



FORMULATION AND EVALUATION OF *SOLANUM TORVUM* LEAF EXTRACT AS GEL AND COMPARISON WITH STANDARD WOUND HEALING FORMULATION

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ABSTRACT

Wound healing is a complex biological process requiring effective management to prevent infection and promote tissue repair. *Solanum torvum* (Turkey berry) is a well-known medicinal plant belonging to the family Solanaceae, whose leaves are rich in bioactive phytoconstituents such as flavonoids, alkaloids, phenolic compounds, saponins, and terpenoids with documented antimicrobial, anti-inflammatory, and antioxidant properties. In the present study, an ethanolic extract of *Solanum torvum* leaves was prepared by Soxhlet extraction and formulated into a topical gel using Carbopol 934 as the gelling agent. The formulated herbal gel was evaluated for various physicochemical parameters including appearance, homogeneity, spreadability, viscosity, pH, drug content, total phenolic content, and washability. The gel exhibited a green color with a smooth, homogeneous consistency, a pH of 5.5 (skin-compatible), spreadability of 13.29 g·cm/sec, viscosity of

26,833cP, and drug content of 96%. Total phenolic content was approximately 15–16 µg/mL gallic acid equivalents. Antimicrobial activity was assessed by the cup-plate method against

Staphylococcus aureus (Gram-positive) and *Escherichia coli* (Gram-negative), yielding zones of inhibition of up to 27 mm and 23 mm, respectively, at 60 µg/mL. The formulated gel demonstrated comparable physicochemical characteristics to a standard wound-healing formulation (Clarithromycin gel), indicating its potential as a safe and effective herbal alternative for topical wound management.

KEYWORDS: *Solanum torvum*, wound healing, herbal gel, Carbopol 934, antimicrobial activity, phytochemicals, topical formulation.

INTRODUCTION

Wound healing is a natural and complex biological process that involves inflammation, tissue regeneration, and remodeling of damaged skin. Proper wound management is essential to prevent infection and to promote faster healing. Although many synthetic wound-healing formulations are available, they may cause side effects, incur high costs, or result in delayed healing in certain cases. Therefore, there is increasing interest in herbal medicines due to their safety, affordability, and effectiveness.^[1]

Medicinal plants have been traditionally used for wound healing owing to their antimicrobial, anti-inflammatory, and antioxidant properties. *Solanum torvum* (commonly known as Sundakkai or Turkey berry), a member of the family Solanaceae, is a widely distributed plant of tropical and subtropical regions. It has been used in traditional medicine for treating various ailments including infections, inflammation, fever, anemia, and skin disorders. Different parts of the plant, including fruits, leaves, and roots, are known to possess therapeutic properties.^[2,3]

The leaves of *Solanum torvum* have attracted considerable attention due to their rich phytochemical content, comprising flavonoids, alkaloids, phenolic compounds, saponins, terpenoids, and antioxidants.^[4,5] These bioactive constituents promote wound healing by reducing inflammation, preventing microbial growth, enhancing collagen synthesis, and accelerating epithelialization. The antimicrobial activity of *Solanum torvum* leaves helps prevent wound infections, while their anti-inflammatory and antioxidant properties support faster tissue repair.^[6,7]

Gel formulations are widely preferred for topical wound management due to their ease of application, good spreadability, non-greasy nature, high water content, and patient

compliance. Herbal gels combine the advantages of natural plant extracts with modern pharmaceutical formulation techniques. The use of suitable gelling agents such as Carbopol 934 helps in achieving desirable consistency, homogeneity, and controlled release of the active constituents.^[2,7]

In the present study, *Solanum torvum* leaf extract was formulated into a topical gel and evaluated for physicochemical properties including pH, viscosity, spreadability, drug content, total phenolic content, and antimicrobial activity. The wound-healing potential of the prepared herbal gel was subsequently compared with a standard wound-healing formulation (Clarithromycin gel) to assess its effectiveness as a herbal alternative for topical wound management.

MATERIALS AND METHODS

Collection and Authentication of Plant Material

Fresh leaves of *Solanum torvum* were collected from Vadamadurai, Dindigul, Tamil Nadu, India, during morning hours to obtain fresh material. The plant was authenticated by a competent botanist. Diseased, damaged, or infected leaves were discarded. Collected leaves were washed thoroughly with clean water to remove dust, soil, and other surface impurities and then blotted dry with clean tissue paper to remove excess moisture.

Drying and Preparation of Plant Powder

The washed plant material was spread in a thin layer on clean trays and shade-dried at room temperature with adequate air circulation to preserve the active constituents. Direct sunlight was avoided to prevent photodegradation of thermolabile phytochemicals. The material was turned occasionally to ensure uniform drying. Once completely dry and brittle, the dried leaves were powdered and stored in airtight containers until further use.

Extraction of *Solanum torvum* Leaf Extract

Approximately 50 g of the dried leaf powder was placed in a thimble (filter paper) and loaded into a Soxhlet extractor. Ethanol was used as the extracting solvent. The extraction was carried out at 60–70 °C for 6–8 hours (10–15 cycles) until the solvent became colorless, indicating complete extraction. The collected solvent extract was filtered through Whatman No. 1 filter paper to remove plant debris. The filtrate was concentrated using a water bath and the dried ethanolic extract of *Solanum torvum* was obtained and weighed for further use.^[28,29,30]

Formulation of Herbal Gel

The herbal gel was formulated in a stepwise manner using Carbopol 934 as the gelling agent. The composition of the formulation is presented in Table 1.

Table 1: Composition of *Solanum torvum* Herbal Gel Formulation.

S. No.	Ingredient	Quantity	Function
1	Carbopol 934	1 g	Gelling agent (viscosity/structure)
2	<i>Solanum torvum</i> extract	2.5 g	Active ingredient (therapeutic agent)
3	Propylene glycol	10 mL	Solvent and penetration enhancer
4	Methyl paraben	0.1 g	Preservative (antimicrobial)
5	Propyl paraben	0.05 g	Preservative (antimicrobial)
6	Triethanolamine	q.s.	pH adjuster and neutralizing agent
7	Distilled water	q.s. to 100 g	Vehicle

Step 1: Preparation of Carbopol Gel Base

Carbopol 934 (1 g) was slowly sprinkled into approximately 50 mL of distilled water with continuous stirring. The dispersion was allowed to soak and swell for 30–45 minutes with intermittent stirring until a smooth, lump-free dispersion was obtained.

Step 2: Preparation of Preservative Solution

Methyl paraben (0.1 g) and propyl paraben (0.05 g) were weighed and dissolved in a small quantity of warm distilled water or propylene glycol with stirring until completely dissolved.

Step 3: Preparation of Extract Solution

Solanum torvum extract (2.5 g) was accurately weighed and dissolved in propylene glycol with thorough mixing to obtain a uniform solution.

Step 4: Incorporation of Ingredients

The preservative solution was added to the Carbopol dispersion with continuous stirring. The extract–propylene glycol solution was then slowly incorporated into the gel base under constant stirring to ensure uniform distribution.

Step 5: pH Adjustment and Gel Formation

Triethanolamine was added dropwise to the mixture with continuous stirring until the pH was adjusted to 6–7, as confirmed by a calibrated pH meter. Upon neutralization, the Carbopol dispersion transformed into a clear, viscous gel. The final weight was made up to 100 g with distilled water and gently stirred to remove entrapped air bubbles.^[31,32]

Step 6: Packaging

The prepared gel was transferred into clean, airtight containers and stored under appropriate conditions until evaluation.

Physicochemical Evaluation Parameters***Organoleptic Evaluation***

Color, odor, texture, consistency, and clarity of the formulated gel were assessed by visual inspection and tactile evaluation to detect instability, phase separation, or formulation defects.^[37]

Homogeneity

A small quantity of gel was pressed between the thumb and index finger and visually inspected for the presence of lumps, aggregates, or coarse particles. A homogeneous gel should appear smooth and uniform without visible particles or phase separation.

Spreadability

A small quantity of gel was placed between two clean glass slides. A definite weight was applied to the upper slide to form a thin layer, after which an additional weight was attached and the time taken for the upper slide to travel a fixed distance was recorded. Spreadability (S) was calculated using the formula

$$S = (M \times L) / T$$

where M = weight tied to the upper slide (g); L = length of the glass slide (cm); T = time taken to separate the slides (sec).

Viscosity

The viscosity of the gel was determined using a Brookfield Viscometer (spindle No. 6 or 7) at 10 rpm. Measurements were taken in triplicate after stabilization (2–3 min) and the average viscosity was recorded in centipoise (cP).

pH Determination

Approximately 1 g of gel was dispersed in 10 mL of distilled water and the pH was measured using a calibrated digital pH meter. The electrode was immersed in the gel dispersion and the reading was recorded after stabilization at room temperature. The experiment was performed in triplicate.^[38]

Drug Content

Accurately weighed 1 g of gel was dissolved in ethanol and stirred thoroughly. The solution was filtered through Whatman filter paper and the filtrate was suitably diluted. Absorbance was measured at 270 nm using a UV–Visible spectrophotometer. Drug content (%) was calculated as.

$$\text{Drug Content (\%)} = (C \times V / W) \times 100$$

where C = concentration from calibration curve (mg/mL); V = volume of solution (mL); W = weight of gel taken (mg).^[36,37,38]

Total Phenolic Content (TPC)

Gallic acid standard solutions (10–100 µg/mL) were prepared and absorbance measured at 270 nm to generate a calibration curve. The absorbance of the *Solanum torvum* extract (100 µg/mL) was measured at the same wavelength and the TPC was expressed as gallic acid equivalents (µg/mL) from the calibration curve.

Washability

Approximately 0.5 g of gel was applied evenly on a glass slide, allowed to stand for 1–2 minutes, and then rinsed with a small quantity of distilled water. The ease of removal was observed and recorded.^[41]

Antimicrobial Studies

The antimicrobial activity of the formulated herbal gel was evaluated by the cup-plate (agar well diffusion) method against *Staphylococcus aureus* (ATCC 25923, Gram-positive) and *Escherichia coli* (ATCC 25922, Gram-negative)^[42] Mueller Hinton Agar (MHA) was prepared, sterilized, and poured into sterile Petri plates under aseptic conditions. The standardized microbial suspension (0.5 McFarland standard, $\sim 1\text{--}2 \times 10^8$ CFU/mL) was swabbed uniformly across the agar surface. Wells of approximately 6–8 mm diameter were bored using a sterile cork borer and labeled appropriately.

Three concentrations of the plant extract (20, 40, and 60 µL) were added to the designated wells. Clarithromycin gel served as the positive control. Plates were incubated at 37 °C for 24 hours. The diameter of zones of inhibition (ZOI) was measured in millimeters using a ruler. Experiments were performed in triplicate.

RESULTS AND DISCUSSION

Organoleptic Evaluation

The formulated herbal gel exhibited a characteristic green color, smooth and homogeneous texture free from lumps, and a pleasant herbal odor. These organoleptic properties are consistent with quality standards expected for topical herbal gel preparations and indicate a well-formulated product.^[37]

HOMOGENEITY

Visual inspection and tactile evaluation confirmed that the formulated gel was homogeneous, with a smooth and uniform consistency. No lumps, aggregates, or coarse particles were detected (Table 2), indicating proper incorporation and uniform distribution of all ingredients throughout the gel matrix.

Table 2: Homogeneity Evaluation Results.

S. No.	Parameter	Observation
1	Homogeneity	Smooth, no lumps
2	Texture	Uniform

Spreadability

The spreadability of the formulated gel was determined in triplicate and the results are presented in Table 3. The average spreadability value of 13.29 g·cm/sec indicates that the gel spreads easily upon application, covering a sufficient surface area with minimal force. This property is important for patient compliance and effective delivery of the active constituents to the wound site.

Table 3: Spreadability Values of the Formulated Herbal Gel.

Trial	Spreadability (g·cm/sec)
1	13.33
2	13.25
3	13.30
Average	13.29

Viscosity

Viscosity measurements recorded across three trials (Table 4) yielded an average value of 26,833 cP, indicating appropriate thickness and consistency for a topical gel. A viscosity in this range ensures that the gel maintains its form at rest while being easily applicable upon shear stress. The result demonstrates adequate stability and acceptable rheological behavior for wound care application.

Table 4: Viscosity Values of the Formulated Herbal Gel.

Trial	Viscosity (cP)
1	26,500
2	27,200
3	26,800
Average	26,833

pH Determination

The pH of the formulated gel was found to be 5.5 (average of three trials, Table 5), which falls within the acceptable skin-compatible range (pH 5.0–7.0). Maintaining a slightly acidic pH is important to match the natural pH of the skin, minimize irritation, and prevent microbial growth at the wound site. The stable and reproducible pH values confirm the consistency of the formulation.

Table 5: pH Values of the Formulated Herbal Gel.

S. No.	Trial	pH Value
1	Trial 1	5.5
2	Trial 2	5.6
3	Trial 3	5.5
	Average	5.5

Drug Content

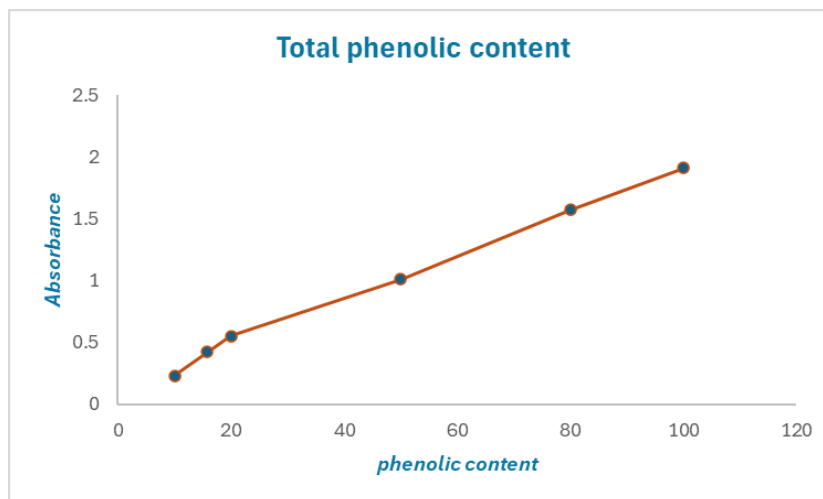
The drug content of the formulated gel was found to be 96%, indicating uniform distribution of the active phytoconstituents within the gel matrix. A drug content exceeding 90% is considered acceptable for topical formulations and confirms adequate incorporation of the *Solanum torvum* extract into the gel base.^[36,37,38]

Total Phenolic Content

Gallic acid was used as a reference standard to construct a calibration curve (Table 6). The absorbance of the *Solanum torvum* leaf extract at 100 µg/mL was 0.42 (Table 7), from which the total phenolic content was calculated to be approximately 15–16 µg/mL gallic acid equivalents. The presence of significant phenolic content is consistent with published phytochemical reports and supports the antioxidant and wound-healing potential of the extract.^[4,5,9]

Table 6: Gallic Acid Calibration Curve Data.

S. No.	Concentration ($\mu\text{g/mL}$)	Absorbance (270 nm)
1	10	0.237
2	20	0.553
3	50	1.018
4	80	1.570
5	100	1.918

**Figure 1: Total phenolic content estimation.****Table 7: Absorbance of *Solanum torvum* Leaf Extract.**

S. No.	Concentration ($\mu\text{g/mL}$)	Absorbance (270 nm)
1	100	0.42

Washability

The prepared *Solanum torvum* leaf extract gel was easily removed from the glass surface with distilled water without leaving any residue, indicating excellent washability. This property is desirable for topical wound-care formulations as it facilitates easy removal during dressing changes and ensures patient comfort.^[41]

Antimicrobial Activity

The antimicrobial activity of the ethanolic extract of *Solanum torvum* leaves was assessed by the cup-plate method and the zones of inhibition (ZOI) at three concentrations are presented in Table 8. The extract demonstrated concentration-dependent antimicrobial activity against both test organisms. At 60 $\mu\text{g/mL}$, the extract produced a ZOI of 27 mm against *Staphylococcus aureus* and 23 mm against *Escherichia coli*. These results indicate potent antibacterial activity, particularly against Gram-positive bacteria, consistent with earlier reports on the antimicrobial properties of *Solanum torvum*.^[6,7,8,10] The observed antimicrobial

effect may be attributed to the rich phenolic and flavonoid content of the extract, which can disrupt microbial cell membranes and inhibit enzymatic activity.

Table 8: Antimicrobial Activity of *Solanum torvum* Leaf Extract (Cup-Plate Method).

S. No.	Organism	Concentration	Zone of Inhibition (mm)
1	Staphylococcus aureus (Gram +ve)	20 µg/mL	20
		40 µg/mL	24
		60 µg/mL	27
2	Escherichia coli (Gram -ve)	20 µg/mL	17
		40 µg/mL	21
		60 µg/mL	23

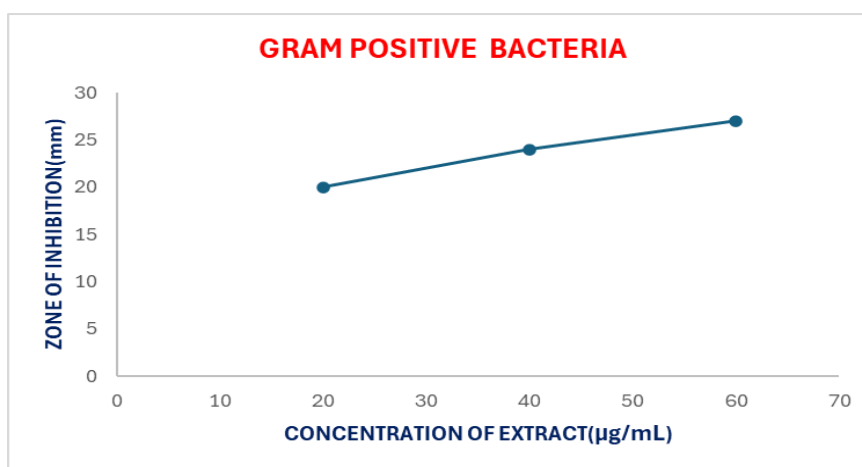


Figure 2: Anti-microbial assay of extract.

Comparison of the formulated *Solanum torvum* herbal gel with the standard Clarithromycin gel demonstrated that the herbal gel possessed comparable physicochemical properties and antimicrobial potential, supporting the feasibility of *Solanum torvum* as a natural alternative for wound management. These findings are in agreement with previous studies reporting the wound-healing and antimicrobial activities of the plant.^[8,23,24]

CONCLUSION

The present study successfully demonstrates the formulation and evaluation of a stable topical herbal gel incorporating an ethanolic extract of *Solanum torvum* leaves using Carbopol 934 as the gelling agent. The formulated gel exhibited satisfactory physicochemical properties including acceptable pH (5.5), high spreadability (13.29 g·cm/sec), appropriate viscosity (~26,833 cP), high drug content (96%), good washability, and confirmed total phenolic content (~15–16 µg/mL GAE). The antimicrobial evaluation revealed significant concentration-dependent activity against both Gram-positive *Staphylococcus aureus* and

Gram-negative *Escherichia coli*, with inhibition zones up to 27 mm and 23 mm, respectively. When compared with the standard Clarithromycin gel formulation, the *Solanum torvum* herbal gel demonstrated comparable characteristics, suggesting its potential as a safe, cost-effective, and efficacious herbal alternative for topical wound care. The phytochemical richness of the plant, particularly its flavonoids, alkaloids, and phenolic compounds, is likely responsible for the observed therapeutic activities. However, further studies including advanced stability testing, in vivo wound-healing models, detailed toxicological evaluation, and clinical investigations are warranted to conclusively establish the therapeutic effectiveness and safety profile of the formulation for large-scale pharmaceutical application.

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