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Fabrication of Sulfasalazine-Loaded Solid Lipid Nanoparticles through Solvent Emulsification Diffusion Technique: Pharmaceutical and Stability Studies

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ABSTRACT

Background: Sulfasalazine (SSZ), a Biopharmaceutical Classification System (BCS) Class IV drug, suffers from poor aqueous solubility and low bioavailability, limiting its therapeutic efficacy. Solid lipid nanoparticles (SLNs) offer a promising nanotechnology-based approach to improve solubility, stability, and controlled drug release. **Objective:** To formulate and optimize sulfasalazine-loaded SLNs using the solvent emulsification diffusion technique, evaluate their physicochemical properties, and assess their potential for sustained drug release. **Methods:** Unloaded SLNs were prepared by varying lipid (stearic acid), surfactant (Tween-80), co-surfactant (PEG-400) concentrations, and stirring times. The optimized formulation (BFM-11) was used to load SSZ at various drug-to-lipid ratios. Zeta size, polydispersity index (PDI), zeta potential, entrapment efficiency (EE), drug-loading capacity (DLC), and in vitro release profiles were assessed. Stability studies were conducted at 5±3°C and 25±2°C for 30 days. **Results:** The optimized formulation (SFM-3) achieved a zeta size of 217.2 nm, PDI of 0.373, zeta potential of -38.72 mV, EE of 89.1%, and DLC of 2.87%. In vitro release demonstrated 21.46% release in the first hour with 92.31% cumulative release over 12 hours. Stability was maintained at 5±3°C but deteriorated at 25±2°C. **Conclusion:** Sulfasalazine-loaded SLNs improved drug solubility, stability, and sustained release, presenting a promising nanotechnology-based strategy for enhancing therapeutic efficacy.

INTRODUCTION

The therapeutic efficacy of many drugs is significantly hindered by their poor solubility in water, resulting in low bioavailability, which limits their clinical utility. Sulfasalazine (SSZ) is one such drug, classified under the Biopharmaceutical Classification System-IV (BCS-IV) due to its low aqueous solubility and limited intestinal permeability, which collectively restrict its bioavailability to less than 15% (9). Despite these limitations, SSZ is a cornerstone in the management of rheumatoid arthritis and inflammatory bowel diseases, such as Crohn's disease and ulcerative colitis, owing to its properties as a Disease-Modifying Anti-Rheumatic Drug (DMARD) (1-4). However, its therapeutic potential is often overshadowed by suboptimal pharmacokinetics and frequent adverse effects, including gastrointestinal distress, skin rashes, and hematological abnormalities, which further complicate its clinical use (11). Addressing these challenges requires innovative approaches that enhance the solubility, stability, and controlled release of SSZ while minimizing its side effects and maximizing its therapeutic index (5-12).

Nanotechnology-based drug delivery systems, particularly solid lipid nanoparticles (SLNs), have emerged as promising carriers for poorly water-soluble drugs due to their ability to encapsulate lipophilic drugs, enhance solubility, and provide controlled release profiles (1, 2). SLNs offer several advantages over traditional polymeric nanoparticles and liposomal systems, including biocompatibility, biodegradability,

lower toxicity, and ease of large-scale production (3, 4). By replacing liquid lipids with solid lipids, SLNs facilitate prolonged drug release, reduced drug mobility, and enhanced stability, making them suitable candidates for improving the pharmacokinetics of drugs like SSZ (5, 6). The entrapment of drugs within a lipid matrix surrounded by surfactants in SLNs ensures a stable and efficient delivery system, overcoming the solubility and permeability barriers inherent to BCS-IV drugs (7). Moreover, SLNs provide the advantage of controlled drug release, which is particularly beneficial for maintaining steady plasma drug concentrations, thereby reducing dosing frequency and improving patient compliance (12).

The clinical significance of SSZ lies in its dual role as a sulfa drug and a mesalazine derivative, formed by the combination of sulfapyridine and salicylate through an azo bond. SSZ acts by modulating the inflammatory response, although its exact mechanism remains incompletely understood. Despite its widespread use, the conventional oral administration of SSZ often leads to suboptimal therapeutic outcomes, largely attributed to its high first-pass metabolism, low bioavailability, and adverse drug reactions (9). Furthermore, SSZ exhibits unique characteristics, such as imparting a yellow-orange discoloration to bodily fluids, which can stain clothing and contact lenses, adding to its limitations in routine clinical practice (12).

In this study, sulfasalazine-loaded solid lipid nanoparticles (SSZ-SLNs) were developed using the optimized solvent emulsification diffusion technique to address the solubility and bioavailability challenges associated with SSZ. The formulation process involved careful optimization of key variables, including lipid concentration, surfactant and co-surfactant ratios, and stirring time, to achieve nanoparticles with optimal zeta size, polydispersity index (PDI), and entrapment efficiency. The in vitro characterization of SSZ-SLNs included assessments of their zeta potential, morphology, drug-loading capacity, and drug release kinetics. Stability studies were conducted under various conditions to evaluate the feasibility of the developed SLNs as a prolonged-release formulation. The ultimate goal was to establish a robust nano-delivery system for SSZ that can enhance its therapeutic efficacy, reduce side effects, and improve patient outcomes in the management of rheumatoid arthritis and inflammatory bowel diseases. The findings of this research contribute to the growing body of evidence supporting the application of nanotechnology-based drug delivery systems to overcome the limitations of conventional drug formulations, particularly for poorly water-soluble drugs like sulfasalazine (6, 8).

MATERIAL AND METHODS

The study was conducted to develop sulfasalazine-loaded solid lipid nanoparticles (SSZ-SLNs) using the solvent emulsification diffusion technique. The experimental design focused on optimizing the formulation parameters, characterizing the physicochemical properties of the nanoparticles, and evaluating their stability and in vitro drug release profiles. Ethical approval for the study was obtained from the relevant institutional review board, and all procedures were carried out in accordance with the Declaration of Helsinki and Good Laboratory Practices.

The materials used in this study included sulfasalazine, which was generously provided by Ferozsons Laboratories, Nowshera, Pakistan. Stearic acid, Polysorbate-80 (Tween-80), and Polyethylene Glycol-400 (PEG-400) were procured from Acros Organics, Thermo Fisher Scientific, New Jersey, USA. All chemicals and reagents used were of analytical grade and were used without further purification. The nanoparticles were prepared by carefully optimizing critical formulation parameters, including lipid concentration, surfactant and co-surfactant ratios, and stirring time. Twelve initial formulations of unloaded solid lipid nanoparticles (SLNs) were prepared to evaluate the effects of these parameters on zeta size and polydispersity index (PDI).

For the preparation of unloaded SLNs, specific quantities of stearic acid were melted at 75°C, followed by the addition of a pre-heated aqueous phase containing Tween-80. The emulsification process was performed under controlled stirring at 1200 RPM to form a hot microemulsion, which was subsequently dispersed in cold deionized water at 2-4°C. The resultant dispersion was centrifuged at 30,000 RPM using an ultracentrifuge to isolate the nanoparticles. Drug-loaded SLNs were prepared by selecting the optimized unloaded formulation (BFM-11) based on its zeta size and PDI. Sulfasalazine was incorporated into the lipid phase at varying drug-to-lipid ratios, followed by the same emulsification and isolation process used for unloaded SLNs. A cryoprotectant (5% fructose) was added before lyophilization to ensure the stability of the nanoparticles during freeze-drying.

The nanoparticles were characterized for zeta size, PDI, and zeta potential using dynamic light scattering (Zetasizer Nano ZS-90, Malvern Instruments, UK). Entrapment efficiency and drug-loading capacity were determined by measuring the unentrapped drug concentration in the supernatant using a UV-Vis spectrophotometer. A calibration curve for sulfasalazine was constructed using phosphate buffer at pH 7.4 to ensure accurate quantification. Scanning electron microscopy (SEM) was employed to evaluate the morphology and size of the nanoparticles, while differential scanning calorimetry (DSC) and X-ray powder diffraction (XRD) were performed to assess the crystalline behavior of the drug and its interaction with the lipid matrix. Fourier-transform infrared spectroscopy

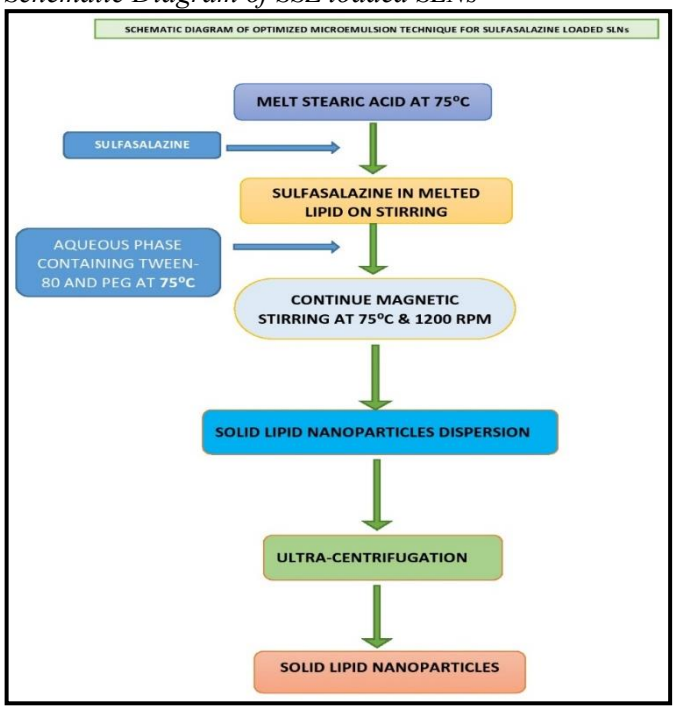
(FT-IR) was conducted to confirm the chemical stability of the drug within the nanoparticles.

The in vitro drug release study was conducted using the dialysis bag method, where 1 mL of SSZ-SLN dispersion was enclosed in a dialysis membrane and immersed in phosphate buffer at pH 7.4. The setup was maintained under continuous stirring at 37±0.5°C. Aliquots were collected at predetermined intervals over 12 hours and analyzed spectrophotometrically to determine the cumulative drug release. The data were fitted into various kinetic models, including zero-order, first-order, Higuchi, Korsmeyer-Peppas, and Hixson-Crowell equations, to elucidate the release mechanism.

Stability studies were conducted in accordance with the International Council for Harmonisation (ICH) guidelines. The optimized formulation (SFM-3) was stored at two conditions: refrigeration (5±3°C) and room temperature (25±2°C, 60±5% RH) for 30 days. Zeta size and PDI were measured at intervals of 1, 3, 8, 15, 22, and 30 days to assess the physical stability of the formulation. Statistical analysis was performed using a two-tailed t-test, with p-values <0.05 considered statistically significant.

Figure 1

Schematic Diagram of SSZ loaded SLNs



All experimental procedures were meticulously planned and executed to ensure reproducibility and reliability of results. Data collection and analysis were performed using appropriate statistical tools, and findings were documented in accordance with standard reporting practices. This comprehensive approach ensured the credibility and relevance of the study in advancing the understanding of nanotechnology-based drug delivery systems.

RESULTS

The preparation and optimization of sulfasalazine-loaded solid lipid nanoparticles (SLNs) involved multiple stages to achieve ideal particle size, uniformity, and drug encapsulation efficiency. The initial focus was on the optimization of unloaded SLNs based on varying lipid-to-surfactant ratios. Formulations BFM-1 to BFM-4 demonstrated a progressive reduction in zeta size, from 855.2 ± 2.5 nm for BFM-1 to 238.9 ± 2.6 nm for BFM-4, with corresponding polydispersity indices (PDIs) ranging from 0.565 ± 0.003 to 0.537 ± 0.004. This indicated that increasing surfactant concentration led to better stabilization of the lipid nanoparticles, as illustrated in Table 1 and Figures 2 and 3.

Subsequent optimization based on surfactant and co-surfactant ratios (Tween-80 and PEG-400) revealed further improvements. Formulations BFM-4 to BFM-9 maintained a relatively narrow size range, with the smallest particle size observed for BFM-8 at 214.1 ± 1.4 nm. The PDI for these formulations ranged from 0.504 ± 0.003 to 0.608 ± 0.002, showing consistent uniformity across different ratios of co-surfactant. This trend emphasizes the importance of balancing surfactant and co-surfactant concentrations for achieving optimal size and stability, as seen in Figures 2 and 3.

Table 1

Unloaded SLNs formulations with size and PDI Mean±SD (n=3)

Formulation	Stearic Acid	Tween-80	PEG-400	Stirring Time	Size	PDI
BFM-1	2	1	00	5 Minutes	855.2 ±2.5nm	0.565 ±0.003
BFM-2	1	1	00	5 Minutes	544.5 ±1.3nm	0.551 ±0.008
BFM-3	2	3	00	5 Minutes	273.3 ±2.9nm	0.650 ±0.002
BFM-4	1	2	00	5 Minutes	238.9 ±2.6nm	0.537 ±0.004
BFM-5	1	1.9	0.1	5 Minutes	236.8 ±5.1nm	0.514 ±0.003
BFM-6	1	1.8	0.2	5 Minutes	233.9 ±2.5nm	0.504 ±0.003
BFM-7	1	1.7	0.3	5 Minutes	217.8 ±1.5nm	0.506 ±0.002
BFM-8	1	1.6	0.4	5 Minutes	214.1 ±1.4nm	0.608 ±0.002
BFM-9	1	1.5	0.5	5 Minutes	215.6 ±2.6nm	0.566 ±0.003
BFM-10	1	1.6	0.4	10 Minutes	212.8 ±1.8nm	0.551 ±0.001
BFM-11	1	1.6	0.4	15 Minutes	205.5 ±2.9nm	0.388 ±0.008
BFM-12	1	1.6	0.4	20 Minutes	203.2 ±2.5nm	0.50 ±0.0010

PEG:Polyethylen Glycol, PDI: Polydispersity Index

Figure 2
Zeta size of unloaded SLNs

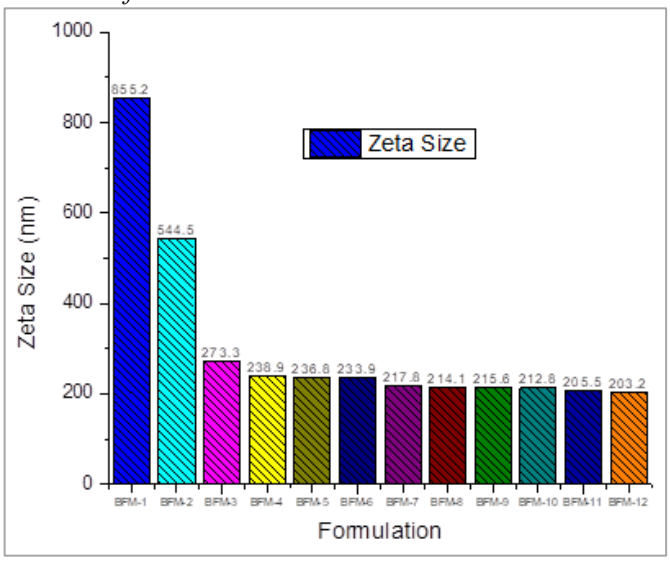


Figure 3
Polydispersity Index (PDI) of unloaded SLNs

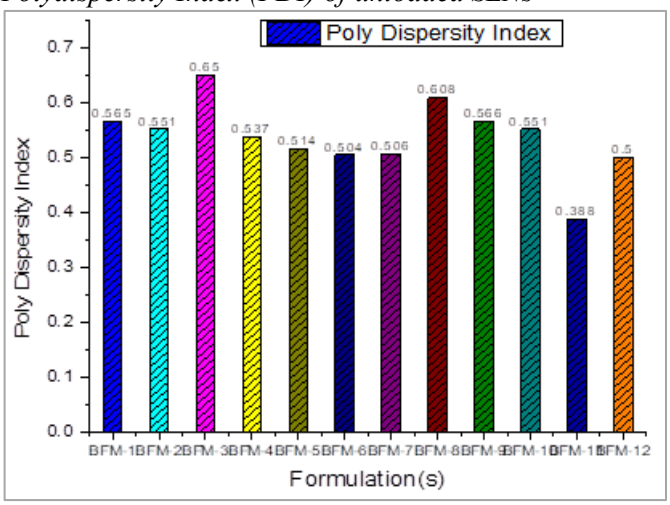


Figure 4
Calibration curve of Sulfasalazine

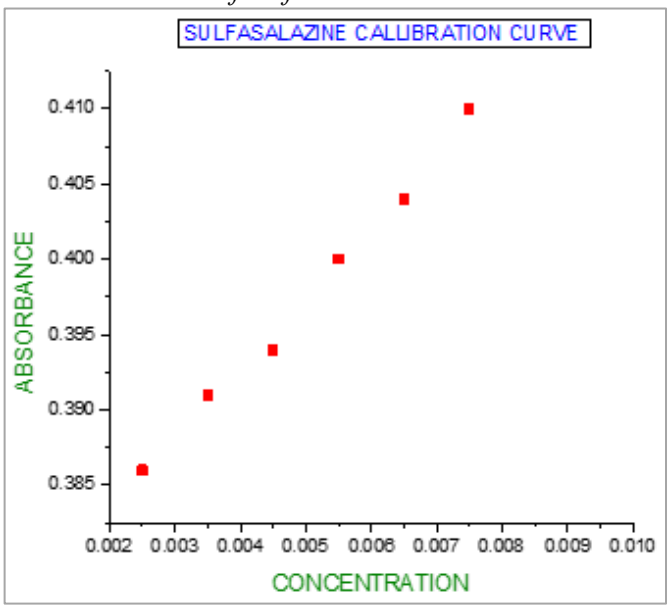


Figure 5
Comparison of Entrapment Efficiency of Different SSZ loaded SLNs

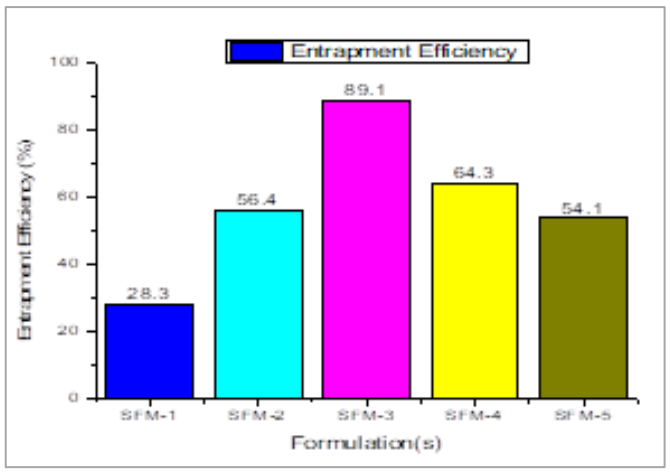


Figure 6
Comparison of Drug Loading Capacity of Different SSZ loaded SLNs

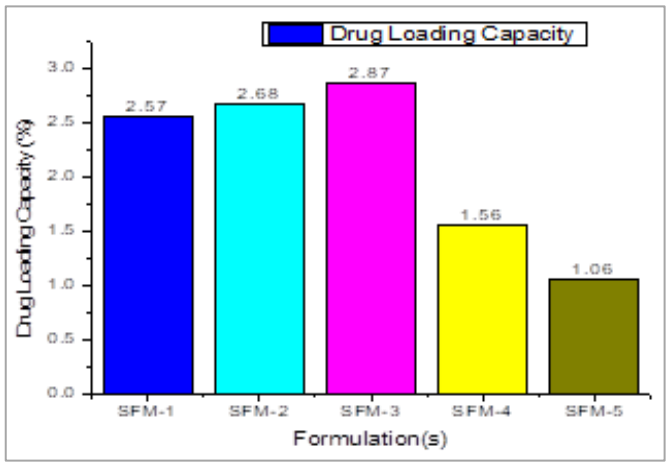


Table 2
Drug-Lipid Ratio based SSZ loaded SLNs formulations with EE & DLC Mean±SD (n=3)

Formulation	SSZ	Stearic Acid	Tween-80	Stirring	PEG-400	EE%	DLC%
SFM-1	200 mg	1 gm	1.6 gm	15 Minutes	0.4 gm	28.3 ±0.05	2.57 ±0.02
SFM-2	100 mg	1 gm	1.6 gm	15 Minutes	0.4 gm	56.4 ±0.07	2.68 ±0.04
SFM-3	66.6m g	1 gm	1.6 gm	15 Minutes	0.4 gm	89.1 ± 0.03	2.87 ±0.05
SFM-4	50.0m g	1 gm	1.6 gm	15 Minutes	0.4 gm	64.3 ±0.03	1.56 ±0.04
SFM-5	40.0m g	1 gm	1.6 gm	15 Minutes	0.4 gm	54.1 ±0.07	1.06 ±0.06

SSZ: Sulfasalazine, PEG:Polyethylene Glycole, EE: Entrapment Efficiency, DLC: Drug Loading Capacity

Figure 7
Zeta Size & PDI of SFM-3

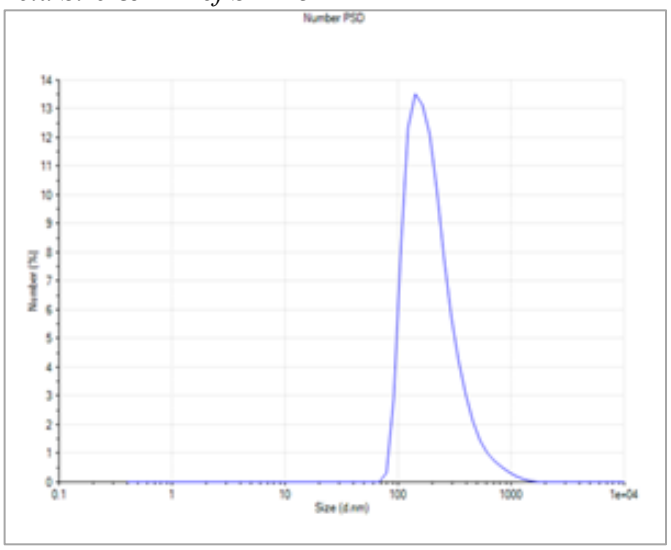


Figure 8
Comparison of Zeta Potential of Different SSZ loaded SLNs

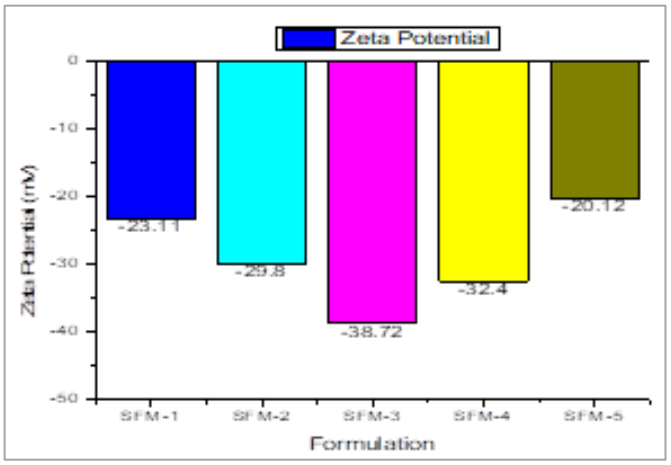


Figure 9
Zeta Potential of SFM-3

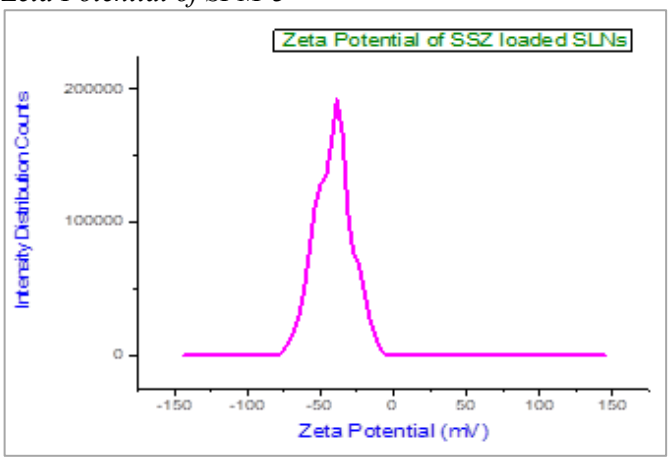


Table3
Cumulative Percent Release from SSZ loaded SLNs

Time(hr)	Cumulative Percent Release				
	SFM-1	SFM-2	SFM-3	SFM-4	SFM-5
0	0	0	0	0	0
1	19.46	17.41	21.46	9.11	7.33
2	33.56	34.78	30.26	11.78	10.78
3	45.55	43.51	39.14	23.51	22.41
4	54.19	55.62	48.19	31.33	27.53
5	68.48	68.88	56.48	34.88	33.18
6	77.21	78.21	64.21	39.21	37.21
7	89.63	93.63	72.63	43.63	41.73
8	92.22	100	79.22	47.42	43.21
10	100	100	85.16	52.55	48.51
12	100	100	92.31	56.35	50.15

Figure 10
Cumulative % drug release

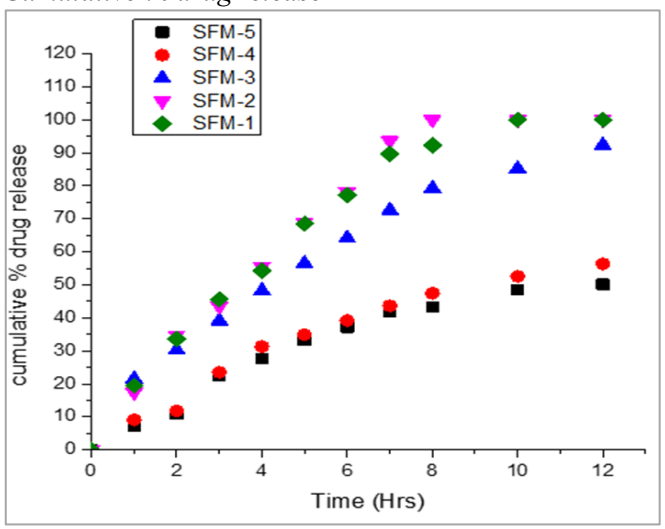


Figure 11(a)
Zero Order Kinetics

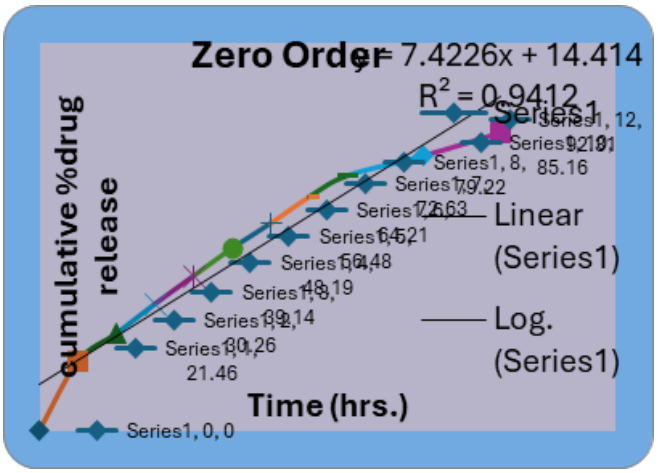


Figure 11(b)
First Order Kinetics

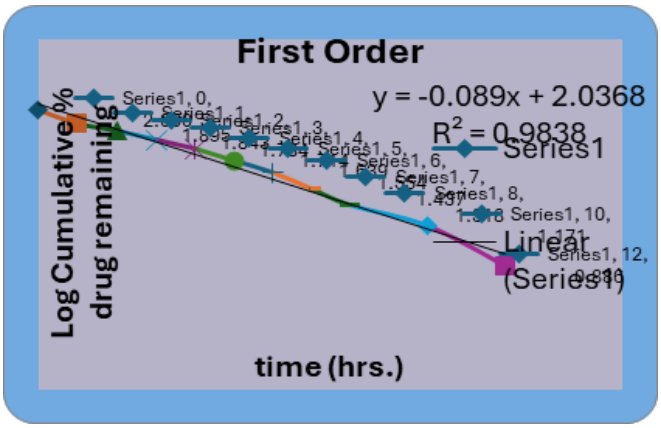


Figure 11(c)
Higushi Model

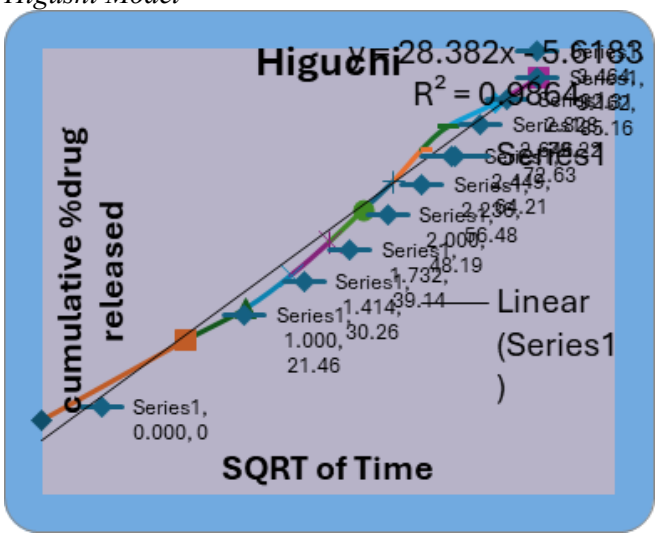


Figure 11(d)
Kors-Peppas Model

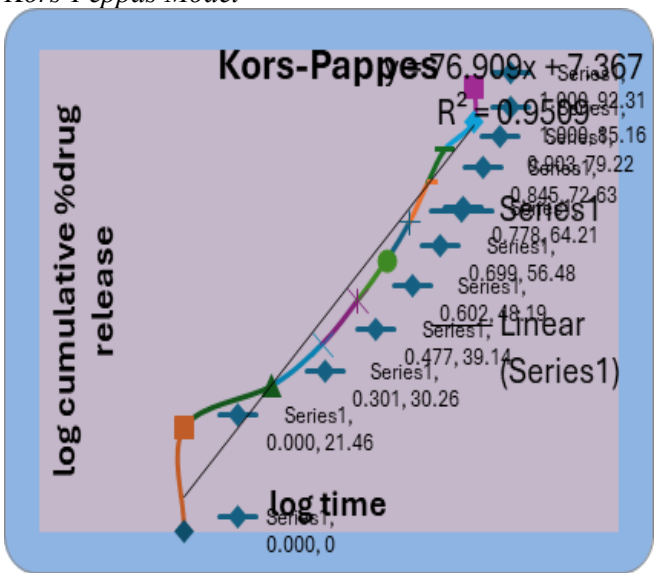


Figure 11(e)
Hixson Model, Different Kinetic Models for SFM-3

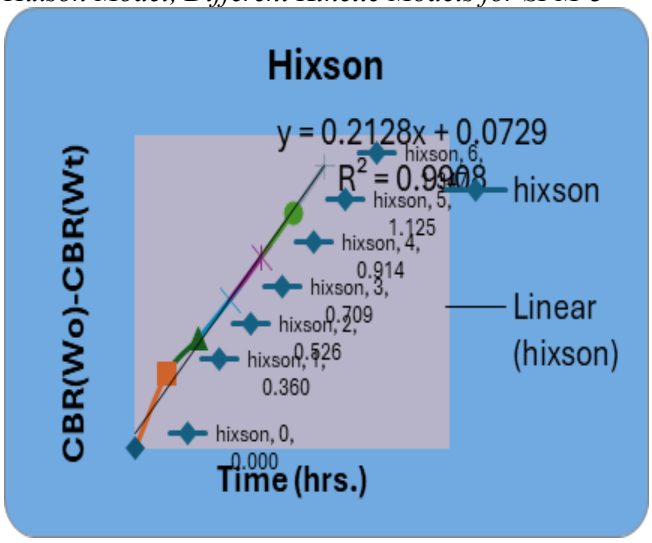


Figure 12
Scanning Electron microscope image of SSZ loaded SLNs (SFM-3)

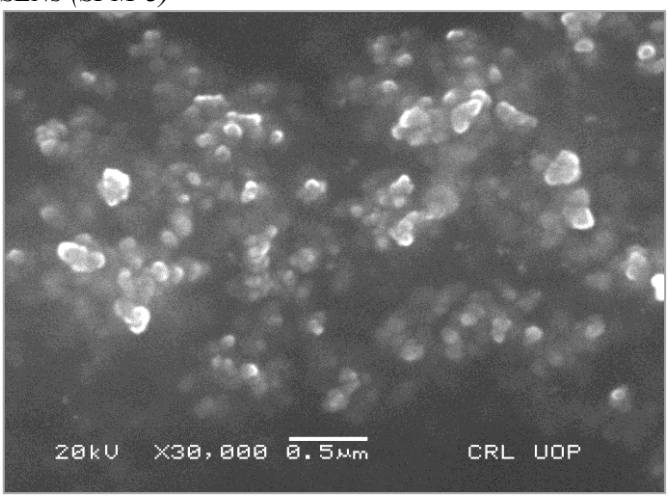


Figure 13
DSC Thermograms of Sulfasalazine (a), Physical Mixture (b) and SSZ loaded SLNs(c)

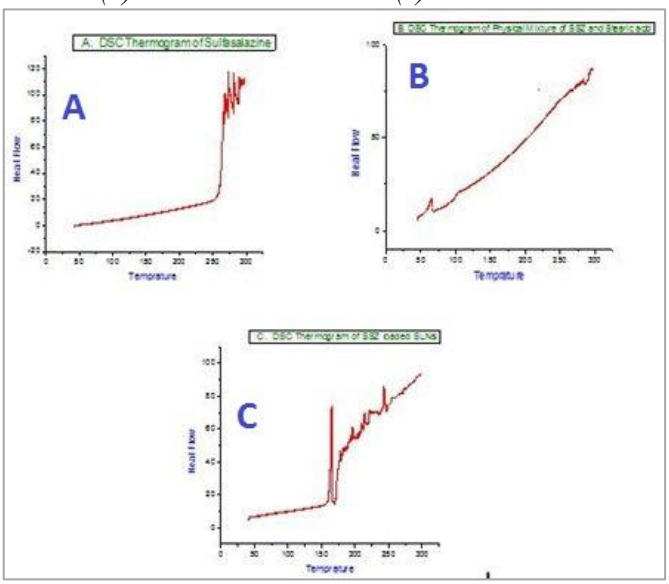


Figure 14
XRD Spectra of Sulfasalazine (A) and Sulfasalazine loaded SLNs (SFM-3)

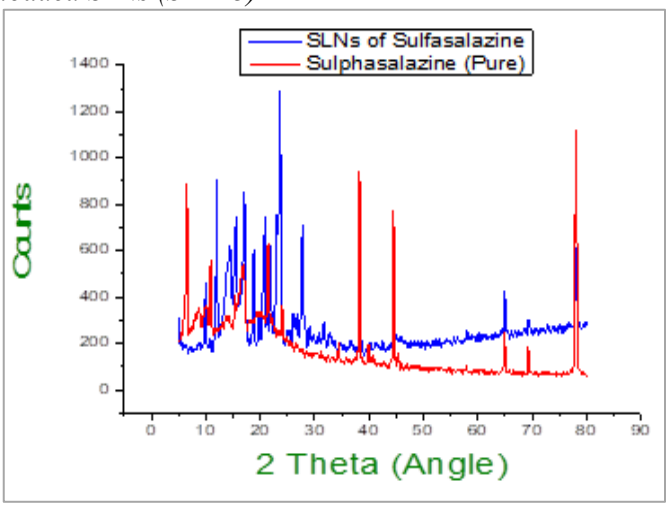


Figure 15

FTIR Spectra of Sulfasalazine (A) and Sulfasalazine loaded SLNs (B)

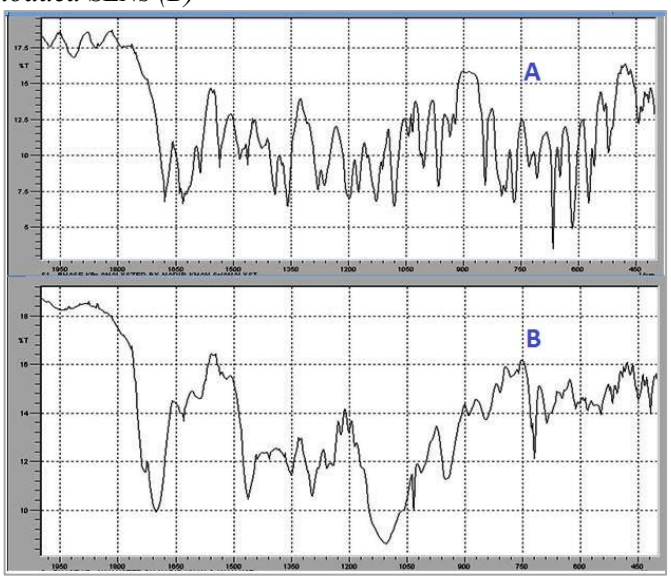


Table 4

Day/ Temperature	Zeta Size (5±3ºC) Size	Zeta Size (25±2ºC)	PDI (5±3ºC)	PDI (25±2ºC)
1st Day	217.2 nm	217.2 nm	0.373	0.373
3rd Day	219.5 nm	239.2 nm	0.376	0.386
8th Day	221.3 nm	254.6 nm	0.380	0.403
15th Day	225.1 nm	269.4 nm	0.381	0.506
22nd Day	226.1 nm	298.5 nm	0.374	0.567
30th Day	227.3 nm	325.5 nm	0.383	0.672
Mean	222.7 nm	256 nm	0.37	0.48
±SD	4.02	30.7	0.004	0.119
p-Value	0.02		0.04	

Stirring time also played a crucial role in the optimization of unloaded SLNs. Formulations BFM-8, BFM-10, BFM-11, and BFM-12 were prepared with stirring times of 5, 10, 15, and 20 minutes, respectively. BFM-11, with 15 minutes of stirring, exhibited the smallest particle size (205.5 ± 2.9 nm) and the lowest PDI (0.388 ± 0.008), highlighting the importance of sufficient but controlled stirring to achieve homogeneity. Further increases in stirring time (20 minutes for BFM-12) did not significantly improve size or PDI, confirming that 15 minutes was optimal for these formulations.

The entrapment efficiency (EE) and drug-loading capacity (DLC) of sulfasalazine-loaded SLNs were determined using formulations SFM-1 to SFM-5, as presented in Table 2. Among these, SFM-3, with a drug-to-lipid ratio of 15:1, exhibited the highest EE (89.1 ± 0.03%) and DLC (2.87 ± 0.05%), indicating the most efficient encapsulation and loading of the drug. Decreasing the drug-to-lipid ratio led to reductions in both EE and DLC, as demonstrated in Figures 5 and 6. This suggests that an optimal balance between the lipid matrix and drug concentration is necessary for achieving effective entrapment.

The zeta size and PDI of drug-loaded SLNs were also evaluated, with SFM-3 again emerging as the optimal formulation. It exhibited a zeta size of 217.2 nm and a PDI of 0.373, indicating a narrow and uniform size distribution, as shown in Figure 7. The zeta potential of SFM-3 (-38.72 ± 1.2 mV) was sufficient to ensure electrostatic stability and prevent aggregation, as depicted in Figures 8 and 9.

The in vitro release profile of sulfasalazine from SLNs was assessed over 12 hours, as summarized in Table 3. The SFM-3 formulation exhibited an initial burst release of 21.46% within the first hour, followed by a sustained release of 92.31% at 12 hours, as shown in Figure 10. This pattern was attributed to the initial release of surface-adsorbed drug molecules, followed by a slower diffusion through the lipid matrix. Kinetic modeling revealed that SFM-3 followed mixed-order kinetics, transitioning from first-order to zero-order release, with a release exponent ($n > 0.89$) characteristic of a super case II diffusion mechanism, as illustrated in Figure 11.

Scanning electron microscopy (SEM) analysis confirmed the spherical morphology and smooth surface of the SLNs, with particle sizes below 225 nm, as depicted in Figure 12. Differential scanning calorimetry (DSC) and powder X-ray diffraction (PXRD) analyses further supported the successful incorporation of sulfasalazine into the lipid matrix. The DSC thermograms of SFM-3 showed an endothermic peak at 168.5°C, indicating the conversion of sulfasalazine from a crystalline to an amorphous state, as shown in Figure 13. PXRD analysis corroborated this finding by demonstrating the absence of sharp crystalline peaks in the lyophilized formulation, as seen in Figure 14.

Fourier-transform infrared spectroscopy (FT-IR) confirmed the chemical stability of the drug within the nanoparticles. The characteristic peaks of sulfasalazine remained unchanged in the SLN formulation, indicating no chemical interaction between the drug and the lipid matrix, as shown in Figure 15.

Stability studies conducted over 30 days under refrigeration (5±3°C) and room temperature (25±2°C) conditions demonstrated that SFM-3 retained its zeta size and PDI under refrigeration, with no significant changes observed. In contrast, samples stored at room temperature exhibited increased zeta size and PDI, likely due to lipid degradation and nanoparticle aggregation. The results of the stability study are presented in Table 4, highlighting the importance of appropriate storage conditions for maintaining the stability of SLNs.

DISCUSSION

The findings of this study demonstrated the successful development and optimization of sulfasalazine-loaded solid lipid nanoparticles (SLNs) using the solvent

emulsification diffusion technique. The study addressed critical limitations of sulfasalazine, a Biopharmaceutical Classification System (BCS) Class IV drug, including poor aqueous solubility and low bioavailability. The optimized formulation (SFM-3) achieved desirable physicochemical characteristics, including a small zeta size, low polydispersity index (PDI), high entrapment efficiency (EE), and prolonged drug release profile, suggesting its potential as a novel drug delivery system. These results aligned with previous research highlighting the advantages of SLNs in enhancing the solubility and controlled release of lipophilic drugs (13-16).

The particle size reduction observed during the optimization of unloaded SLNs was consistent with studies indicating that higher surfactant concentrations stabilize nanoparticles by reducing surface tension and preventing aggregation (3). The role of co-surfactants such as PEG-400 in further decreasing zeta size and improving uniformity was similarly supported by earlier work demonstrating their ability to enhance the fluidity of the lipid matrix and facilitate nanoparticle stabilization (4). The study also found that stirring time played a pivotal role in achieving optimal particle size and PDI, with 15 minutes being identified as the optimal duration. This was consistent with previous findings that controlled stirring ensures proper emulsification and minimizes particle aggregation (17-21).

The drug-loaded SLNs, particularly SFM-3, exhibited high EE and drug-loading capacity, likely due to the optimal drug-to-lipid ratio of 15:1. This finding was comparable to prior studies that reported increased entrapment efficiency when drug concentrations were balanced against lipid matrix capacity (6). The study also highlighted the reduction in EE and drug-loading capacity at higher lipid concentrations, a phenomenon attributed to reduced drug incorporation efficiency as the lipid phase becomes saturated. These results emphasized the critical need for careful optimization of formulation parameters to achieve maximum drug entrapment and stability (22).

The in vitro drug release profile of SFM-3 demonstrated an initial burst release followed by sustained release over 12 hours. This behavior, commonly observed in SLNs, was attributed to the rapid diffusion of surface-adsorbed drug molecules and the slower release of drug encapsulated within the lipid core. Kinetic modeling revealed mixed-order release kinetics, transitioning from first-order to zero-order, with a super case II diffusion mechanism indicative of matrix relaxation and diffusion-controlled release. These findings corroborated earlier research on the controlled release capabilities of SLNs for lipophilic drugs such as cyclosporine A and camptothecin (23, 24).

The conversion of sulfasalazine from a crystalline to an amorphous state, as confirmed by DSC and PXRD analyses, was a significant outcome of the formulation process. Amorphous forms of drugs are known to exhibit improved solubility and bioavailability compared to their crystalline counterparts (9). Furthermore, FT-IR analysis indicated no chemical interaction between sulfasalazine and the lipid matrix, ensuring the chemical stability of the drug. These findings strengthened the case for SLNs as a reliable and biocompatible delivery system for sulfasalazine.

The stability studies provided important insights into the storage conditions required for SLNs. While the optimized formulation (SFM-3) retained its physicochemical properties under refrigeration (5±3°C), significant changes in zeta size and PDI were observed at room temperature (25±2°C). This highlighted the temperature sensitivity of SLNs, which has been a common limitation reported in earlier studies (10). These results underscored the need for appropriate storage conditions to maintain the stability and efficacy of SLNs during their shelf life.

Despite the promising results, the study had certain limitations. The in vitro release study did not fully replicate the physiological conditions of drug release in the human gastrointestinal tract, and further in vivo studies are required to confirm the bioavailability and therapeutic efficacy of sulfasalazine-loaded SLNs. Additionally, the scalability of the solvent emulsification diffusion technique for industrial production was not evaluated, which is an important consideration for future applications. The long-term stability of the nanoparticles beyond 30 days also warrants further investigation to ensure their practicality for clinical use.

The study's strengths included the systematic optimization of formulation parameters and comprehensive characterization of the SLNs, which provided valuable insights into their potential as a drug delivery system. The use of advanced analytical techniques such as SEM, DSC, PXRD, and FT-IR ensured the reliability and reproducibility of the results. Moreover, the incorporation of kinetic modeling added depth to the understanding of drug release mechanisms, contributing to the growing body of literature on nanotechnology-based drug delivery systems ().

Future studies should focus on scaling up the production process and evaluating the in vivo pharmacokinetics and pharmacodynamics of sulfasalazine-loaded SLNs. Additionally, exploring alternative lipid and surfactant combinations may further enhance the stability and drug-loading capacity of the nanoparticles. The integration of advanced technologies such as freeze-drying optimization and polymeric coatings could also improve the long-term stability and controlled release properties of SLNs. Overall, the

findings of this study represented a significant step forward in the development of nanotechnology-based solutions for improving the therapeutic efficacy of sulfasalazine and similar lipophilic drugs (24).

CONCLUSION

The study successfully demonstrated that sulfasalazine-loaded solid lipid nanoparticles (SLNs) developed through the solvent emulsification diffusion technique provide an efficient drug delivery system, overcoming the limitations of poor solubility and low bioavailability associated with sulfasalazine. The optimized formulation (SFM-3) exhibited high entrapment efficiency, controlled drug release, and stability under appropriate storage conditions, making it a promising candidate for improving the therapeutic efficacy of sulfasalazine. These findings have significant implications for human healthcare, as SLNs offer a biocompatible and scalable approach to enhance the bioavailability and clinical outcomes of poorly water-soluble drugs, potentially improving patient compliance and reducing drug-related adverse effects in the treatment of inflammatory and autoimmune diseases.

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