IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 11, April 2025
Impact Factor: 7.67

Formulation and Evaluation of Nanosponges Loaded Terminalia Chebula Gel for Wound Healing

Miss. Poonam A. Jadhav, Ms. Anagha Anil Galande,
Mr. Chetan Abasaheb Gaikwad, Mr. Harsh Ramchandra Gabhale
PDEA Shankarrao Ursal Collage of Pharmaceutical Sciences and Research Centre, Kharadi, Pune

Abstract: *Terminalia chebula, a key herb in traditional Ayurvedic medicine, is known for its potent antioxidant, antimicrobial, and anti-inflammatory properties, making it a suitable candidate for wound healing applications. To enhance its therapeutic efficacy and overcome limitations such as poor solubility and stability, a novel nanosponge-based gel formulation was developed. Nanosponges were prepared using the quasi-emulsion solvent diffusion method and loaded with ethanolic extract of Terminalia chebula. These nanosponges were further incorporated into a Carbopol 934-based gel to facilitate sustained topical delivery at the wound site and to minimize systemic dispersion.*

The formulated nanosponges and nanosponge gel were evaluated for various physicochemical and in vitro parameters, including particle size, entrapment efficiency, pH, spreadability, viscosity, drug content, and in vitro drug release. The results demonstrated satisfactory characteristics, with sustained drug release and good stability. The incorporation of Terminalia chebula extract into a nanosponge gel system presents a promising strategy for effective and safe wound healing, offering the advantages of enhanced bioavailability, prolonged action, and localized therapeutic effect..

Keywords: Nanosponges, Terminalia chebula ,Wound healing, Gel

I. INTRODUCTION

Nanotechnology is defined as designing and alteration of materials at nanoscale levels to create products that shows advanced properties.The term “Nanosponge” means the nanoparticles having porous structures. It provides solution for several formulation related problems. Owing to their small size and porous nature they can bind poorly- soluble drugs within the matrix and improve their bioavailability by modifying the pharmacokinetic parameters of actives.[2] The average diameter of a nanosponge is below 1 µm but fractions below 500 nm can be selected.[3]The nanosponges are encapsulating type of nanoparticles which encapsulates the drug molecules within its core. Now regarding its mechanism of drug release, the sponge particles contain an open structure and it contains the active ingredients which are free to move in and out from the particles and into the medium until equilibrium is reached. In case of topical drug delivery, once the finished product is applied to the target tissue, the active ingredient which is already present in the vehicle will be absorbed into it, depleting the vehicle, which will become unsaturated, hence disturbing the equilibrium. This will lead to flow of the active drug ingredient from the sponge particles into the vehicle and from it to the target tissue until the vehicle is either dried/absorbed.

The USP defines gels (sometimes called jellies) as semisolid systems containing either suspensions made up of small inorganic particles, or large organic molecules diffused by a liquid.

A wound is a serious injury resulting from damage or disruption to the skin's normal structure and function.Wound healing is a complex process involving four stages: haemostasis, inflammation, proliferation and remodelling, regulated by growth factors, cytokines and ECM (Extracellular matrix) proteins.

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II. MATERIAL AND EQUIPMENTS

The raw materials like drug, polymers, excipients, and chemicals required for the present work were procured from different sources. Following materials were used for the formulations and evaluation of Nano sponges and gel

Sr.no	Drug/Excipients/Polymer/Solvent	Manufacturer
1	Fruit of Terminalia chebula	Botanical Survey of India,Western Regional Centre, Pune.
2	Ethyl cellulose	Research-Lab Fine Chem Industries, Mumbai.
3	HydroxyPropylMethylCellulose	Research-Lab Fine Chem Industries, Mumbai.
4	Dichloromethane	Siso Research Laboratories Pvt.Ltd, New Mumbai.
5	Carbopol 934	Research-Lab Fine Chem Industries, Mumbai.
6	Methylparaben	Research-Lab Fine Chem Industries, Mumbai.
7	Propylparaben	Research-Lab Fine Chem Industries, Mumbai.
8	Triethanolamine	Research-Lab Fine Chem Industries, Mumbai.

Table No 1: List of Drug, Excipients, Polymer and Solvent

Preformulation studies:

Characterization of Terminalia chebula extract:

a. Organoleptic properties:

Terminalia chebula fruit extract was evaluated for its organoleptic properties such as colour, odour, and taste.

b. Determination of pH:

The crude powder of Terminalia chebula was dissolved in distilled water and was kept in water bath for 20 min, filtered and then pH of the filtrate was noted down with the help of pH meter.

c.Preliminary Phytochemical Screening:

Preliminary phytochemical screening means to investigate the plant material in terms of its active constituents. In order to detect the various constituents present in the Aqueous extracts of Terminalia chebula, was subjected to the phytochemical tests as per standard methods (Khandelwal, 2015, 25th edition)

Identification of Terminalia chebula extract:

1. Ultraviolet spectroscopy:

The UV spectrum of Terminalia chebula extract in distilled water was obtained using Jasco UV spectrophotometer (Jasco V-730 Spectrophotometer, Japan). Scanning was carried over a wavelength region of 200-400 nm.

2. Infrared spectroscopy:

IR study was carried to check purity of drug. It was determined by Fourier Transform Infrared spectrophotometer (Jasco FT/IR-4600, Japan). The sample was scanned over wavelength region of 4000 to 400 cm by dispersing sample in KBr and compressing into disc by applying pressure of 5 tons for 5 min in hydraulic press. The pellet was placed in light path and the spectrum was obtained.

3. Differential scanning calorimetry (DSC):

DSC performed in order to access the thermal properties and thermal behavior of the drug and the extract. It measures the heat flow in and out of both sample and reference during a controlled temperature program. The nature of the pure drug and its thermal behavior was studied by differential scanning calorimetry (DSC). About 5mg of the sample was sealed in the aluminium pan and heated at the rate of 10°C/min, covering a temperature range of 40°C to 300°C under nitrogen atmosphere of flow rate 10ml/min and DSC Thermogram for pure drug and extract was obtained.

Calibration curve of Terminalia chebula extract in distilled water

Accurately weighed 100 mg (0.1 gm) Terminalia chebula extract was taken and transferred to 100 ml volumetric flask and volume was made to 100 ml with distilled water (Stock I). The 1ml solution from above stock I solution was again

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diluted with distilled and volume was made to 10ml (Stock II). The final solutions of stock II were then prepared in distilled water. From Stock II solution aliquots of 2, 4, 6, 8, and 10 ml were transferred to 10 ml volumetric flasks and final volume was made to 10ml with distilled water. The UV absorbance of these solutions were recorded.

Drug-excipient compatibility studies:

1. Visual observations: The samples subjected to drug-excipient compatibility studies were assessed for any visual changes. The samples were observed for change in color and nature.

Pure sample	Drug + Excipient
Terminalia chebula extract	---------
Hydroxyl Propyl Methyl Cellulose(HPMC)	Drug +HPMC
Ethycellulose	Drug + Ethyl cellulose .
Carbopol 934	Drug +Carbopol934

Table No.2: Samples used in drug-excipient compatibility studies

2. Infrared Spectroscopy: IR was determined by Fourier Transform infrared spectrophotometer (Jasco FT/IR-4600, Japan).

Preparation of Blank Nanosponges:

Blank nanosponges were prepared by Quasi- Emulsion solvent diffusion method. The inner phase was prepared by dissolving Ethycellulose in a suitable solvent i.e. dichloromethane. The inner phase was then poured into the HPMC solution in water (Outer Phase). Following 60 min of stirring (rpm 800-900), the mixture was filtered to separate the nanosponges. The nanosponges were dried in an air heated oven at 40°C for 12 h.

Sr. No	Ingredients	Use
1	Terminalia chebula extract	API
2	Ethycellulose	Polymer
3	Hydroxyl Propyl Methyl Cellulose(HPMC)	Polymer(Stabilizer)
4	Dichloromethane	Solvent
5	Distilled water	Vehicle

Table No.3: Ingredients used for formulation of nanosponges of Terminalia chebula fruit extract.

Batch No.	F1	F2	F3	F4	F5	F6	F7	F8	F9
Ethyl cellulose(gm)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Dichloromethane(ml)	20	20	20	20	20	20	20	20	20
HPMC(gm)	0.25	0.25	0.25	0.50	0.50	0.50	0.75	0.75	0.75
Distilled water(ml)	100	100	100	100	100	100	100	100	100

Table No.4: Composition of blank Nanosponges

Preparation of drug loaded Nanosponges:

Drug loaded nanosponges were prepared by Quasi-Emulsion solvent diffusion method. The inner phase was prepared by dissolving Ethyl cellulose in a suitable solvent i.e. dichloromethane. Then drug was added to solution and dissolved under ultra-sonication at 35 °C. The inner phase was then poured into the HPMC solution in water (Outer Phase). Following 60 min of stirring (rpm 800-900), the mixture was filtered to separate the Nanosponges. The Nanosponges were dried in an air heated oven at 40°C for 12 h.

Batch No.	F1	F2	F3	F4	F5	F6	F7	F8	F9
Drug(gm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ethyl cellulose(gm)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Dichloromethane(ml)	20	20	20	20	20	20	20	20	20
HPMC(gm)	0.25	0.25	0.25	0.50	0.50	0.50	0.75	0.75	0.75

DOI: 10.48175/IJARSCT-25900

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Distilled water(ml)	100	100	100	100	100	100	100	100	100

Table No.5: Composition of drug loaded Nanosponges

Evaluation of Nanosponges:

1) Visual inspection: The visual inspection of nanosponges was determined by optical microscopy.

2) Determination of production yield: The production yield of the nanosponges was determined by calculating accurately the initial weight of the raw materials and the final weight of the nanosponges obtained.

$$\text{Production Yield (PY)} = \frac{\text{Practical mass of nanosponges}}{\text{Theoretical Mass(Polymer+Drug)}} x100 \text{--------- (Eq-1)}$$

4) Actual drug content and Entrapment Efficiency:

The actual drug content was determined by the amount of drug which was entrapped in nanosponges. The weighed amount of drug loaded nanosponges (50mg) was kept in 10ml ethanol and soaked for 3 h. The samples were filtered and analyzed against blank using UV spectrophotometer Entrapment efficiency was calculated by following formula:

$$\text{Entrapment efficiency (\%)} = \frac{\text{Total amount of drug} - \text{Free unentrapped drug}}{\text{Total amount of drug}} x100 - - - - \text{(Eq-2)}$$

4) Infrared spectroscopy:

It was determined by Fourier Transform infrared spectrophotometer (Jasco FT/IR-4600, Japan.) using KBr pellet method. FTIR spectra of individual drug and excipient and nanosponge formulation were recorded in the wavelength range of 4000 to 400 cm[21]

5) Differential Scanning Calorimetry (DSC):

Thermal analysis is an important evaluation technique to find any possible interaction between the drug and excipient. Such interaction can be identified by any change in thermogram. Thermogram of pure Terminalia chebula fruit extract and finished nanosponges formulations were obtained using DSC instrument equipped with an intercooler. Indium standard was used to calibrate the DSC temperature and enthalpy scale. The powder sample of nanosponges was kept in the aluminium pan and heated at constant rate of 5°C/min up to 300°C. Inert atmosphere was maintained by purging nitrogen at the flow rate of 10ml/min.

6) Particle size analysis:

Particle size analysis of prepared nanosponges was carried out by using a particle size analyzer.

Formulation and evaluation of Terminalia chebula extract nanosponges gel

Preparation of Terminalia chebula extracts nanosponges gel:

1% Carbopol 934 was allowed to soak for 24 h in distilled water. On next day accurately weighed Terminalia chebula extract nanosponges were added to the gel base. Triethanolamine was added drop wise to the formulation for adjustment of required pH (4.5-5.5) and to obtain the gel in required consistency. Finally preservatives were added in the carbopol solution

Batch No.	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
Nanosponges eq. to 100mg drug	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Methyl paraben(g)	0.015	0.020	0.025	0.015	0.020	0.025	0.015	0.020	0.025
Propyl paraben(g)	0.05	0.010	0.015	0.05	0.010	0.015	0.05	0.010	0.015
Triethanolamine(ml)	q.s	q.s	q.s	q.s	q.s	q.s	q.s	q.s	q.s
Carbopol 934(gm)	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
Distilled water(ml)	q.s	q.s	q.s	q.s	q.s	q.s	q.s	q.s	q.s

Table No.6: Composition of Gel containing Nanosponges of Terminalia chebula extract

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Evaluation:

1) Physical appearance: The physical appearance of the formulation was checked visually.

Color: The color of the formulation was checked out against white and black background.

Consistency: The consistency was checked by applying on skin.

Odor: The odor of gel was checked by mixing the gel in water and taking the smell.

2) Determination of pH: The pH of gel was determined using digital pH meter by dipping the glass electrode completely into the gel system.

3) Determination of Spreadability:

Spreadability was determined by modified wooden block and glass slide apparatus. The apparatus consisted of a wooden block with fixed glass and a pulley. A pan was attached to another glass slide (movable) with the help of a string. For the determination of Spreadability measured amount of gel was placed on the fixed glass slide. The movable glass slide with a pan attached to it, was placed on other fixed glass slide such that the gel was sandwiched between the two slides for 5 min. About 10gm of weight was added to the pan. Time taken for the slides to separate was noted. Spreadability was determined using formula:

$$S=M.L/T \qquad \text{------- (Eq-3)}$$

4) Viscosity:

Viscosity of the gels was determined using Brookfield viscometer (Spindle type, S-63; model LV DVE) at 30 rpm.The gel was taken in a beaker and the spindle was dipped in it for about 5 minutes and then the reading was taken.

5) Determination of drug content:

The drug content of gel formulation was determined by dissolving an accurately weighed quantity (1g) of gel in 100 ml of solvent .The solutions were kept for stirring up to complete dissolution of the formulations. Solutions were filtered and were subjected to spectrophotometric analysis. The drug content was calculated from calibration data.

$$\text{Drug Content} = \frac{\text{Actual conc}}{\text{Theoretical conc.}} x100 \quad ----(\text{Eq-4})$$

6) In vitro drug release studies:

The study was performed using Franz diffusion cells by using semipermeable membrane. 1 gm of gel was placed in the donor compartment and the receptor compartment was filled with mixture of phosphate buffer (pH 7.4) maintained at 37°C and stirred by using magnetic stirrer bars. For in-vitro release studies, semipermeable membrane was soaked in the same buffer solution for 24 hr. before mounting on the diffusion cells. Samples were removed after every 30 min and sink condition was maintained by replacing same volume of liquid kept at same temperature. The samples were analyzed for the content of Terminalia chebula by UV-spectroscopy at Lambda max 274 nm.

7) Stability study:

The optimized gel formulation was subjected to a stability testing as per ICH guidelines at a temperature of 40 ± 2°C and RH 75± 5%. Prepared formulation gel was sealed in glass vials and kept in humidity chamber maintained at 40°C and RH 75+ 5%. The gel was analyzed for the change in appearance and pH at an interval of 7, 15, 30 day

III. RESULTS AND DISCUSSION

A. Collection of plant material

B. Authentication of plant material:

The authentication of fruits was done from Botanical Survey of India, Western Regional Centre, Pune(Maharashtra) and it was confirmed that the procured fruits were of Terminalia chebula plant.

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C. Extraction of Terminalia chebula fruits:

Extract was obtained in sufficient quantity from the fruits of Terminalia chebula by soxhlet extraction method.

D. Preformulation study:

A) Characterization of Terminalia chebula extract:

a. Organoleptic properties:

Color: Color of the fruit was found to be brown

Odor: Odor of the fruits was found to be aromatic in nature.

b. Determination of pH:

pH of the extract was found to be 5.10, while as per literature standard it is reported to be 4.43. As experimental values were in good agreement with official values, it could be concluded that procured extract was in pure form.

c. Preliminary Phytochemical Screening:

Sr.No	Constituents	Tests	Observations
1	Tannis	1.$FeCl_3$ solution 2.Bromine water solution 3.Acetic acid solution 4.Potassium dichromate 5.Lead acetate solution 6.Iodine solution	Present Present Present Present Present Present
2	Alkaloids	1.Wager's test 2.Hager's test	Present Present
3	Flavonoids	1.Sulphuric acid test	Present
4	Carbohydrates	1.Fehlings test	Present

Table No. 7: Phytochemical tests

Parameters	
Ash value **Total ash value** **Water soluble ash value** **Acid insoluble ash value**	 2% 3.6% 2.5%
Loss on drying	8.78%
Extractive values **Alcohol soluble extractives** **Water soluble extractive**	 9.81% 13.15%

Table No.8: Characterization of extract

B) Identification of Terminalia chebula extract:

1. Ultraviolet spectroscopy:

a) λmax value:

The wavelength of maximum absorbance (λ max) was found to be 274 nm in distilled water which is same as reported.

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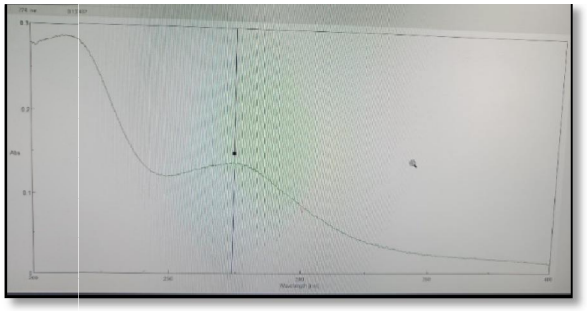

Fig.No 1. U.V absorbance of Terminalia chebula in distilled water

b)Calibration curve of Terminalia chebula extract in distilled water:

Sr.No	Concentration (µg/ml)	Absorbance
1	2	0.0419
2	4	0.0574
3	6	0.0782
4	8	0.0933
5	10	0.1116

Table No.9: Absorbance of Terminalia chebula extract in distilled water

The calibration curve for Terminalia chebula extract in distilled water was plotted by using following results of absorbance at various concentrations.

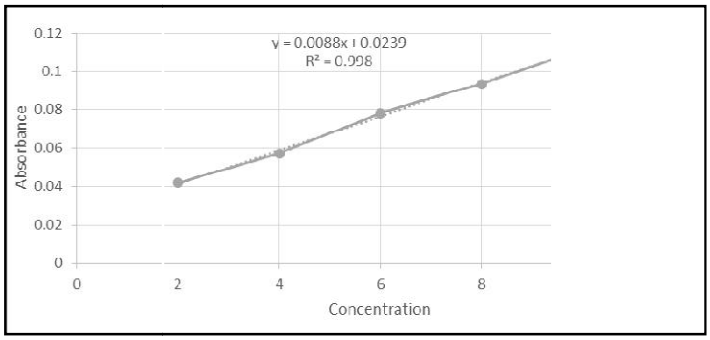

Fig No.2: Calibration curve of Terminalia chebula extract in distilled water

C) Infrared spectroscopy

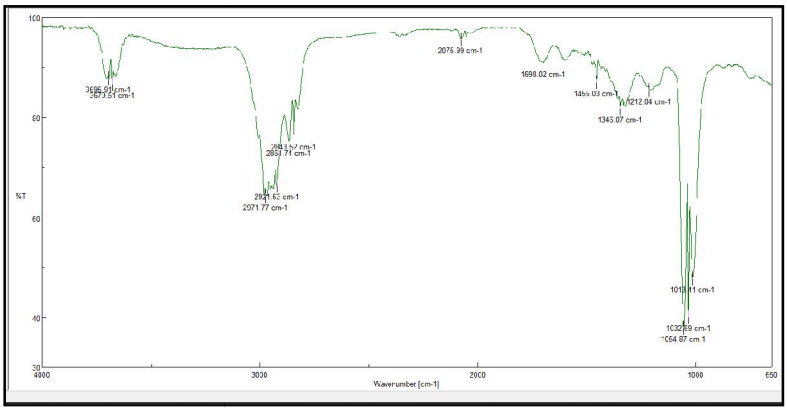

Fig.No.3: FTIR spectrum of Terminalia chebula fruit powder

DOI: 10.48175/IJARSCT-25900

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D) Drug-excipient compatibility studies.

1. Visual observations: No notable change was observed in the sample on visual observation. There was no observable color change.

2. Infrared spectroscopy:

FTIR spectrum of the mixture of Terminalia chebula extract and excipients was compared with spectra of individual components. An FTIR spectrum of physical mixture shows significant peaks of Terminalia chebula extract and respective excipient indicating no chemical interaction between Terminalia chebula extract and excipient.

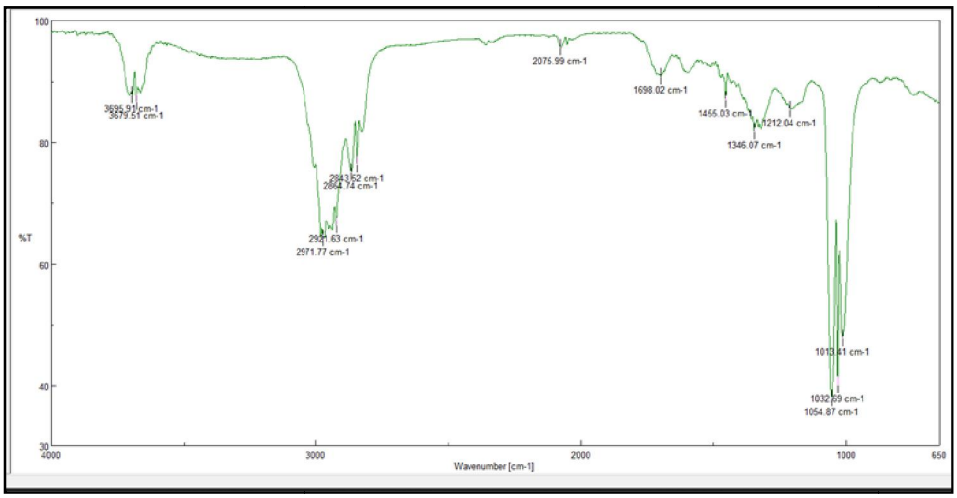

Fig.No.4: FTIR spectrum of Terminalia chebula fruit powder

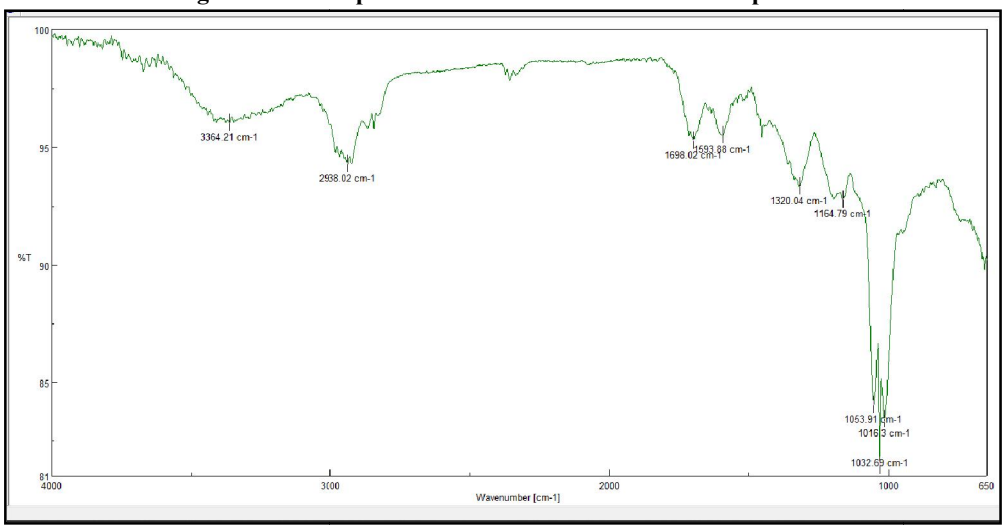

Fig.No.5: IR spectra of Physical mixture of Terminalia chebula and HPMC

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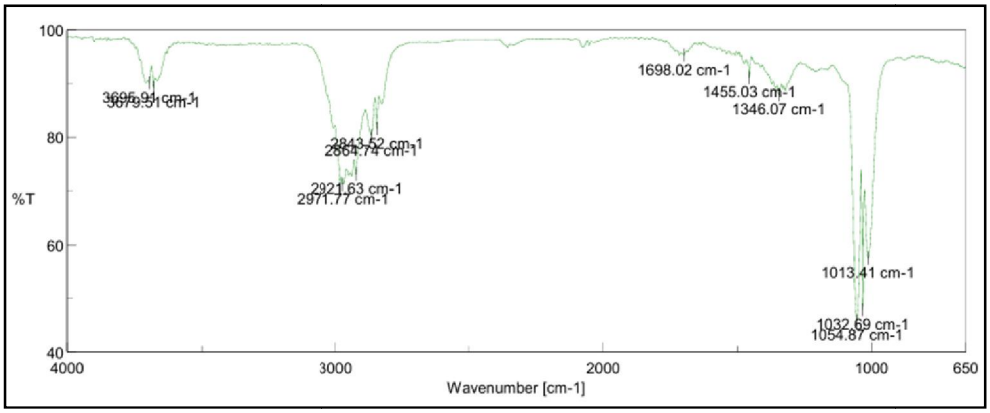

Fig.No.6: IR spectra of Physical mixture of Terminalia chebula and Ethylcellulose

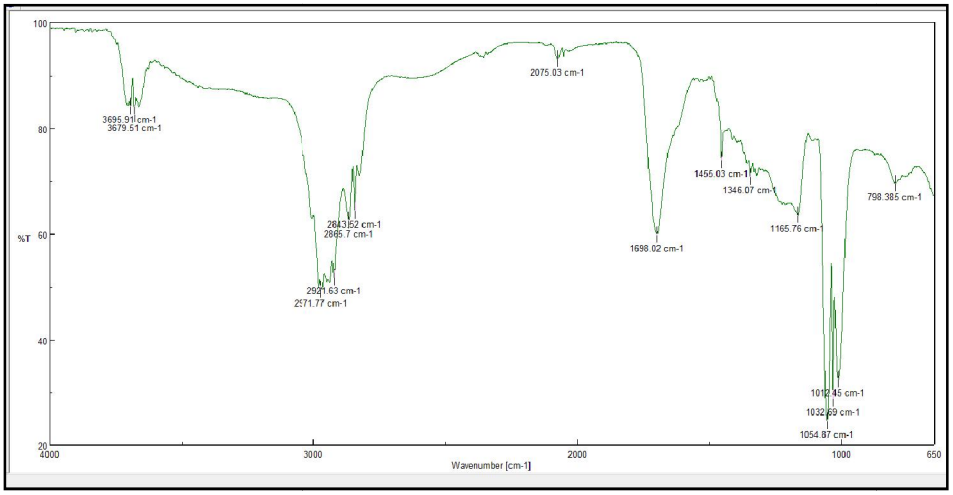

Fig.No.7: IR spectra of Physical mixture of Terminalia chebula and Carbopol 93

E) Evaluations of Terminalia chebula extract nanosponges:

Visual inspection:

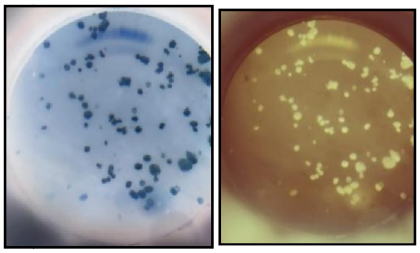

Fig No.8: Optical microscope images of nanosponges

In this figure, the nanosponges were observed in the optical microscope. From the figure it could be concluded that the obtained product was in nano range.

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Determination of Production Yield, Entrapment Efficiency and Actual Drug Content:

Production Yield, Entrapment Efficiency and Actual Drug Content was calculated-

Batches	Amount of Ethyl cellulose(g)	Amount of HPMC(g)	Theoretical Yield(g)	Practical Yield(g)	Production Yield (%)	Entrapment efficiency (%)	Actual drug content (%)
F1	0.5	0.25	1.25	0.59	47.2	72.4	72.4
F2	1	0.25	1.75	1.18	67.4	82.2	82.2
F3	1.5	0.25	2.25	0.97	43.1	44.4	44.4
F4	0.5	0.50	1.5	0.36	24	28.6	28.6
F5	1	0.50	2	0.71	35.5	50.8	50.8
F6	1.5	0.50	2.5	1.01	40.4	62.8	62.8
F7	0.5	0.75	1.75	0.73	41.7	70.0	70.0
F8	1	0.75	2.25	1.15	51.1	79.0	79.0
F9	1.5	0.75	2.75	0.97	35.2	37.6	37.6

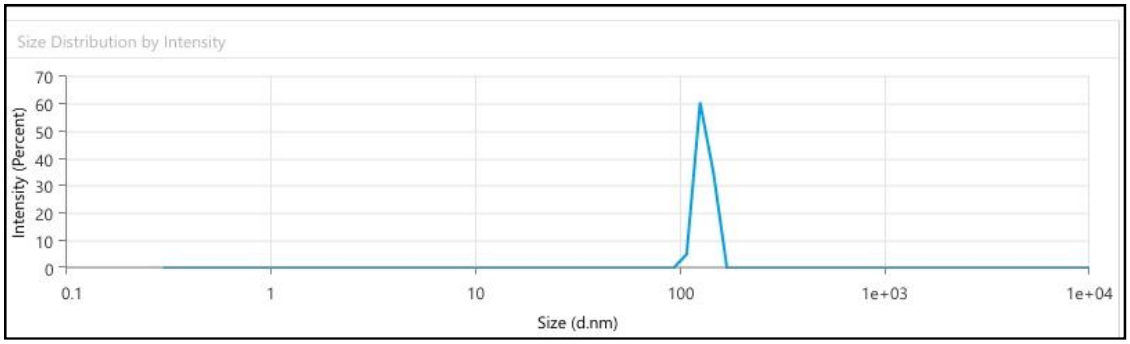
Table No. 10: Production Yield. Entrapment Efficiency and Actual Drug Content of Terminalia chebula extract nanosponges

The % production yield of all batches was ranged from 24% to 67.4%, it was found that the production yield was affected by polymer concentration.

Use of higher amount of HPMC while preparing nanosponges at higher amount of polymers caused slightly an increased viscosity of the dispersed phase. When solvent from inner phase diffused out, nearly all of the dispersed phase was converted to the form of solid nanosponges and separated particles appeared and also it has given higher present entrapment efficiency and %actual drug content.

Particle size analysis:

Particle size of nanosponges should be in the range of 50 -500 nm. The visual inspection of all batches for particle size using optical microscope revealed that the particle size was increased with the increase in the Ethyl cellulose amount. This might be due to increasing polymer wall thickness which led to the larger size of nanosponges. The F2 batch possessed more percent of intact, uniform, spherical particles in optical microscopy; so the batch F2 was chosen for further analysis. A mean particle size of formulation F2 was found to be 486.5 nm.



Infra-red Spectroscopy:

Drug Containing Nanosponges:

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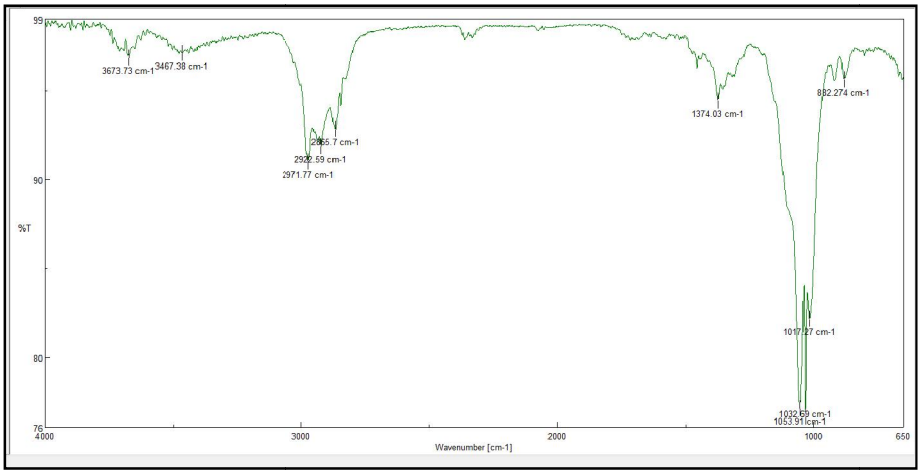

Fig.No.9: IR spectrum of Drug **Containing Nanosponges**

Differential Scanning Calorimetry (DSC):

The shift and reduction of the thermal peak in the nanosponge formulation indicate successful encapsulation of Terminalia chebula and a change in its physical state, suggesting good compatibility with the polymer matrix.

F) Evaluations of Terminalia chebula extract nanosponges gel:

1. Physical appearance: The prepared gel formulations of Terminalia chebula fruit extract nanosponges were visually inspected for their color, consistency and odor. Physical appearance of gel is given below:

Color: Pale brown

Consistency: Good

Odor: Aromatic

2. Determination of pH, Viscosity, Spreadability & Drug content:

Batches	pH	Viscosity (cps)	Spreadability (g.cm/sec)	Drug content (%)
F1	4.6	2889	53.57	72.0
F2	4.9	2848	58.62	80.1
F3	5.0	2870	32.60	60.2
F4	4.7	3120	20.84	48.1
F5	4.5	2895	45.16	63.0
F6	4.8	3012	27.83	68.2
F7	5.2	3128	45.45	70.4
F8	5.5	3270	20.55	77.1
F9	4.5	2899	40.81	55.2

Table No.11: pH, Viscosity, Spreadability & Drug concent of all batches

From the above table it was found that pH of all prepared formulation ranged between 4.5 to 5.5 and the spreadability ranges from 20.55 to 58.62 g.cm/sec and the viscosity from 2842–3270 cps, and the drug content ranges from 55.2% to 80.1%.Hence, the test results show that the gel has good viscosity properties and is in accordance with the spreadability.and the drug content is also good.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
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ISSN: 2581-9429
Volume 5, Issue 11, April 2025
Impact Factor: 7.67

3. In vitro drug release studies:

In vitro drug release study of gel was carried out using phosphate buffer pH 7.4 using Franz diffusion cell.

Sr.No	Time(min)	Absorbance	Concentration (ug/mL)
1	0	0	0
2	30	0.046	2.102
3	60	0.085	4.732
4	90	0.115	5.617
5	120	0.150	6.19
6	150	0.206	6.268
7	180	0.230	6.893

Table No.12: In-vitro Drug Release Data of Terminalia chebula Loaded Gel

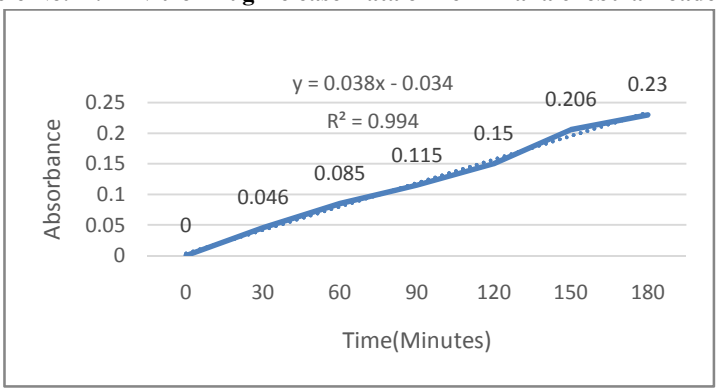

Fig.No.10: Absorbance vs. Time (min)

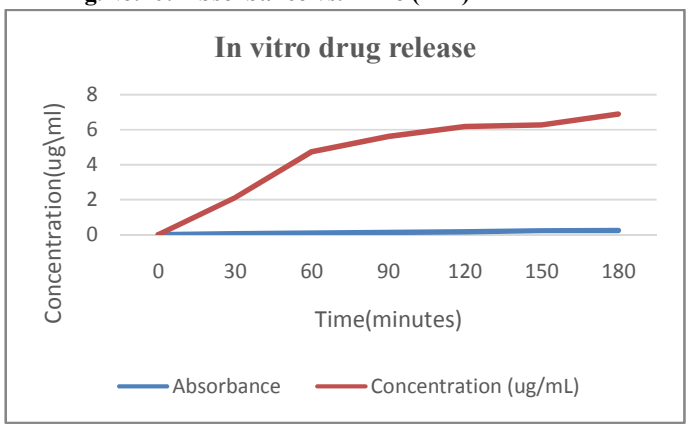

Fig.No.11: Absorbance vs. Concentration.

From the results it can be concluded that the concentration is the more significant indicator of drug release, and it clearly shows that drug release is increasing with time. The steady rise in concentration suggests that the formulation is effectively permeating through the membrane and reaching the receptor compartment. At the end of 3hrs, the total amount of drug release from the formulation was found to be 68.93%.

4. Stability study:

The stability studies of formulated gel were carried out at room temperature for one month. The effect of temperature, humidity and time on the physical characteristics of the gel was for assessing the stability of the prepared formulations. The results were shown in Table no.19. Therefore no evidence of degradation of drug was observed.

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Time interval(days)	Formulations		
	Appearance	pH	Homogeneity
0	Pale brown	4.5	Homogeneous
7	Pale brown	4.8	Homogeneous
15	Pale brown	4.9	Homogeneous
30	Pale brown	4.9	Homogeneous

Table No.13: Appearance, pH and homogeneity of formulation

IV. CONCLUSION

The present study was aimed at overcoming the limitations associated with conventional wound healing formulations by utilizing nanotechnology-based drug delivery systems to enhance the therapeutic potential of herbal extracts. Terminalia chebula, a well-known medicinal plant with remarkable wound healing properties, was selected and successfully incorporated into nanosponges using the Quasi-Emulsion Solvent Diffusion method. This approach provided a novel system for the controlled and sustained release of its bioactive constituents.

The developed Terminalia chebula-loaded nanosponges were further formulated into a gel base, offering an effective and innovative strategy for wound healing therapy. The nanosponges gel not only enhanced the wound healing potential of Terminalia chebula but also exhibited controlled and sustained drug release, improved stability, and better skin penetration. Among all the prepared formulations, F2 demonstrated significant wound healing activity, confirming its potential as an effective wound healing agent.

V. FUTURE PERSPECTIVES

Terminalia chebula has many other medicinal activities, such as antioxidant, antimicrobial, antidiabetic. Anti-inflammatory, etc. so further these prepared nanosponges can be for this activities and suitable dosage form can be formulated accordingly.Various other dosage forms can be formulated, such as solid, liquid.

Further exploration into incorporating other herbal extracts like Curcuma longa, Aloe vera, Azadirachta indica, etc can lead to the development of polyherbal nanosponges gels with synergistic wound healing effects. Various other dosage forms can be formulated, such as solid, liquid.

Future research should focus on animal study to validate its efficacy and safety in human subjects. This will pave the way for its integration into modern therapeutic regimens as a safe, natural, and effective wound-healing agent.

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