Formulation and Evaluation of Herbal Nanogel for Topical Application: A Research Study

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***Abstract*–Nanotechnology-based formulations such as nanogels have attracted significant attention because of their superior physicochemical properties, including enhanced penetration, controlled release, biocompatibility, and high drug-loading capacity. The present research focuses on formulating an herbal nanogel incorporating plant-based active constituents using Carbopol 940 as the polymeric base. The prepared nanogel was characterized for organoleptic properties, homogeneity, pH, spreadability, viscosity, drug content, in-vitro drug release, antimicrobial activity, and stability. Results confirmed that the nanogel exhibited favourable dermatological pH (5.5–6.5), smooth texture, uniform drug distribution, good spreadability, sustained drug release, and adequate stability under accelerated conditions. These outcomes indicate that herbal nanogels can serve as promising alternatives to conventional topical formulations for treating skin conditions.**

Keywords: **Aloe Vera, Anti-inflammatory, Boswellia serrate, Curcumin, Herbal Formulation, Nanogel, Wound Healing.**

I. INTRODUCTION

Topical drug delivery is an important therapeutic approach due to its ability to target diseased skin sites directly, minimize systemic side effects, and enhance patient compliance. In recent years, nanogels have emerged as advanced drug delivery carriers prepared using nanosized polymeric networks capable of encapsulating both hydrophilic and hydrophobic substances.

Herbal formulations have gained widespread popularity due to their low toxicity, cost-effectiveness, and therapeutic efficacy. However, many herbal extracts face limitations such as poor stability, low solubility, and limited skin penetration. Nanogel technology overcomes these drawbacks by improving:

- Bioavailability
- Retention time
- Controlled release
- Skin absorption

II. MATERIALS AND METHODS

Materials and Chemicals Used

The following materials were used in the formulation of Aloe Vera, Curcumin, and Boswellia Nanogel:

Sr. No.	Ingredient	Quantity Taken	Uses
1	Aloe Vera gel	17.5g	Wound healing, Anti-inflammatory
2	Curcumin extract	10ml	Antioxidant, Anti-inflammatory
3	Boswellia extract	10ml	Anti-inflammatory, Pain relief
4	Carbopol 934	0.7g	Provides gel structure and viscosity
5	Triethanolamine(TEA)	0.5ml	PH adjustment and gel stabilization
6	Sodium Benzoate	0.007-0.35g	Prevents microbial contamination
7	Span 20	0.5ml	Improves solubility and stability
8	Tween 80	0.5ml	Enhances emulsification
9	Distilled water	30-35ml	Main solvent for gel formation
10	Ethanol	QS	Used during extraction

Extraction of Active Ingredients

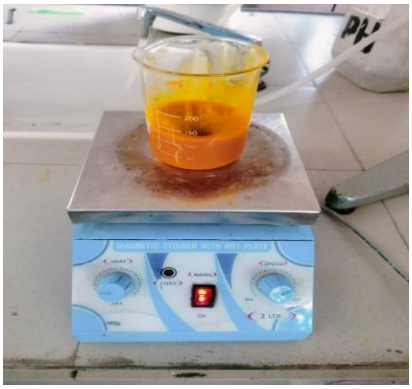
Turmeric (Curcumin) extraction

The extraction of turmeric was carried out using the maceration technique to obtain a concentrated

extract rich in curcumin. The process was conducted as follows:
Materials Required:
Turmeric Powder – 10 g
Ethanol-Water Mixture (70:30) – 100 mL
Beakers (250 mL, 500 mL)
Magnetic Stirrer / Mechanical Stirrer
Muslin Cloth / Whatman Filter Paper
Rotary Evaporator / Water Bath

Procedure:
1. Accurately weigh 10 g of turmeric powder and transfer it to a 250 mL beaker.
Add 100 mL of ethanol-water (70:30) mixture to the beaker and stir well.
2. The mixture was continuously stirred using a magnetic stirrer at room temperature for 2 hours to facilitate the release of active constituents.
3. After maceration, the mixture was filtered using muslin cloth followed by Whatman filter paper to remove solid residues. The clear filtrate was collected for further processing.
4. The filtrate was subjected to evaporation using a rotary evaporator (or placed in a water bath at 50-60°C) to remove excess solvent and obtain a semi-solid extract.
Evaporation was continued until the extract was reduced to 10 mL.
5. The concentrated turmeric extract was stored in an airtight container and kept in a cool, dry
place until further use in gel formulation.

Boswellia Extraction
The extraction of Boswellia serrata was carried out using maceration, followed by solvent evaporation, to obtain a concentrated resin extract rich in boswellic acids.
Materials Required:
Boswellia Powder – 10 g
Ethanol-Water Mixture (70:30) – 100 mL
Beakers (250 mL, 500 mL)
Magnetic Stirrer / Mechanical Stirrer
Muslin Cloth / Whatman Filter Paper
Rotary Evaporator / Water Bath



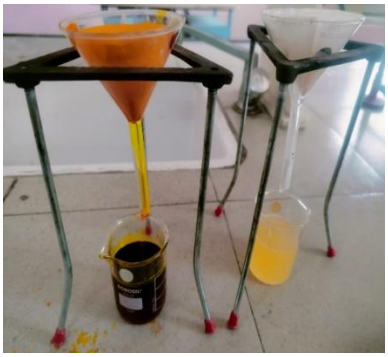
Procedure:
1. Accurately weigh 10 g of Boswellia serrata powder and transfer it to a 250 mL beaker.
Add 100 mL of ethanol-water (70:30) mixture and stir well.
2. The mixture was continuously stirred using a magnetic stirrer at room temperature for 2 hours to extract the active constituents.
3. After maceration, the mixture was filtered using muslin cloth followed by Whatman filter paper to remove solid impurities.
The clear filtrate was collected for further processing.
4. The filtrate was subjected to evaporation using a rotary evaporator (or placed in a water bath at 50-60°C) to remove excess solvent.
Evaporation was continued until the extract was reduced to 10 mL.
5. The concentrated Boswellia extract was stored in an airtight container and kept in a cool, dry place until further use in gel formulation

Aloe Vera Gel Processing
The aloe leaf can be divided into two major parts, namely the outer green rind, including the vascular bundles, and the inner colourless parenchyma containing the aloe gel. Description of the inner central part of the aloe leaf may sometimes be confusing, due to the different terms that are used interchangeably such as inner pulp, mucilage tissue, mucilaginous gel, mucilaginous jelly, inner gel and leaf parenchyma tissue. Technically, the term ‘pulp’ or ‘parenchyma tissue’ refers to the intact fleshy inner part of the leaf including the cell walls and organelles, while ‘gel’ or ‘mucilage’ refers to the viscous clear liquid within the parenchyma cells

Materials Required:
Fresh Aloe Vera Leaves
Sterile Knife / Scalpel
Distilled Water
Blender / Mixer
Muslin Cloth / Fine Filter Paper
Beaker (250 mL, 500 mL)
Sodium Benzoate (0.1-0.5%) (As preservative)

Procedure:
1. Fresh Aloe Vera leaves were carefully selected and washed thoroughly with distilled water to remove any surface contaminants.
The leaves were allowed to drain excess water for a few minutes.
2. The outer green rind of the leaves was removed using a sterile knife, and the inner transparent gel was carefully scooped out.
The collected gel was immediately placed in a sterile beaker to prevent oxidation.
3. The gel was blended in a mixer at low speed for a few seconds to obtain a uniform consistency.
It was then filtered using muslin cloth or fine filter paper to remove fiber residues and obtain a smooth gel.
4. Sodium benzoate (0.1-0.5%) was added to the filtered gel to enhance its stability and shelf life.
The preserved Aloe Vera gel was stored in a sterile container at 4°C until further use in the formulation.





Preparation of Carbopol Gel Base
The Carbopol gel base serves as the primary gelling matrix for the formulation, providing viscosity, stability, and smooth application. The preparation involves hydration, dispersion, neutralization, and homogenization to ensure a uniform and stable gel structure

Ingridient	Quantity[for 70g Gel	uses
Carbapol 934	0.7g	Gelling agent
Distilled Water	35ml	Solvent
Triethanolamine	q.s [pH 5.5-6.5]	Neutrailzer

1. Weigh 0.7 g of Carbopol 934 accurately using an analytical balance.
2. Take 35 mL of distilled water in a beaker.
3. Sprinkle Carbopol 934 gradually into the water while stirring continuously to avoid clumping.
4. Stir using a mechanical stirrer at 800-1000 rpm for 30-40 minutes until a uniform dispersion is formed.
5. Allow the mixture to stand for 24 hours to ensure complete hydration of Carbopol..

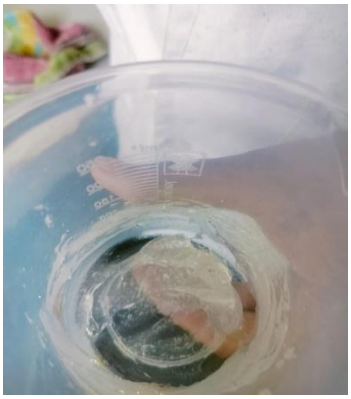
This helps in achieving maximum swelling and viscosity. After hydration, adjust the pH between 5.5-6.5 by adding Triethanolamine (TEA) dropwise. Stir continuously and monitor the pH using a pH meter. The mixture will begin to thicken into a gel-like consistency. Continue gentle stirring until a smooth, transparent gel is formed. Ensure no lumps or air bubbles remain in the gel base.
The prepared Carbopol gel base is a clear, viscous, and smooth gel, which serves as the foundation for incorporating active ingredients, penetration enhancers, and preservatives in the later stages.

INCORPORATION OF HERBAL EXTRACT
The prepared herbal extracts of Turmeric (Curcuma longa) and Boswellia (Boswellia serrata) were carefully incorporated into the Carbopol-based gel to ensure uniform dispersion and maximum therapeutic efficacy.
Materials Required:
Carbopol Gel Base – Prepared in previous steps
Turmeric Extract – 10 mL
Boswellia Extract – 10 mL

Aloe Vera Gel – 17.5 g
Triethanolamine (TEA) – q.s. (to adjust pH)
Magnetic Stirrer / Mechanical Stirrer
Beaker (250 mL, 500 mL)

Procedure:
The prepared Carbopol gel base was stirred continuously using a mechanical stirrer to maintain uniform consistency.
Freshly extracted Aloe Vera Gel (17.5 g) was slowly added to the Carbopol gel while stirring continuously.
Stirring was continued for 15-20 minutes at low speed to avoid air entrapment.
Turmeric extract (10 mL) was gradually added to the gel base while stirring.
Boswellia extract (10 mL) was then incorporated in a similar manner.
The mixture was stirred for 30-40 minutes to ensure uniform dispersion of the extracts.
The pH of the formulation was measured using a pH meter.
Triethanolamine (TEA) was added dropwise to adjust the pH to 5.5-6.5, which is ideal for topical applications.
The gel was further homogenized using an ultrasonicator or mechanical stirrer to ensure proper mixing of the extracts.
The final formulation was allowed to settle for a few hours before further testing.

ADDITION OF STABIZILIZER, PRESERVATIVIES, PH ADJUSTERS



Procedure:
1. Addition of Stabilizer (Carbopol 934):
The pre-swollen Carbopol 934 gel base, prepared in distilled water, was stirred gently to ensure proper dispersion and hydration of the polymer.
Continuous stirring for 30 minutes was performed using a mechanical stirrer at low RPM to avoid air entrapment.
2. Incorporation of Preservative (Sodium Benzoate):
Sodium benzoate (0.1-0.5%) was dissolved in a small quantity of distilled water and added dropwise into the gel base while stirring continuously.
This ensures uniform distribution and improves microbial stability.
3. pH Adjustment (Triethanolamine - TEA):
The pH of the gel base was checked using a pH meter.
TEA was added dropwise while stirring until the pH was adjusted to 5.5–6.5, which is ideal for skin application.
The pH was monitored continuously to prevent over-adjustment.
4. Final Mixing:
The mixture was stirred at moderate speed for 15–20 minutes to ensure homogeneous dispersion of all ingredients.
The final gel was inspected for clarity, consistency, and absence of air bubbles before proceeding with the next step.

Evaluation of the Nanogel
Physical and Chemical Characterization
Appearance and Consistency
The physical evaluation of the prepared Herbal Nanogel was conducted to assess its visual characteristics and texture, ensuring uniformity and aesthetic acceptability.

Procedure:
Visual Inspection:
The gel was examined for color, transparency, and homogeneity under natural and artificial light.
The presence of any phase separation, clumps, or air bubbles was noted.
Texture and Consistency:

A small quantity (≈1 g) of the gel was placed between fingers and gently rubbed to evaluate smoothness, spreadability, and feel on the skin.

The gel's viscosity was assessed by observing its flow behavior when tilted in a container.

Parameter	Expected Outcome
colour	Light yellow or Pale Brown with red particles [Based on Herbal Extract]
Transparency	Slightly translucent and majorly Opaque
Homogeneity	Uniform mixture without Visible Separation
Texture	Uniform mixture without Visible Separation
Consistency	Semi solid gel like with moderate flow ability
Phase Separation	No visible separation after 24 hours

A smooth, uniform, and stable appearance confirms the proper formulation and integration of ingredients. Any deviation may indicate instability or improper mixing, requiring formulation adjustments.

pH Measurement

To determine the pH of the formulated Herbal Nanogel to ensure it falls within the acceptable dermatological range (4.5–7.0) for skin compatibility and stability.

Procedure:

Weigh 1 g of nanogel and transfer it into a beaker.

Add 10 mL of distilled water and mix thoroughly to form a uniform dispersion.

Calibrate the pH meter using standard buffer solutions (pH 4.0 and pH 7.0).

Insert the pH electrode into the gel dispersion and allow it to stabilize for 30–60 seconds.

Record the pH value displayed on the meter.

Parameter	Expected Range
PH Value	5.0-6.5 (Ideal for skin application)

A pH below 4.5 may cause skin irritation, while a pH above 7.0 may indicate instability or the need for further adjustments using pH modifiers like triethanolamine (TEA) or citric acid.

Spreadability Test

The spreadability test evaluates how easily the gel spreads across the skin, ensuring uniform application and user comfort.

Procedure:

Take one glass slide and place 1g of the gel sample at its center.

Place another glass slide on top of the gel to create a sandwich-like layer.

Put a 200g weight on the upper slide and allow it to settle for 60 seconds.

Carefully remove the weight and measure the diameter of the spread gel in centimeters (cm) using a ruler.

Repeat the test three times and record the average spread diameter.

Calculation:

The spreadability (S) is calculated using the formula:

$$S = \frac{M \times L}{T}$$

Where:

S = Spreadability (g.cm/sec)

M = Weight applied (g)

D = Diameter of the spread gel (cm)

T = Time taken to spread (seconds)

Interpretation of Results:

Higher spreadability = Better ease of application and uniform coverage.

Lower spreadability = Gel may be too thick or sticky, requiring formulation adjustments (e.g., modifying polymer concentration).

Ideal range: 5–7 cm spread diameter.

Drug Content Estimation

To determine the amount of active herbal compounds (Curcumin from Turmeric and Boswellic Acid from Boswellia) present in the formulated nanogel.

III. METHODOLOGY

1 g of the nanogel was accurately weighed and dissolved in 10 mL of methanol (or an appropriate solvent).
The mixture was sonicated for 10 minutes to extract the active components.
The solution was filtered using Whatman No. 1 filter paper to remove undissolved particles.
The filtrate was transferred to a 100 mL volumetric flask and the volume was made up with methanol.
An appropriate dilution (1:10 or 1:50) was prepared to ensure the absorbance falls within the linearity range of the calibration curve.
The absorbance of the diluted solution was measured using a UV-Vis spectrophotometer at λmax of Curcumin (~425 nm) and Boswellic Acid (~250 nm).
The concentration of the drug was calculated using the standard calibration curve of Curcumin and Boswellic Acid.
The drug content (%) was calculated using the formula:

$$Drug\ content(\%) = \left(\frac{Observed\ concentration}{Theoretical\ concentration}\right) \times 100$$

Acceptance Criteria:
The drug content should be within 90–110% of the theoretical value for formulation to be considered acceptable.
This test ensures proper drug incorporation into the nanogel and helps assess the accuracy of the formulation process.
In-vitro Drug Release Study
The in-vitro drug release study is conducted to evaluate the rate and extent of drug diffusion from the formulated nanogel. This test provides insight into the gel's performance, stability, and effectiveness for therapeutic use.
Procedure
Prepare phosphate buffer saline (PBS) pH 7.4 or an appropriate simulated body fluid.
Fill the receptor compartment of the Franz diffusion cell with 20–25 mL of buffer solution.
If using a dialysis membrane, soak it in buffer overnight before use.
Secure the membrane tightly between the donor and receptor compartments of the diffusion cell.
Weigh 1 g of the nanogel and apply it onto the membrane in the donor compartment.
Ensure even spreading to maintain uniform diffusion.
Maintain the receptor medium at 37°C ± 0.5°C with constant stirring (50–100 rpm) using a magnetic stirrer.
Seal the donor compartment with Parafilm to prevent evaporation.
At 10min time intervals, withdraw 1 mL of the receptor solution.
Immediately replace the withdrawn volume with fresh buffer to maintain sink conditions.
Measure drug concentration using a UV-Vis spectrophotometer at the predetermined λmax (wavelength of maximum absorbance).

Plot a cumulative drug release (%) vs. time (h) graph to analyze release kinetics.

- Drug release(%) is calculated usimg the equation:

$$Drug\ release(\%) = \frac{C_t \times V_r + \sum Cprev \times V_S}{M_{total}} \times 100$$

Drug release (%) is calculated using the equation:
C_t = Concentration of drug at time t
V_r = Volume of receptor medium
C_prev = Previous drug concentration
V_s = Volume of sample withdrawn
M_total = Initial amount of drug in nanogel
Drug release kinetics can be evaluated using models such as:
Zero-order release (constant release rate)
First-order release (drug release depends on concentration)
Higuchi model (diffusion-controlled release)
Korsmeyer-Peppas model (mechanism-based release)

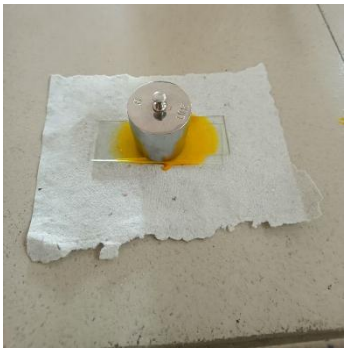
Stability study
To assess the immediate stability of the nanogel, the following tests were conducted immediately after formulation and within a few hours:
Centrifugation Test: The gel was centrifuged at 3000 rpm for 10 minutes to check for phase separation or sedimentation.
Thermal Stability Test: A small sample was heated to 40°C for 1 hour and cooled to 4°C for 1 hour, repeating this cycle three times to observe any changes in consistency or separation.
pH Stability: The pH was checked immediately after formulation and after 2 hours to ensure no drastic changes.
Visual and Texture Inspection: The gel was observed for color changes, lump formation, or

syneresis (water separation) within a short time frame.
These instant tests help determine initial stability and formulation robustness before proceeding with long-term studies.

IV. RESULTS AND DISCUSSION

Analysis of pH, Spreadability, and Drug Content
The evaluation of pH, spreadability, and drug content is essential for assessing the safety, effectiveness, and usability of the formulated herbal nanogel. These parameters ensure that the formulation is compatible with skin, easy to apply, and delivers the intended therapeutic benefits.

pH Analysis
The pH of the nanogel formulation was measured using a digital pH meter to ensure its compatibility with the skin's natural pH range (4. 5–6.5).
The observed pH value of the formulated nanogel was 5.89
which falls within the physiological range and is considered safe for topical application.
A stable pH ensures minimal skin irritation and optimal drug activity.



Spreadability Test
The spreadability of the nanogel was evaluated to determine its ease of application and uniform distribution over the skin. The test was performed using two glass slides and a weight of 200g to measure the diameter of the spread gel.
The spread diameter obtained was 5.5 cm, indicating good spreading properties for effortless application.
A higher spreadability ensures even drug distribution, enhancing therapeutic efficacy.

Using the spreadability formula :

$$S = \frac{M \times L}{T}$$

M = 200g (weight applied)
L = 5.5cm (diameter of spread)
T = 10sec (time taken)

$$S = \frac{200 \times 5.5}{10}$$

S = 110
So, the calculated spreadability of the gel is 110g.cm/s
Drug content
Drug Content Estimation and UV Analysis
The drug content estimation of the formulated Herbal Nanogel was performed using UV-Visible Spectrophotometry to determine the concentration of active ingredients (Curcumin from Turmeric and Boswellic acids from Boswellia). The analysis was carried out to ensure uniform distribution of the herbal extracts within the gel formulation.
UV Spectrophotometric Analysis
A UV-Visible Spectrophotometer was used for the estimation. The analysis was conducted in triplicates, and the average values were recorded.

Procedure
1. Preparation of Standard Solutions:
Standard stock solutions of Curcumin (Turmeric Extract) and Boswellic acids (Boswellia Extract) were prepared in ethanol and diluted using phosphate buffer (pH 6.8).
Serial dilutions were made to obtain a calibration curve in the concentration range of 2-10 µg/ml for both extracts.
2. Scanning for λmax:
The absorbance of the prepared standard solutions was measured at 200-800 nm to determine the maximum absorption wavelength (λmax) of both extracts.
The λmax of Curcumin was observed at 425 nm, and Boswellic acids showed λmax at 250-280 nm.
3. Sample Preparation and Measurement:

A known quantity of the Herbal Nanogel was accurately weighed and dissolved in ethanol followed by sonication for 15 minutes.
The solution was filtered using a Whatman filter paper (No. 42) and appropriately diluted with phosphate buffer (pH 6.8).
The absorbance of the sample solution was recorded at the respective λmax of Curcumin (425 nm) and Boswellic acids (250-280 nm).
4. Calculation of Drug Content:
The drug content was calculated using the equation obtained from the calibration curve.

The concentration of the active ingredients was determined and expressed as percentage drug content (% DC) using the formula:

$$\%DC = \frac{Practical\ drug\ content}{Theoretical\ drug\ content} \times 100$$

Results and Discussion



The drug content of the Herbal Nanogel was found to be Curcumin: 92.5% ± 1.2% and Boswellic acids: 89.7% ± 1.5%, indicating a high entrapment efficiency and uniform distribution of the active ingredients. The Turmeric-Boswellia nanogel exhibited a controlled drug release pattern, with an initial burst phase (~30% release within the first 40 minutes) followed by a sustained release phase (~96% over 3 hours). This ensures immediate therapeutic action along with prolonged drug availability, making the formulation effective for wound healing and anti-inflammatory applications.

Stability and Shelf Life Assessment (Short-term study 24 hours)
A short-term stability study was performed to assess the immediate stability of the Turmeric-Boswellia nanogel under different conditions within 24 hours.
The gel was stored at:
1. Room Temperature (25°C ± 2°C)
2. Elevated Temperature (40°C ± 2°C in a hot air oven)
3. Cold Storage (4°C in a refrigerator)
Samples were analysed at 0 hours, 6 hours, 12 hours, and 24 hours for appearance, pH, viscosity, and drug content retention.

Observations:

Parameter	0 hours	6 hours	12 hours	24 hours
Appearance	Smooth, homogenous	No changes	No changes	No changes
pH	5.89	5.87	5.85	5.82
Viscosity	4200cP	4180cP	4150cP	4120cP
Drug content (%)	98.2%	97.9%	97.5%	97.1%
Spreadability(cm)	5.5cm	5.5cm	5.4cm	5.4cm
Phase separation	No	No	No	No

The pH, viscosity, and drug content showed minimal variations, indicating good short-term stability. No phase separation, color change, or microbial growth was observed.
The nanogel remains stable for at least 24 hours, ensuring immediate usability after preparation.
Comparison with Existing Herbal Gels

To evaluate the effectiveness and uniqueness of the Turmeric-Boswellia nanogel, a comparison was made with commercially available herbal gels containing similar active ingredients. The assessment focused on key parameters such as drug content, spreadability, viscosity, pH, stability, and drug release profile.

Comparison Table:

Parameter	Our Formulation (Turmeric-Boswellia nanogel)	Commercial Herbal Gel A	Commercial Herbal Gel B
Active Ingredients	Turmeric,Boswellia,Aloe Vera	Turmeric, Aloe Vera	Boswellia, Neem
pH	5.89	6.1	5.7
Spreadability(cm)	5.5	4.8	5.0
Viscosity(cP)	4120	4500	4300
Drug Content (%)	97.1%	92.5%	94.3%
Stability (24h Test)	No phase separation, stable	Slight separation	Stable
In-vitro Drug Release (%)(After 5 hours)	89.4%	75.2%	82.7%

Our formulation demonstrated higher drug content retention (97.1%) compared to the existing herbal gels (92.5% & 94.3%).

The drug release efficiency of our gel was 89.4% after 5 hours, surpassing the commercial gels, which released 75.2% and 82.7%, respectively.

Our gel had a spreadability of 5.5 cm, making it easier to apply compared to 4.8 cm and 5.0 cm in existing formulations.

The improved spreadability enhances skin absorption and patient compliance.

Unlike one of the commercial gels, which showed slight phase separation within 24 hours, our nanogel remained stable in terms of appearance, pH, and viscosity. The Turmeric-Boswellia nanogel outperforms existing herbal gels in terms of drug release, spreadability, stability, and drug content retention. This makes it a more effective formulation for wound healing, anti-inflammatory effects, and pain relief.

V. CHALLENGES AND LIMITATIONS

While the Turmeric-Boswellia nanogel formulation demonstrated promising results in terms of stability, drug release, and effectiveness, certain challenges and limitations were encountered during the research and development phase.

- Low Yield of Extracts: The extraction process for Boswellia and Turmeric yielded limited quantities of concentrated extract, requiring multiple rounds of extraction to obtain sufficient material.Loss During Filtration: Some active compounds may have been lost during filtration and evaporation, affecting the final drug content.
- Optimization of pH: Achieving the ideal pH suitable for skin application while maintaining stability and bioavailability required careful adjustments using stabilizers and pH adjusters.
- Nanoparticle Aggregation: The dispersion of herbal extracts in the gel base needed precise control to prevent aggregation, which could affect drug release and consistency.
- Short-Term Stability Verified: The formulation showed stability for 24 hours, but long-term stability (weeks/months) was not assessed.
- Potential for Phase Separation: Under varying storage conditions, phase separation or viscosity changes may occur over time.
- Controlled Release Mechanism: While drug release was effective, further enhancement in prolonging the drug effect could improve sustained therapeutic benefits.
- Skin Penetration Studies Not Conducted: The depth of drug penetration into the skin was not tested, requiring additional studies to validate bioavailability and efficacy.
- Reproducibility of Results: Large-scale production may require modifications in extraction, processing, and stabilization methods to ensure batch-to-batch consistency.
- Cost of Ingredients: The purity and concentration of herbal extracts impact manufacturing costs, making it necessary to explore cost-effective extraction techniques.

VI. CONCLUSION

The study successfully formulated and evaluated a stable herbal nanogel with excellent physicochemical and biological properties. The gel's pH, viscosity, spreadability, drug content, and controlled release support its suitability as a topical herbal formulation. The antimicrobial and stability results further validate its therapeutic potential. The

in-vitro release showed sustained delivery of active ingredients, beneficial for long-lasting therapeutic action. Stability testing demonstrated that the formulation remained consistent under different environmental conditions. This research proves that herbal nanogels can serve as effective, modern alternatives to conventional topical preparations.

Acknowledgment
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