aspect of assessing the efficacy of drug loading and delivery. Encapsulation efficiency determination involves quantifying the amount of drug encapsulated within the NLCs relative to the total amount of drug initially added during the formulation process. Accurate quantification methods are essential for ensuring the reproducibility and reliability of encapsulation efficiency measurements, thereby facilitating the optimization of NLC formulations for targeted drug delivery applications. Several methods are commonly employed for the quantification of encapsulation efficiency in NLCs, each offering specific advantages and considerations.

One widely used technique is ultracentrifugation, wherein NLC formulations are subjected to high centrifugal forces, causing drug-loaded nanoparticles to sediment while unencapsulated drug remains in the supernatant. The concentration of drug in the supernatant is then determined using analytical methods such as high-performance liquid chromatography (HPLC) or spectrophotometry, allowing for the calculation of encapsulation efficiency based on the difference between the total drug added and the amount detected in the supernatant.

RESULTS AND DISCUSSION:

A. Formulation Characterization Results:

1. Particle size distribution:

In the formulation characterization results for batches A and B of nanostructured lipid carriers (NLCs), the Z average and polydispersity index (PI) were determined to assess the particle size distribution and uniformity of the formulations. For batch A, the Z average particle size was measured to be 227.0 nm, indicating the average size of particles within the formulation. This value suggests that the majority of particles in batch A have a diameter of approximately 227.0 nm. Additionally, the polydispersity index (PI) for batch A was calculated to be 0.454. A PI value of 0.454 indicates a moderate degree of polydispersity, suggesting some variability in particle sizes within the formulation. However, despite this variability, the formulation still exhibits relatively uniform particle size distribution. In contrast, for batch B, the Z average particle size was found to be larger, measuring 343.2 nm. This indicates that the average size of particles in batch B is significantly larger compared to batch A, with a diameter of approximately 343.2 nm. Additionally, the polydispersity index (PI) for batch B was slightly lower, calculated to be 0.442. A PI value of 0.442 suggests a slightly narrower size distribution compared to batch A, indicating a more homogeneous formulation with less variability in particle sizes. Overall, the Z average and polydispersity index (PI) values obtained for batches A and B provide valuable insights into the particle size distribution and uniformity of the nanostructured lipid carrier (NLC) formulations. While batch A exhibits a smaller average particle size and slightly higher polydispersity compared to batch B, both formulations demonstrate relatively uniform particle size distribution, which is crucial for their stability and performance in targeted drug delivery applications. These results highlight the importance of careful characterization and optimization of NLC formulations to ensure consistent and reliable performance in pharmaceutical applications.

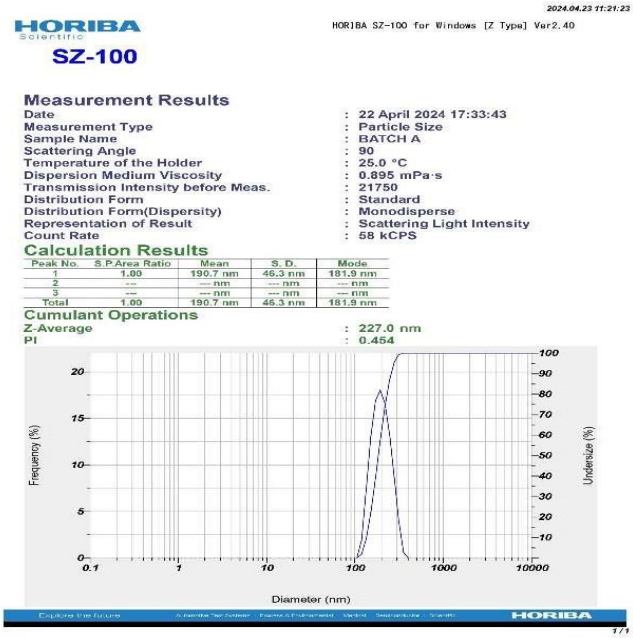

Fig 05: Particle size report of Batch A.

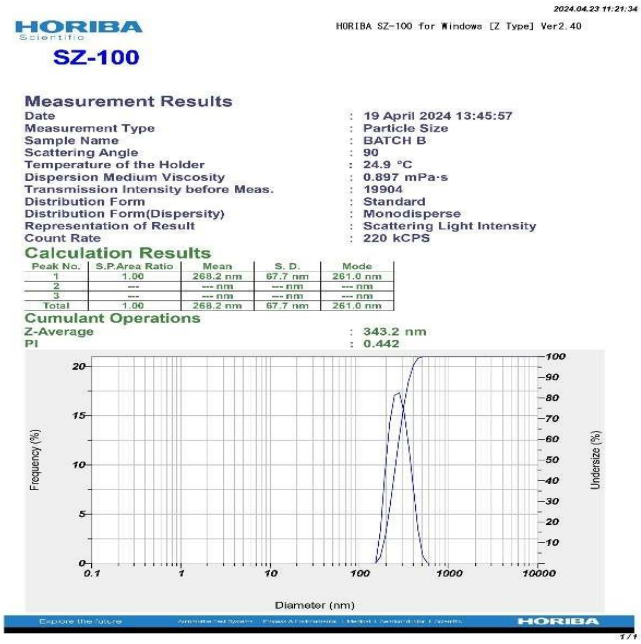

Fig 06: Particle Size Report of Batch B

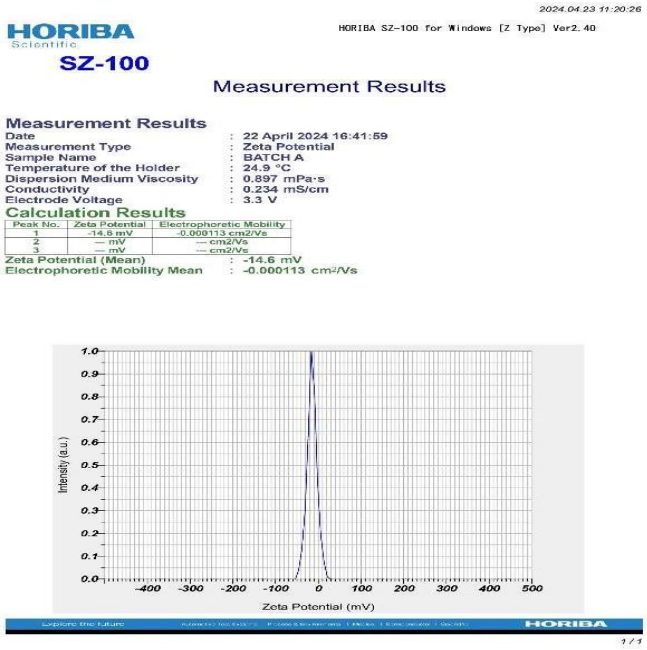

Fig 07: Zeta Potential Report of Batch A

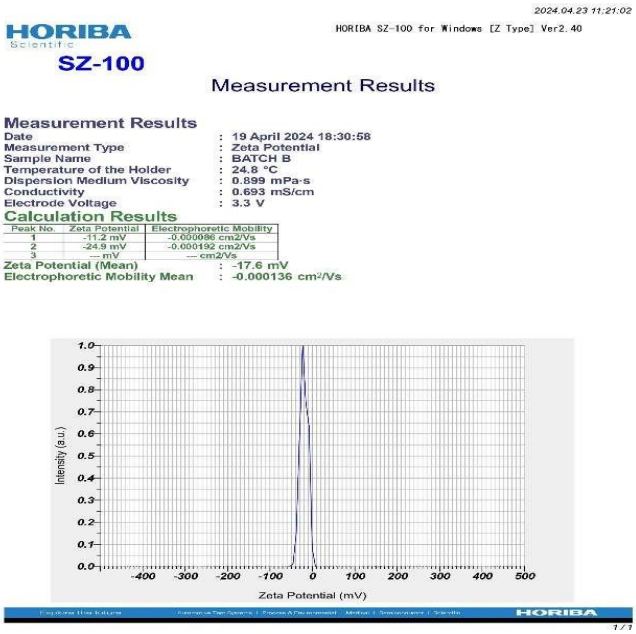

Fig 08: Zeta Potential Report of Batch B

Quantification by FTIR:

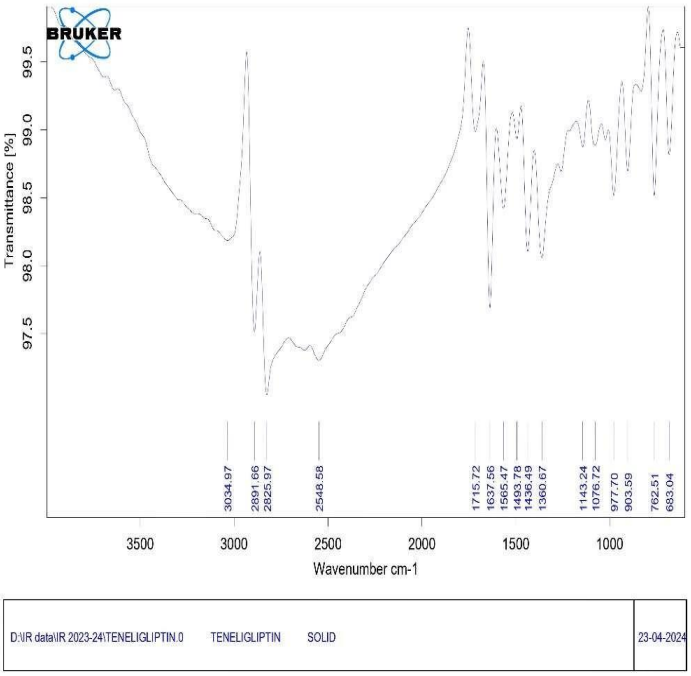

Fig 09: FTIR Report of Teneligliptin Standard

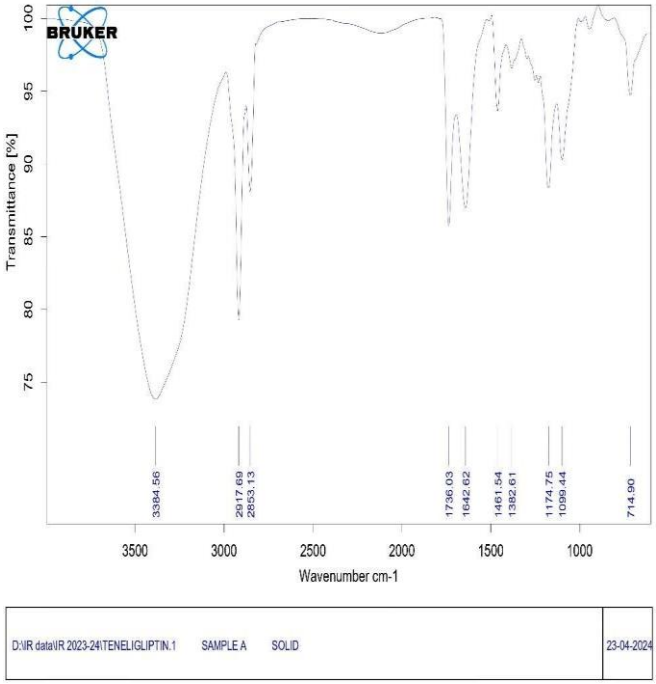

Fig 10: FTIR Report of Batch A

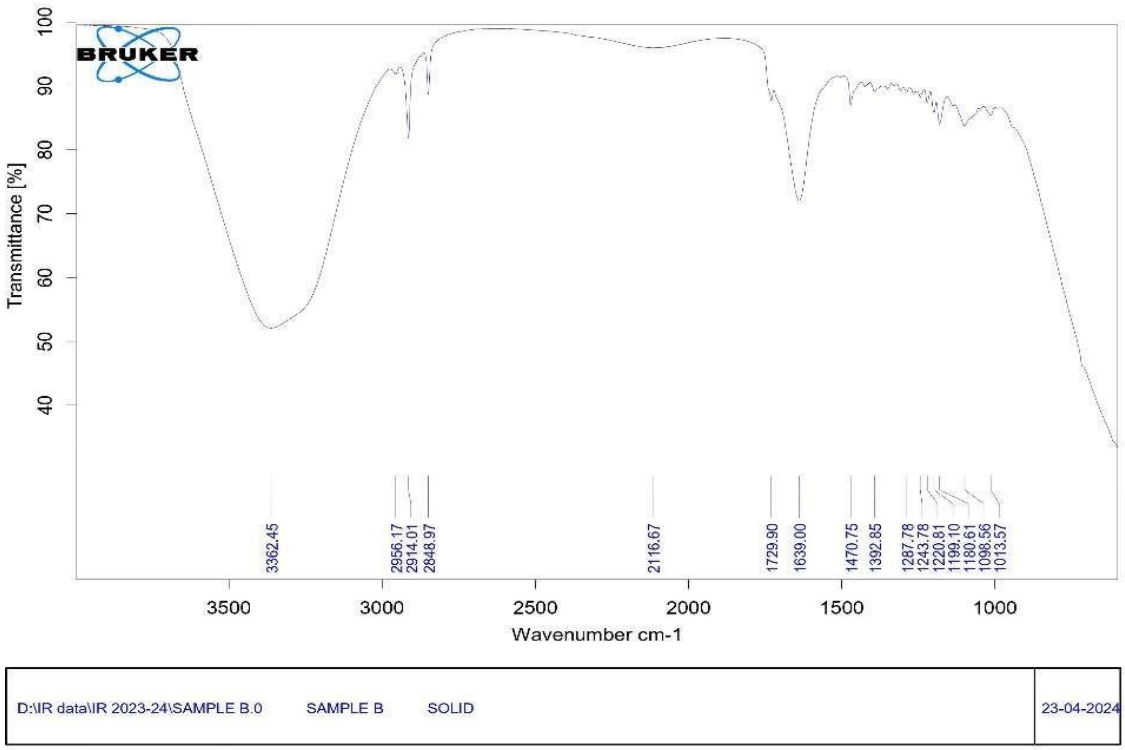

Fig 11: FITR Report of Batch B

Quantification by UV:

Sr. No	Concentration µg/ml	Absorbance
1.	0	0
2.	10	0.2123
3.	20	0.3798
4.	30	0.5866
5.	40	0.7944
6.	50	0.9977

Table 02: Concentration v/s Absorbance of Nano emulsion

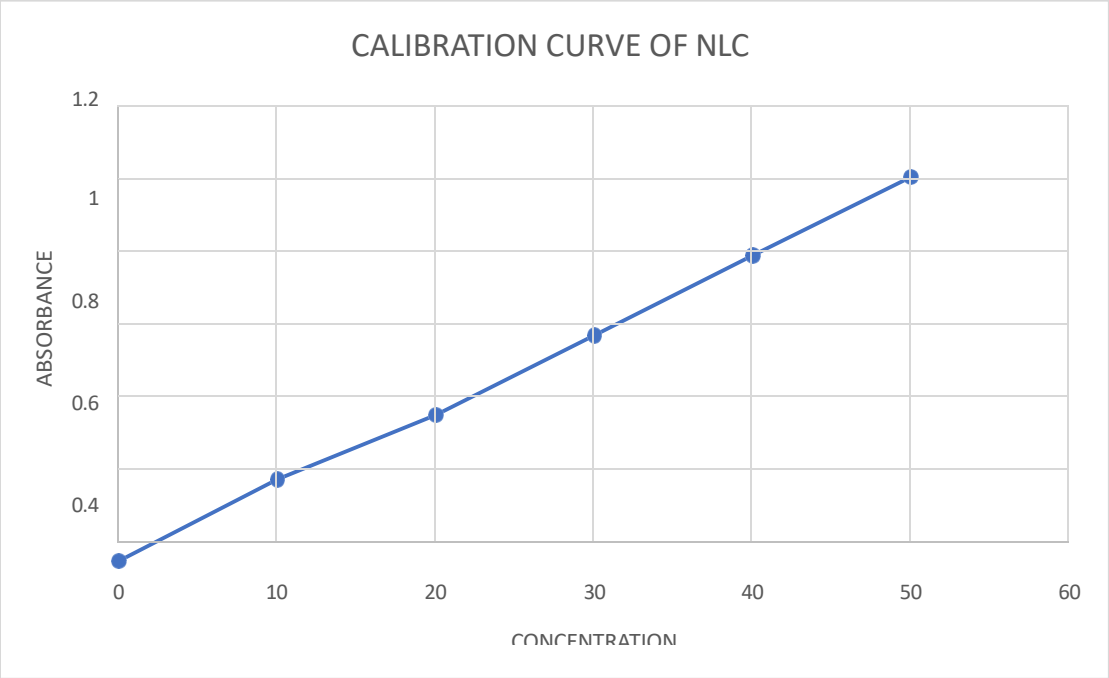

Fig 12: Calibration Curve of NLC

B. Interpretation of Results:

1. Correlation between formulation parameters and NLC characteristics:

In the results and discussion section, exploring the correlation between formulation parameters and nanostructured lipid carrier (NLC) characteristics provides valuable insights into the factors influencing the performance and properties of NLC formulations. By analyzing the relationship between various formulation parameters and NLC characteristics, researchers can elucidate the underlying mechanisms driving formulation behavior and optimize formulation parameters to achieve desired outcomes in targeted drug delivery applications. One aspect of the correlation analysis involves investigating the influence of lipid composition on NLC characteristics such as particle size, zeta potential, and drug loading capacity. Different lipid components exhibit unique physicochemical properties that can affect the structural integrity and stability of NLCs. For example, the selection of lipids with specific melting points or

crystallinity may impact the particle size distribution and drug encapsulation efficiency of NLC formulations. By systematically varying lipid composition and analyzing its effects on NLC characteristics, researchers can identify optimal lipid combinations for achieving desired formulation properties. Similarly, the role of surfactants in NLC formulations is another important factor to consider in correlation analysis. Surfactants play a crucial role in stabilizing NLCs by reducing interfacial tension and preventing particle aggregation. The type and concentration of surfactants can influence NLC characteristics such as particle size, zeta potential, and drug release kinetics. By modulating surfactant properties, researchers can tailor NLC formulations to achieve specific particle sizes, surface charges, and drug release profiles suitable for targeted drug delivery applications. Furthermore, the impact of formulation process parameters on NLC characteristics is a key aspect of correlation analysis. Factors such as homogenization technique, processing temperature, and pressure can affect the morphology, size distribution, and stability of NLC formulations. Optimizing these process parameters enables precise control over NLC characteristics, ensuring reproducibility and consistency in formulation performance. By identifying optimal process conditions through correlation analysis, researchers can enhance the scalability and efficiency of NLC production for commercialization. Moreover, exploring the correlation between NLC characteristics and in vitro/in vivo performance provides valuable insights into formulation efficacy and therapeutic outcomes. For example, correlating particle size and surface charge with cellular uptake and tissue distribution can elucidate the impact of NLC characteristics on drug delivery efficiency and bioavailability. Understanding these relationships facilitates the design of NLC formulations with enhanced targeting capabilities, improved drug release profiles, and reduced off-target effects. In summary, correlation analysis between formulation parameters and NLC characteristics is crucial for understanding the factors influencing formulation behavior and optimizing NLC formulations for targeted drug delivery applications. By systematically investigating these correlations, researchers can identify key formulation parameters that significantly impact NLC characteristics and fine-tune formulation strategies to achieve desired therapeutic outcomes.

CONCLUSION:

This dissertation has explored the formulation and evaluation of Nanostructured Lipid Carriers (NLCs) for targeted drug delivery systems, demonstrating their potential to enhance therapeutic efficacy while minimizing side effects. By systematically selecting and optimizing various formulation parameters, this study has contributed significantly to the understanding and development of effective NLC-based drug delivery systems. The double emulsification method proved to be an effective technique for producing NLCs. By varying key factors such as lipid type, surfactant concentration, and homogenization parameters, we were able to identify optimal conditions that resulted in desirable NLC characteristics. The use of Dynamic Light Scattering (DLS) allowed for precise measurement of particle size and zeta potential, providing valuable insights into the physical stability and surface charge of the NLCs. Additionally, UV spectrometry and Fourier Transform Infrared Spectroscopy (FTIR) were employed to quantify the encapsulated drug and confirm the chemical integrity of the druglipid matrix, respectively. The findings from this study highlight the critical role of formulation parameters in determining the performance of NLCs. For instance, the choice of lipid and surfactant types significantly influenced the particle size, while the homogenization conditions impacted the physical stability and drug release profiles. These insights are invaluable for the rational design and optimization of NLC formulations for specific therapeutic applications. Furthermore, the

optimized NLCs demonstrated excellent controlled drug release profiles, making them suitable for targeted drug delivery. The ability to fine-tune these formulations to achieve desired release kinetics and stability profiles underscores the versatility and potential of NLCs as a drug delivery platform.

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