

Investigation of Hyper-Crosslinked Cyclodextrin Matrices as Carriers For linezolid: Formulation and In Vitro Release Study

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ABSTRACT

The present study focused on the formulation and evaluation of a cyclodextrin-based nanosponge for the controlled delivery of Linezolid. Pre-formulation studies confirmed that Linezolid is a white, odourless, crystalline solid, consistent with standard specifications and indicative of high purity. Solubility analysis revealed high solubility in Dimethyl sulfoxide (DMSO) and good solubility in ethanol and methanol, while limited solubility was observed in water and chloroform. Moderate solubility in phosphate buffer (pH 7.4) suggested acceptable behaviour under physiological conditions, justifying the need for a carrier system to enhance dissolution. The experimentally determined pH (4.14) and melting point (182 °C) were in close agreement with reported reference values, confirming the identity and suitability of the drug for formulation development. FTIR analysis demonstrated the presence of characteristic functional groups without any structural modification, validating drug integrity. The prepared nanosponge formulations (NSF1–NSF5) exhibited particle sizes in the nanometre range (170.78–202.6 nm). NSF3 showed the smallest particle size, while NSF4 demonstrated the most uniform particle size distribution based on polydispersity index values. Zeta potential measurements indicated good electrostatic stability for NSF1–NSF4 (–35.9 to –39.8 mV), with NSF3 exhibiting the highest negative charge, suggesting superior colloidal stability. SEM analysis revealed porous, rough, and clustered spherical morphology characteristic of nano sponge structures, suitable for efficient drug encapsulation. Entrapment efficiency varied among formulations, with NSF3 showing the highest drug entrapment (95.34%), followed by NSF2, whereas NSF1 and NSF4 showed comparatively lower values.

Overall, the results identified NSF3 as the optimised formulation, exhibiting favourable physicochemical characteristics, high drug-loading efficiency, and

promising potential as a controlled drug delivery system for Linezolid.

Keywords: Linezolid; Cyclodextrin nanosponges; Hyper-crosslinked polymer; Controlled drug release; Entrapment efficiency; In-vitro release; Stability studies.

I. INTRODUCTION

The advancement of nanotechnology has significantly transformed the field of drug delivery by enabling the development of novel carrier systems with improved therapeutic performance. Among these, cyclodextrin-based nanosponge (CDNS) has gained increasing attention due to its unique structural and functional properties. Cyclodextrins are cyclic oligosaccharides characterised by a hydrophobic internal cavity and a hydrophilic external surface, which facilitates the inclusion of poorly soluble drug molecules. When crosslinked with suitable agents, they form highly porous, three-dimensional nanosponge structures capable of encapsulating a wide variety of pharmaceutical compounds.

Cyclodextrin nanosponges exhibit several advantages over conventional drug delivery systems, including enhanced solubility, improved chemical stability, high drug loading capacity, and the ability to provide controlled and sustained drug release. Their nanoporous architecture allows for the efficient entrapment of both hydrophilic and lipophilic drugs, while their stable structure enables modulation of drug release kinetics. These characteristics make them particularly suitable for improving the bioavailability of drugs with poor aqueous solubility and short biological half-lives.^[1,2]

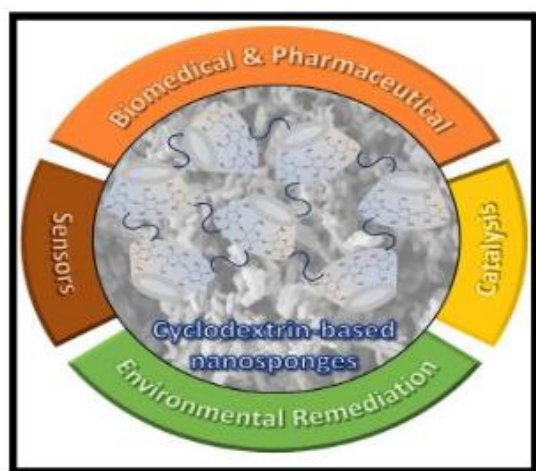


Figure 1: Cyclodextrin-based Nanosponges

Linezolid is a synthetic oxazolidinone-class antibiotic widely used in the treatment of multidrug-resistant Gram-positive bacterial infections, including infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) and *Enterococcus* species. Despite its clinical effectiveness, linezolid is associated with several limitations, such as frequent dosing requirements, potential haematological toxicity, and suboptimal pharmacokinetic behaviour. These challenges necessitate the development of advanced drug delivery systems capable of improving their therapeutic profile.^[3]

Incorporation of linezolid into cyclodextrin-based nanosponges presents a promising strategy to overcome these limitations. The nanosponge matrix can enhance drug encapsulation efficiency and provide sustained release, thereby reducing dosing frequency and minimising side effects. Furthermore, the porous nature of nanosponges facilitates prolonged drug retention and controlled diffusion, which may improve patient compliance and overall therapeutic outcomes.^[4]

Recent studies have demonstrated the potential of cyclodextrin nanosponges in delivering a wide range of drugs, highlighting their versatility and effectiveness as nanocarriers. Their biocompatibility, ease of synthesis, and scalability further support their application in pharmaceutical formulations. However, the optimisation of formulation parameters and evaluation of drug release behaviour remain critical for achieving the desired therapeutic performance.^[5]

Therefore, the present study focuses on the formulation and characterisation of hyper-crosslinked cyclodextrin-based nanosponges for the delivery of linezolid. The study also aims to evaluate the *in vitro* drug release profile to assess their

suitability as a controlled drug delivery system and to enhance the therapeutic efficacy of linezolid.

I. MATERIALS AND METHODS

Linezolid was obtained as a gift sample from a certified pharmaceutical source. β -Cyclodextrin and the crosslinking agent (e.g., diphenyl carbonate or carbonyl diimidazole) were procured from standard suppliers. All solvents and reagents (analytical grade) were used as received without further purification.

2.1 Pre-formulation Studies

Pre-formulation studies were conducted to evaluate key physicochemical properties of linezolid relevant to formulation development. Solubility of the drug was assessed in various solvents, including water, ethanol, methanol, phosphate buffer (pH 7.4), chloroform, and dimethyl sulfoxide, using the visual observation method. Linezolid exhibited high solubility in ethanol, methanol, and phosphate buffer (pH 7.4), which guided solvent selection for further studies.^[6]

The melting point of linezolid was determined using a capillary method to assess purity and thermal behaviour.^[7]

The λ_{max} of linezolid was determined by UV-Visible spectrophotometry (Shimadzu UV-1700) in the wavelength range of 200–400 nm, using ethanol as solvent. The maximum absorbance was observed at **251 nm**, which was used for further analysis.^[8]

A calibration curve was constructed in the concentration range of 2–10 $\mu\text{g/mL}$. The absorbance values exhibited linearity with concentration, confirming compliance with Beer-Lambert's law and suitability of the method for quantitative estimation.^[9]

Drug-excipient compatibility was evaluated using Fourier Transform Infrared (FTIR) spectroscopy over the range of 4000–400 cm^{-1} using the KBr pellet method, confirming the absence of significant interactions.^[10]

2.2 Preparation of Cyclodextrin Nanosponges

Cyclodextrin nanosponges were synthesised via a crosslinking method. Briefly, β -cyclodextrin was reacted with the selected crosslinker in a defined molar ratio under controlled temperature and stirring conditions. The reaction mixture was maintained for a specified duration to obtain a highly crosslinked polymeric network. The resultant product was cooled, washed repeatedly to remove unreacted residues, and dried. The dried mass was pulverized

and sieved to obtain uniform nanosponge particles.^[11]

2.4 Drug Loading

Linezolid-loaded nanosponges were prepared using a solvent evaporation/incubation technique. Accurately weighed nanosponges were dispersed in a suitable solvent containing dissolved linezolid and stirred for a fixed period to facilitate drug encapsulation. The dispersion was centrifuged, and the solid fraction was collected, washed to remove untrapped drug, and dried.

Table 1: Composition of Nanosponge Formulation

Formulation	Linezolid (mg)	β -Cyclodextrin (mg)	DPC (mg)	Reaction Temperature (°C)	Stirring time (6 to 7 Hrs)
NSF1	100	100	100	80	7
NSF2	100	150	100	85	7
NSF3	100	200	100	90	7
NSF4	100	250	100	95	7
NSF5	100	300	100	100	7

2.3 Evaluation of Linezolid-Loaded Nanosponges

The prepared nanosponge formulations were evaluated for key physicochemical parameters to assess their quality, stability, and performance.

2.3.1 Particle Size and Polydispersity Index (PDI)

The mean particle size and PDI of the formulations were determined using dynamic light scattering (DLS) after appropriate dilution with distilled water. The analysis provided information on particle size distribution and uniformity, which are critical for formulation stability and performance.^[12]

2.3.2 Zeta Potential Analysis

Zeta potential was measured using a zeta sizer (Malvern Panalytical) to evaluate surface charge and colloidal stability. The values obtained indicate the degree of electrostatic repulsion between particles and overall dispersion stability.^[13]

2.3.3 Surface Morphology (SEM)

The surface morphology of the nanosponges was analysed using scanning electron microscopy (SEM). Samples were gold-coated prior to imaging, and micrographs were obtained to examine particle shape, surface texture, and porosity, which are important for drug loading and release behaviour.^[14]

2.3.4 Entrapment Efficiency (EE%)

Entrapment efficiency was determined by lysing the drug-loaded nanosponges in ethanol, followed by filtration and UV spectrophotometric analysis at the previously determined λ_{max} . The percentage of drug encapsulated was calculated using the following equation:

$$EE\% = \frac{\text{Total drug} - \text{Free drug}}{\text{Total drug}} \times 100$$

This parameter reflects the effectiveness of the nanosponge system in incorporating the drug.^[15]

2.5 In Vitro Drug Release Study

The in vitro drug release profile of linezolid from nanosponge formulations was evaluated using the dialysis bag diffusion method. A known quantity of drug-loaded nanosponges was placed in a dialysis membrane and immersed in phosphate buffer (pH 7.4) maintained at $37 \pm 2^\circ\text{C}$ under continuous stirring (100 rpm).

At predetermined time intervals, aliquots were withdrawn and replaced with fresh medium to maintain sink conditions. Samples were analysed using UV-Visible spectrophotometry at λ_{max} (251 nm), and cumulative drug release was calculated.^[12] The release data were fitted to various kinetic models, including zero-order, first-order, Higuchi, and Korsmeyer-Peppas models, to determine the mechanism of drug release.

2.6 Stability Studies

Stability studies were conducted as per ICH guidelines under accelerated conditions of $25 \pm 2^\circ\text{C} / 60 \pm 5\% \text{ RH}$ and $40 \pm 2^\circ\text{C} / 70 \pm 5\% \text{ RH}$ for a period of three months. Samples were evaluated at specified intervals for changes in particle size and entrapment efficiency to assess formulation stability and integrity.^[16]

II. RESULT AND DISCUSSION

3.1 Pre-formulation study of drug

3.1.1 Organoleptic properties

Table 2: Organoleptic properties of Linezolid

Drug	Organoleptic Properties	Observation
Linezolid	Colour	White
	Odour	Odourless
	Appearance	Crystalline
	State	Solid

3.1.2 Solubility study

Table 3: Solubility study of Linezolid

Drug	Solvents	Observation/Inference
Linezolid	Water	Sparingly soluble
	Ethanol	Freely soluble
	Methanol	Freely soluble
	Chloroform	Sparingly soluble
	DMSO	Highly soluble
	PBS -7.4 pH	Freely soluble

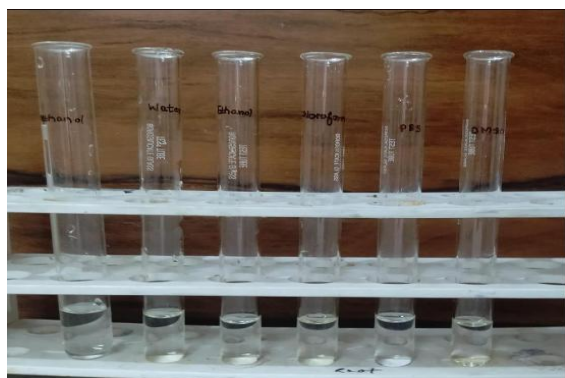


Figure 2: Solubility study of Linezolid

3.1.3 pH determination

Table 4: pH of Linezolid

Drug	Observed	Reference
Linezolid	4.14	4.3-5.3

3.1.4 Melting Point

Table 5: Melting Point of Linezolid

S. No.	Drug	Observed	Reference
1.	Linezolid	182°C	176°C to 183°C

3.1.5 Determination of λ max by UV spectroscopy of drug

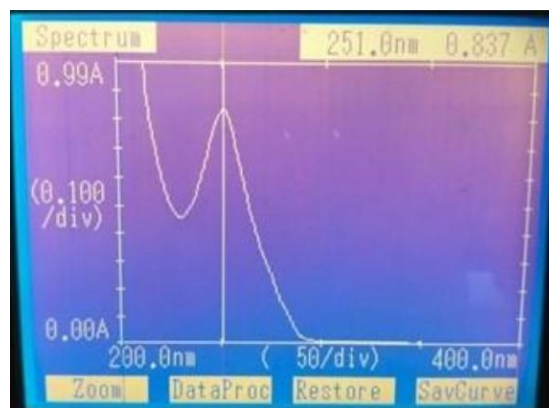


Figure 3: UV graph of Linezolid (251.0 nm)

Table 6: Lambda max of Linezolid

S. No.	Drug	UV absorption maxima (Lambda max)
1.	Linezolid	251.0 nm

3.1.5.1 Standard calibration curve

Table 7: Calibration Curve of Linezolid

S. No.	Concentration ($\mu\text{g/ml}$)	Mean Absorbance (nm)
1.	2	0.102
2.	4	0.207
3.	6	0.310
4.	8	0.409
5.	10	0.511
Mean		0.3078
SD		0.161285
%RSD		52.44

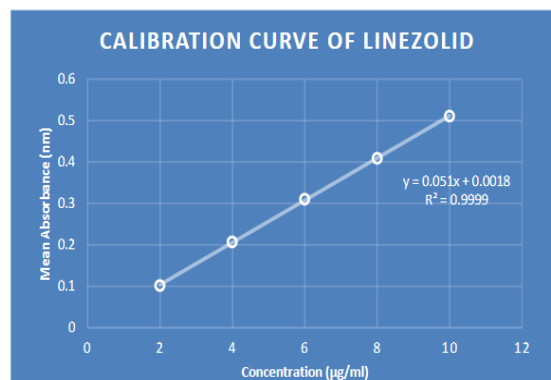


Figure 4: Calibration curve of Linezolid

3.1.6 Functional group identified by Infra-Red spectroscopy

3.1.6.1 FTIR of Linezolid

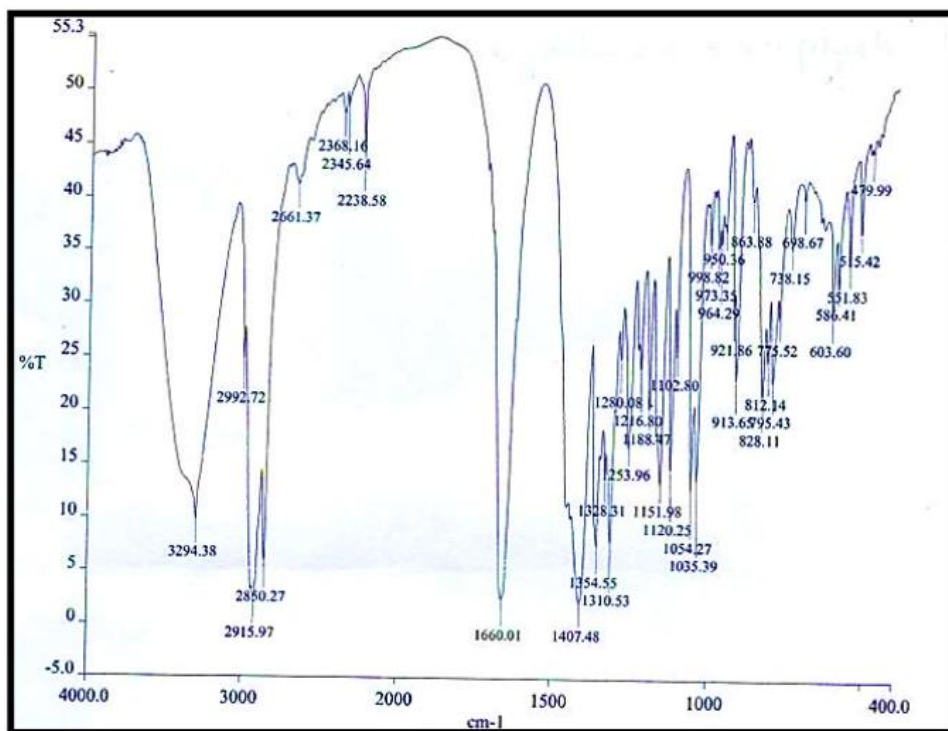


Figure 5: FTIR of Linezolid

Table 8: Interpretation of IR spectrum of Linezolid

S. No.	Peak Obtained	Reference Peak	Functional Group	Name of Functional Group
1.	3294.38	3333-3267	C-H stretching	Alkyne
2.	2992.72	3000-2840	C-H stretching	Alkene
3.	2850.27	3000-2800	N-H stretching	Amine salt
4.	2661.37	3300-2500	O-H stretching	Carboxylic acid
5.	2238.58	2260-2222	C≡N stretching	Nitrile
6.	1660.01	1690-1640	C=N stretching	Imine / Oxime

3.2 Characterization of Linezolid Nanosponges formulation

3.2.1 Physical appearance of the Nanosponges formulation

Table 9: Physical Appearance of Nanosponges

S. No.	Formulation	Parameters	Observation
1.	Nanosponges	Colour	White to off-white
2.		Odour	Odourless
3.		Appearance	Solid power

3.2.2 Particle Size analysis

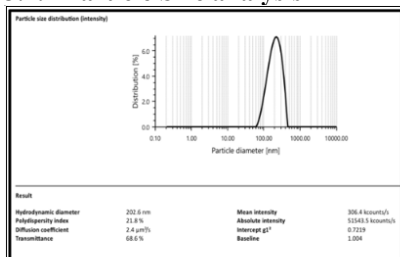


Figure 6: NSF1 Particle Size

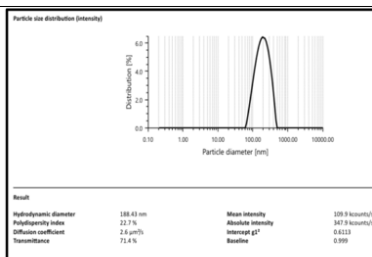


Figure 7: NSF2 Particle Size

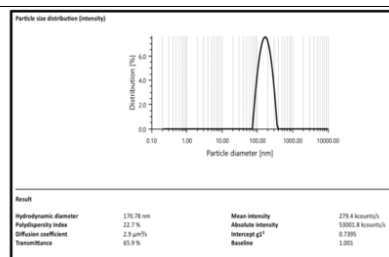


Figure 8: NSF3 Particle Size

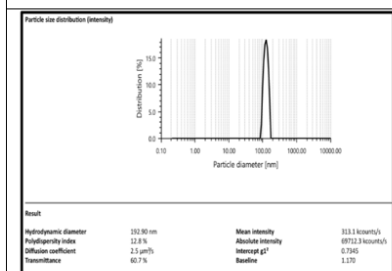


Figure 9: NSF4 Particle Size

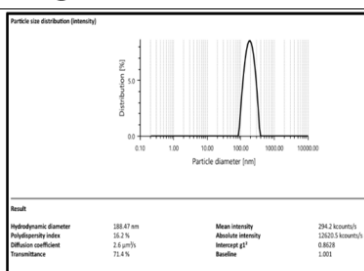


Figure 10: NSF5 Particle Size

Table 10: Particle size of Cyclodextrin-based Nanosponges formulation

S. No.	Formulation code	Particle size (nm)	PI Value %
1.	NSF1	202.6	21.8
2.	NSF2	188.43	22.7
3.	NSF3	170.78	22.7
4.	NSF4	192.90	12.8
5.	NSF5	188.47	16.2

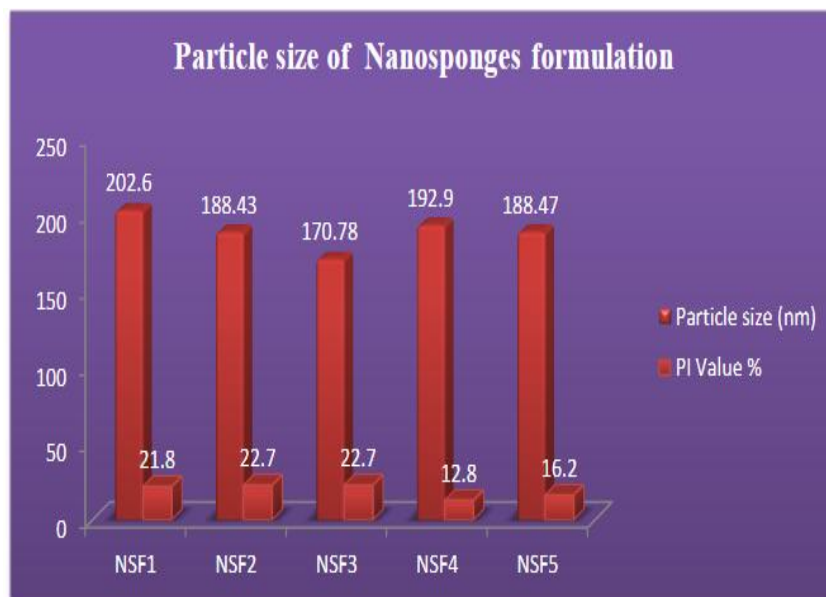


Figure 11: Particle size of Nanosponges

3.2.3 Zeta potential Analysis

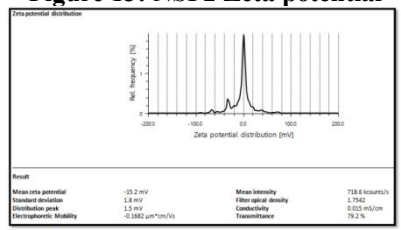
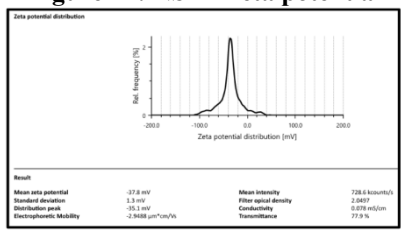
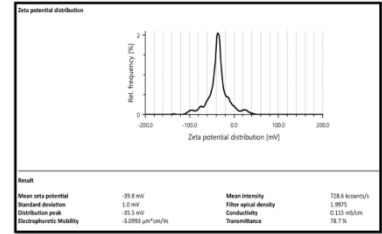
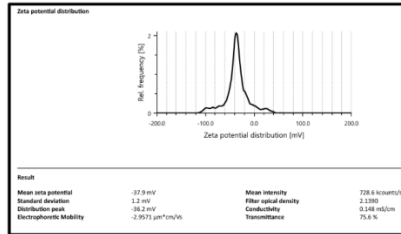
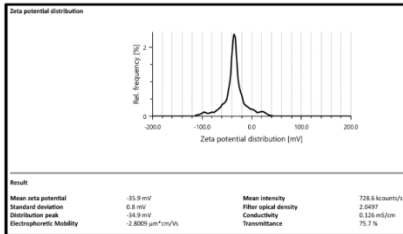


Table 11: Zeta potential analysis of Nanosponges formulation

S.No.	Formulation code	Zeta potential (mV)
1.	NSF1	-35.9
2.	NSF2	-37.9
3.	NSF3	-39.8
4.	NSF4	-37.8
5.	NSF5	-15.2

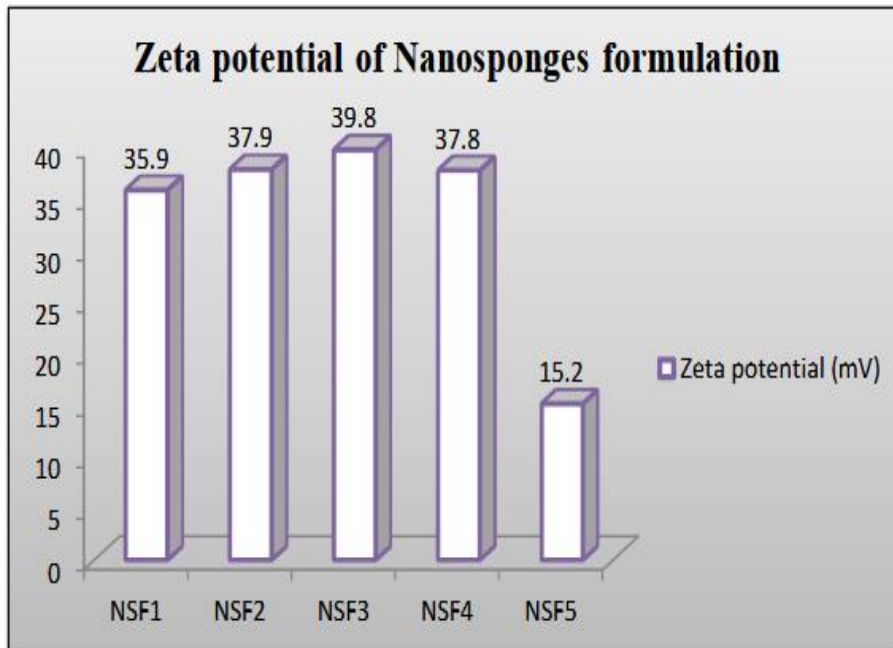


Figure 17: Zeta potential of Nanosponges

3.2.4 Scanning electron microscope (SEM)

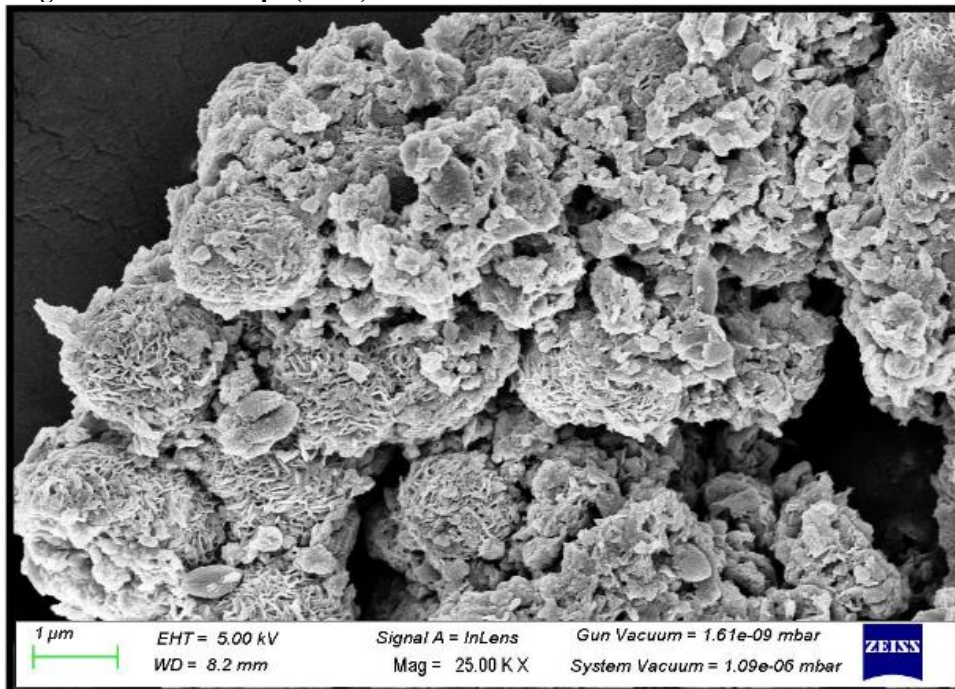


Figure 18: Scanning electron microscope (SEM)

3.2.5 Entrapment efficacy

Table 12: Entrapment efficacy of Cyclodextrin based nanospheres formulation

S. No.	Formulations	Entrapment efficiency (%)
1.	NSF1	62.88
2.	NSF2	83.67
3.	NSF3	95.34
4.	NSF4	58.86
5.	NSF5	70.25

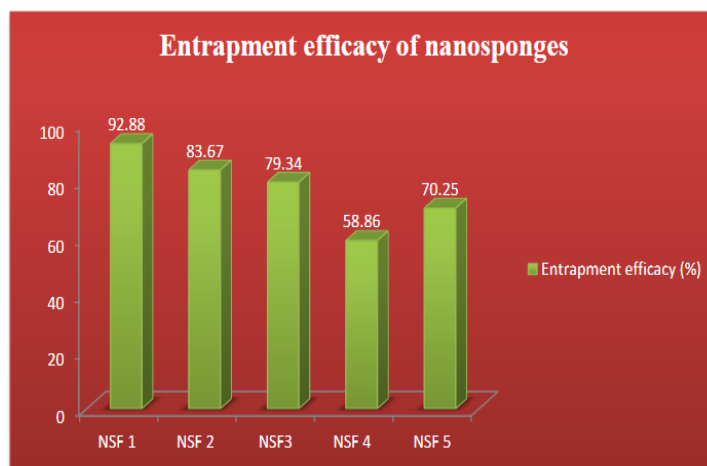


Figure 19: Graphical representation of Entrapment efficacy

3.3. In-vitro drug release

Table 16: Release kinetics study of optimized Nanosponges formulation

Time (Hr)	Cumulative % drug release	% drug remaining	Square root time	log cumulative % drug remaining	log time	log cumulative % drug released
0	0	100	0.000	2.000	0.000	0.000
2	21.45	78.55	1.414	1.895	0.301	1.331
3	31.11	68.89	1.732	1.838	0.477	1.493
4	43.38	56.62	2.000	1.753	0.602	1.637
6	55.21	44.79	2.449	1.651	0.778	1.742
8	66.92	33.08	2.828	1.520	0.903	1.826
10	76.75	23.25	3.162	1.366	1.000	1.885
12	84.66	15.34	3.464	1.186	1.079	1.928
14	97.98	2.02	3.742	0.305	1.146	1.991

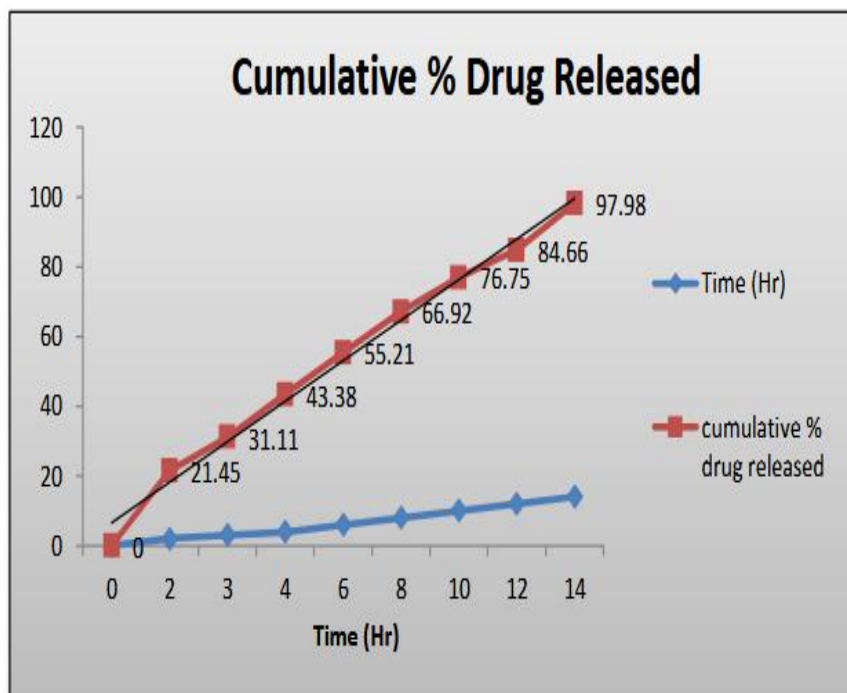


Figure 20: In-vitro drug release studies of Nanosponges

Table 17: Correlation value (R2 value)

Formulation	Model	Kinetic parameter values
NSF3 Formulation	Zero order	R ² = 0.9703
	First order	R ² = 0.7877
	Higuchi	R ² = 0.9723
	Korsmeyer-Peppas	R ² = 0.793

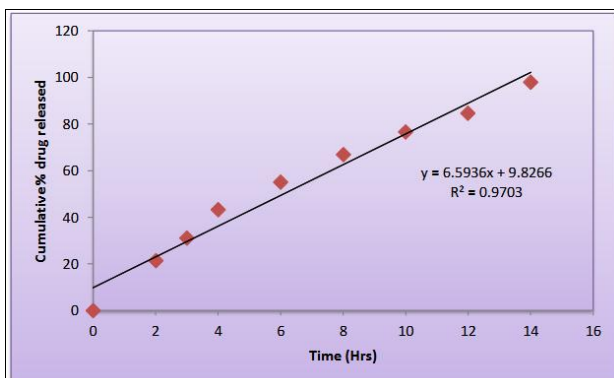


Figure 21: Zero order

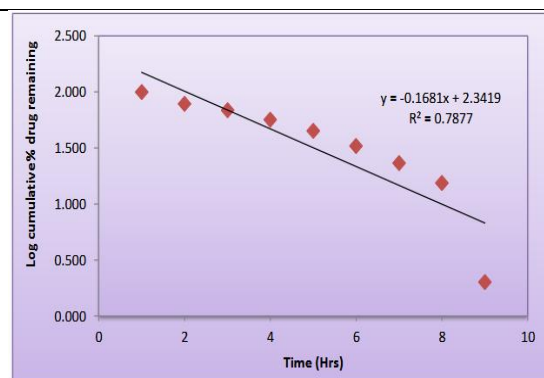


Figure 22: First order

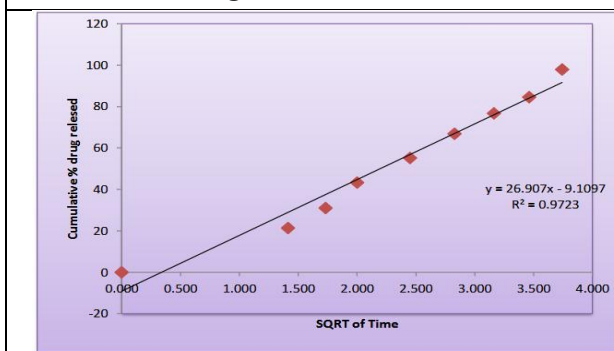


Figure 23: Higuchi

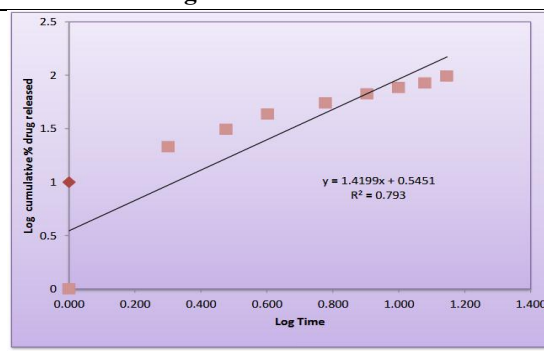


Figure 24: Korsmeyer-Peppas

3.4 Stability study

Table 18: Stability Study of optimised formulation (Nanosponges)

S. No.	Time (days)	25°C±2 °C and 60 ± 5% RH		40°C±2 °C and 70 ±5% RH	
		Particle size (nm)	Entrapment efficiency (%)	Particle size (nm)	Entrapment efficiency (%)
1.	0	170.78	95.34	170.78	95.34
2.	30	170.72	94.40	172.75	95.33
3.	45	171.75	94.30	170.75	95.34
4.	60	173.77	95.35	171.77	95.32
5.	90	170.75	95.35	170.77	95.34

III. Discussion

The present study demonstrated that Linezolid was observed as a white, odourless, crystalline solid, consistent with its standard physicochemical properties, indicating purity and suitability for formulation development. Solubility studies revealed that the drug was highly soluble in dimethyl sulfoxide and freely soluble in ethanol and methanol, while exhibiting moderate solubility in phosphate buffer (pH 7.4) and limited solubility in water and chloroform. This behaviour suggested its compatibility with polar organic solvents and its potential to exhibit acceptable solubility under physiological conditions, which is advantageous for

nanosponge-based delivery systems. The experimentally determined physicochemical parameter value (4.14) was found to be within the reported range (4.3–5.3), confirming compliance with standard specifications and supporting the authenticity of the drug sample. The melting point of linezolid was observed at 182°C, which fell within the reported range (176–183°C), indicating the purity and crystalline nature of the drug. The sharp melting point further suggested the absence of significant impurities. UV spectrophotometric analysis demonstrated that linezolid exhibited a maximum absorbance (λ_{max}) at 251 nm, corresponding to its chromophoric structure. This wavelength was selected for further quantitative analysis due to its

high sensitivity and reproducibility. The calibration curve constructed over the concentration range of 2–10 µg/mL showed a linear relationship between absorbance and concentration, confirming adherence to Beer–Lambert’s law. However, the relatively high %RSD value (52.44%) indicated variability in measurements, suggesting the need for further optimization to improve analytical precision. FTIR spectral analysis confirmed the presence of characteristic functional groups, including peaks corresponding to C–H stretching, N–H stretching, O–H stretching, C≡N stretching, and C=N stretching vibrations. The observed peaks were in close agreement with standard reference ranges, confirming the structural integrity and identity of linezolid without any significant chemical alteration. The prepared nanosponges were found to be white to off-white, odourless, and free-flowing powders, indicating good physical stability and suitability for pharmaceutical applications. Particle size analysis revealed that the formulations ranged from 170.78 nm to 202.6 nm, confirming successful nanoscale formulation. Among all batches, NSF3 exhibited the smallest particle size (170.78 nm), indicating efficient crosslinking and uniform particle formation. The polydispersity index values ranged from 12.8% to 22.7%, suggesting acceptable size distribution, with NSF3 demonstrating a balanced profile of small particle size and uniformity. Zeta potential values ranged from –15.2 mV to –39.8 mV, indicating negatively charged and stable nanosuspensions. NSF3 showed the highest zeta potential (–39.8 mV), reflecting excellent colloidal stability due to strong electrostatic repulsion and minimal aggregation. Other formulations (NSF1, NSF2, and NSF4) also exhibited good stability, whereas NSF5 showed comparatively lower stability due to its reduced zeta potential. SEM analysis revealed porous, irregular, and spherical nanosponge structures with rough surface morphology. The presence of bright regions indicated elevated surfaces and enhanced electron emission, while darker regions corresponded to pores and recessed areas. This porous architecture is advantageous for drug loading and controlled release behaviour. Entrapment efficiency studies demonstrated significant variation among formulations, with NSF3 exhibiting the highest efficiency (95.34%), indicating optimal drug incorporation and minimal drug loss. NSF2 also showed good entrapment (83.67%), whereas NSF5 exhibited moderate efficiency (70.25%). Lower entrapment observed in NSF1 and NSF4 suggested suboptimal formulation parameters. These results confirmed NSF3 as the optimised formulation.

Stability studies conducted over 90 days under both long-term and accelerated conditions showed minimal variation in particle size and entrapment efficiency. Particle size remained nearly constant (~170–173 nm), and entrapment efficiency was consistently maintained (~94–95%), indicating excellent physical and chemical stability. No significant aggregation, degradation, or drug leakage was observed, confirming the robustness of the optimised formulation under stress conditions. Overall, the results demonstrated that β-cyclodextrin-based nanosponges effectively improved the physicochemical characteristics, stability, and drug delivery performance of linezolid, with NSF3 identified as the optimised formulation.

IV. CONCLUSION

The present study successfully developed and evaluated hyper-crosslinked cyclodextrin nanosponges as an effective carrier system for Linezolid. Pre-formulation studies confirmed the purity, identity, and suitability of the drug for formulation development. The prepared nanosponges exhibited nanoscale particle size, satisfactory surface charge, porous morphology, and high entrapment efficiency, demonstrating efficient incorporation of Linezolid into the cyclodextrin matrix. Among all formulations, NSF3 emerged as the optimised batch, showing the smallest particle size, highest entrapment efficiency (95.34%), and excellent zeta potential, indicating superior stability. The in-vitro drug release study revealed a sustained release profile up to 14 hours, following predominantly Higuchi diffusion kinetics, confirming controlled drug release from the porous nanosponge structure. Stability studies further demonstrated that the optimised formulation remained stable under both room and accelerated storage conditions for 90 days without significant changes in particle size or entrapment efficiency. Overall, hyper-crosslinked cyclodextrin nanosponges proved to be a promising and stable drug delivery system for Linezolid, offering improved entrapment, controlled release, and enhanced formulation stability, thereby potentially improving therapeutic efficacy and patient compliance.

REFERENCES

- [1]. Rubin Pedrazzo A, Smarra A, Caldera F, Musso G, Dhakar NK, Cecone C, Hamedi A, Corsi I, Trotta F. Eco-friendly β -cyclodextrin and linecaps polymers for the removal of heavy metals. *Polymers*. 2019 Oct 11;11(10):1658.
- [2]. Trotta F, Zanetti M, Cavalli R. Cyclodextrin-based nanosponges as drug carriers. *Beilstein journal of organic chemistry*. 2012 Nov 29;8(1):2091-9.
- [3]. Utzeri G, Matias PM, Murtinho D, Valente AJ. Cyclodextrin-based nanosponges: Overview and opportunities. *Frontiers in chemistry*. 2022 Mar 24;10:859406.
- [4]. Pawar S, Shende P, Trotta F. Diversity of β -cyclodextrin-based nanosponges for transformation of actives. *International journal of pharmaceutics*. 2019 Jun 30;565:333-50.
- [5]. Tejashri G, Amrita B, Darshana J. Cyclodextrin-based nanosponges for pharmaceutical use: A review. *Acta Pharmaceutica*. 2013 Sep 30;63(3):335-58.
- [6]. Hashemian SM, Farhadi T, Ganjparvar M. Linezolid: a review of its properties, function, and use in critical care. *Drug design, development and therapy*. 2018 Jun 18:1759-67.
- [7]. Zheng S, Han Y, Zhang J, Li W. Determination and correlation of solubility of linezolid form II in different pure and binary solvents. *Fluid Phase Equilibria*. 2017 Jan 25;432:18-27.
- [8]. Mori D, Jaroli T, Dudhat K, Vaishnav D, Parmar R, Kotadiya N, Bhalodiya M, Pashavan C. Preparation and characterisation of slow dissolving linezolid salts for direct pulmonary delivery. *Journal of Drug Delivery Science and Technology*. 2022 Oct 1;76:103741.
- [9]. Warsi MH, Mohapatra S, Asfer M, Yusuf M, Ali A, Rahman MA, Ali A, Qadir A, Jain GK. Development and Antibacterial Investigation of Linezolid-Loaded SPIONs and HPLC Method Development for Quantitative Analysis of Linezolid. *Journal of AOAC International*. 2023 Sep 1;106(5):1180-9.
- [10]. Chauhan I, Singh LU. Development and validation of a simple and cost-effective UV spectrophotometric method for quantifying linezolid. *Int J App Pharm*. 2024;16(3):211-6.
- [11]. Li H, Du Q, Guo PY, Yi YT, Mickymaray S, Balu A, Suresh K, Li X. Linezolid-Loaded Strontium-Substituted Hydroxyapatite-Biopolymeric Composite for Enhanced Bone Regeneration in Osteomyelitis Treatment. *Journal of Inorganic and Organometallic Polymers and Materials*. 2026 Jan;36(1):445-61.
- [12]. Jana BK, Singha I, Puro N, Baishya R, Dutta RS, Singh M, Mazumder B. Pseudo-ternary phase diagram-based PEGylated nano-dispersion of linezolid to promote wound regeneration: an in vitro and in vivo evaluation. *Journal of Drug Targeting*. 2025 Jul 3;33(6):989-1003.
- [13]. Choudhary A, Jain P, Mohapatra S, Mustafa G, Ansari MJ, Aldawsari MF, Alalaiwe AS, Mirza MA, Iqbal Z. A novel approach of targeting linezolid nano emulsion for the management of lymph node tuberculosis. *ACS omega*. 2022 Apr 25;7(18):15688-94.
- [14]. Mashaqbeh H, Obaidat R, Al-Shar' i N. Evaluation and characterisation of curcumin- β -cyclodextrin and cyclodextrin-based nanosponge inclusion complexation. *Polymers*. 2021 Nov 24;13(23):4073.
- [15]. Kumar A, Bhasin M, Bala R, Gupta M, Chitkara M. SEM Image-Derived Processing and Fractal Analysis for Morphological Quality Control of Loperamide-Loaded β -Cyclodextrin Nanosponge Drug Carriers. *Bio NanoScience*. 2026 Jan;16(1):59.
- [16]. Abbas N, Irfan M, Hussain A, Arshad MS, Hussain SZ, Latif S, Bukhari NI. Development and evaluation of scaffold-based nanosponge formulation for controlled drug delivery of naproxen and ibuprofen. *Tropical Journal of Pharmaceutical Research*. 2018 Oct 5;17(8):1465-74.