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A Comparative Stability Study of Niosomes Prepared by Sonication Method and Ether Injection Methods

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ABSTRACT

Objective: *The objective of this study is to compare the stability of Niosomes prepared using two different methods: the Sonication method and the ether injection method. By evaluating the stability parameters such as size distribution, encapsulation efficiency, and storage stability, the study aims to determine the more effective preparation technique for producing stable Niosomes.*

Materials and Methods: *Niosomes were prepared using two distinct methods: Sonication and ether injection. For the Sonication method, surfactants and cholesterol were dissolved in an organic solvent and then sonicated to form Niosomes. In the ether injection method, the same components were dissolved in ether and injected into an aqueous phase to form Niosomes. Both preparations were characterized for size distribution using dynamic light scattering, encapsulation efficiency using UV-visible spectrophotometer, and storage stability by monitoring changes in size and encapsulation efficiency over time at various temperatures.*

Results and Discussion: *The results indicated that Niosomes prepared by the Sonication method exhibited a smaller and more uniform size distribution compared to those prepared by the ether injection method. Encapsulation efficiency was found to be higher in Niosomes produced by Sonication. Over a storage period of 30 days, Niosomes from both methods showed changes in size*

and encapsulation efficiency; however, Niosomes prepared by the Sonication method demonstrated better stability, with less significant changes. These findings suggest that the sonication method may be more suitable for producing stable Niosomes, likely due to the more controlled and uniform size distribution it achieves.

Conclusion: *In conclusion, the comparative study reveals that Niosomes prepared by the Sonication method exhibit superior stability compared to those prepared by the ether injection method. The Sonication method yields Niosomes with a smaller, more uniform size distribution and higher encapsulation efficiency, making it a preferable technique for noisome preparation in applications requiring long-term stability.*

Keywords: *Niosomes, Sonication Method, Ether Injection Methods*

INTRODUCTION

The pharmaceutical industry continually seeks innovative drug delivery systems to enhance the efficacy, safety, and patient compliance of therapeutic agents. Among various drug delivery systems, Niosomes have garnered considerable attention due to their potential in encapsulating both hydrophilic and hydrophobic drugs, enhancing drug stability, and enabling controlled release.[1]Niosomes are non-ionic surfactant-based vesicles, similar in structure to liposomes but often more stable and cost-effective. They offer several advantages, including biocompatibility, biodegradability, and the ability to improve the therapeutic index of drugs.[2]

The preparation methods of Niosomes significantly impact their physicochemical properties, which in turn affect their stability and performance as drug delivery systems. Two commonly employed methods for noisome preparation are the Sonication method and the ether injection method. Each method has its unique mechanism of action, advantages, and limitations, which can influence the characteristics and stability of the resultant Niosomes.[3]

The Significance of Noisome Stability

Stability is a critical parameter for Niosomes as it determines their shelf-life, efficacy, and safety. Stable Niosomes maintain their size, shape, encapsulation efficiency, and release profile over time, ensuring consistent therapeutic performance. Instability, on the other hand, can lead to aggregation, fusion, or leakage of the encapsulated drug, thereby compromising the efficacy and safety of the formulation.[4] Therefore, a thorough understanding of the stability characteristics of Niosomes prepared by different methods is essential for optimizing their formulation and ensuring their practical applicability.

Sonication Method of Noisome Preparation

The Sonication method involves the use of ultrasonic energy to reduce the size of the vesicles formed from the hydration of a surfactant and cholesterol mixture. This method is relatively straightforward and can produce Niosomes with a uniform size distribution. During Sonication, the application of ultrasonic waves causes cavitation, leading to the formation and subsequent collapse of micro bubbles

in the solution. This process generates shear forces that break down larger vesicles into smaller ones. The Sonication method is advantageous for producing small and homogenous Niosomes, which are desirable for certain drug delivery applications. However, the high energy input during Sonication can potentially cause degradation of sensitive drugs or surfactants.[5, 6]

Ether Injection Method of Noisome Preparation

The ether injection method involves the gradual addition of a solution of surfactants and cholesterol in ether into an aqueous phase. As the ether evaporates, the surfactant molecules self-assemble into Niosomes. This method is known for its simplicity and ability to form Niosomes without the need for high energy input. The slow addition of ether allows for controlled noisome formation, and the method can be easily scaled up for industrial applications. However, the ether injection method may result in a broader size distribution of Niosomes, and the residual solvent can pose toxicity issues if not completely removed.[7, 8]

Comparative Analysis of Sonication and Ether Injection Methods

Comparing the stability of Niosomes prepared by Sonication and ether injection methods requires a comprehensive evaluation of various stability parameters, including size distribution, encapsulation efficiency, and storage stability. Size distribution affects the misdistribution, cellular uptake, and drug release profile of Niosomes. A uniform size distribution is generally preferred as it ensures consistent performance. Encapsulation efficiency indicates the capacity of Niosomes to retain the drug, which directly impacts the dosage and therapeutic effect. Storage stability is assessed by monitoring changes in size, encapsulation efficiency, and drug release profile over time under different storage conditions. [9]

Objectives and Scope of the Study

This study aims to provide a detailed comparative analysis of the stability of Niosomes prepared by Sonication and ether injection methods. The specific objectives are to:

1. **Evaluate the size distribution of Niosomes prepared by each method.**
2. **Assess the encapsulation efficiency of Niosomes for a model drug.**
3. **Investigate the storage stability of Niosomes over a specified period under various conditions.**
4. **Identify the advantages and limitations of each method in terms of noisome stability.**

MATERIAL AND METHOD

Materials

The following materials were used in this study:

1. **Non-ionic surfactants:** Span 60 (Sorbitanmonostearate) - 2 g, Tween 60 (Polysorbate 60) 2 g
2. **Cholesterol:** - 2 g

3. **Organic solvents:** Chloroform - 50 Ml, Ether - 50 mL
4. **Aqueous phase:** Distilled water - 100 mL, Phosphate-buffered saline (PBS, pH 7.4) - 100 mL
5. **Model drug:** Curcumin - 100 mg
6. **Equipment:** Ultrasonicator (Sonicator, Model: Q700), Rotary evaporator (Model: HeidolphHei-VAP), Dynamic light scattering (DLS) instrument (Model: Malvern Zetasizer Nano ZS), UV-visible spectrophotometer (Model: Shimadzu UV-1800), Centrifuge (Model: Eppendorf 5804 R), pH meter (Model: Thermo Scientific Orion Star A211)

Methods

Preparation of Niosomes

Niosomes were prepared using two different methods: sonication and ether injection. The same surfactant composition (Span 60 and Tween 60 in a 1:1 ratio) and cholesterol were used in both methods to ensure comparability.

Sonication Method

Formulation of Niosomes: Dissolve 2 g of Span 60 and 2 g of Tween 60, and 2 g of cholesterol in 50 mL of chloroform in a round-bottom flask.Add 100 mg of curcumin to the mixture. Remove the chloroform using a rotary evaporator at 60°C under reduced pressure to form a thin film on the flask wall. Hydrate the thin film with 100 mL of PBS (pH 7.4) by rotating the flask at 60°C for 1 hour. Sonicate the hydrated suspension using a probe sonicator at 20 kHz for 15 minutes, with a pulse on for 5 seconds and off for 5 seconds to prevent overheating.

Characterization of Niosomes: Measure the size distribution using a dynamic light scattering (DLS) instrument. Determine the encapsulation efficiency by centrifuging the niosome suspension at 15,000 rpm for 30 minutes and measuring the absorbance of the supernatant at 425 nm using a UV-visible spectrophotometer. The encapsulation efficiency (EE%) is calculated using the formula:

$$EE\% = \text{Amount of free curcumin in supernatant} / \text{Total amount of curcumin} \times 100$$

Storage Stability: Store the noisome suspension at 4°C, 25°C, and 37°C.Monitor changes in size distribution and encapsulation efficiency over 30 days, with measurements taken on days 0, 7, 14, 21, and 30.

Ether Injection Method

Formulation of Niosomes: Dissolve 2 g of Span 60, 2 g of Tween 60, and 2 g of cholesterol in 50 mL of ether. Add 100 mg of curcumin to the mixture. Inject the ether solution slowly into 100 mL of PBS (pH 7.4) under constant stirring at 60°C.Continue stirring until all the ether evaporates, forming Niosomes.

Characterization of Niosomes: Measure the size distribution using a dynamic light scattering (DLS) instrument. Determine the encapsulation efficiency by centrifuging the noisome suspension at 15,000

rpm for 30 minutes and measuring the absorbance of the supernatant at 425 nm using a UV-visible spectrophotometer. The encapsulation efficiency (EE%) is calculated using the formula:

EE% = Amount of free curcumin in supernatant / Total amount of curcumin x 100

Storage Stability: Store the noisome suspension at 4°C, 25°C, and 37°C.Monitor changes in size distribution and encapsulation efficiency over 30 days, with measurements taken on days 0, 7, 14, 21, and 30.

Comparative Analysis

To compare the stability of Niosomes prepared by the Sonication and ether injection methods, several parameters were evaluated:

1. **Size Distribution:** Size distribution of Niosomes was measured using a dynamic light scattering (DLS) instrument. The mean particle size and polydispersity index (PDI) were recorded.
2. **Encapsulation Efficiency:** Encapsulation efficiency was determined by measuring the amount of free curcumin in the supernatant after centrifugation. The absorbance was measured at 425 nm using a UV-visible spectrophotometer.
3. **Storage Stability:** Changes in size distribution and encapsulation efficiency were monitored over 30 days at different temperatures (4°C, 25°C, and 37°C). Measurements were taken on days 0, 7, 14, 21, and 30 to evaluate the stability of the Niosomes.
4. **Statistical Analysis:** All experiments were performed in triplicate, and the results were expressed as mean ± standard deviation. Statistical analysis was performed using Graph Pad Prism software. Differences between groups were analyzed using one-way ANOVA followed by Tukey's post-hoc test. A p-value < 0.05 was considered statistically significant.

Additional Characterization

To gain a comprehensive understanding of the stability and properties of Niosomes, additional characterization was performed:

1. **Morphology:** The morphology of Niosomes was examined using transmission electron microscopy (TEM). Samples were prepared by placing a drop of noisome suspension on a carbon-coated copper grid, followed by negative staining with 1% phosphotungstic acid. The grid was then air-dried and observed under a TEM.
2. **Zeta Potential:** The zeta potential of Niosomes was measured using a zeta potential analyzer (Malvern Zetasizer Nano ZS). Zeta potential provides information about the surface charge of the Niosomes, which can influence their stability and interactions with biological membranes.
3. **In Vitro Release Study:** The release profile of curcumin from Niosomes was studied using a dialysis method. Noisome suspensions (2 mL) were placed in a dialysis bag (MWCO 12-14 kDa) and immersed in 50 mL of PBS (pH 7.4) at 37°C with continuous stirring. At predetermined intervals (0, 1, 2, 4, 8, 12, 24, 48, and 72 hours), 1 mL of the release medium was withdrawn and replaced with fresh PBS. The amount of curcumin released was quantified using a UV-visible spectrophotometer at 425 nm.

4. **pH Stability:** The stability of Niosomes was also evaluated at different pH levels (pH 5, 7.4, and 9) to mimic various physiological conditions. Noisome suspensions were incubated at these pH levels, and changes in size distribution and encapsulation efficiency were monitored over 30 days.

RESULT AND DISCUSSION

Size Distribution

The size distribution of Niosomes is a critical factor influencing their stability, drug release, and overall performance in drug delivery applications. The size distribution of Niosomes prepared by the Sonication and ether injection methods was measured using dynamic light scattering (DLS). The mean particle size and polydispersity index (PDI) of Niosomes were recorded immediately after preparation and monitored over 30 days under different storage conditions (4°C, 25°C, and 37°C).

Table 1: Initial Size Distribution

Preparation Method	Mean Particle Size (nm)	Polydispersity Index (PDI)
Sonication	121.4 ± 5.2	0.234 ± 0.012
Ether Injection	178.6 ± 8.3	0.312 ± 0.018

The initial size distribution analysis revealed that Niosomes prepared by the Sonication method had a smaller mean particle size and a lower PDI compared to those prepared by the ether injection method. The Sonication method produced Niosomes with a mean particle size of 121.4 nm and a PDI of 0.234, indicating a more uniform size distribution. In contrast, the ether injection method resulted in Niosomes with a mean particle size of 178.6 nm and a PDI of 0.312, suggesting a broader size distribution (table 1).

Size Distribution Over Storage

The size distribution of Niosomes was monitored over 30 days at 4°C, 25°C, and 37°C. The changes in mean particle size are presented in the tables 2, 3, 4 below.

Table 2: Storage at 4°C

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	122.1 ± 5.4	182.4 ± 8.7
14	123.3 ± 5.6	185.7 ± 8.9
21	124.5 ± 5.9	189.2 ± 9.2

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
30	125.8 ± 6.1	193.1 ± 9.5

Table 3: Storage at 25°C

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	123.6 ± 5.5	188.2 ± 8.8
14	125.9 ± 5.8	197.4 ± 9.4
21	128.4 ± 6.2	204.3 ± 9.8
30	131.2 ± 6.5	210.7 ± 10.2

Table 4: Storage at 37°C

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	126.5 ± 5.6	198.7 ± 9.3
14	132.4 ± 5.9	215.4 ± 10.1
21	138.6 ± 6.4	230.8 ± 10.8
30	145.2 ± 6.8	248.6 ± 11.4

The size distribution analysis over storage showed that Niosomes prepared by the Sonication method exhibited smaller increases in mean particle size compared to those prepared by the ether injection method. At 4°C, the mean particle size of sonicated Niosomes increased by approximately 4.4 nm over 30 days, while the mean particle size of ether-injected Niosomes increased by 14.5 nm. The trend was similar at 25°C and 37°C, with sonicated Niosomes demonstrating better size stability.

Encapsulation Efficiency

Encapsulation efficiency (EE) is a key parameter indicating the amount of drug successfully entrapped within the Niosomes. The EE of curcumin-loaded Niosomes was determined immediately after preparation and monitored over 30 days under different storage conditions.

Table 5: Initial Encapsulation Efficiency

Preparation Method	Encapsulation Efficiency (EE%, ± SD)
Sonication	72.4 ± 2.3
Ether Injection	65.8 ± 2.7

The initial encapsulation efficiency results indicated that Niosomes prepared by the Sonication method had a higher EE (72.4%) compared to those prepared by the ether injection method (65.8%) represented in table 5.

Encapsulation Efficiency Over Storage

The encapsulation efficiency of Niosomes was monitored over 30 days at 4°C, 25°C, and 37°C. The changes in EE are presented in the tables 6, 7, 8 below.

Table 6: Storage at 4°C

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	71.8 ± 2.2	64.9 ± 2.6
14	70.9 ± 2.1	63.5 ± 2.5
21	69.7 ± 2.0	62.2 ± 2.4
30	68.5 ± 1.9	60.8 ± 2.3

Table 7: Storage at 25°C

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	70.3 ± 2.1	63.2 ± 2.5
14	68.1 ± 2.0	60.4 ± 2.3
21	65.7 ± 1.9	57.3 ± 2.1
30	63.2 ± 1.7	54.1 ± 2.0

Table 8: Storage at 37°C

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	68.9 ± 2.1	59.7 ± 2.4
14	64.2 ± 1.8	53.6 ± 2.2
21	59.5 ± 1.6	47.1 ± 2.0
30	54.7 ± 1.4	41.3 ± 1.8

The encapsulation efficiency analysis over storage showed that Niosomes prepared by the sonication method exhibited better EE stability compared to those prepared by the ether injection method. At 4°C, the EE of sonicated Niosomes decreased by 3.9% over 30 days, while the EE of ether-injected Niosomes decreased by 5%. The trend was more pronounced at 25°C and 37°C, with sonicated Niosomes demonstrating superior encapsulation efficiency stability.

Morphology

The morphology of Niosomes was examined using transmission electron microscopy (TEM). Representative TEM images of Niosomes prepared by the Sonication and ether injection methods are shown below.

Sonication Method: Niosomes prepared by the Sonication method appeared as spherical vesicles with a uniform size distribution. The vesicles were well-defined and exhibited smooth surfaces.

Ether Injection Method: Niosomes prepared by the ether injection method also appeared as spherical vesicles but with a broader size distribution. Some vesicles showed irregular shapes and sizes, indicating a less uniform preparation process.

Zeta Potential

The zeta potential of Niosomes provides information about their surface charge, which can influence their stability and interactions with biological membranes. The zeta potential of Niosomes prepared by the Sonication and ether injection methods was measured.

Table 9: Initial Zeta Potential

Preparation Method	Zeta Potential (mV, ± SD)
Sonication	-34.2 ± 1.5
Ether Injection	-28.7 ± 1.8

The initial zeta potential measurements indicated that Niosomes prepared by the Sonication method had a higher negative surface charge (-34.2 mV) compared to those prepared by the ether injection method (-28.7 mV) shown in table 9. This higher negative charge could contribute to the improved stability of sonicated Niosomes due to enhanced electrostatic repulsion between particles.

In Vitro Release Study

The release profile of curcumin from Niosomes was studied using a dialysis method. The cumulative release of curcumin over 72 hours was measured and is presented in the table below.

Table 10: Cumulative Release of Curcumin

Time (hours)	**Sonication (Cumulative Release % ± SD)**	**Ether Injection (Cumulative Release % ± SD)**
0	0.0 ± 0.0	0.0 ± 0.0
1	6.8 ± 0.4	8.3 ± 0.5
2	12.7 ± 0.6	15.9 ± 0.7
4	21.4 ± 0.8	27.6 ± 1.1
8	34.5 ± 1.2	41.8 ± 1.4
12	44.8 ± 1.5	53.3 ± 1.8
24	62.3 ± 2.0	68.7 ± 2.3
48	78.1 ± 2.4	84.9 ± 2.7
72	88.4 ± 2.6	93.2 ± 3.0

The in vitro release study showed that Niosomes prepared by the ether injection method exhibited a faster release of curcumin compared to those prepared by the Sonication method. The cumulative release of curcumin from ether-injected Niosomes reached 93.2% at 72 hours, whereas the cumulative release from sonicated Niosomes was 88.4% (table 10). The slower release profile of sonicated Niosomes could be beneficial for sustained drug delivery applications.

pH Stability

The stability of Niosomes was also evaluated at different pH levels (pH 5, 7.4, and 9) to mimic various physiological conditions. The changes in size distribution and encapsulation efficiency were monitored over 30 days.

Size Distribution at Different pH Levels

Table 11: Size Distribution at pH 5

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	124.7 ± 5.5	183.2 ± 8.7
14	127.8 ± 5.8	187.9 ± 9.0
21	130.9 ± 6.1	192.6 ± 9.3
30	134.1 ± 6.3	197.4 ± 9.6

Table 12: Size Distribution at pH 7.4

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	122.1 ± 5.4	182.4 ± 8.7
14	123.3 ± 5.6	185.7 ± 8.9
21	124.5 ± 5.9	189.2 ± 9.2
30	125.8 ± 6.1	193.1 ± 9.5

Table 13: Size Distribution at pH 9

Day	Sonication (Mean Particle Size ± SD, nm)	Ether Injection (Mean Particle Size ± SD, nm)
0	121.4 ± 5.2	178.6 ± 8.3
7	125.6 ± 5.6	184.5 ± 8.8
14	129.8 ± 5.9	190.2 ± 9.1
21	134.2 ± 6.3	195.8 ± 9.4
30	138.6 ± 6.7	201.6 ± 9.7

Encapsulation Efficiency at Different pH Levels

Table 14: Encapsulation Efficiency at pH 5

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	71.1 ± 2.2	64.3 ± 2.6
14	69.8 ± 2.1	62.9 ± 2.5
21	68.4 ± 2.0	61.4 ± 2.4
30	67.1 ± 1.9	60.0 ± 2.3

Table 15: Encapsulation Efficiency at pH 7.4

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	71.8 ± 2.2	64.9 ± 2.6
14	70.9 ± 2.1	63.5 ± 2.5
21	69.7 ± 2.0	62.2 ± 2.4
30	68.5 ± 1.9	60.8 ± 2.3

Table 16: Encapsulation Efficiency at pH 9

Day	Sonication (EE% ± SD)	Ether Injection (EE% ± SD)
0	72.4 ± 2.3	65.8 ± 2.7
7	70.9 ± 2.1	63.6 ± 2.5
14	69.3 ± 2.0	61.4 ± 2.3
21	67.8 ± 1.9	59.1 ± 2.2
30	66.2 ± 1.8	56.9 ± 2.1

The pH stability studies indicated that Niosomes prepared by the Sonication method exhibited better stability in terms of size distribution and encapsulation efficiency across different pH levels. This stability suggests that sonicated Niosomes are more robust and can maintain their integrity under varying physiological conditions, making them suitable for diverse drug delivery applications.

Discussion

The comparative stability study of Niosomes prepared by the Sonication method and ether injection method revealed significant differences in their physicochemical properties and stability profiles.

Size Distribution: Niosomes prepared by the Sonication method had a smaller mean particle size and a narrower size distribution compared to those prepared by the ether injection method. This uniformity is advantageous for drug delivery applications as it ensures consistent behavior and predictable pharmacokinetics.

Encapsulation Efficiency: The Sonication method resulted in higher encapsulation efficiency of curcumin compared to the ether injection method. The higher EE observed with sonicated Niosomes can be attributed to the efficient encapsulation process facilitated by the Sonication technique, which ensures better incorporation of the drug within the noisome vesicles.

Storage Stability: The size distribution and encapsulation efficiency of sonicated Niosomes were more stable over 30 days of storage at different temperatures compared to ether-injected Niosomes. This enhanced stability can be attributed to the more uniform particle size and higher zeta potential of sonicated Niosomes, which contribute to reduced aggregation and leakage of the encapsulated drug.

Morphology: TEM analysis confirmed the spherical shape and uniform size of sonicated Niosomes, while ether-injected Niosomes showed a broader size distribution with some irregularly shaped vesicles. The uniform morphology of sonicated Niosomes further supports their stability and suitability for drug delivery applications.

Zeta Potential: The higher negative zeta potential of sonicated Niosomes indicates greater surface charge, which enhances their colloidal stability by preventing aggregation through electrostatic repulsion. This characteristic is crucial for maintaining the stability and dispensability of noisome.

CONCLUSION

In this comparative study, Niosomes prepared by the Sonication and ether injection methods were evaluated for their stability and encapsulation efficiency. The findings indicate that Niosomes prepared via Sonication demonstrated superior stability, with a smaller and more uniform particle size, higher encapsulation efficiency, and better retention of these properties over time and under various storage conditions. Additionally, the sonicated Niosomes exhibited higher zeta potential and more consistent morphology, further contributing to their stability. Conversely, Niosomes prepared by the ether injection method showed larger particle sizes, broader size distribution, and lower encapsulation efficiency, with greater variability over time. These results suggest that the Sonication method is more effective for preparing stable Niosomes, making it a preferable technique for applications in drug delivery.

REFERENCES

1. Moghassemi, S., &Hadjizadeh, A. (2014). Nano-niosomes as nanoscale drug delivery systems: An illustrated review. Journal of Controlled Release, 185, 22-36.
2. Sankhyan, A., &Pawar, P. (2012). Recent trends in niosome as vesicular drug delivery system. Journal of Applied Pharmaceutical Science, 2(6), 20-32.
3. Chauhan, A., &Sanyal, S. (2017). Niosomes as efficient drug delivery systems: Advances and applications. Indian Journal of Pharmaceutical Sciences, 79(1), 41-49.
4. Uchegbu, I. F., &Vyas, S. P. (1998). Non-ionic surfactant based vesicles (niosomes) in drug delivery. International Journal of Pharmaceutics, 172(1-2), 33-70.
5. Varshosaz, J., &Pardakhty, A. (2007). Niosome as carriers of antigens and vaccines. Iranian Journal of Pharmaceutical Research, 6(2), 1-8.
6. Bhardwaj, P., Tripathi, P., Gupta, R., &Pandey, S. (2020). Niosomes: A review on niosomal research in the last decade. Journal of Drug Delivery Science and Technology, 56, 101581.
7. Alsarra, I. A. (2009). Evaluation of proniosomes-derived niosomes containing captopril for oral administration. AAPS PharmSciTech, 10(1), 183-192.
8. Pardakhty, A., Moazeni, E., &Najafabadi, A. R. (2011). The effect of formulation variables on the properties of niosomes of cholesterol, dicetyl phosphate and Span 60 prepared by reverse-phase evaporation method. Iranian Journal of Pharmaceutical Research, 10(3), 505-514.
9. Shilakari, G., Singh, V., &Arora, S. (2013). Formulation and evaluation of niosomal gel of an antihypertensive drug. International Journal of Pharmacy and Pharmaceutical Sciences, 5(3), 595-599.