EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 12
Issue: 9
Year: 2025

DESIGN AND DEVELOPMENT OF PINAVERIUM BROMIDE LOADED COLON TARGETING NANOSPONGES USING PH SENSITIVE POLYMERS

Pulkit Kirar, Vinod Dhote*, Kanika Dhote, Surendra Jain

Truba Institute of Pharmacy, Bhopal (M.P).

***Corresponding Author: Dr. Vinod Dhote**
Truba Institute of Pharmacy, Bhopal (M.P).

Article Received on 16/07/2025 **Article Revised on 06/08/2025** **Article Accepted on 27/08/2025**

ABSTRACT
Irritable Bowel Syndrome (IBS) is a chronic gastrointestinal disorder characterized by abdominal pain and altered bowel habits without any detectable structural or biochemical abnormalities. Due to its complex and multifactorial nature, current treatment strategies primarily offer symptomatic relief rather than a definitive cure. This paper explores the potential of a novel drug delivery system—nanosponges—to address the challenges of IBS management. Nanosponge-loaded gels were formulated and evaluated for their physicochemical properties and *in vitro* drug release profile. The study aimed to create a stable and effective delivery system that could offer sustained release of a therapeutic agent for localized treatment of IBS symptoms. The results from the optimized formulation demonstrated high percentage yield, excellent entrapment efficiency, and a controlled release profile, indicating that nanosponges are a promising approach for the management of this condition.

KEYWORDS: Irritable Bowel Syndrome, nanosponges, sustained release, colon targeting.

1. INTRODUCTION

The gastrointestinal (GI) tract, or the digestive tract, is a system of organs that processes food, extracts nutrients, and expels waste. Its functions include digestion, motility, secretion, and absorption. GI disorders can be either functional, like Irritable Bowel Syndrome (IBS), or structural, such as hemorrhoids or colon cancer. IBS is a prevalent functional disorder with no known definitive cure. Its pathogenesis is complex and not fully understood, involving factors like gut-brain axis dysfunction, immune dysregulation, and altered gut microbiota. Symptoms often include chronic abdominal pain, bloating, and altered bowel habits such as diarrhea or constipation.[1-8]

Traditional treatments for IBS include lifestyle changes and medications like anticholinergics and antibiotics. However, these therapies often provide only partial relief and may have significant side effects. The need for more effective and targeted treatments has led to the development of novel drug delivery systems (NDDS). Nanosponges, a modern category of materials with tiny, nanometer-wide cavities, have emerged as a promising technology. These three-dimensional scaffold networks can encapsulate both hydrophilic and lipophilic drugs, enhancing their stability and bioavailability. Nanosponges can be prepared using various methods, including the emulsion solvent diffusion method.[10-13]

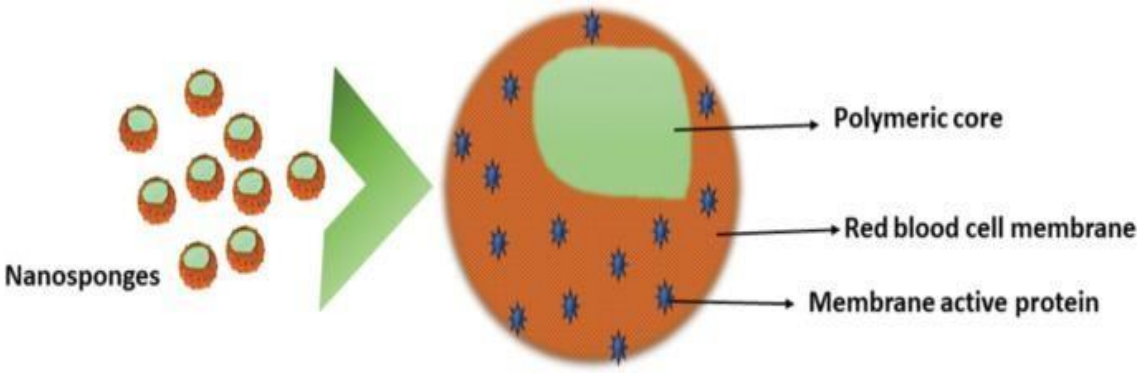


Figure 1: Structure mof nanosponge.

The aim of this research is to design and develop a novel colon-targeted nanosponge drug delivery system for Pinaverium bromide using pH-sensitive polymers. The objective is to improve bioavailability, site-specific drug release, and therapeutic efficacy, while minimizing systemic side effects and enhancing patient compliance in the management of gastrointestinal disorders like IBS.

2. MATERIALS AND METHODS

The research focused on the formulation and evaluation of a nanosponge-based drug delivery system. Pinaverium bromide, Gift sample obtained from bioplus life science Bangalore. Poly-methyl-metha-acrylate Research lab fine chem industries Mumbai, Eudragit S-100 Evonik Industries, Mumbai, Dibutyl phthalate Loba chemie pvt ltd, Mumbai Ethanol, Qualigens Fine Chemicals, Mumbai, Dichloromethane Qualigens Fine Chemicals, Mumbai, Disodium hydrogen phosphate, S. D. Fine Chem. Ltd., Mumbai.

2.1. Nanosponge Formulation

Nanosponges were prepared using the emulsion solvent diffusion method. This method involves using ethyl cellulose as the polymer and polyvinyl alcohol (PVA) as a stabilizing agent. The procedure involved preparing a dispersed phase by dissolving the polymer and drug in a solvent like dichloromethane. This was then added drop-wise to a continuous phase prepared with PVA in distilled water. The mixture was stirred for a specified time to allow for the formation of the nanosponges.[14-20]

Table 1: Composition of Pinaverium bromide nanosponges.

Ingredients	F1	F2	F3	F4	F5	F6
Pinaverium bromide (mg)	50	50	50	50	50	50
Polyvinyl alcohol (mg)	200	300	400	500	600	800
Eudragit S-100 (mg)	100	150	200	250	300	350
Pluronic F68 (mg)	100	100	100	100	100	100
Dichloromethane	15	15	15	15	15	15
Distilled water (ml)	100	100	100	100	100	100

2.2. Evaluation Parameters

The formulated nanosponges were evaluated for several parameters to assess their quality and performance.

- **Microscopic Studies:** Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were used to study the morphology of the nanosponges, looking for characteristics like spherical shape and porous nature.
- **Percentage Yield:** The weight of the final product was measured to determine the efficiency of the preparation method.
- **Drug Entrapment Efficiency:** This was determined to find the percentage of drug successfully loaded into the nanosponges.
- **Particle Size and Zeta Potential:** These measurements were taken to ensure the particles were within the desirable nanoscale range and had sufficient surface charge to prevent aggregation, which is crucial for stability.
- **In Vitro Drug Release:** This study was conducted to measure the rate and extent of drug release from the nanosponge formulation over time. The data was analyzed using various mathematical models like Zero-Order, First-Order, Higuchi, and Korsmeyer-Peppas kinetics to determine the drug release mechanism.

3. RESULTS AND DISCUSSION

A) Results of physical evaluation

The evaluation of sensory characteristics is a fundamental aspect of preformulation studies, particularly when designing targeted drug delivery systems such as colon-specific formulations. Pinaverium bromide, a spasmolytic agent used in the treatment of irritable bowel syndrome (IBS), was observed to be white to off-white in colour, which indicates a high degree of purity and absence of colored impurities that could affect the stability or acceptability of the final product. The odor was faint, which is advantageous in minimizing patient aversion in cases where taste or smell might influence compliance, although for colon-targeted delivery, the drug is typically delivered via coated or encapsulated systems that bypass the upper gastrointestinal tract. The taste of Pinaverium bromide was noted to be bitter, which, while generally undesirable, is not of primary concern in colon-targeted systems due to the protective coatings or encapsulation that prevent exposure to the oral cavity or stomach environment.

Table 2: List of sensory characters of Pinaverium bromide.

S. No.	Sensory characters	Result
1.	Colour	White to off-white
2.	Odor	Faint odor
3.	Taste	Bitter
4.	Appearance	Crystalline powder

B) Results of Solubility

The solubility study of Pinaverium bromide was carried out in various solvents to assess its behavior in different physiological and formulation environments, particularly relevant for the development of a colon-targeted drug delivery system. The drug was found to be freely soluble in distilled water and 0.1 N hydrochloric acid, indicating its high solubility in aqueous and acidic media. This property suggests that Pinaverium bromide can dissolve readily in the stomach's acidic environment, which necessitates the use of an appropriate coating (e.g., pH-

sensitive polymers like Eudragit S-100) to prevent premature release when colon targeting is desired.

In 0.1 N NaOH**,** ethanol, methanol, and chloroform, the drug showed solubility**,** though not as high as in acidic or neutral water. This indicates a moderate affinity of the drug for both hydrophilic and hydrophobic solvents, making it a suitable candidate for formulations involving mixed solvent systems or emulsification techniques, such as the emulsion solvent diffusion method used in nanosponge preparation.

Pinaverium bromide was also found to be soluble in phosphate buffer pH 7.2**,** which mimics the pH of the small intestine and proximal colon. This is a critical finding for colon-targeted delivery, as it supports the rationale for designing a pH-dependent release system that remains intact in the stomach and small intestine but releases the drug upon reaching the colon where the pH is above 7.0. The solubility at this pH ensures that, once released, the drug will be adequately absorbed or exert its local therapeutic effect in the colon.

Table 3: Solubility of Pinaverium bromide.

Solvent used	Results of Solubility
Distilled Water	Freely soluble
0.1 N Hydrochloric acid	Freely soluble
0.1 N NaOH	Soluble
Ethanol	Soluble
Methanol	Soluble
Chloroform	Soluble
Phosphate buffer pH 7.2	Soluble

C) Results of melting point

The melting point of the standard Pinaverium bromide was recorded in the range of 159– 164°C, while the sample exhibited a melting point range of 162–164°C. The close agreement between the sample and standard values indicates the purity and identity of the sample, with the narrow melting range further supporting its high purity and absence of significant impurities.

Table 4: Melting point of Pinaverium bromide.

S. No.	Melting point of standard Pinaverium bromide	Melting point of sample Pinaverium bromide
1.	159-164°C	162-164°C

D) Results of identification test using FTIR spectroscopy

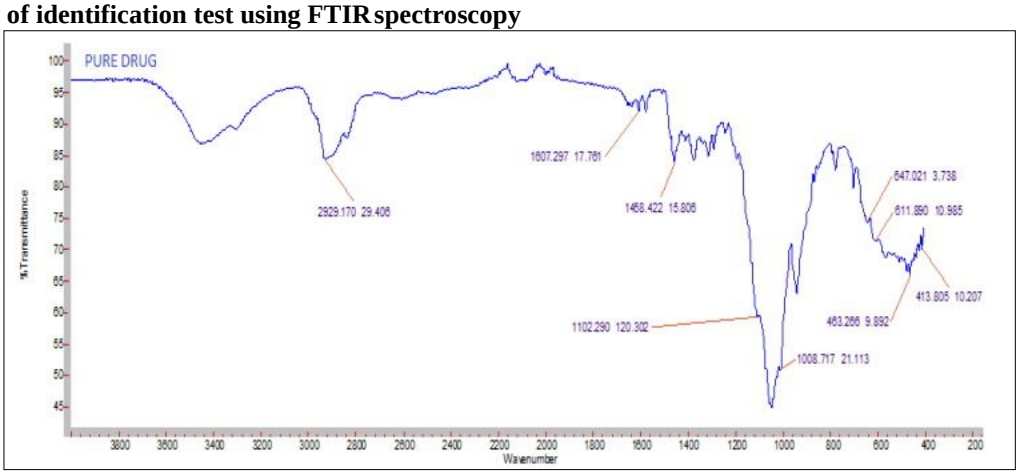


Figure 2: FT-IR Spectrum of Pinaverium bromide (Standard).

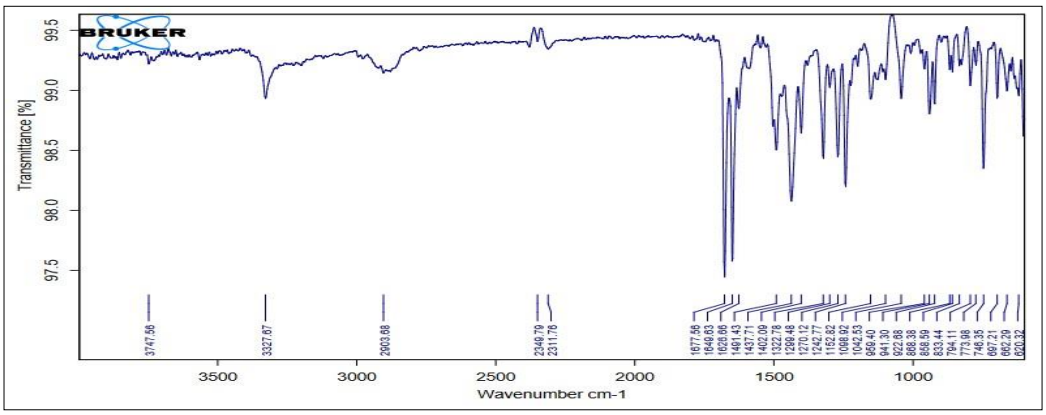


Figure 3: FT-IR Spectrum of Pinaverium bromide (Sample).

Table 4: Interpretation of FT-IR spectra.

S. No.	References value (cm-1)	Peak Position (cm-1)	Functional Groups
1	3050–3100	2903.68	Aromatic C–H stretch
2	1635–1750	1677.58	C=O stretch (ester/carboxylic acid)
3	1600 – 1450	1626.66	Aromatic C=C stretch
4	1310 – 1350	1322.78	Asymmetric and symmetric S=O stretch (sulfone group)
5	1250–1300	1270.12	C–O–C stretch (ether linkage)
6	700–850	833.44	Aromatic C–H out-of-plane bending
7	500-650	620.32	C–Br stretch

E) Results of Loss on drying

Results: Result of loss on drying of Pinaverium bromide was found to be 0.176±0.005%.

F) Results of Moisture content determination

The moisture content of a drug substance is a crucial parameter in preformulation studies, as it affects the stability, flow properties, compressibility, and shelf-life of the final dosage form. The Karl Fischer titration method, a widely accepted and accurate technique for determining trace amounts of water, was employed to assess the moisture content of Pinaverium bromide.

In this study, the Karl Fischer (KF) reagent used had a factor of 0.362**,** indicating the amount of water (in mg) that reacts with 1 mL of the KF reagent. The volume of KF reagent consumed during the titration of Pinaverium bromide was 0.2 mL. Based on this, the calculated moisture content was 0.0724%.

This low moisture content indicates that Pinaverium bromide is relatively non-hygroscopic**,** making it suitable for storage and formulation under normal conditions without requiring stringent moisture control. Such low hygroscopicity minimizes the risk of hydrolysis, agglomeration, or changes in flowability and compressibility during processing and storage. Additionally, low residual moisture is particularly favorable for colon-targeted drug delivery systems**,** where moisture-sensitive coatings or carriers (like Eudragit polymers) may be used.

Table 5: Moisture content determination.

S. No.	Drug	KF Factor	Amount of KF Reagent consumed	Moisture content
1	Pinaverium bromide	0.362	0.2ml	0.0724

G) Results of λ_{max} of Pinaverium bromide

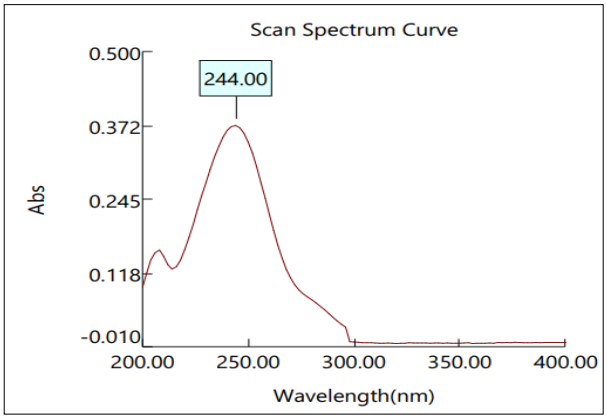


Figure 4: Wavelength maxima of Pinaverium bromide in phosphate buffer pH 7.2.

Table 6: Calibration curve of Pinaverium bromide at 244nm.

S. No.	Concentration (µg/ml)	Mean absorbance
1	5	0.202
2	10	0.374
3	15	0.615
4	20	0.823
5	25	1.018

***Average of three determinations (n=3)**

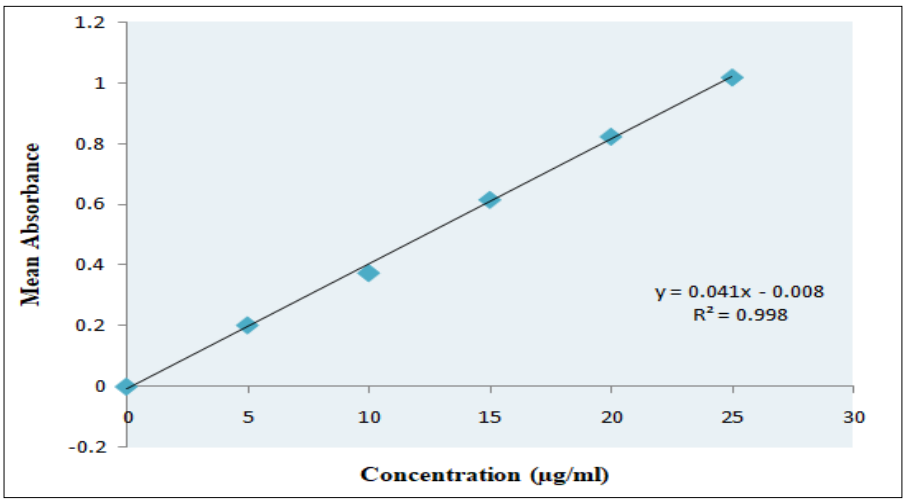


Figure 5: Calibration curve of Pinaverium bromide in phosphate buffer pH 7.2.

The linear regression analysis was done on Absorbance data points. The results are as follow for standard curve
Slope = 0.041
The intercept = -0.008
The correlation coefficient (r^2) = 0.998

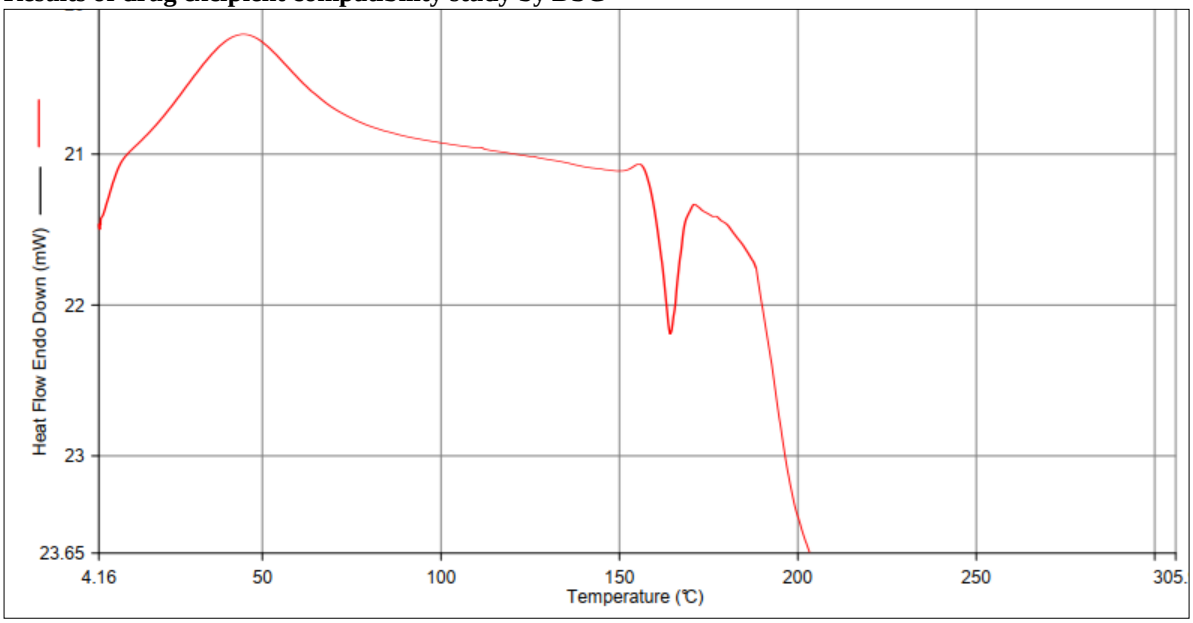
The determination of the wavelength maxima (λmax) and the construction of a calibration curve are essential components of UV-Visible spectrophotometric analysis, particularly in the quantification of drug content and in-vitro release studies during formulation development.

Pinaverium bromide was scanned in the phosphate buffer pH 7.2, and the maximum absorbance was observed at 244 nm, which is consistent with the drug's reported UV absorption properties. This wavelength was selected for further quantitative analysis due to its high and stable absorbance, which ensures sensitivity and specificity in measurements.

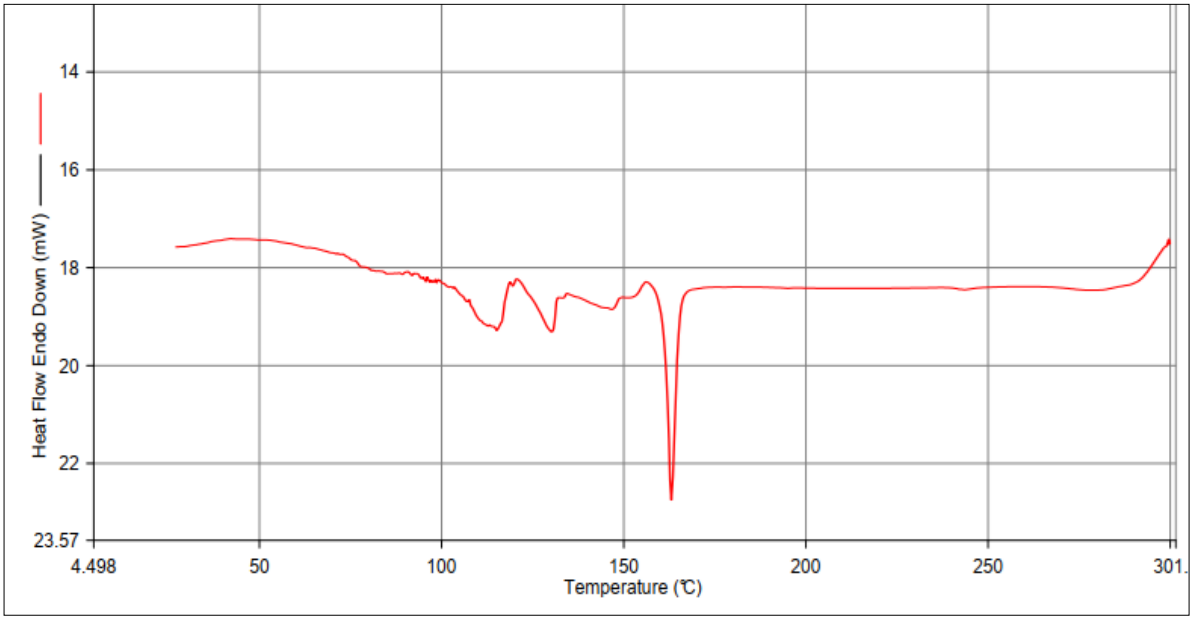
The calibration curve was constructed by measuring the absorbance of standard solutions of Pinaverium bromide in concentrations ranging from 5 to 25µg/mL. The mean absorbance values were found to increase linearly with concentration, as shown in Table 7.6. The slope of the standard curve was calculated to be 0.041, and the intercept was –0.008, indicating a strong linear relationship.

The correlation coefficient (r^2) was found to be 0.998, which is very close to 1. This high r^2 value confirms the linearity of the method across the tested concentration range, indicating that the method is reliable and can be used for accurate quantification of Pinaverium bromide in various formulations.

H) Results of drug excipient compatibility study by DSC



(a)



(b)

Figure 6: a) DSC thermogram of pure drug (Pinaverium bromide), b) DSC thermogram of pure drug (Physical Mixture, Drug + excipients).

Differential Scanning Calorimetry (DSC) is a widely used thermal analysis technique for characterizing the thermal behavior of drugs and their compatibility with excipients. In the present study, the DSC thermograms of pure Pinaverium bromide and its physical mixture with excipients were analyzed to evaluate any possible interactions.

The DSC thermogram of pure Pinaverium bromide showed a sharp endothermic peak at 165 °C, corresponding to its melting point, indicating the crystalline nature and thermal stability of the drug in its pure form. This sharp peak reflects the purity of the drug and the absence of polymorphic transitions.

In the DSC thermogram of the physical mixture (Pinaverium bromide + excipients), the melting endotherm of Pinaverium bromide was still visible at approximately 165 °C, though there may have been slight broadening or shift in the peak. The persistence of the drug's melting point in the mixture suggests that no significant interaction occurred between the drug and the excipients used in the formulation. However, slight changes in the peak shape or temperature can be attributed to the dilution effect or minor physical interactions rather than chemical incompatibility.

Results of evaluation of prepared nanosponges formulations

Percentage yield

The percentage yield of nanosponges is a critical parameter that reflects the efficiency of the formulation process and the reproducibility of the method. In the present study, six different formulations (F1 to F6) of Pinaverium bromide nanosponges were prepared using varying concentrations of polyvinyl alcohol and Eudragit S-100 via the emulsion solvent diffusion technique. The percentage yield of the formulations ranged from 69.98 ± 0.74% (F6) to 83.32 ± 0.85% (F4), indicating a good production efficiency across all formulations. Among them, F4 exhibited the highest yield, which may be attributed to the optimal ratio of polymer to drug, facilitating efficient nanosponge formation with minimal product loss during filtration and drying steps.

A decrease in yield observed in F6 (69.98 ± 0.74%) might be due to the higher concentration of polyvinyl alcohol, which can lead to increased viscosity of the external phase and possible aggregation or inefficient recovery of nanosponges. On the other hand, lower polymer concentrations in F1 and F3 may have resulted in reduced structural integrity or loss of nanosponges during processing, reflected in comparatively lower yields of 74.65 ± 0.45% and 72.25 ± 0.25%, respectively.

Table 7: Percentage yield for different formulation.

Formulation code	Percentage Yield*
F1	74.65±0.45
F2	76.65±0.36
F3	72.25±0.25
F4	83.32±0.85
F5	77.12±0.32
F6	69.98±0.74

***Average of three determinations (n=3)**

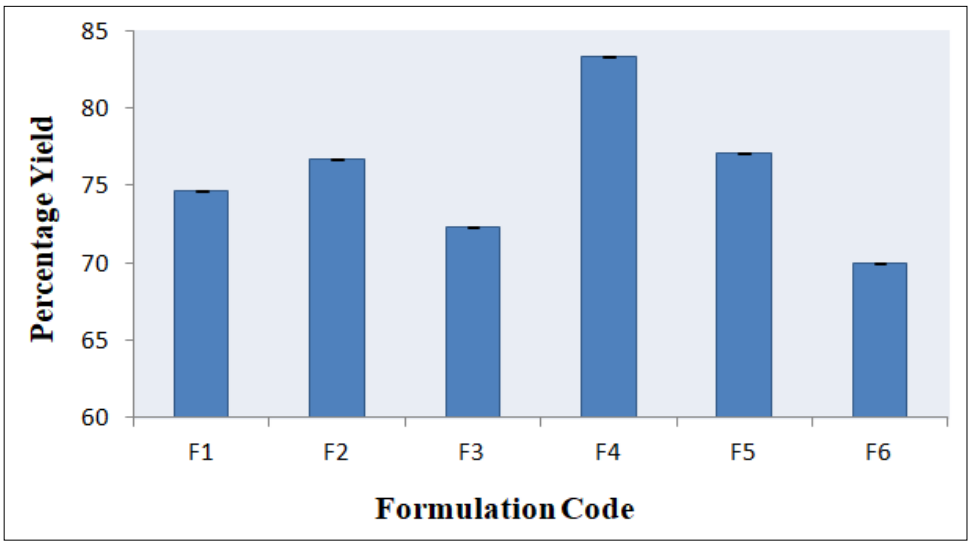


Figure 7: Graph of percentage yield for different formulation.

Table 9: Entrapment efficiency for different nanosponges formulations F1 to F6.

Formulation code	% Entrapment Efficiency
F1	72.25±0.45
F2	74.65±0.32
F3	70.32±0.88
F4	81.15±0.36
F5	74.45±0.71
F6	68.85±0.58

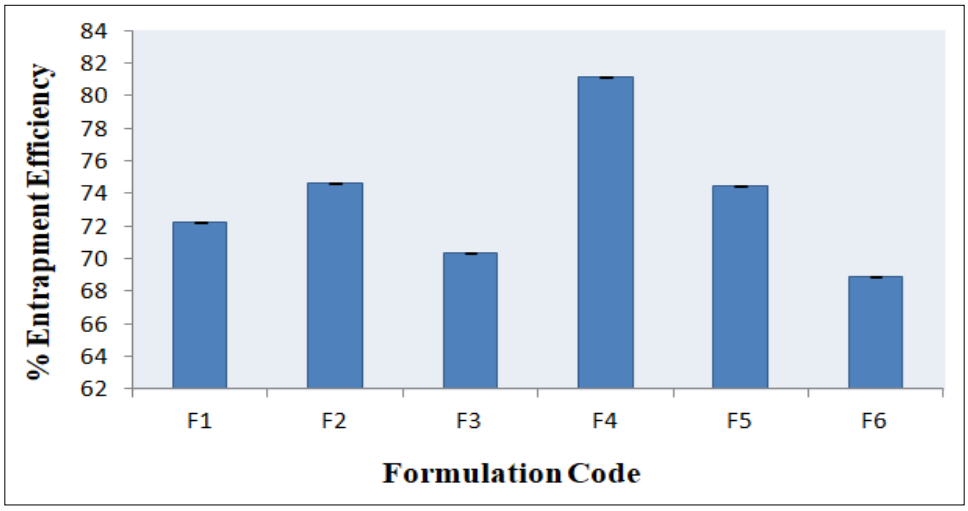


Figure 7.7: Graph of entrapment efficiency for different formulation.

7.2.2 Measurement of mean particle size

Particle size plays an important role in the performance and behavior of nanosponges, especially in drug release, bioavailability, and targeted delivery. In this study, the particle size of different nanosponge formulations (F1–F6) was measured using Photo Correlation Spectroscopy (PCS) on a Malvern particle size analyzer at a scattering angle of 90°.

The results revealed that the particle size varied significantly across formulations, ranging from 165.58 nm (F4) to 374.45 nm (F6). Among the formulations, F4 exhibited the smallest mean particle size (165.58 nm), which is advantageous for drug delivery to the colon due to enhanced permeation, better mucoadhesion, and prolonged retention time.

The larger particle size in F6 (374.45 nm) could be attributed to the high concentration of polyvinyl alcohol (PVA), which increases the viscosity of the external phase and restricts effective emulsification during the solvent diffusion process. Additionally, higher polymer concentration may lead to the aggregation of nanosponges, thereby increasing the particle size.

Table 7.9: Measurement of particle size different nanosponges formulations F1 to F6.

Formulation code	Particle size (nm)
F1	285.56
F2	296.65
F3	238.85
F4	165.58
F5	210.25
F6	374.45

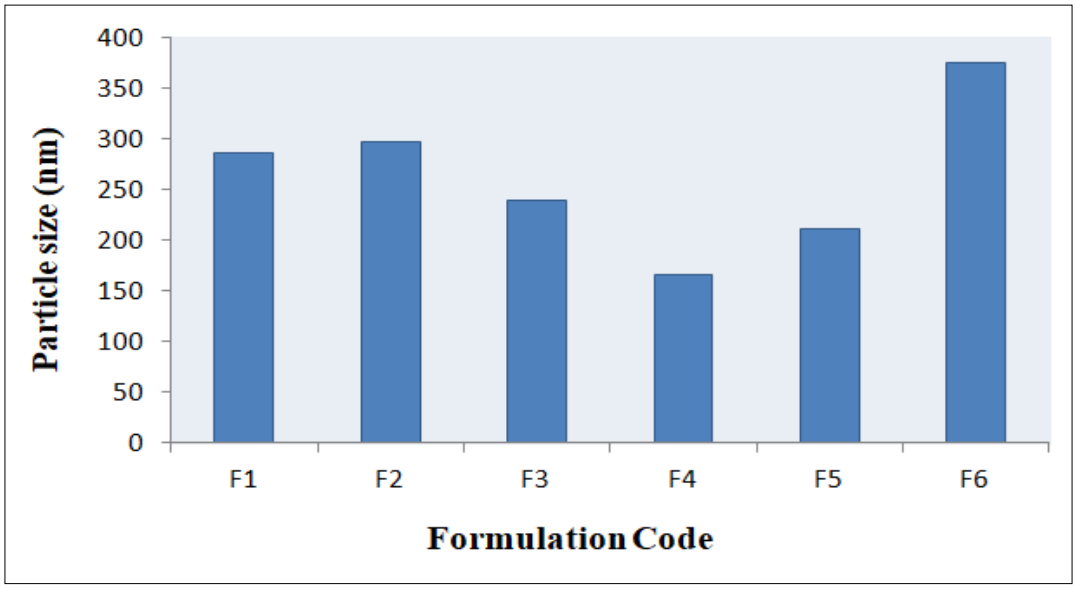


Figure 7.8: Graph of particle size different nanosponges formulations F1 to F6.

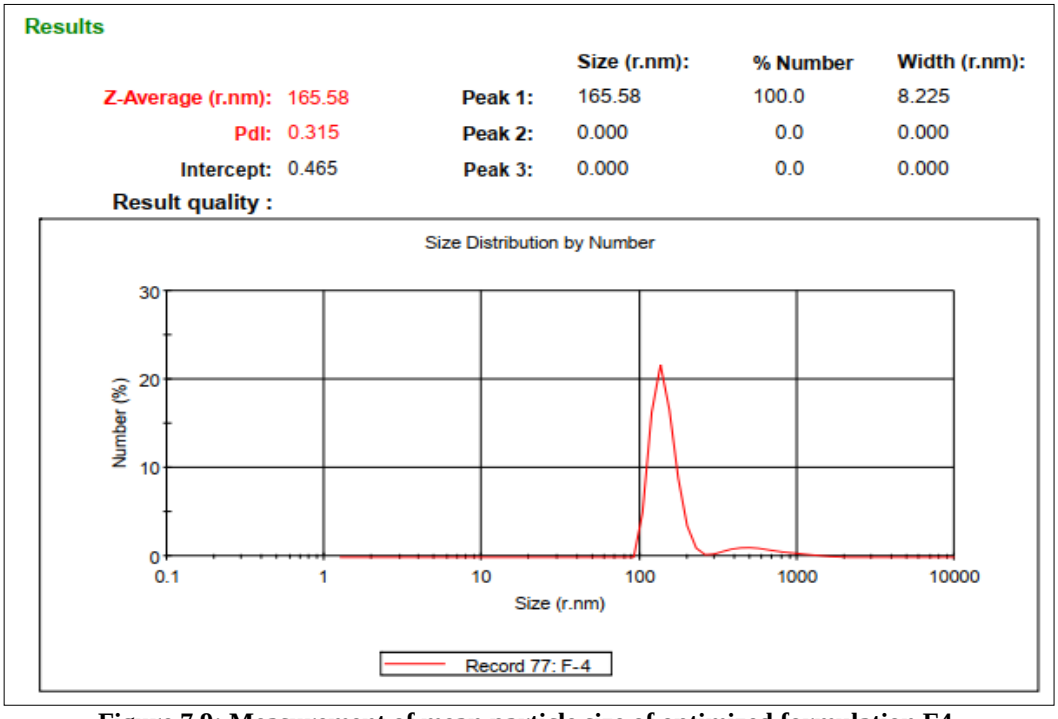


Figure 7.9: Measurement of mean particle size of optimized formulation F4.

Determination of zeta potential

Zeta potential is a crucial indicator of the stability of colloidal dispersions, as it reflects the surface charge of nanoparticles and their tendency to repel or attract each other. In the present study, the zeta potential of Pinaverium bromide-loaded nanosponges (F1 to F6) was determined using a zeta sizer (Malvern Instruments) by measuring the electrophoretic mobility of particles in water at 25°C.

Table 10: Measurement of zeta potential of different nanosponges formulations F1 to F6.

Formulation Code	Zeta Potential (mV)
F1	–18.45 ± 0.36
F2	–20.32 ± 0.41
F3	–22.74 ± 0.52
F4	–26.15 ± 0.37
F5	–23.65 ± 0.45
F6	–16.78 ± 0.33

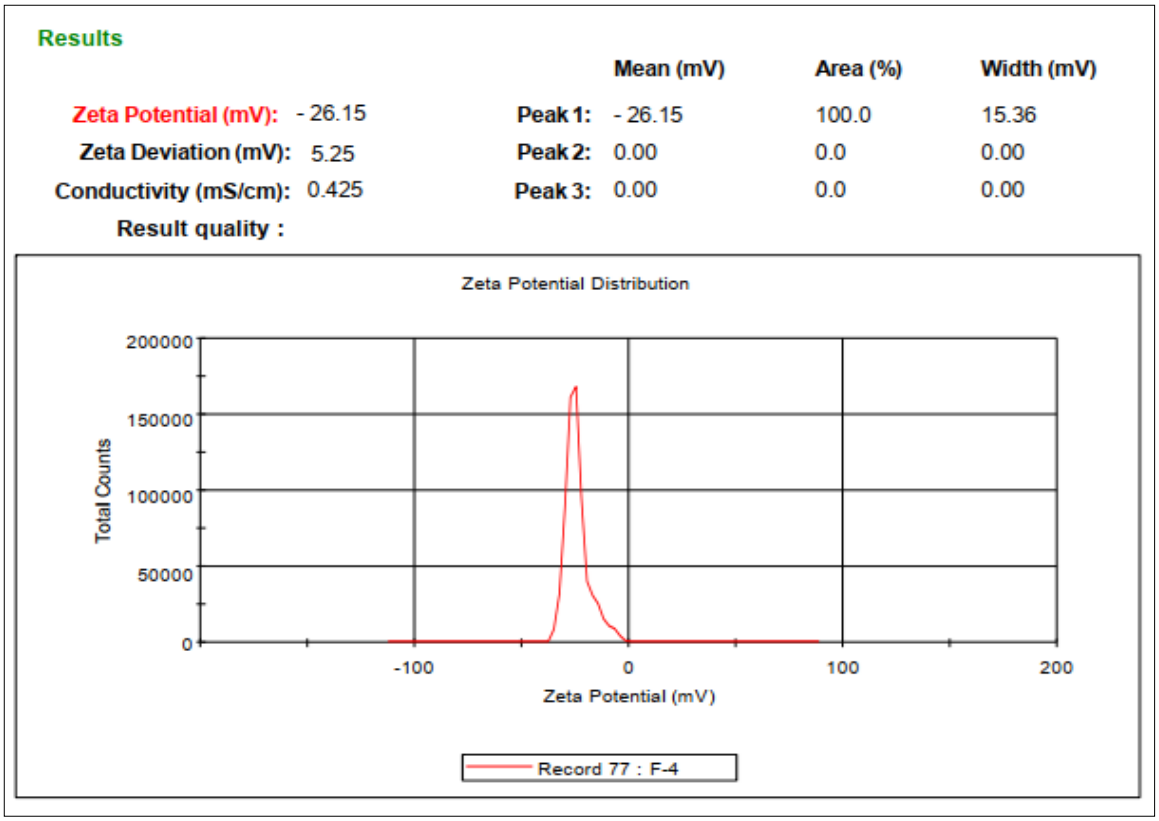


Figure 9: Graph of zeta potential of optimized formulation F4.

The evaluation parameters for the different formulations demonstrated varying characteristics. The optimized formulation, F4, was found to be the most promising. It exhibited a high percentage yield of 83.32% and an entrapment efficiency of 81.15%. The mean particle size of F4 was 165.58 nm, which is ideal for improved bioavailability and enhanced mucosal penetration. The zeta potential of -26.15 mV indicated good stability by preventing particle aggregation.

SEM analysis showed that the F4 nanosponges were spherical with a porous surface, which is a key characteristic for sustained drug release. The *in vitro* drug release study confirmed this, showing a controlled release profile with 96.65% of the drug released over 12 hours, unlike the rapid burst release of the plain drug. The release kinetics of F4 best fit the First-order and Higuchi models, suggesting that the release rate is dependent on the concentration of the drug remaining and that the release mechanism is primarily diffusion-controlled.

4. SUMMARY AND CONCLUSION

The formulation and evaluation of a nanosponge-loaded gel for the management of Irritable Bowel Syndrome was successful. The emulsion solvent diffusion method proved to be an effective technique for creating nanosponges with desirable properties. The optimized formulation, F4, showed a high percentage yield, excellent drug entrapment efficiency, and a sustained drug release profile over 12 hours. These findings suggest that nanosponges are a viable and effective platform for the controlled delivery of therapeutic agents, offering a potential solution to the chronic management challenges of IBS.

REFERENCES

1. Owens DE, Peppas NA. Opsonization, biodistribution, and pharmacokinetics of polymeric nanoparticles. Int J Pharm., 2006; 307(1): 93-102.
2. Dhote, V. K., & Dhote, K. (2020). Gastroretentive dosage form: Novel approach to drug delivery. *LAP LAMBERT Academic Publishing*. ISBN: 9786202523943ResearchGate+1

3. Dhote, V. K., & Dhote, K. (2020). Micro beads for targeted delivery of medicaments. *LAP LAMBERT Academic Publishing*. ISBN: 9786202523868
4. Dhote, V. K., & Dhote, K. Fundamentals of polymers science applied in pharmaceutical product development. In S. P. Pandey, T. Shukla, & R. K. Tekade (Eds.), *Basic Fundamentals of Drug Delivery*, 2019; 85–112. Academic Press. https://doi.org/10.1016/B978-0-12-817909-3.00003-0
5. Dhote, V. K., & Dhote, K. Coarse dispersion. In S. P. Pandey, T. Shukla, & R. K. Tekade (Eds.), *Basic Fundamentals of Drug Delivery*, 2018; 113–132. Academic Press. https://doi.org/10.1016/B978-0-12-817909-3.00004-2
6. Dhote, V. K., & Dhote, K. Colloidal drug delivery systems. In S. P. Pandey, T. Shukla, & R. K. Tekade (Eds.), *Basic Fundamentals of Drug Delivery*, 2018; 133–152. Academic Press. https://doi.org/10.1016/B978-0-12-817909-3.00005-4
7. Dhote, V. K., & Dhote, K. (2017). Development of novel fast melt granules for Balchaturbhadrika churna. *LAP LAMBERT Academic Publishing*. ISBN: 9786202075695ResearchGate
8. Shivani S, Poladi KK. Nanosponges-novel emerging drug delivery system: a review. Int J Pharm Sci Res., 2015; 6: 529.
9. Selvamuthukumar S, Anandam S, Krishnamoorthy K, Rajappan M. Nanosponges: A novel class of drug delivery system-review. Journal of Pharmacy & Pharmaceutical Sciences, Jan. 17, 2012; 15(1): 103-11.
10. Dhote, V. K., & Dhote, K. Micropellets: A promising strategy for controlled release of lansoprazole. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(3): 1–7. https://www.ajper.com/AbstractView.aspx?PID=2015-4-3-1ResearchGate
11. Ghurghure SM, Pathan MS, Surwase PR. Nanosponges: A novel approach for targeted drug delivery system. Int. J. Chem. Studies, Nov. 2018; 2(2).
12. Singh S, Monika K, Nanosponges as Emerging Carriers for Drug Delivery, Sys Rev Pharm., 2022; 13(1): 55-62.
13. Dhote, V. K., Mishra, D. K., & Dhote, K. Formulation and characterization of microbeads as a carrier for the controlled release of rioprostil. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(4): 1–6. https://www.ajper.com/AbstractView.aspx?PID=2015-4-4-1ResearchGate+1
14. Suchita G. Waghmare, Rasika R. Nikhade, Dr. Satish and B. Kosalge. Nanosponges:a novel approach for controlled release drug delivery system. International Journal of Pharmacy and Pharmaceutical research, 2017; 9(3): 101-116.
15. Sharma R, Roderick B and Pathak K. Evaluation of kinetics and mechanism of drug release from econazole nitrate nanosponges loaded carbopol Hydrogel. Indian Journal of Pharmaceutical Education and Research, 2011; 45(1): 25-31.
16. Dhote, V. K., & Dhote, K. Dendrimer: Novel strategies for drug delivery system. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(4): 1–7. https://www.ajper.com/AbstractView.aspx?PID=2015-4-4-2Google Scholar
17. Dhote, K., Dhote, V. K., & Khatri, K. Phytochemical screening and pharmacological activity in Punica granatum. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(4): 1–6. https://www.ajper.com/AbstractView.aspx?PID=2015-4-4-3ResearchGate
18. Nilholm C, Larsson E, Roth B, Gustafsson R, Ohlsson B. Irregular dietary habits with a high intake of cereals and sweets are associated with more severe gastrointestinal symptoms in IBS patients. Nutrients, 2019; 11: 1279.
19. Dhote, K., Dhote, V. K., & Mishra, D. K. Management of diabetes mellitus: Herbal remedies. *Asian Journal of Biomaterial Research,* 2015; *1*(1): 12–16. https://www.ajbr.in/AbstractView.aspx?PID=2015-1-1-3Google Scholar+2ResearchGate+2
20. Dhote, K., Dhote, V. K., & Khatri, K. Formulation and evaluation of herbal cosmetic formulation containing Calendula officinalis. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(4): 1–6. https://www.ajper.com/AbstractView.aspx?PID=2015-4-4-4ResearchGate
21. Shastrulagari S, Poladi KK. "Nanosponges: Novel Emerging Drug Delivery System." IJPSR, 2015; 6(2): 529–540.
22. Dhote, V. K., Dhote, K., & Mishra, D. K. Floating gastro retentive systems: A potential emergence to oral drug delivery system. *Asian Journal of Pharmaceutical Education and Research,* 2015; *4*(4): 1–6. https://www.ajper.com/AbstractView.aspx?PID=2015-4-4-5ResearchGate+2GGU+2
23. Staudacher HM, Ralph FSE, Irving PM, Whelan K, Lomer MCE. Nutrient intake, diet quality, and diet diversity in irritable bowel syndrome and the impact of the low FODMAP diet. J Acad Nutr Diet, 2020; 120: 535–47.
24. Prabhu PP, Mehta CH, Nayak UY. Nanosponges-revolutionary approach: A review. Research Journal of Pharmacy and Technology, 2020; 13(7): 3536-44.
25. Shivani S, Poladi KK. Nanosponges-novel emerging drug delivery system: a review. Int J Pharm Sci Res., 2015; 6: 529.
26. Selvamuthukumar S, Anandam S, Krishnamoorthy K, Rajappan M. Nanosponges: A novel class of drug delivery system-review. Journal of Pharmacy & Pharmaceutical Sciences, Jan 17, 2012; 15(1): 103-11.

27. Ghurghure SM, Pathan MS, Surwase PR. Nanosponges: A novel approach for targeted drug delivery system. Int. J. Chem. Studies, Nov. 2018; 2(2).
28. Singh S, Monika K, Nanosponges as Emerging Carriers for Drug Delivery, Sys Rev Pharm., 2022; 13(1): 55-62.