International Journal of Innovative Research and Scientific Studies, 8(12) 2025, pages: 202-211

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Development and evaluation of sulfadiazine-loaded gastric floating microsponge for repurposed cancer therapy

Mohammad Jamal Akbar[1], Mohammed Jafar[1*], Abdulaziz Ali Halawi[1], Abdullah Aljasser[1], Mohd Sajjad Ahmad Khan[2], Mohammed F. Aldawsari[3]

[1]*Department of Pharmaceutics, College of Pharmacy, Imam Abdulrahman Bin Faisal University, Dammam 34212, Saudi Arabia.*
[2]*Department of Basic Sciences, Deanship of Preparatory Year and Supporting Studies, Imam Abdulrahman Bin Faisal University, Dammam, 34212, Saudi Arabia.*
[3]*Department of Pharmaceutics, College of Pharmacy, Prince Sattam Bin Abdulaziz University, Al-kharj 11942, Saudi Arabia.*

Corresponding author: Mohammed Jafar (*Email: mjomar@iau.edu.sa*)

Abstract

Sulfadiazine has gained renewed interest as a repurposed anticancer agent owing to its ability to inhibit folate-dependent metabolic pathways and disrupt tumor cell proliferation. However, its therapeutic potential is hindered by poor aqueous solubility, short gastric residence time, and limited absorption from the gastrointestinal tract. This study aimed to develop a gastro-retentive floating microsponge system to enhance gastric retention and sustain release of sulfadiazine for improved absorption. Microsponges were prepared using the quasi-emulsion solvent diffusion method with Eudragit RS 100 as the polymer matrix. Three formulations (F-1, F-2, F-3) were evaluated for production yield, drug content, entrapment efficiency, floating behavior, in-vitro drug release, surface morphology, thermal characteristics, and short-term stability. All formulations appeared as white, free-flowing microsponge powders with high production yields (91.11–97.72%). Entrapment efficiency ranged from 57.65% to 80.14%, increasing with polymer concentration. All formulations remained buoyant for more than 12 hours, confirming effective floating behavior. SEM analysis revealed spherical, porous structures, while DSC thermograms indicated reduced crystallinity of the encapsulated drug. In-vitro drug release demonstrated sustained release over 8 hours, with F-1 showing the fastest release and F-2 the most controlled profile. Stability studies showed no changes in appearance and minimal variation in drug content over three months. The results suggest that sulfadiazine-loaded gastric floating microsponges can enhance gastric residence, support sustained delivery, and improve the therapeutic potential of sulfadiazine as a repurposed anticancer agent.

Keywords: Cancer, Microsponge, Gastro-retentive delivery, Sulfadiazine, Sustained release.

DOI: 10.53894/ijirss.v8i12.11053
Funding: This study received no specific financial support.
History: Received: 28 October 2025 / **Revised:** 19 November 2025 / **Accepted:** 24 November 2025 / **Published:** 11 December 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Acknowledgement: We would like to thank the college of pharmacy, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia, for providing facility to conduct this research work. We would like to extend our sincere thanks to Institute of research and medical consultation at Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia, for SEM characterization of our samples.
Publisher: Innovative Research Publishing

1. Introduction

Drug repurposing has become an attractive strategy in modern drug development due to its ability to reduce development costs, shorten clinical timelines, and explore novel mechanisms of action for existing drugs [1]. Among repurposed molecules, sulfadiazine—traditionally used as an antimicrobial—has emerged as a promising anticancer candidate [2]. Sulfadiazine interferes with folate metabolism, a pathway frequently exploited by rapidly dividing cancer cells. Emerging studies suggest that sulfadiazine suppresses metabolic pathways associated with tumor proliferation, reduces inflammatory mediators in the tumor microenvironment, and may sensitize cancer cells to chemotherapeutic agents [3]. These findings provide a strong rationale for designing improved delivery systems for sulfadiazine to enhance its pharmacokinetic and therapeutic performance.

Sulfadiazine's physicochemical profile provides a strong rationale for developing a gastro-retentive microsponge system. As detailed by Stober and DeWitte, the drug has extremely low aqueous solubility, particularly at gastric and intestinal pH, leading to dissolution-limited absorption and variability in its oral bioavailability. Its poor solubility also contributes to acidic-pH–dependent crystalluria, emphasizing the need for controlled release and localized dissolution rather than rapid bolus exposure. Although sulfadiazine is absorbed after oral administration, the extent of uptake is restricted by its slow dissolution and rapid transit through the upper gastrointestinal tract, reducing the time available for absorption. A gastro-retentive microsponge system can address these limitations by prolonging gastric residence, providing a large porous surface area for enhanced dissolution, and maintaining the drug within the optimal absorption window. This approach supports more consistent release, minimizes solubility-related complications, and improves the likelihood of efficient uptake for both therapeutic and repurposed applications [4, 5].

Gastro-retentive drug delivery systems (GRDDS) aim to prolong gastric residence by using mechanisms such as floating, swelling, bioadhesion, and density modification [6]. Floating drug delivery systems are widely used due to their simplicity, safety, and effectiveness. They remain buoyant over gastric fluids, allowing sustained drug release at the absorption site [7].

Microsponges are highly porous, polymer-based microparticles capable of entrapping drugs within a controlled-release matrix [8]. Their porous structure results in low density, making them ideal candidates for floating dosage forms [9]. Eudragit RS 100, a pH-independent and permeable polymer containing quaternary ammonium groups, is widely used for controlled release and microsphere/microsponge preparation due to its excellent film-forming and encapsulation properties [10].

By incorporating sulfadiazine into a floating microsponge system, it may be possible to improve gastric retention, maintain controlled drug release, enhance dissolution behavior, and ultimately maximize its anticancer potential. This study aims to design and evaluate such a delivery system and provides a comprehensive evaluation, including characterization, release studies, morphology, thermal behavior, and stability assessment.

2. Methodology

2.1. Materials

Sulfadiazine (SDZ) was obtained as a pure analytical-grade powder. Eudragit RS 100 (EGT RS100), a pH-independent, water-insoluble acrylic–methacrylic copolymer, was used as the rate-controlling polymer. Dichloromethane (DCM) served as the volatile organic solvent for the internal phase, while polysorbate-80 acted as the stabilizer and emulsifying agent in the external aqueous phase. Distilled water was used throughout the study. All solvents and reagents used were of analytical grade and utilized without further purification.

2.2. Methods

2.2.1. Preparation of Sulfadiazine Loaded Microsponge

Sulfadiazine-loaded microsponges were prepared using the quasi-emulsion solvent diffusion method. First, Eudragit RS 100 was dissolved in dichloromethane (DCM) to form the internal organic phase, and 1 g of sulfadiazine was dispersed into this solution. The amount of polymer was varied across the three formulations (1 g for F-1, 1.5 g for F-2, and 2 g for F-

3) Table 1. Separately, the external aqueous phase was prepared by mixing polysorbate-80 with distilled water to act as a stabilizer during microsponge formation [11].

The organic phase was then added dropwise into the aqueous phase under continuous stirring. This produced a quasi-emulsion in which DCM gradually diffused out of the droplets, causing the polymer to solidify around the drug and form porous microsponge particles. Stirring at 1500 rpm was continued for 90 minutes to complete solvent diffusion and particle formation. The resulting microsponges were collected by filtration, washed with water to remove any unentrapped drug, and air-dried at room temperature before being stored for further evaluation.

Table 1.
Composition of sulfadiazine loaded microsponge formulations.

Composition	Formulations		
	F-1	F-2	F-3
Sulfadiazine (gm)	1	1	1
Eudragit RS 100 (gm)	1	1.5	2
Dichloromethane (mL)	8	8	8
Polysorbate 80 (mL)	0.6	0.6	0.6
Distilled Water (mL Up to)	100	100	100

2.2.2. Physicochemical characterization of sulfadiazine loaded with microsponges

2.2.2.1. Physical Appearance

The dried microsponges were visually inspected for their color, texture, surface uniformity, and flow characteristics. All formulations were examined under adequate lighting conditions.

2.2.2.2. Production Yield

Production yield was calculated to assess the efficiency of the fabrication method. The theoretical mass (drug + polymer) and practical mass (dried microsponges) were recorded using a calibrated analytical balance. Yield (%) was determined using:

$$Production\ yeild = \frac{Practical\ weight\ of\ the\ final\ microsponge}{Theoretical\ weight\ (SDZ + EGT)} X100$$

This parameter reflects the extent of material loss during emulsification, filtration, and washing.

2.2.2.3. Drug Content and Entrapment Efficiency

A weighed amount of each microsponge formulation was crushed gently using mortar and pestle. The powdered sample was dissolved in methanol (5 mL), vortexed (2–3 min), and centrifuged at 2000 rpm for 10 minutes. The supernatant was appropriately diluted with 0.1 N HCl and analyzed at the λmax of 242 nm.

$$\%\ \text{Drugcontent} = \frac{\text{Actual amount of SDZ in microsponge}}{\text{Weighed amount of microsponges}} \times 100$$

$$\%\ Entrapment\ efficiency = \frac{Actual\ amount\ of\ SDZ\ in\ microsponge}{Theoretical\ amount\ of\ SDZ\ in\ microponge} \times 100$$

This study helped determine the extent of drug encapsulation within the microsponge matrix.

2.2.3. In-Vitro Floating Study

The floating behavior of the prepared microsponges was assessed using a USP Type II paddle dissolution apparatus (Electrolab, India). A measured quantity of each formulation was added to 900 mL of simulated gastric fluid (0.1 N HCl, pH 1.2) maintained at 37 ± 0.5 °C. The paddle speed was set to 50 rpm to mimic gentle gastric motility conditions. The microsponges were visually observed throughout the study to evaluate their buoyancy performance under physiological conditions.

Two parameters were monitored during the experiment. The floating lag time was recorded as the time required for the microsponges to rise to the surface and begin floating. The total floating duration reflected the time for which the microsponges remained buoyant without sinking. These measurements provided details about the suitability of microsponges as a gastro-retentive system and their ability to sustain prolonged gastric residence.
This test assessed gastric retention capability, a critical requirement for gastro-retentive delivery systems.

2.2.4. In-Vitro Drug Release Study

In-vitro release was performed using USP Type II paddle apparatus (LOGAN, USA). Microsponges containing an equivalent of the oral dose of sulfadiazine were placed in small cellophane membranes tied beneath the paddle to prevent disintegration during agitation.

The dissolution medium consisted of 500 mL 0.1 N HCl maintained at 37 ± 0.5 °C and stirred at 50 rpm. Aliquots of 5 mL were withdrawn at predetermined intervals up to 8 hours and replaced with fresh medium to maintain sink conditions. Samples were filtered, diluted if necessary, and analyzed at the λmax of 242 nm.

2.2.5. Scanning Electron Microscopy (SEM)

The surface morphology of pure sulfadiazine, pure Eudragit RS 100, and the optimized microsponge formulation (F-2) was examined using a TESCAN VEGA3 SEM (Czech Republic). Each sample was fixed onto an aluminum stub using double-sided carbon adhesive tape, followed by sputter-coating with a thin layer of gold–palladium to improve electrical conductivity. Imaging was carried out at an accelerating voltage of 20 kV. SEM micrographs were captured at different magnifications to assess particle shape, surface texture, porosity, and the overall structural characteristics of the microsponges compared with the raw materials.

2.2.6. Differential Scanning Calorimetry (DSC)

Thermal behavior of sulfadiazine (A), the physical mixture of drug and polymer (B), and the optimized microsponge formulation F-2 (C) was analyzed using a DSC 214 Polyma instrument (NETZSCH, Germany). Accurately weighed samples (4–8 mg) were sealed in aluminum pans, and an empty sealed pan served as the reference. The samples were heated from 50 °C to 300 °C at a controlled heating rate of 10 °C/min under a nitrogen atmosphere flowing at 40–60 mL/min. The resulting thermograms were evaluated to identify melting transitions, peak shifts, disappearance or broadening of thermal events, and any changes in crystallinity that could indicate drug–polymer interactions or successful encapsulation within the microsponge matrix.

2.2.7. Stability Study

The optimized microsponge formulation (F-2) was subjected to a three-month stability study under accelerated conditions of 40 ± 2 °C and 75 ± 5% relative humidity. Samples were stored in airtight containers and evaluated at one-month intervals. Each sample was examined for changes in physical appearance, color, powder flow properties, and drug content, using the analytical method described previously in Section 2.2.2.3. The stability results were used to determine whether the formulation maintained physical integrity and drug content over the test period.

3. Results and Discussion

3.1. Physicochemical Characterization of Sulfadiazine Loaded Microsponge

3.1.1. Physical Appearance

All three formulations were obtained as fine, white, free-flowing powders without any noticeable aggregation or discoloration (Table 2). This uniform physical appearance indicates that the quasi-emulsion solvent diffusion method successfully produced consistent microsponge particles. The absence of clumping or moisture retention suggests that solvent evaporation occurred efficiently and uniformly throughout the process, allowing the polymer to solidify evenly around the dispersed drug. Moreover, the smooth and homogeneous texture of the powders implies that the emulsification step was well controlled, ensuring adequate stabilization of droplets during microsponge formation. Such stability also reflects compatibility between sulfadiazine and Eudragit RS 100, as no visible signs of drug–polymer incompatibility, phase separation, or degradation were observed. A consistent appearance across all batches is an important quality attribute since it supports reproducibility of the manufacturing method and indicates that the microsponges can be easily handled, stored, and further processed into oral solid dosage forms such as powders, capsules, filled sachets, or compressed tablets.

3.1.2. Production Yield

The production yield of the microsponges ranged from 91.11% for F-1 to 97.72% for F-3, (Table 2) demonstrating a clear increase in yield with increasing polymer concentration. This trend can be attributed to the stabilizing effect of Eudragit RS 100, as higher amounts of polymer provide better droplet protection during emulsification, reducing material loss during filtration and washing. When polymer levels are low, droplets may be more susceptible to rupture or coalescence, causing partial loss of drug–polymer material before solidification is complete. Conversely, a more concentrated polymer solution forms a robust matrix that retains drug content more effectively within each droplet. High production yields observed across all formulations further reinforce the robustness and efficiency of the quasi-emulsion method, highlighting its suitability for scale-up. From an industrial perspective, such consistently high yields translate to cost-effective manufacturing, minimal raw material wastage, and predictable batch-to-batch performance, which are essential for commercial viability. Similar results were reported in the literature on the same drug carrier system [12].

3.1.3. Drug Content and Entrapment Efficiency

The entrapment efficiency showed a strong dependence on polymer concentration, ranging between 57.65% and 80.14%, with the highest value recorded for formulation F-3 (Table 2). Increasing the amount of Eudragit RS 100 in the internal phase likely contributed to the formation of thicker polymer walls, thereby minimizing the loss of sulfadiazine into the aqueous phase during emulsification. Lower polymer concentrations, as in F-1, allow greater opportunity for drug diffusion out of the droplets, leading to comparatively lower entrapment despite higher measured drug content. The enhanced entrapment in F-3 reflects more efficient encapsulation of sulfadiazine, which is particularly important for repurposed anticancer molecules where dose precision and therapeutic consistency are critical. High entrapment efficiency not only ensures minimal drug wastage but also strengthens the sustained-release potential of the microsponges by providing a well-integrated drug–polymer matrix that regulates diffusion more effectively [13, 14]. This leads to improved dosing accuracy, predictable release behavior, and better pharmacological performance.

3.2. In-Vitro Floating Study

All microsponge formulations exhibited excellent buoyancy, maintaining flotation for more than 12 hours with negligible floating lag time (Table 2). The rapid and sustained floating ability is primarily attributed to the porous internal structure created during solvent diffusion, where entrapped air pockets reduce particle density and enable the microsponges to remain above the surface of gastric fluid. Eudragit RS 100 provides adequate mechanical strength, preventing collapse or fragmentation of the microsponges during stirring. Prolonged gastric retention is highly desirable for drugs like sulfadiazine, which are absorbed mainly from the stomach or upper intestine. Maintaining the formulation's presence in the stomach allows for extended drug release in the region of optimal absorption, improving bioavailability and maximizing therapeutic effects. This prolonged gastric residence is also advantageous for localized treatment strategies, such as h. pylori infections gastric or gastrointestinal tumors where sustained exposure may improve drug penetration and efficacy [10, 15].

Table 2.
Physicochemical evaluation of sulfadiazine loaded microsponge formulations.

*Parameters	Formulations		
	F-1	F-2	F-3
Physical appearance	White solid	White solid	White solid
Product Yield (%)	91.11±1.25	95.25±1.12	97.72±1.32
Drug content (%)	30.75±0.68	23±0.66	26.66±1.02
Entrapment efficiency (%)	61.72±0.77	57.65±0.98	80.14±0.83
In-vitro floating time (h)	> 12	> 12	> 12

Note: *Each experiment was done in triplicate, and the findings were presented as mean SD (n = 3).

3.3. In-Vitro Drug Release Study

The cumulative percentage drug release was calculated and plotted (Figure 1) for F-1, F-2, and F-3 microsponge formulations. Although both F-2 and F-3 were prepared with higher polymer concentrations than F-1, the drug release study revealed that F-2 exhibited a slower and more controlled release profile (~52% at 8 hours) compared to F-3 (~72% at 8 hours). This behavior can be attributed to differences in the internal microstructure formed during emulsification. While F-3 contained the highest amount of Eudragit RS 100, its very high polymer load likely led to increased viscosity of the organic phase, resulting in the formation of particles with thicker walls but lower internal porosity [16]. Reduced porosity limits the number of aqueous diffusion channels, allowing dissolution medium to penetrate the microsponge network more readily and accelerating drug diffusion [17-19]. In contrast, F-2 achieved a more balanced combination of polymer concentration and pore formation. The moderate polymer level allowed F-2 to form a well-interconnected porous matrix with uniformly distributed diffusion pathways. This structure creates a longer tortuous path for drug molecules to traverse before exiting the microsponge, producing a deeper sustained-release effect than F-3 despite the latter's higher polymer content [9].

F-2 was considered the optimized formulation because it demonstrated the best overall balance of critical quality attributes. It exhibited a desirable sustained-release profile without the excessive initial release observed in F-1 or the moderately faster release seen in F-3.

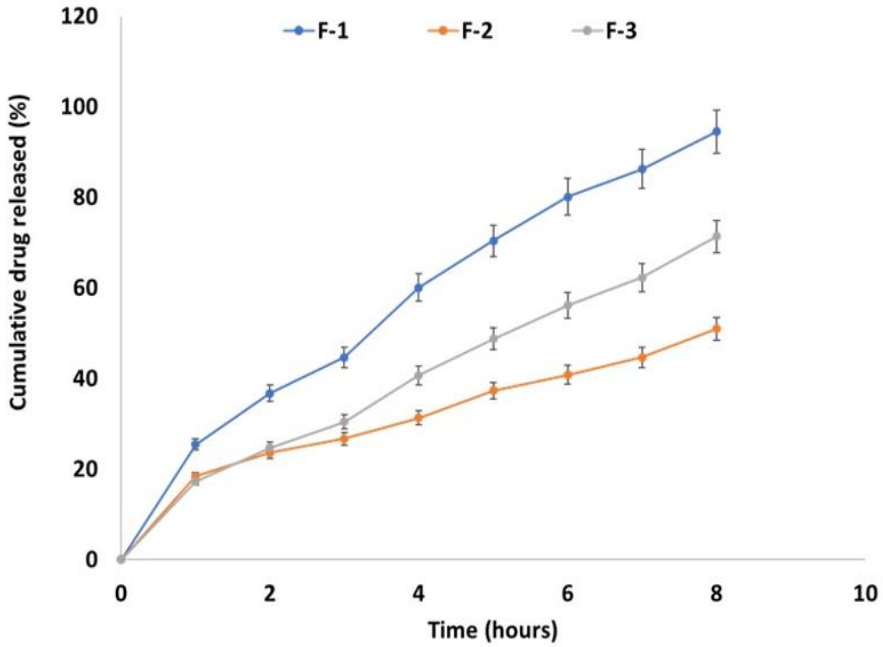

Figure 1.
In-vitro drug release profile of sulfadiazine loaded microsponge formulations.

3.4. Scanning Electron Microscopy (SEM)

SEM analysis revealed clear morphological distinctions between raw materials and the optimized microsponge formulation (Figure 2). Pure sulfadiazine appeared as elongated, needle-shaped crystals, reflecting its crystalline structure, while Eudragit RS 100 particles were observed as smooth, discrete, nearly spherical units. In contrast, the microsponges of formulation F-2 displayed well-defined spherical to semi-spherical particles with a rough, porous outer surface. The presence of uniformly distributed pores confirms successful formation of the microsponge structure via solvent diffusion and polymer precipitation. These morphological characteristics play a crucial role in determining functional performance: the porous network enhances wetting and dissolution, supports buoyancy by trapping air, and contributes to sustained drug release by regulating the diffusion rate [20, 21]. The structural integrity observed in SEM images indicates that the fabrication method produced robust microsponges capable of withstanding handling and mechanical agitation during gastric retention.

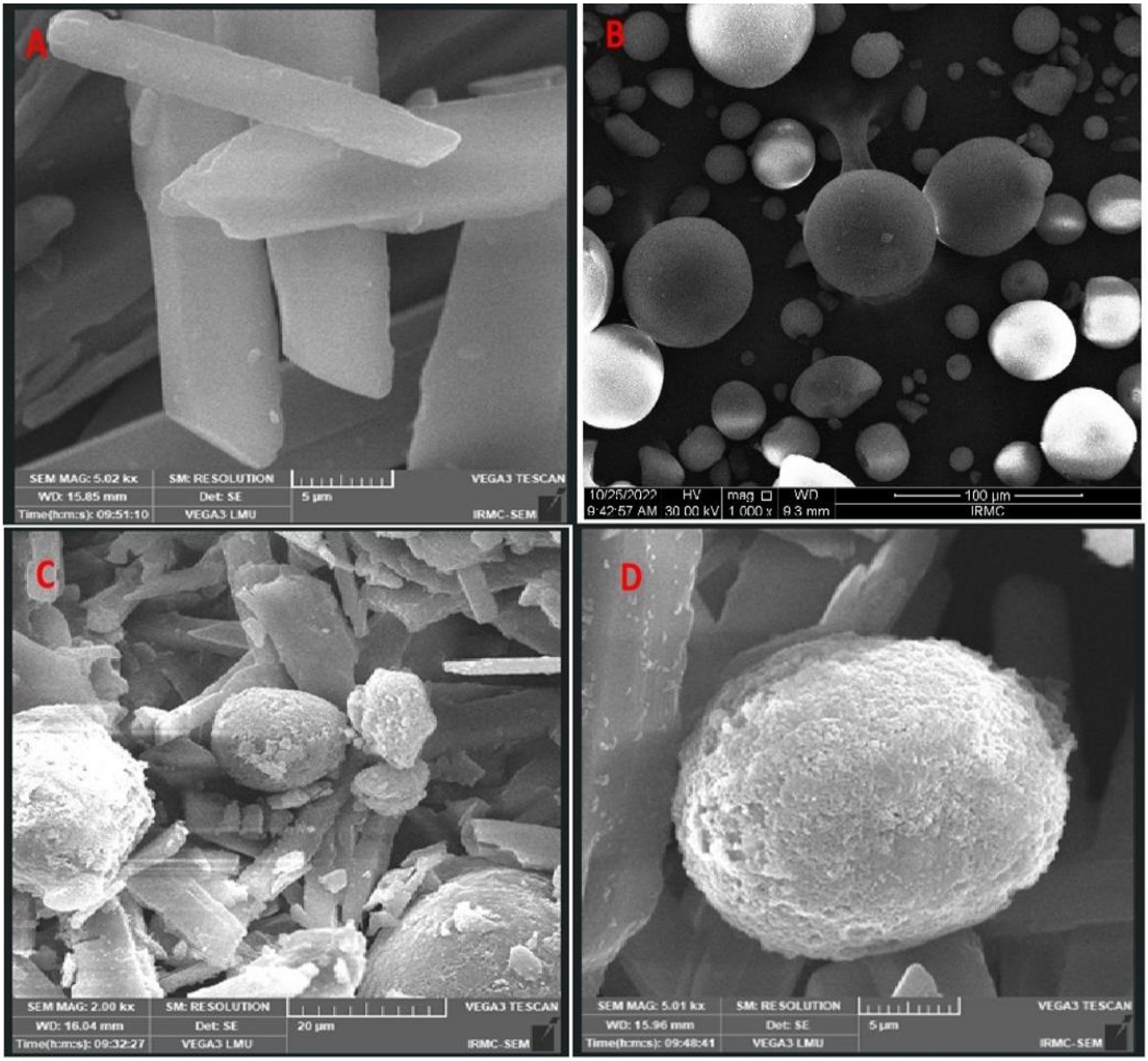

Figure 2.
SEM images of A) sulfadiazine, B) Eudragit RS100, C) and D) F-2 microsponge.
Source: Panel B) is adapted from our previously published study [12].

3.5. Differential Scanning Calorimetry (DSC)

The sharp melting endotherm of pure sulfadiazine [4] confirms its crystalline state (Figure 3A). When blended with Eudragit RS100 in the physical mixture, the appearance of an additional low-temperature endotherm and the depression of the sulfadiazine melting point reflect initial physical interactions between the drug and polymer. The polymer softening around 154–160 °C facilitates partial dissolution of sulfadiazine into the polymer phase during heating, which accounts for

the broader and shifted drug peak (Figure 3B). These changes suggest reduced crystal perfection, formation of eutectic-like behavior, or partial molecular dispersion, but the presence of a recognizable sulfadiazine melting endotherm indicates that the drug remains largely crystalline in the physical mixture.

In microsponge formulation, thermal behavior changes further. The shift of the low-temperature transition to about 161.2 °C (Figure 3C) and the pronounced broadening of the sulfadiazine-related endotherm support deeper incorporation of the drug within the porous Eudragit RS100 network. The lower intensity and reduced enthalpy of the melting peak demonstrate partial amorphization or crystal size reduction, meaning that a fraction of the drug is molecularly dispersed or confined within the microsponge pores. These solid-state changes are favorable for improving dissolution and sustaining release because smaller or partially amorphous drug domains dissolve more readily.

Importantly, neither the physical mixture nor the microsponge displayed any new sharp peaks or exothermic events, confirming no chemical incompatibility or degradation between sulfadiazine and Eudragit RS100. The DSC results therefore support that sulfadiazine is thermally compatible with the polymer and is successfully incorporated into the microsponge system with reduced crystallinity, consistent with the intended sustained-release behavior.

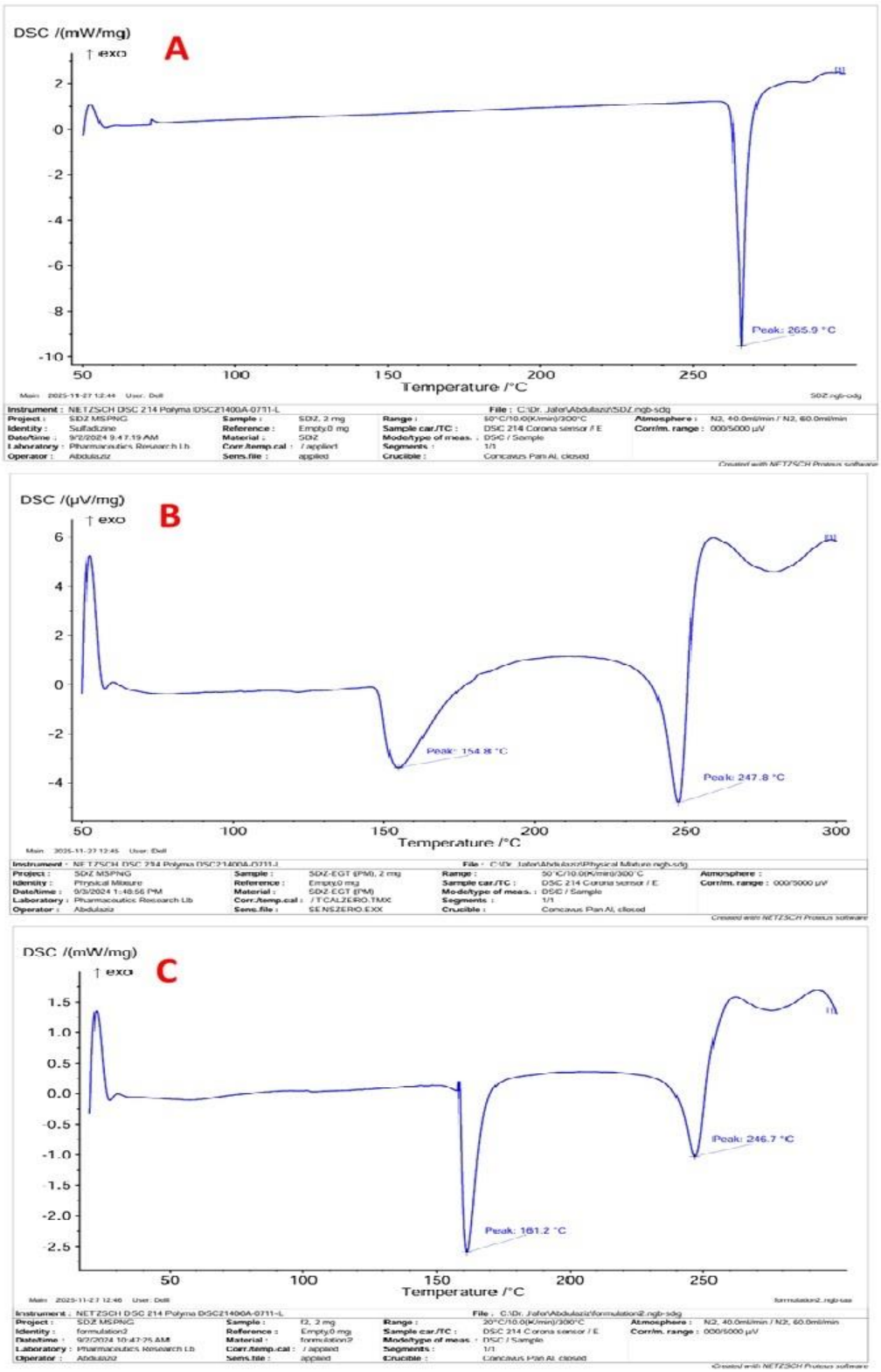

Figure 3.
DSC thermograms of A) Sulfadiazine B) Sulfadiazine-Eudragit RS 100 physical mixture C) F-2 microsponge.

3.6. Stability Study

The three-month stability study of microsponge formulation F-2 demonstrated excellent physical and chemical stability (Table 3). No visible changes in color, appearance, or flow properties were observed, indicating that the microsponges remained structurally intact under accelerated storage conditions. Drug content remained within the acceptable range (23–24%), showing minimal degradation or loss of potency over time. The maintenance of drug content and physical attributes suggests that the microsponge system effectively protects sulfadiazine from environmental stress, including temperature and humidity fluctuations. Stable performance over the test period indicates that the formulation is suitable for long-term storage and transportation, providing confidence in its reliability and therapeutic consistency throughout shelf life. Overall,

the stable performance indicates suitability for long-term storage and reliable therapeutic consistency throughout the product's shelf life.

Table 3.
Stability data of sulfadiazine loaded gastric floating microsponge (F-2 formulation).

Sl.No.	Duration (Months)	Physical appearance	*Drug content (%)
1	0	-	23±0.66
2	1	No change	23.32±0.77
3	2	No change	24.01±0.92
4	3	No change	23.89±1.21

Note: *The drug content experiment was done in triplicate, and the findings were presented as mean SD (n = 3)

4. Conclusion

Sulfadiazine-loaded gastric floating microsponges were successfully formulated using the quasi-emulsion solvent diffusion method, producing high-yield, porous, buoyant particles with sustained drug release and strong stability characteristics. The microsponges remained floating for more than 12 hours, ensuring prolonged gastric retention—a critical advantage for drugs with limited absorption windows. SEM confirmed the desired morphology, while DSC verified reduced crystallinity, supporting enhanced dissolution. Drug release patterns demonstrated sustained release behavior suitable for maintaining consistent plasma concentrations.

These findings collectively indicate that gastric floating microsponges present a promising platform for repurposed sulfadiazine delivery in cancer therapy. By enhancing gastric retention, improving dissolution, stabilizing the drug, and providing sustained release, this system may significantly improve the therapeutic performance of sulfadiazine as an anticancer agent. Further in-vivo studies are recommended to validate bioavailability improvements and therapeutic outcomes.

References

[1] L. Pinzi, N. Bisi, and G. Rastelli, "How drug repurposing can advance drug discovery: Challenges and opportunities," *Frontiers in Drug Discovery*, vol. 4, p. 1460100, 2024. https://doi.org/10.3389/fddsv.2024.1460100

[2] N. Bano, S. Parveen, M. Saeed, S. Siddiqui, M. Abohassan, and S. S. Mir, "Drug repurposing of selected antibiotics: An emerging approach in cancer drug discovery," *ACS Omega*, vol. 9, no. 25, pp. 26762-26779, 2024. https://doi.org/10.1021/acsomega.4c00617

[3] M. Gomaa *et al.*, "Sulfadiazine exerts potential anticancer effect in hepg2 and mcf7 cells by inhibiting tnfα, il1b, cox-1, cox-2, 5-lox gene expression: Evidence from in vitro and computational studies," *Pharmaceuticals*, vol. 17, no. 2, p. 189, 2024. https://doi.org/10.3390/ph17020189

[4] A. Delrivo, A. Zoppi, G. Granero, and M. Longhi, "Studies of ternary systems of sulfadiazine with β-cyclodextrin and aminoacids," *Ars Pharmaceutica*, vol. 57, no. 4, pp. 167–176, 2016.

[5] H. Stober and W. DeWitte, "Sulfadiazine. In K. Florey (Ed.)," *Analytical Profiles of Drug Substances and Excipients*, vol. 11, pp. 523–551, 1982.

[6] J. Tripathi, P. Thapa, R. Maharjan, and S. H. Jeong, "Current state and future perspectives on gastroretentive drug delivery systems," *Pharmaceutics*, vol. 11, no. 4, p. 193, 2019. https://doi.org/10.3390/pharmaceutics11040193

[7] M. N. Ali, A. Malek, P. Akter, A. A. Al Juhan, F. Safrin, and F. Akter, "A comprehensive review on floating drug delivery system," *Saudi Journal of Medical and Pharmaceutical Sciences*, vol. 11, no. 5, pp. 383–393, 2025.

[8] G. Singhvi, P. Manchanda, N. Hans, S. K. Dubey, and G. Gupta, "Microsponge: An emerging drug delivery strategy," *Drug Development Research*, vol. 80, no. 2, pp. 200-208, 2019. https://doi.org/10.1002/ddr.21492

[9] M. Jafar, A. A. Mohsin, M. S. Khalid, A. M. Alshahrani, F. S. Alkhateeb, and A. S. Alqarni, "Ranitidine hydrochloride stomach specific bouyant microsponge: Preparation, in-vitro characterization, and in-vivo anti-ulcer activity," *Journal of Drug Delivery Science and Technology*, vol. 55, p. 101453, 2020. https://doi.org/10.1016/j.jddst.2019.101453

[10] M. Jafar *et al.*, "Preparation and in vitro-in vivo evaluation of luteolin loaded gastroretentive microsponge for the eradication of helicobacter pylori infections," *Pharmaceutics*, vol. 13, no. 12, p. 2094, 2021. https://doi.org/10.3390/pharmaceutics13122094

[11] M. Jafar *et al.*, "Development of apigenin loaded gastroretentive microsponge for the targeting of Helicobacter pylori," *Saudi Pharmaceutical Journal*, vol. 31, no. 5, pp. 659-668, 2023. https://doi.org/10.1016/j.jsps.2023.03.006

[12] M. Jafar, M. S. A. Khan, M. J. Akbar, H. S. AlSaihaty, and S. S. Alasmari, "Obliteration of H. pylori infection through the development of a novel thyme oil laden nanoporous gastric floating microsponge," *Heliyon*, vol. 10, no. 8, p. e29246, 2024. https://doi.org/10.1016/j.heliyon.2024.e29246

[13] R. A. M. Osmani *et al.*, "Microsponges based novel drug delivery system for augmented arthritis therapy," *Saudi Pharmaceutical Journal*, vol. 23, no. 5, pp. 562-572, 2015. https://doi.org/10.1016/j.jsps.2015.02.020

[14] G. Wadhwa, S. Kumar, V. Mittal, and R. Rao, "Encapsulation of babchi essential oil into microsponges: Physicochemical properties, cytotoxic evaluation and anti-microbial activity," *Journal of Food and Drug Analysis*, vol. 27, no. 1, pp. 60-70, 2019. https://doi.org/10.1016/j.jfda.2018.07.006

[15] S. Saini, J. Chhabra, A. Sharma, M. Kumar, I. Singh, and R. Pahwa, "Assessing the potential of gastroretentive technology for gastric cancer targeting," *Journal of Applied Pharmaceutical Science*, vol. 13, no. 5, pp. 033-040, 2023. https://dx.doi.org/10.7324/JAPS.2023.130301

[16] U. Farooq *et al.*, "Enhanced gastric retention and drug release via development of novel floating microspheres based on Eudragit E100 and polycaprolactone: Synthesis and in vitro evaluation," *Designed Monomers and Polymers*, vol. 20, no. 1, pp. 419-433, 2017. https://doi.org/10.1080/15685551.2017.1326702

[17] J. Baranauskaite, S. Sefer, A. Zevzikoviene, A. Zevzikovas, and L. Ivanauskas, "Optimized enoxolone-loaded microsponges for drug delivery: A design of experiments approach," *Pharmaceuticals*, vol. 18, no. 7, p. 938, 2025. https://doi.org/10.3390/ph18070938

[18] M. Rahman *et al.*, "Therapeutic application of microsponges-based drug delivery systems," *Current Pharmaceutical Design*, vol. 28, no. 8, pp. 595-608, 2022. https://doi.org/10.2174/1381612828666220118121536

[19] M. Lengyel, N. Kállai-Szabó, V. Antal, A. J. Laki, and I. Antal, "Microparticles, microspheres, and microcapsules for advanced drug delivery," *Scientia Pharmaceutica*, vol. 87, no. 3, p. 20, 2019. https://doi.org/10.3390/scipharm87030020

[20] M. Bhatia and M. Saini, "Formulation and evaluation of curcumin microsponges for oral and topical drug delivery," *Progress in Biomaterials*, vol. 7, no. 3, pp. 239-248, 2018. https://doi.org/10.1007/s40204-018-0099-9

[21] N. Srinatha, S. Battu, and B. Vishwanath, "Microsponges: A promising frontier for prolonged release-current perspectives and patents," *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 13, no. 1, p. 60, 2024. https://doi.org/10.1186/s43088-024-00519-4