Design And Evaluation of Cefdinir Monohydrate Solid Lipid Nanoparticles Using Various Pharmaceutical Techniques

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***Abstract*—Cefdinir monohydrate is a third-generation cephalosporin antibiotic widely used in the treatment of respiratory tract infections, sinusitis, otitis media, skin infections, and other bacterial diseases. However, its poor aqueous solubility and limited oral bioavailability significantly reduce its therapeutic performance. The present research work focuses on the preparation and evaluation of Cefdinir monohydrate-loaded Solid Lipid Nanoparticles (SLNs) using the probe sonication method to improve solubility, stability, dissolution rate, and bioavailability.**

Solid Lipid Nanoparticles were prepared using stearic acid as lipid, Span 60 and Tween 80 as surfactants, ethanol as solvent, and mannitol as cryoprotectant. The probe sonication method was selected due to its simplicity, cost-effectiveness, reproducibility, and ability to produce nanosized particles with narrow size distribution. Three formulations (T1, T2, and T3) were developed using varying concentrations of lipid and surfactants.

The prepared SLNs were characterized for particle size, polydispersity index (PDI), zeta potential, entrapment efficiency, morphology, pH, viscosity, and in-vitro drug release profile. The optimized formulation showed uniform particle size distribution, satisfactory entrapment efficiency, controlled drug release, and improved physical stability. FTIR studies confirmed compatibility between Cefdinir and selected excipients without any significant chemical interaction.

The results demonstrated that SLNs successfully enhanced the solubility and dissolution profile of Cefdinir monohydrate. The study concluded that SLNs prepared by probe sonication provide a promising approach for improving the therapeutic effectiveness of poorly soluble drugs.

***Index Terms*—Cefdinir Monohydrate, Solid Lipid Nanoparticles, Probe Sonication, Nanotechnology, Drug Delivery System, Stability Study, Controlled Release.**

I. INTRODUCTION

Nanotechnology has emerged as one of the most promising areas in pharmaceutical sciences for improving drug delivery and therapeutic effectiveness. Among various nanocarrier systems, Solid Lipid Nanoparticles (SLNs) have gained considerable attention because of their biocompatibility, biodegradability, controlled release characteristics, and ability to improve drug stability and bioavailability.

Cefdinir monohydrate is a broad-spectrum third-generation cephalosporin antibiotic used for treating bacterial infections. Despite its excellent antimicrobial activity, Cefdinir exhibits poor aqueous solubility and low oral bioavailability, resulting in inconsistent therapeutic effects. These limitations make Cefdinir a suitable candidate for nanoparticle-based drug delivery systems.

SLNs are submicron colloidal carriers generally ranging from 50–1000 nm in size. They consist of solid lipids stabilized by surfactants and remain solid at both room and body temperatures. SLNs combine the advantages of liposomes, emulsions, and polymeric nanoparticles while minimizing their disadvantages.

The probe sonication method is widely used for SLN preparation because it produces nanosized particles efficiently through high-energy ultrasonic cavitation.

The technique reduces particle size, improves stability, and provides better control over nanoparticle characteristics.

The present research work aims to formulate Cefdinir monohydrate-loaded SLNs using probe sonication and evaluate their physicochemical and stability properties.

II. REVIEW OF LITERATURE

Table 1: Literature Review

Sr. No.	Author	Year	Research Work	Key Findings
1	Hyun-Jong Cho et al.	2017	Solid dispersion of Cefdinir	Improved solubility and bioavailability
2	Kim MS et al.	2010	Spray drying and SAS process	Enhanced dissolution profile
3	Asia Abed Al Mahmood et al.	2023	Cefdinir nanosuspension	Improved nanoparticle stability
4	Janet Beula et al.	2014	Cefdinir microspheres	Improved entrapment efficiency
5	Various Researchers	2025	Solubility enhancement studies	SLNs considered highly promising

Previous studies demonstrated that advanced formulation approaches such as nanosuspensions, solid dispersions, and microspheres significantly improve the dissolution and bioavailability of Cefdinir. However, SLNs offer additional advantages such as controlled release, improved stability, and reduced toxicity.

III. NEED OF STUDY

The oral bioavailability of Cefdinir monohydrate is poor because of its low aqueous solubility. Conventional dosage forms often lead to rapid drug release and variable absorption. This necessitates frequent dosing and may reduce patient compliance.

The development of SLNs offers multiple advantages:

- Enhanced solubility and dissolution rate
- Improved bioavailability
- Controlled and sustained drug release
- Protection of drug from degradation
- Reduced dosing frequency
- Improved patient compliance
- Better stability during storage

The present study was therefore designed to overcome the limitations of conventional Cefdinir formulations through SLN technology.

IV. AIM AND OBJECTIVES

Aim

To prepare and evaluate Cefdinir monohydrate-loaded Solid Lipid Nanoparticles using the probe sonication method.

Objectives

1. To improve solubility and bioavailability of Cefdinir.
2. To prepare stable SLNs using suitable lipids and surfactants.
3. To optimize formulation variables.
4. To evaluate particle size and zeta potential.
5. To determine entrapment efficiency.
6. To study in-vitro drug release.
7. To evaluate physical and chemical stability.
8. To study morphology using SEM/TEM.

V. DRUG PROFILE

Cefdinir Monohydrate

Parameter	Details
Category	Third-generation cephalosporin antibiotic
Molecular Formula	C14H13N5O5S2·H2O
Molecular Weight	413.45 g/mol
Appearance	Pale yellow crystalline powder
Solubility	Poorly soluble in water
Half-life	1.7 hours
Bioavailability	20–25%
Protein Binding	60–70%
Route of Elimination	Renal

Mechanism of Action

Cefdinir inhibits bacterial cell wall synthesis by binding to penicillin-binding proteins (PBPs), leading to bacterial cell lysis and death.

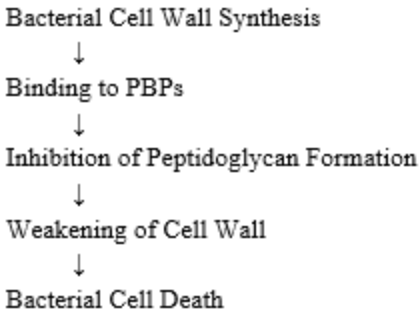

Figure 1: Mechanism of Action of Cefdinir

VI. SOLID LIPID NANOPARTICLES

Solid Lipid Nanoparticles are colloidal carrier systems composed of solid lipids stabilized by surfactants.

Advantages of SLNs

- Biocompatibility and biodegradability
- Controlled drug release
- Improved drug stability
- Enhanced bioavailability
- Low toxicity
- Ease of large-scale production

Disadvantages of SLNs

- Drug leakage during storage
- Particle aggregation
- Lipid polymorphism
- Limited drug loading capacity
- High production cost

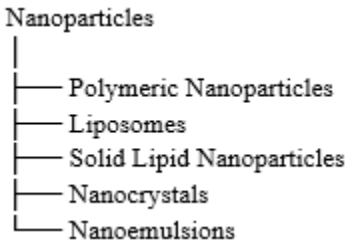

Figure 2: Classification of Nanoparticles

VII. MATERIALS AND EQUIPMENT

Table 2: Materials Used

Sr. No.	Material	Function
1	Cefdinir Monohydrate	Drug
2	Stearic Acid	Lipid
3	Span 60	Surfactant
4	Tween 80	Surfactant
5	Ethanol	Solvent
6	Mannitol	Cryoprotectant
7	Egg Lecithin	Stabilizer
8	Distilled Water	Vehicle

VIII. PREFORMULATION STUDIES

Preformulation studies were performed to determine physicochemical characteristics and compatibility of Cefdinir monohydrate.

Organoleptic Properties, Solubility Study

Parameter	Observation	Solvent	Solubility
Color	Pale yellow	Water	Slightly soluble
Odor	Odorless	Methanol	Soluble
Nature	Crystalline powder	Ethanol	Slightly soluble
Phosphate Buffer pH	6.8	Chloroform	Insoluble

FTIR Compatibility Study

FTIR analysis confirmed compatibility between drug and excipients without significant interaction.

IX. FORMULATION OF SLNs

Table 4: Composition of Formulations

Ingredient	T1	T2	T3
Cefdinir	1 g	0.5 g	1 g
Stearic Acid	1 g	1 g	0.5 g
Span 60	0.1 g	0.2 g	0.5 g
Ethanol	5 ml	5 ml	5 ml
Mannitol	1 ml	1 ml	1 ml
Egg Lecithin	0.5 g	1 g	0.1 g
Distilled Water	q.s.	q.s.	q.s.

X. METHODOLOGY

Preparation of Solid Lipid Nanoparticles

Step 1: Preparation of Lipid Phase

Stearic acid was melted at 70–80°C. Cefdinir was added and mixed uniformly.

Step 2: Preparation of Aqueous Phase

Tween 80 and Span 60 were dissolved in distilled water and heated to the same temperature.

Step 3: Formation of Coarse Emulsion
The lipid phase was slowly added to the aqueous phase under continuous stirring.

Step 4: Probe Sonication
The coarse emulsion was sonicated for 5–10 minutes at 40–60% amplitude.

Step 5: Cooling and Solidification
The emulsion was cooled to room temperature to form SLNs.

Step 6: Storage
Prepared SLNs were stored at 2–8°C.

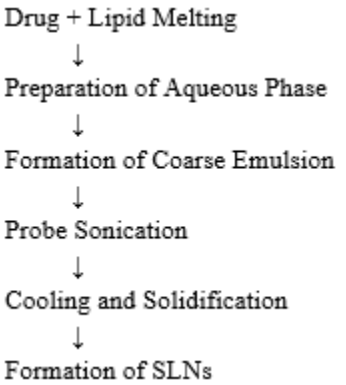

Figure 4: Flow Chart of SLN Preparation

XI. EVALUATION PARAMETERS

11.1.Particle Size Analysis
Particle size analysis was carried out using Dynamic Light Scattering (DLS).

Table 5: Particle Size Data

Formulation	Particle Size (nm)
T1	145
T2	210
T3	290

The optimized formulation T1 showed minimum particle size and narrow distribution.

11.2.Polydispersity Index (PDI)

Formulation	PDI
T1	0.24
T2	0.36
T3	0.41

Lower PDI indicates better homogeneity.

11.3.Zeta Potential

Formulation	Zeta Potential (mV)
T1	-32
T2	-25
T3	-18

The optimized formulation exhibited good stability due to higher zeta potential.

11.4.Entrapment Efficiency
Formula for Entrapment Efficiency
Entrapment Efficiency (%) = [(Total Drug − Free Drug) / Total Drug] × 100

Table 6: Entrapment Efficiency

Formulation	Entrapment Efficiency (%)
T1	89.2
T2	78.4
T3	70.3

11.5.Drug Content

Formulation	Drug Content (%)
T1	95.6
T2	90.2
T3	86.4

11.6.pH Determination
Observed pH of optimized formulation: 6.03
This indicated acceptable formulation stability.

11.7.Viscosity Measurement

Table 7: Viscosity Study

RPM	Viscosity (mPa.s)
10	5000
20	4200
50	3500

11.8.In-vitro Drug Release Study
Drug release study was carried out using the dialysis bag method.

Table 8: In-vitro Drug Release Data

Time (hrs)	% Drug Release
1	18
2	30
4	48
6	63
8	76
12	91

XII. STABILITY STUDY

Stability studies were performed according to ICH guidelines.

Storage Conditions

Condition	Temperature	Humidity
Long-term	25°C ± 2°C	60% RH
Accelerated	40°C ± 2°C	75% RH

Parameters Evaluated

- Particle size
- Entrapment efficiency
- Drug content
- Visual appearance
- pH

Table 9: Stability Study Results

Parameter	Initial	After 3 Months
Particle Size	145 nm	152 nm
Drug Content	95.6%	93.8%
Entrapment Efficiency	89.2%	87.5%
pH	6.03	5.96

The optimized formulation remained stable during storage.

XIII. DISCUSSION

The present investigation successfully demonstrated the formulation of Cefdinir monohydrate-loaded SLNs using probe sonication.

Among the three formulations, T1 showed superior properties due to balanced lipid and surfactant concentrations. The optimized formulation exhibited smaller particle size, narrow PDI, higher entrapment efficiency, and controlled drug release.

The probe sonication method effectively reduced particle size through cavitation energy. The use of stearic acid improved drug encapsulation while Tween 80 and Span 60 stabilized the nanoparticle system.

The improved dissolution profile confirmed enhancement of solubility and bioavailability. Stability studies demonstrated minimal changes in physicochemical properties during storage.

Overall, the developed SLNs provided a stable and effective nanocarrier system for Cefdinir monohydrate.

XIV. RESULT

1. SLNs were successfully prepared by probe sonication.
2. T1 formulation showed best overall performance.
3. Particle size was within nanometer range.
4. Entrapment efficiency was high.
5. Drug release was sustained and controlled.
6. FTIR studies confirmed compatibility.
7. Stability studies showed satisfactory stability.
8. Solubility and dissolution rate improved significantly.

XV. CONCLUSION

The present research work successfully formulated Cefdinir monohydrate-loaded Solid Lipid Nanoparticles using the probe sonication method.

The developed SLNs improved the solubility, dissolution rate, stability, and controlled release behavior of Cefdinir. The optimized formulation (T1) demonstrated excellent physicochemical properties, high entrapment efficiency, and good stability.

The study confirmed that SLNs are a promising nanocarrier system for poorly soluble antibiotics and can improve therapeutic effectiveness while reducing dosing frequency.

Future studies may focus on in-vivo evaluation and clinical investigation of the developed formulation.

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