Research Article

Formulation and Evaluation of Nanosponges of an Antileprosy Drug: Topical Application

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ABSTRACT

Recent advances in nanotechnology have concreted the way to develop nanogels with numerous potential applications in nanomedicine. When compared to other nanocarriers, nanosponges have a large drug loading capacity, making them ideal for resolving operational stability, solubility, and delayed-release, as well as designing drug delivery systems for routes other than oral administration. Nanosponges drug delivery systems have two key advantages: controlled release of loaded actives and improved solubility of poorly water-soluble medicines. The development of nanosponges as drug delivery systems is discussed in this article, with an emphasis on nanosponges based on the emulsion solvent diffusion approach. In this study, an attempt was made to improve drug solubility. It formulated nanosponges-based Dapsone topical gel using Ethylcellulose polymer in various concentrations and Polyvinyl alcohol as a surfactant, which was evaluated for pH, Viscosity, spreadability, percentage of drug release, and kinetics modelling release studies. Among all six formulations, the F5 batch was deemed to have the best entrapped (97%) nanosponges with the highest percentage of drug release (95.89%). The SEM analysis concluded that the formulation particles are porous. The particle size determination concluded that the particles are nano in size, which is recognized in the preparation as Nanosponges.

Keywords: Nanosponges, Anti leprosy Drug, Nanomedicine, and Emulsion solvent diffusion method.Nanosponges, Anti leprosy Drug, Emulsion solvent diffusion method, Dapsone topical gel, Ethylcellulose polymer and Polyvinyl alcohol.

INTRODUCTION

Nanotechnology is the design, manufacture, characterization, and use of numerous nanoscale materials in several prospective fields, especially in medicine, on an atomic, molecular, and supramolecular scale.[1] Medicine, immunology, cardiology, endocrinology, ophthalmology, cancer, and pulmonology are just a few of the domains where nanotechnology might have an influence. It's also popular in specialist fields including brain targeting, tumour targeting, and gene delivery. Nanotechnology may also be used to develop more effective pharmaceutical systems, devices, and materials.

Nanosponges are microscopic sponges around the size of a virus that may be loaded with a variety of medications. These small sponges may circulate the body until they reach a particular target spot, where they attach to the surface and start releasing the medicine in a regulated and predictable way. Because of its unique design, the nanosponges polymeric system uniquely meets the criteria and may also enhance product stability. Nanosponges are already in use in a variety of fields, such as cosmetics and medicines. The engineering capabilities of nanosponges are attributed to the comparatively simple chemistry of their polyesters and crosslinking peptides when compared to many other

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nanoscale drug delivery methods. They are soluble in water but do not dissolve chemically. They may also be carried by mixing them with water. They're employed to cover up undesirable odours and tastes, as well as to turn liquids into solids. The nanosponges may preferentially attach to the target spot due to the chemical linkers.[2]

Fungal infections currently account for about the fourth most common disease globally that affecting millions of people every year. The skin serves as a defence system for the human body. Topical drug delivery systems have established a reputation for themselves and have the potential for efficient drug delivery due to the vehicles used in their preparation that ultimately affect the rate of drug permeation across the skin.[1] Topical delivery provides excellent advantages such as patient compliance due to ease of applicability and non-invasive design, on-site delivery minimizing systemic side effects, and effective targeting ability. The topical form of dapsone is also effective in maximizing the amount of active ingredient in any topical formulation and ensuring the maximization of its transdermal penetration into the body, with potentially fewer side effects. Hence this study presents the development and evaluation of a nanosponges delivery system to improve the dose frequency and avoid possible systemic side effects.[3] The advantages of Nanosponges are compositions remain stable at pH levels ranging from 1 to 11. At higher temperatures, these compositions retain their stability. These formulas may be used with a wide range of vehicles and substances. Because of their 0.25m average pore size, which bacteria cannot penetrate, they are self-sterilizing. These formulas are free-flowing and have the potential to save money. Ingredient entrapment and fewer adverse effects, as well as better stability, elegance, and formulation flexibility, are all benefits of this technique.[4] The disadvantages of Nanosponges are the ability to load drugs is restricted. It is composed entirely of tiny molecules and is only able to hold tiny molecules. Paracrystalline or crystalline nanosponges are available. The degree of crystallisation determines the loading capacity of nanosponges in the first place. Paracrystalline nanosponges have a wide range of loading capabilities.[5]

MATERIALS AND METHODS

Dapsone was purchased from the Tokyo chemical industry.,co ltd, Tokyo and polyvinyl alcohol, dichloromethane, carbopol, methy paraben, triethanolamine, propyleneglycol, ethanol are obtained from mercury scientific lab, Salem, India.

Spectroscopic Studies

UV Spectral Analysis

The ultraviolet and visible spectra (UV–Vis) were collected using a Shimadzu spectrophotometer in the 200–400 nm range; a 2.5×10^{-5} mol L^{-1} ethanolic solution was prepared for this analysis.

Standard Calibration Graph of Dapsone

Weigh the equivalent amount of drug (50mg) was taken in a 100 ml volumetric flask and it was dissolved in a small amount of ethanol. Finally, the volume was made up to the mark with acetate buffer pH 5.5 (Stock 1 i.e., 1000 mg/ml). The secondary stock was prepared by taking 10 ml of primary stock in 100ml of a volumetric flask and the volume was made up to mark(Stock II 100µg/ml). 10 ml from stock II and the volume was made up to the mark (Stock II 10 µg/ml). From the above stock solutions III different concentrations of solutions were prepared (i.e. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10µg/ml with ethanol which were analysed by UV-visible spectrometer at 295 nm.[6] The preparation procedure is given in Table 1 and Figures 1-2.

ATR- FTIR Spectroscopic Studies

To identify and validate the drug, the ATR-FTIR spectrum was used. The spectrum was recorded in the wavelength range of 4000 to 400 cm^{-1}. A uniformly mixed sample of the drug was filled into the die cavity of the sample holder, and an IR spectrum was recorded using an FTIR-IR spectrophotometer.[7] The results are shown in the Figure 3-5.

Table 1: Determination of (λ_{max}) of Dapsone.

Parameters	Value
R^2	0.9946
Slope	0.0212
Intercept	0.005

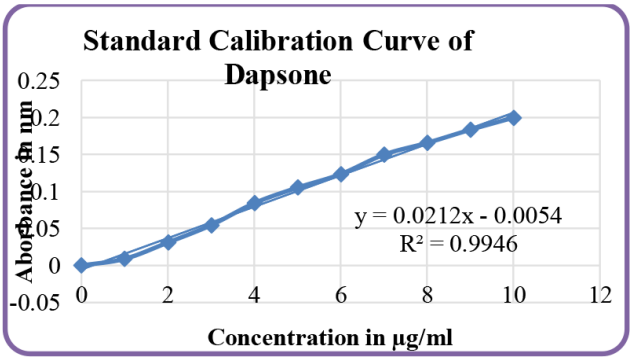

Figure 1: Standard Calibration Graph of Dapsone.

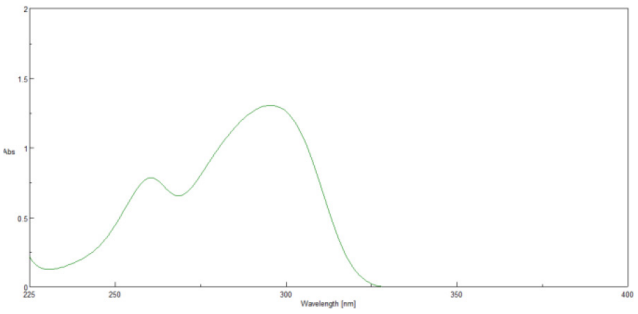

Figure 2: Maximum absorbance of dapsone at 295nm.

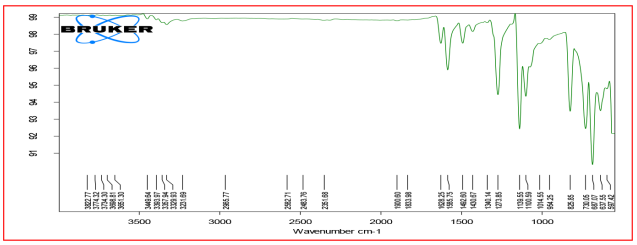

Figure 3: ATR-FTIR spectrum of Pure Dapsone.

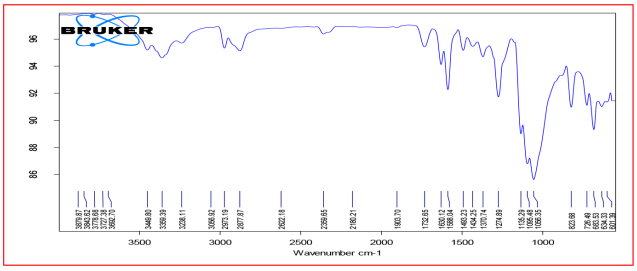

Figure 4: ATR-FTIR spectrum of Pure Dapsone and All Excipients.

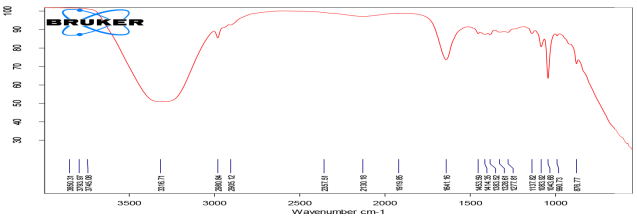

Figure 5: ATR-FTIR spectrum of Dapsone loaded Nanosponges F5 gel.

Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry was used to investigate solid characterization. Using this method, a weighed amount of nanosponges was placed in a crucible. To cover and press the crucible, a pressing machine was used. The crucible was then placed inside the instrument. For DSC analysis, a sample (3–5 g) was heated from 0–25°C in a nitrogen environment at a scanning speed of 100°C/min. The DSC thermogram was used to investigate the solid-state chemistry of the drug in composite polymeric nanosponges.[8] The results are shown in the Figure 6.

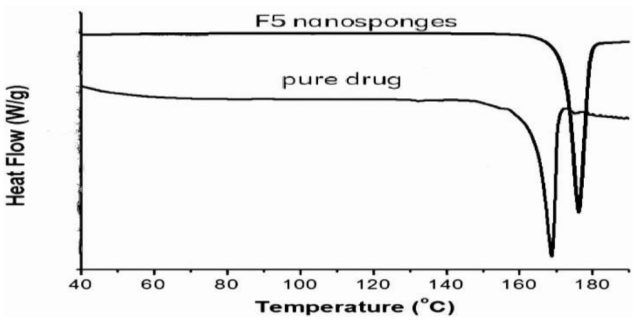

Figure 6: Differential Scanning Calorimetry (DSC) of pure drug anf F5 formulation.

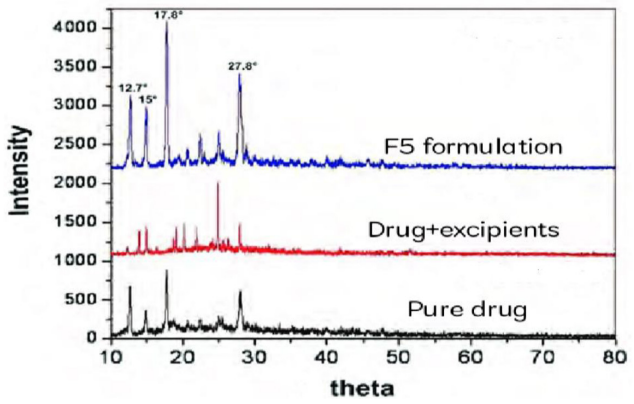

Figure 7: Power x ray diffraction of pure drug, drug+excipients, F5 formulation.

Powder X-Ray diffraction (PXRD)

Diffraction analysis was performed using a powder X-ray diffractometer (Multiflex, M/s. Rigaku, Japan). The sample substances were exposed to nickel-filtered CuK radiation (40kV, 30mA) and scanned from 2 to 70, 2 at a step size of 0.045 and a step period of 0.5s for powder XRD examinations. Separate XRD experiments were carried out on drugs, lipids, physical mixtures of drug and lipid, and lyophilized drug-loaded solid lipid microparticles.[9] The results are shown in the Figure 7.

DETERMINATION OF SOLUBILITY

The solubility of dapsone powder (approximately 1gm) in Dichloromethane, Ethanol and water was studied in a test tube.

PREFORMULATION STUDIES OF PURE DRUG

Preformulation study refers to pharmaceutical and analytical research conducted prior to and supporting

Table 2: Preformulation study such as bulk density, tapped density, hausner ratio, percentage compressibility index, and angle of repose.

Sl. No.	Parameters	Results	Conclusion
1	Bulk Density (gm/cm^3)	0.245	Good
2	Tapped Density (gm/cm^3)	0.326	Good
3	Angle of Repose (θ)	30^0 40'	Excellent
4	Carr's Index (%)	23.5	Excellent Flow
5	Hausner Ratio	1.10	Better Flow

Table 3: Preparation of drug-loaded nanosponges.

Sl. No	Ingredients(mg/ml)	F1	F2	F3	F4	F5	F6
1	Drug	50	50	50	50	50	50
2	Ethyl cellulose	120	100	80	60	40	20
3	Polyvinyl alcohol	10	10	10	10	10	10
4	Dichloromethane	20	20	20	20	20	20
5	Distilled water	100	100	100	100	100	100

formulation development efforts of the drug substance's dosage form. Preformulation provides the fundamental knowledge required to develop a suitable formulation for toxicological use.[9] The preformulations studies for the drug were measured by Bulk Density, Tapped Density, Angle of Repose, Carr's index (or percent compressibility) and Hausner ratio. The results are shown in the Table 2.

FORMULATION DEVELOPMENT OF NANOSPONGES

Preparation of Nanosponges using Emulsion Solvent Diffusion Method

The emulsion solvent diffusion approach was utilised to manufacture drug-loaded nanosponges using a suitable polymer. A precise quantity of medication and polymer has been dissolved in 20 ml of an organic solvent to form the dispersed phase. A particular quantity of copolymer is dissolved in 100 mL of distilled water to form the aqueous phase. Drop by drop, the dispersion phase was introduced to the aqueous phase while stirring at 1000 rpm for roughly 2 hr on a magnetic stirrer. The nanosponges were collected via filtration and then dried in a 40°C oven for around 24 hr.[10] The following is a list of the steps involved in the preparation process Table 3.

Evaluation Studies of Nanosponges

Percentage Yield

The empty container in which the gel formulation had been previously stored and then the container was reweighed with the gel formulation inside.

Table 4: Evaluation of nanosponges formulation F1,F2,F3,F4,F5,F6.

Formulation Code	Percentage yield %	Entrapment efficiency(%)
F1	92.33%	95%
F2	93.75%	94%
F3	94.28%	93%
F4	91.22%	92%
F5	95.89%	97%
F6	91.33%	94%

*Mean±SD (n=3)

Sem Studies

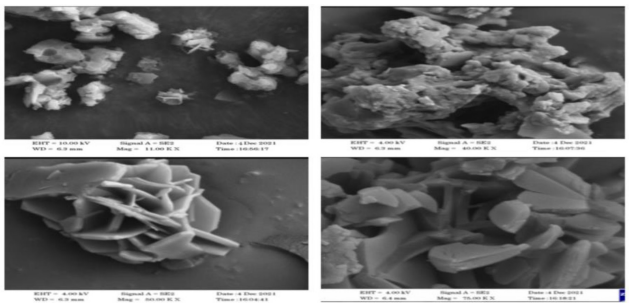

Figure 8: SEM for drug-loaded Nanosponges at X11 K, X40 K, X50 K, X75.

$$\text{Percentage yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times \text{ical}$$

Entrapment Efficiency

The gel was taken from different areas in the mixer and analysed for drug content to verify consistent formation. The results are shown in the Table 4.

$$\text{Entrapment efficiency} = \frac{\text{mass of drug}}{\text{mass of drug in the formulation}} \times \text{ormu}$$

Scanning Electron Microscopy

Scanning electron microscopy was used to analyze the morphology of the nanosponges that had been produced. The SEM may be used to characterize the shape and size of microscopic objects in relation to particle size. The SEM images of optimized drug-loaded nanosponges formulation (F5) were scanned at various magnifications.[11] The results are shown in the Figure 8.

In vitro drug release

Dapsone skin penetration from gel formulation was examined using a Franz diffusion cell. The effective

Table 5: *In vitro* cumulative % drug release profile for nanosponges.

Time(hrs/min)	F1	F2	F3	F4	F5	F6
	Cumulative % drug release					
0	**0**	**0**	**0**	**0**	**0**	**0**
30	**17.09**	**11.39**	**14.01**	**10.21**	**6.21**	**7.54**
1	32.51	20.21	15.09	20.62	8.35	12.17
2	36.42	22.22	25.31	32.72	17.41	24.58
3	45.42	30.09	31.69	36.32	25.74	33.19
4	50.31	34.21	35.03	40.29	33.35	41.79
5	55.51	37.02	39.61	42.25	45.61	48.69
6	59.41	41.35	41.34	47.91	57.87	52.75
7	60.21	44.31	43.65	58.41	61.94	61.38
8	62.72	50.85	45.32	59.86	63.43	67.54
9	65.46	52.31	50.32	61.92	77.29	77.28
10	70.32	60.21	52.09	67.59	89.94	81.19
11	81.31	65.71	59.31	69.43	93.35	84.14
12	83.42	75.09	68.21	70.19	97.59	88.68

*Mean±SD (n=3)

permeation area and receptor cell volume of a diffusion cell were 2.4 cm and 20 ml, respectively. The temperature was maintained at 36 0.5°C throughout the duration of the experiment. A magnetic stirrer continuously swirled 20 ml of pH 5.5 acetic buffer in the receptor compartment at 100 rpm. The egg membrane divided the donor and receptor compartments. On the membrane surface that was not in touch with the acetic buffer, 1g of gel formulation was applied. The contents of the diffusion cell were continually agitated. 1 ml of material was collected from the receptor compartment of the diffusion cell at predefined time intervals and analysed by spectrometric technique at 295 nm after suitable dilution. The receptor phase was immediately supplied with an equivalent amount of fresh pH 5.5 acetic buffer.[12] The results are shown in the Table 5 and Figure 9.

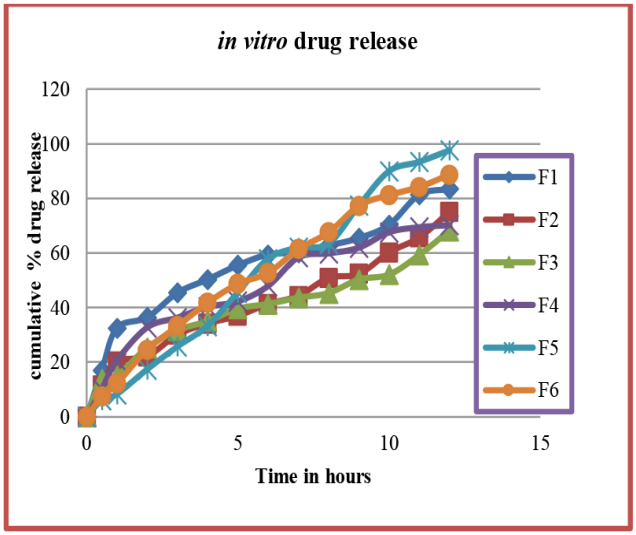

Figure 9: *In vitro* cumulative % drug release profile for nanosponges.

Determination of short-time stability studies for nanosponges

The use of an improved nanosponge formulation for stability testing increased stability conditions at (40°C/75%RH). The nanosponge formulations were tested for load efficiency and *in-vitro* drug release during a three-month period. All of these variables are compared to the original sample and analysed to determine whether it fits the requirements. If it does, the batch is considered to have passed the test.[13] The results are shown in the Table 6.

Table 6: Determination of short-time stability studies for nanosponges.

Parameters	Initial	After One Month 40/75 (°C/ RH)	After Second Month 40/75 (°C/ RH)	After Third Month 40/75 (°C/ RH)
Entrapment efficiency%	94.6	94.2	94.2	93.7
In vitro drug release	96.05	95.57	94.53	94.15

*Mean±SD (n=3)

Table 7: Preparation of drug-loaded nanosponges topical gel.

Sl. No	Ingredients(gm)	F1	F2	F3	F4	F5	F6
1	Equivalent weight Drug loaded nanosponges(50mg)	100	100	100	100	100	100
2	Carbapol	60.00	50.00	40.00	30.00	20.00	10.00
3	Propylene glycol	5.00	5.00	5.00	5.00	5.00	5.00
4	Methyl paraben	2.00	2.00	2.00	2.00	2.00	2.00
5	Triethanolamine (q.s)	1.00	1.00	1.00	1.00	1.00	1.00
	Purified water(q.s)	100	100	100	100	100	100

Table 8: Evaluation of Nanosponges Loaded Topical Gel.

Formulation code	pH	Viscosity(cps)	Spreadability gm.cm²
F1	6.2	30,190.01	11.88
F2	6.8	32,357.30	10.57
F3	6.4	61,102.01	11.10
F4	6.8	97,482.04	10.84
F5	7.1	97,489.04	11.95
F6	6.9	39,273.04	11.09

*Mean±SD (n=3)

Formulation Development of Nanosponges Topical Gel

Transparent carbopol dispersion was made in water with moderate agitation and a frequent sprinkling of carbopol to prevent lump formation, resulting in a clean homogenous dispersion. The formulation of drug-loaded nanosponges was disseminated in polythene glycol and ethanol. The drug solvent system was given a dose of methyl paraben, which was dissolved in water. To neutralize and adjust to the final weight, triethanolamine was used. Ultra sonication was used to de-gas the gel that had been prepared.[14] The preparation procedure is given in the Table 7.

Evaluation of Formulated Gel[15-17]

Determination of pH

A weighted quantity of each gel formulation was transferred to a 10 ml beaker and a digital pH metre was used to measure it. The pH of the topical gel formulation should be between 3 and 9 to treat skin infections. The results are shown in the Table 8.

Determination of Viscosity

The viscosity of a fluid is determined by subjecting it to oscillating vibrations and observing the fluid's damping effects. Measurement of power input, oscillation decay time, or variations in the resonated frequency may all be used to assess these. After preparing a gel with various concentrations of Carbapol, the spindle was cleaned in the instrument. The spindle was then rotated in the gel until a constant reading in the viscometer was displayed. Repeat the methods until the average value is obtained.

Determination of Spreadability

Glass slides and a wooden block, which was provided by a pulley at one end, were used to test spreadability. Spreadability was measured using this method using the Slip and Drag properties of gels. This block was fitted with a ground glass slide. On the ground slide, an excess of gel (approximately 1 g) of various formulations was applied. After that, the gel was sandwiched between this slide and another glass slide with the same dimensions as the fixed ground slide. The excess gel was scraped off the edges, and the top plate was then pulled for 20 g; the shorter time it took to separate the two slides, the greater the spreadability. The following formula was used to determine spreadability.

$$S= ML/T$$

S represents the gel formulation's spreadability.
M, Is the upper plate's weight (g) attached,
The length of the glass plates (in centimetres) is L.
T is the amount of time it takes for the plates to slide the entire length of a track.

In vitro Release Studies

Dapsone skin penetration from gel formulation was examined using a Franz diffusion cell. The effective permeation area and receptor cell volume of the diffusion cell were 2.4 cm and 20 ml, respectively. The temperature was maintained at 36±0.5°C throughout the duration of the experiment. A magnetic stirrer constantly stirred 20 ml of pH 5.5 acetic buffer in the receptor compartment at 100 rpm. The egg membrane divided the donor and receptor compartments. On the membrane surface that was not in touch with the acetic buffer, 1g of gel formulation was applied. The contents of the diffusion cell were continually agitated. 1 ml of material was collected from the receptor compartment of the diffusion cell at predefined time intervals and analysed by spectrometric technique at 295 nm after

Table 9: *In vitro* cumulative % drug release profile for Dapsone.

Time (hrs/min)	F1	F2	F3	F4	F5	F6	Marketed formulation
	Cumulative % drug release						
0	0	0	0	0	0	0	0
30	19.09	13.39	13.01	11.21	4.11	6.54	30.54
1	33.51	23.21	14.09	21.62	8.15	13.17	51.59
2	38.42	27.22	26.31	31.72	15.21	25.58	62.41
3	47.42	33.09	30.69	34.32	28.54	34.19	73.62
4	51.31	36.21	32.03	38.29	36.45	40.79	80.35
5	57.51	39.02	34.61	41.25	46.21	49.69	87.71
6	60.41	44.3	36.3	45.91	54.77	53.75	91.83
7	62.21	48.31	43.65	53.41	60.34	62.38	93.57
8	66.72	50.85	44.32	58.86	67.73	68.54	95.36
9	73.46	56.31	48.32	60.92	78.69	76.28	0.87
10	79.32	66.21	52.09	63.59	86.54	80.19	0.69
11	86.31	70.71	57.31	66.43	92.15	82.14	0.55
12	88.42	74.09	66.21	68.19	96.49	87.68	0.32

*Mean±SD (n=3)

Evaluation of Nanosponges Loaded Topical Gel

In vitro Drug Permeation Studies

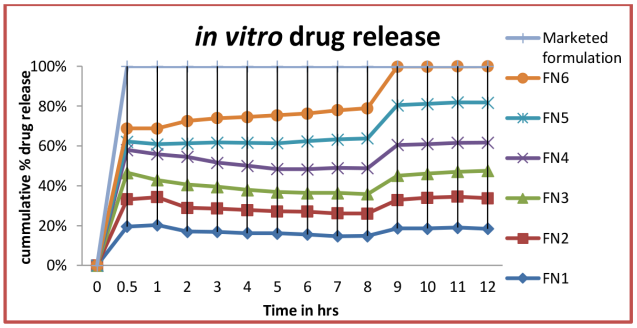

Figure 10: Cumulative % Release Graphs for the Formulations F1, F2,F3.F4,F5,F6.

suitable dilution. The receptor phase was immediately supplied with an equivalent amount of fresh pH 5.5 acetic buffer.[12] The results are shown in the Table 9 and Figure 10.

Stability Studies

At (40°C/75 % RH), the optimised nanosponge formulation for stability determination accelerated stability conditions. The pH, Spreadability, and viscosity of nanosponge formulations were tested during a three-month period. All of these characteristics are compared to the first sample and analysed to determine whether it satisfies the criteria. The batch has passed the test if this is the case.[13] The results are shown in the Table 10.

RESULTS

UV SPECTROSCOPIC STUDIES

Standard Calibration Graph of Dapsone

Sl. No.	Concentration (mcg/ml)	Absorbance
1	1	0.0089
2	2	0.031
3	3	0.0544
4	4	0.0841
5	5	0.1051
6	6	0.1233
7	7	0.1496
8	8	0.1655
9	9	0.1833
10	10	0.1996

Solubility Studies

Dapsone solubility studies were carried out in test tubes using dichloromethane, ethanol, and distilled water. Dapsone is soluble in dichloromethane at 30mg/ml and ethanol at 10mg/ml, but it is insoluble in water.

Preformulation Studies

Preformulation research refers to pharmaceutical and analytical research conducted before and in support of formulation development activities for a pharmacological substance's dosage form. Preformulation provides the foundational information required to generate appropriate formulations for toxicological application.

Table 10: Stability studies of optimized formulation F5 at an accelerated temperature of 40ºC.

Parameters	Initial	After 1 month		After 2 month		After 3 month	
		A.T	R.T	A.T	R.T	A.T	R.T
Appearance	White	White	White	White	White	White	White
pH	6.5	6.6	6.6	6.6	6.6	6.8	6.8
Viscosity(cps)	33255±516	33255±516	33255±516	33254±515	33254±515	33254±515	33254±515
Spreadability(cm)	7.8	7.8	7.8	7.8	7.8	7.7	7.7

*Mean±SD (n=3)

DISCUSSION[19-20]

UV Spectroscopic Studies

The scanning of the 10µg/ml solution of Dapsone in the ultraviolet range (200-400nm) the maximum peak observed at λ_{max} as 295 nm. The standard concentrations of Dapsone were produced and showed high linearity, with an R^2 value of 0.9946, indicating that it follows the Beer-Lambertslaw. Calibration curve was plotted against drug concentrations versus absorbance.

ATR- FTIR Spectroscopic Studies

Based on the findings, it can be concluded that there were no extra peaks in the physical mixture and that all of the excipients are API compliant. Excipients have no interaction with API, according to the compatibility research conducted at ATR-FTIR.

Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry was utilised to assess the pure drug's compatibility and adjust the formulation based on the findings. The improved formulation and pure drug DSC thermograms revealed a pronounced endothermic peak at 175–176°C, which matched its melting point.

Powder X-ray diffraction

The crystallinity of a pure drug, a pure drug with excipients, and optimal formulation F5 may be determined using the peak size and shape of XRD. According to the graph above, reducing the crystalline form of the medicine and excipients improves the medication's solubility and release.

Solubility Studies

Dapsone solubility studies were carried out in test tubes using dichloromethane, ethanol, and distilled water which helps for the solvent selection used for further studies.

Preformulation Studies

It provides the necessary information to describe the nature of the drug substance as well as a framework for the drug combination with pharmaceutical receivers in dose form. As a result, the following preformulation investigations were carried out on the medication sample acquired. As per-flow ability scale, the drug has good characteristics to flow. The pure drug did not make any effect on the flow of the blend. Then bulk density was found to be 0.245g/cm^3, tapped density was found to be 0.326g/cm^3, angle of repose was found to be 30^0 40'.cars indexes was found to be 23.5% as excellent flow, Hausner ratio was found to be 1.10 as better flow. The micrometric characteristics are within the pharmacopeial specifications.

Evaluation of Nanosponges

Determination of percentage yield

The emulsion solvent diffusion technique was used to make nanosponges. The % yield of nanosponges was calculated based on the findings from 91.22% to 95.89%. when PVA and ethyl cellulose were used in the preparation of nanosponges. It shows that reducing the polymer concentration increased the production of yield.

Entrapment Efficiency

From the results, the entrapment efficiency of prepared nanosponges that had ranged from 92%to 97%. when PVA was used in the preparation of nanosponges, It was found that lowering the polymer concentration increased the nanosponges' trapping effectiveness. The entrapment efficiency of F5 entrapment was found to be 97%, which indicates the F5 formulation exhibited the maximum entrapment efficiency percentage with drug content loaded.

SEM Studies

Scanning Electron Microscopy SEM analyses of the formulated dapsone nanosponges were performed to evaluate the surface morphology of nanosponges. Here SEM study for the formulation, SEM images are visible in 75x, 50x, 40x, 11x shows nanosponges was porous with a smooth surface morphology and spherical in shape at 200nm range. Due to evaporation of the solvent, the nanosponge's shell was found to be

smooth and porous where the outer surface was shiny and smooth and the inner surface was porous.

In vitro Drug Release

The *in vitro* release studies of gel from an optimised formulation are based on the above findings FN1 to FN6 were performed. In *in vitro* release studies, formulation FN1 – 83.42%, FN2 – 75.09%, FN3 – 68.21%, FN4 – 70.19%, FN5 – 97.59% and FN6 – 88.68%, based on this study the Nanosponges formulation FN1 to FN6 are selected to formulate as a topical gel.

Determination of Short-time stability Studies for Nanosponges

At 40°C/75 % RH for 3 months, a stability study was performed for the optimised formulation of nanosponges according to ICH guidelines. The results revealed that the nanosponges' physical and chemical characteristics did not change much, indicating that the formulation (F5) was stable.

Evaluation of Nanosponges Loaded Topical Gel

Determination of pH

The pH of the formulation was determined in order to ensure that it can be used without causing skin irritation. The pH range of the formulations F1 to F6 of dapsone-loaded nanosponges is 6.2 to 7.1, while F5 has a pH range of 7.1, so the formulation can be used without risk of skin irritation. This also indicated that the formulation's ingredients had no effect on the pH of the formulation

Determination of Viscosity

A formulation's viscosity is determined by its physicochemical properties as well as the temperature conditions. The measurement of this parameter helps in identifying the right consistency and fluidity of the product, as well as demonstrating its performance over time. During storage stability, the outcome of a viscosity assessment is a function of time. The viscosity of F1 to F6 has a range of 30,190.01cps to 97,489.04 cps. In that F5 formulation of drug-loaded nanosponges topical gel in the range of 97,489.04cps.

Determination of Spreadability

The spreadability of formulations was found to decrease with increasing gelling agent concentration F1 to F6 was 10.57cm to 11.95cm. Spreadability of the F5 formulation value for optimised nanosponges gel was found to be 11.95cm. It ensures that the formulation has a good wet contact duration and is easily applied without runoff when applied to the application site.

In vitro Drug Permeation Studies

The *in vitro* release studies of gel from an optimised formulation are based on the above findings FN1 to FN6 were performed. In *in vitro* release studies, formulation FN1 – 88.42%, FN2 – 74.09%, FN3 – 66.21%, FN4 – 68.19%, FN5 – 96.49% and FN6 – 87.68%, In that FN5 drug-loaded nanosponges as the highest drug release rate of 96.49%, indicating that it was an optimized formulation. When compared to marketed formulations, carbopol gel containing nanosponges formulation FN5 produced better spreadability and consistency. The FN5 nanosponges gel developed demonstrated appropriate pH, no skin irritation, and good spreadability are within the pharmacopeial specifications.

Stability Studies

The stability study was undertaken in the investigation of the stability of topical gel formulation strategies as per ICH guidelines. The stability studies for the optimized F5 gel formulation were conducted for a period of three months. The study results indicated negligible levels of changes were observed in appearance, pH, viscosity, and spreadability indicating that stability problems during storage at accelerated temperature and 40°C/75% RH were observed. Appearance of the gel is white, pH was found to be 6.5-6.8, viscosity was found in the range of 33254±515 cps to 33255±516 cps, spreadability was found to be 7.7 cm to 7.8 cm are within the pharmacopeial specifications.

SUMMARY AND CONCLUSION

Dapsone-loaded nanosponges were initially developed for drug delivery through the use of a topical application. It delivers drugs to specific sites in a targeted manner. Because of their use, can solubility and poorly water-soluble drugs improve drug bioavailability. Nanosponges include upper a novel method of encapsulating a medicine in a polymeric substance. Following the preparation of nanosponges formulations using formulation codes F1, F2, F3, F4, F5, and F6, the results of evaluation studies such as percentage yield, entrapment efficiency, Surface morphology, *in vitro* release studies, and stability studies for a three-month period revealed that there was no significant change in physical and chemical parameters of the nanosponges, indicating that formulation (F5) was found to be an optimised formulation. Then, utilising formulation codes FN1, FN2, FN3, FN4, FN5, and FN6, the improved formulation was used to generate a gel formulation that underwent evaluation tests such as pH, viscosity, spreadability, and *in vitro*

release experiments and stability studies over a three-month period. Based on these data, it can be concluded that Dapsone-loaded nanosponges gel formulations, especially the FN5, offer regulated site-specific drug release, better formulation efficiency, improved stability, drug dosage, and patient compliance.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

ATR-FTIR: Attenated Total Reflectance-fourier Transform Infrared; **A.T:** Accelerated Tempeture; **DSC:** Differential Scanning Calorimetry; **FN:** Formulation Nanosponges; **NS:** Nanosponges; **R.T:** Room Temperature.

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