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Research Article

Formulation and Evaluation of *Ficus Bengalensis* Aerial Root Extract-Based Herbal Gel for Wound Healing

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ABSTRACT

Wound healing is a complex biological process often impaired by microbial infections, necessitating effective antimicrobial therapies. This study focuses on the formulation and evaluation of a herbal gel using aerial root extracts of Ficus benghalensis (Indian Banyan tree), known for its traditional medicinal applications. The aerial roots were extracted using Soxhlet apparatus with various solvents, and phytochemical screening confirmed the presence of alkaloids, glycosides, terpenoids, saponins, phenols, and tannins—compounds with known therapeutic activities. Eight gel formulations (F1–F8) were developed using Carbopol 940 as the gelling agent and evaluated for parameters such as physical appearance, pH, drug content, Spreadability, viscosity, antimicrobial activity, and in-vitro drug diffusion. All formulations exhibited smooth texture and yellowish-amber color. The drug content ranged from 93.8% to 100.24%, with F5 showing the highest content. pH values were within the skin-compatible range (6.23–7.56). Among the formulations, F5 demonstrated superior viscosity (28,803 cP) and the highest in-vitro drug diffusion (75 ± 3%) over 8 hours. Antimicrobial testing against Staphylococcus aureus indicated significant bacteriostatic activity. These results suggest that the F5 gel formulation is a promising candidate for topical wound healing due to its optimal physicochemical properties and effective antimicrobial performance.

INTRODUCTION

The skin serves as the body's primary protective barrier against dehydration, environmental factors, and microbial invasion. A wound is defined as the disruption of the normal anatomical structure and functional continuity of tissue caused by physical, chemical, or microbial injury, leading to impairment of the skin barrier. Wound healing is a complex and dynamic biological process involving inflammation, tissue proliferation, and remodeling phases. Microbial contamination of wounds can significantly delay healing and may

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result in serious infections, highlighting the need for effective topical antimicrobial therapies. [1]

Topical drug delivery systems are widely preferred for wound management due to their ability to deliver therapeutic agents directly to the site of action, reducing systemic side effects. Among these systems, gels have gained considerable importance because of their non-greasy nature, ease of application, good patient compliance, and controlled drug release properties. Gels are semi-solid dosage forms in which the movement of the dispersed phase is restricted by a three-dimensional network of particles or solvated macromolecules [2]. The presence of a continuous liquid phase allows efficient diffusion of drug molecules through the polymeric matrix, resulting in drug release characteristics comparable to those of simple solutions [3].

Natural products have been used as medicinal agents for centuries and continue to play a crucial role in healthcare systems worldwide. According to the World Health Organization (WHO), a significant portion of traditional medical practices relies on plant-derived extracts or their active constituents. It is estimated that nearly 80% of the global population depends on herbal medicines as a primary source of healthcare [4]. Herbal formulations are generally considered safer, with fewer adverse effects and better long-term tolerability compared to synthetic drugs.

India is rich in medicinal plant biodiversity, with *Ficus bengalensis* Linn. (family Moraceae), commonly known as the banyan tree (Figure 1), being one of the most important medicinal plants. Various parts of the plant, including bark, leaves, latex, fruits, roots, and aerial roots, have been reported to possess antimicrobial, antifungal, anti-inflammatory, and wound healing properties [5]. The aerial roots are particularly rich in bioactive compounds such as lupeol, γ-sitosterol, and palmitic acid, which exhibit significant antibacterial and anti-inflammatory activities [6, 7].

Despite its extensive traditional use, limited studies have focused on developing optimized topical gel formulations using *Ficus bengalensis* aerial root extract for wound healing. Therefore, the present study aims to formulate and evaluate a herbal gel containing aerial root extract of *Ficus bengalensis* using Carbopol 940 as a gelling agent. The formulation was optimized using a statistical design approach and evaluated for physicochemical properties, antimicrobial activity, and in vitro drug diffusion to assess its potential as an effective topical wound healing agent.



A) B)

Figure 1: Ficus bengalensis Tree

MATERIAL AND METHODS

MATERIAL

Aerial root extracts of the Indian banyan tree were collected using a Soxhlet apparatus. extraction was carried out at Tatyaraoji More College of Pharmacy Omerga Dist. Dharashiv. The extracts were then concentrated using a rotary evaporator, and the concentrated extract was stored in an airtight glass container until further use, The extraction process is carried out in accordance with The Ayurvedic Pharmacopoeia of India Carbopol 940 and Propylene glycol was purchased from Ana lab fine Chemicals, Mumbai. Propyl paraben, Methyl paraben and Glycerin, Triethanolamine were purchased from Loba Chime Pvt. Ltd. Boiser, Palghar etc.

METHODS

Preparation of Root Extract

The fresh aerial root of Ficus Bengalensis collected, were dried in hot air oven at 60 ^{0}C for 6-8 hours to make them free from moisture and grind using an electrical grinder. The resultant powder was passed through sieve no. 60 and was examined microscopically by mounting in chloral hydrate solution and phloroglucinol solution. About 40gm of powder used for Soxhlet extraction by using solvents like petroleum ether, toluene, dichloromethane, ethyl acetate, methanol, and water respectively. This extraction is carried out to determine the active ingredient present in aerial root of Ficus Bengalensis. [8]

Development of Formulation

To prepare the gel formulation, Carbopol 940 was first dispersed in distilled water and stirred using a mechanical stirrer at 1200 rpm for 30 minutes. The mixture was then left to stand overnight. The concentration of the gelling agent was adjusted as specified in the formulation table.

Next, preservatives and Glycerin were added to the gel and mixed thoroughly. The root extract, prepared in propylene glycol, was then incorporated into the polymer dispersion. The remaining amount of distilled water was added, and the formulation was neutralized to pH 7 using triethanolamine, with continuous stirring for 10 minutes. [9, 10]

Experimental method

Statistical analysis is utilized to identify crucial elements and analyze the impact of each formulation factor on each answer using DOE (Design of Experiments) software. We can comprehend the effects of two independent factors on a two dependent variable using a sort of experimental design of Response Surface. In that Central Composite design used to prepare formulation. Each independent variable has two numerical levels in this sort of design (Table 2). [11,12]

Table 2: Formulation of gel by DOE

Ingredients	F1	F2	F3	F4	F5	F6	F7	F8
Extract	0.80gm	0.80gm	0.80gm	0.80gm	0.80gm	0.80gm	0.80gm	0.80gm
Carbopol 940	2gm	0.79gm	1gm	2gm	1.5gm	1gm	2.20gm	1.5gm
Propylene glycol	1gm	5.5gm	1gm	10gm	11.86gm	10gm	5.5gm	0.86gm
Methyl paraben	0.2ml	0.ml	0.2ml	0.2ml	0.2ml	0.2ml	0.ml	0.2 ml
Propyl paraben	0.1ml	0.1ml	0.1ml	0.1ml	0.1ml	0.1ml	0.1ml	0.1ml
Glycerin	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml
Triethanolamine	Q.S.	Q.S.	Q.S.	Q.S.	Q.S.	Q.S.	Q.S.	Q.S.
Water	100ml	100ml	100ml	100ml	100ml	100ml	100ml	100ml

CHARACTERIZATION OF HERBAL GEL FORMULATION [13,14,15,16]

Physical Evaluation: Physical parameters such as color and appearance were evaluated.

Drug Content

Take 1 gm of emulgel. Mix it in suitable solvent. Filter it to obtain clear solution. Determine its absorbance using UV spectrometer. Standard plot of measured drug is prepared by same solvent after suitable dilution.

pH

The pH of various gel formulations was determined by using digital pH meter. 2.5gm of gel was accurately weighed and dispersed in 25ml of distilled water and stored for two hours. The measurement of pH of each formulation was carried out in triplicate and the average values are represented. The pH of dispersions was measured using pH meter.

Spreadability

Spreadability of the gel was measured using a wooden block apparatus with a pulley system, based on the slip and drag characteristics of the formulation. About 2 g of gel was placed between two ground glass slides of equal dimensions, with a 1 kg weight applied for 5 minutes to ensure uniform spreading and remove air bubbles. After scraping off the excess gel, a 50 g weight was applied using a string attached to the top slide. The time taken for the top slide to move 6.5 cm was recorded, with shorter times indicating better Spreadability.

Spreadability was calculated using the following formula: $S = M \times L / T$

Where,

S = Spreadability,

M = Weight in the pan (tied to the upper slide),

L = Length moved by the glass slide and

T = Time (in sec.) taken to separate the slide completely each other.

Viscosity [17]

The viscosity of the emulgel was determined using a Brookfield Viscometer (Model LMDV-60). Approximately 50 g of the emulgel was transferred into a clean, dry beaker. Spindle No. 4 was attached to the viscometer and immersed vertically into the sample, ensuring it did not touch the bottom or sides of the container.

The measurement was carried out at 30 RPM at room temperature. The spindle was allowed to rotate until a stable reading was obtained. The viscosity was recorded in centipoise (cP) as displayed on the digital screen. All measurements were performed in triplicate to ensure accuracy and reproducibility.

Antimicrobial Activity [18]

The antimicrobial activity of the formulated gel was evaluated using the ditch plate technique, a method commonly employed to assess the bacteriostatic and fungistatic properties of semisolid formulations.

Agar plates were prepared and sterilized following standard procedures. A ditch was created in the center of each agar plate and filled with the test formulation. Prepared microbial cultures were streaked across the agar surface at a right angle from the ditch to the edge of the plate.

The plates were then incubated at 25 °C for 18–24 hours. After incubation, bacterial growth was observed, and zones of inhibition were measured to assess the antimicrobial effectiveness of the formulation.

In-vitro Drug Diffusion [19,20]

The in vitro drug diffusion of the gel was evaluated using a Franz diffusion cell with a semi-permeable membrane. The receptor compartment was filled with phosphate buffer (pH 6.8) and maintained at 37 ± 0.5 °C with continuous stirring. At specific time intervals, samples were withdrawn and analyzed using a UV-Visible spectrophotometer to determine the amount of drug diffused across the membrane.

RESULT AND DISCUSSION

Preliminary phyto-chemical screening

Different preliminary phyto-chemical screening tests are done and results of the tests are as mentioned below in (Table 3).

Table 3: Phytochemicals present in Root of *Ficus Bengalensis*

Phytochemicals	Status
Tests for Alkaloids	(+)ve
Tests for Glycosides	(+)ve
Tests for Terpenoids	(+)ve
Tests for Saponins	(+)ve
Tests for Phenols	(+)ve
Tests for Xanthoproteic	(-)ve
Tests for Tannins	(+)ve
Tests for Carbohydrates	(-)ve

Evaluation of Topical Gel Formulation [21,22,23,24].

Physical Evaluation

Physical parameters such as color and appearance were checked (Table 4 & 5).

Table 4: Physical Evaluation Parameters

Sr. No /Code	F1	F2	F3	F4	F5	F6	F7	F8
Color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color	Yellowish-amber color
Texture	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
Odour	Distinctive smell	Distinctive smell	Distinctive smell	Distinctive smell	Distinctive smell	Distinctive smell	Distinctive smell	Distinctive smell

Table 5: Drug Content, pH and Spreadability

Sr.no/ Code	F1	F2	F3	F4	F5	F6	F7	F8
Drug Content	93.8±0.6	94.01±0.4	98.72±0.6	97.12±0.3	100.24±0.4	99.8±0.6	96.08±0.6	97.03±0.6
pH	6.82 ±0.2	6.84 ±0.1	6.55 ±0.5	7.19 ±0.6	7.02 ±0.3	6.68 ±0.2	7.56 ±0.4	6.23 ±0.2
Spreadability	0.8882±0.2	0.8652±0.1	0.4795±0.2	0.4672±0.3	0.5136±0.2	0.4643±0.4	0.8199±0.2	0.8697±0.4

(Where all test was performed by three times n=3, ±SD)

Antimicrobial Activity

Nutrient agar media was used in microbial growth study. In this method the blank and sample Petri plates were used and gel sample were aseptically transferred on to the sample plates in a cross pattern, the microbial growth was observed. Antimicrobial activity was assessed against staphylococcus aureus strain and found to exhibit significant antimicrobial activity.

Viscosity

The viscosity of the gel formulations varied significantly among the batches. Batch F5 showed the highest viscosity (28,803 cP), followed by F4 (23,908 cP) and F6 (23,581 cP), indicating thicker and more viscous gel consistency (Table 6). On the other hand, Batches F3 (8,812 cP), F8 (8,752 cP), and F1 (9,139 cP) exhibited lower viscosities, suggesting a comparatively less thick formulation as given in (Figure 2) 3D plot of DOE. The

differences in viscosity may influence the drug release behavior, Spreadability, and overall performance of the gel, with higher viscosities potentially leading to constant drug diffusion.

Table 6: Viscosity of the gel formulations

Batch	Viscosity(cP)
F1	9139
F2	16129
F3	8812
F4	23908
F5	28803
F6	23581
F7	16591
F8	8752

(Where all test was performed by three times n=3, ±SD)

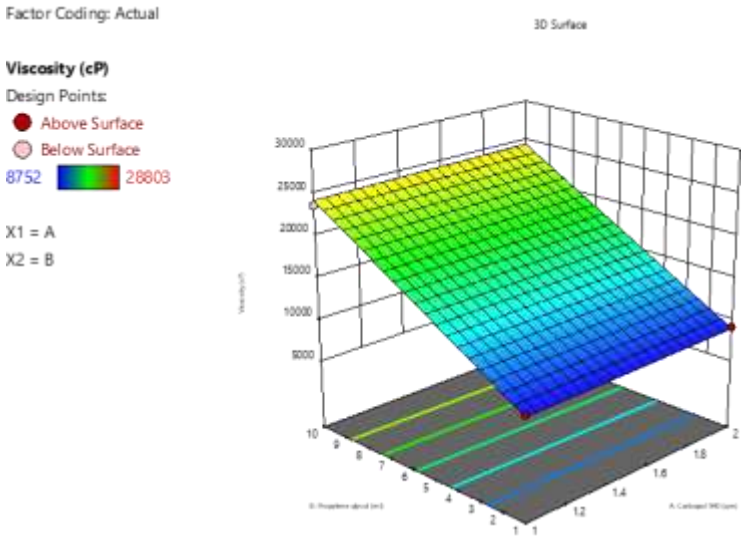

Figure 2: 3D plot of viscosity of the gel

In-vitro Drug Diffusion

Among the eight gel formulations tested for in vitro drug diffusion over 8 hours, Batch F5 exhibited the highest drug release (75 ± 3%), followed closely by F1 (72 ± 6%), F4 (70 ± 2%), and F3 (69 ± 1%) (Table 7). These batches demonstrated superior drug release profiles compared to the others. In contrast, Batches F6, F7, and F8 showed the lowest drug release percentages, all around 50%, indicating relatively poor diffusion characteristics. Overall, Batch F5 can be considered the most effective formulation in terms of sustained drug release as given in (Figure 3) 3D plot of DOE.

Table 7: In-vitro Drug Diffusion gel formulations

Batch	Time in (Hrs.)	% Drug release
F1	8	72±6
F2	8	52±3
F3	8	69±1
F4	8	70±2
F5	8	75±3
F6	8	50±2
F7	8	51±1
F8	8	49±3

(Where all test was performed by three times n=3, ±SD)

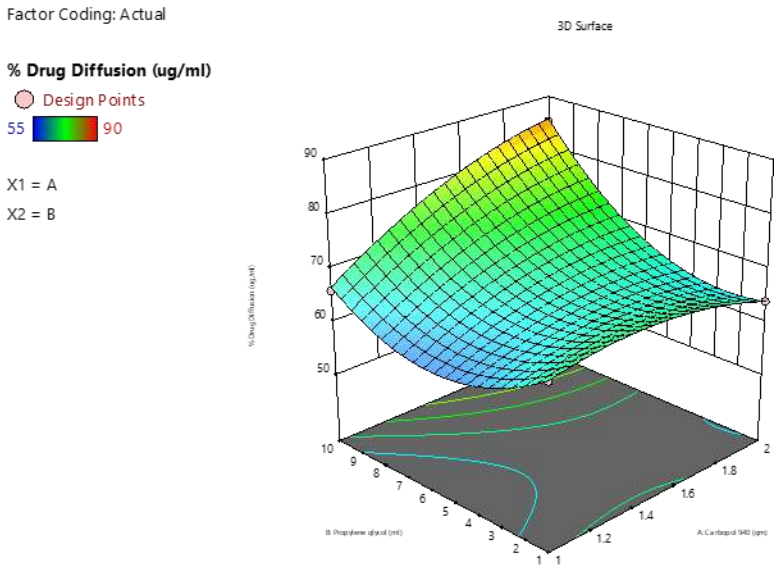

Figure 3: 3D plot of In-vitro drug diffusion of the gel

CONCLUSION

The present study successfully formulated and evaluated a herbal gel containing aerial root extract of *Ficus bengalensis* (Indian Banyan tree), aiming to explore its antimicrobial and antifungal potential for topical application. The extract, rich in bioactive phytoconstituents like lupeol, gamma-sitosterol, and palmitic acid, was effectively incorporated into a gel base using Carbopol 940 and other standard excipients.

Among the eight formulations (F1–F8) developed using Central Composite Design (CCD) for optimization, Formulation F5 emerged as the most effective based on comprehensive evaluation criteria:

- Drug Content: F5 showed the highest drug content ($100.24 \pm 0.4\%$), indicating uniform and efficient dispersion of the extract.
- pH: The pH of F5 (7.02 ± 0.3) was within the ideal range for skin compatibility, ensuring safety upon topical application.
- Viscosity: F5 demonstrated the highest viscosity (28,803 cP), which supports better gel consistency and potentially prolonged drug retention at the site of application.
- In-vitro Drug Diffusion: F5 showed the highest drug release ($75 \pm 3\%$) over 8 hours, confirming efficient and sustained drug diffusion.
- Antimicrobial Activity: The gel exhibited significant antimicrobial activity against *Staphylococcus aureus*, indicating its therapeutic potential in treating skin infections.

The preliminary phytochemical screening confirmed the presence of essential therapeutic compounds such as alkaloids, glycosides, terpenoids, phenols, and tannins, which contribute to the observed biological activities.

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