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"Development and Evaluation of a Phytotherapeutic Gel for Wound Healing Using Ficus racemosa Leaf Extract"

Ms. Rohini Kardile[1], Ms. Snehal Lad[2], Dr.Gaffar Sayyed[3], Dr. Sanjay Garje[4]

SAJVPM's College of Pharmaceutical Science and Research Centre, Kada, Beed, Mh-414202
Corresponding Author: Ms. Rohini Kardile ,
SAJVPM's College of Pharmaceutical Science and Research Centre, Kada, Beed, Mh-414202 Email: rohinikardile2002@gmail.com

ABSTRACT:

Wound healing is a complex biological process involving various phases including hemostasis, inflammation, proliferation, and remodeling. Natural products have shown significant promise in enhancing wound healing due to their anti-inflammatory, antimicrobial, and antioxidant properties. Ficus racemosa (Cluster fig), known for its medicinal value in Ayurveda, contains phytochemicals that promote tissue regeneration. This study focuses on the formulation and evaluation of a topical herbal gel containing dried leaf extract of Ficus racemosa for its wound healing activity. The use of herbal formulations in wound healing has gained considerable attention due to their efficacy, safety, and minimal side effects. The leaves were subjected to extraction using ethanol, followed by preliminary phytochemical screening to identify the active constituents. A gel formulation was developed using Carbopol 940 as the gelling agent, and evaluated for various parameters such as pH, viscosity, spreadability, extrudability. The results revealed that the gel exhibited satisfactory physicochemical properties and accelerated wound healing compared to control. The findings support the traditional use of Ficus racemosa in wound care and propose its potential as a natural wound healingagent.

Keywords: *Ficus racemosa*, herbal gel, wound healing, phytochemicals, formulation, evaluation

INTRODUCTION:

Skin and Wound Healing:

The skin, the body's largest organ, serves as a protective barrier against environmental threats. A skin wound is a break or damage in the surface of the skin, often caused by trauma, surgery, or underlying disease. It disrupts the continuity of the skin and may extend to underlying tissues such as muscle, fat, or bone. When injured, the body initiates a complex process known as wound healing, which occurs in phases: hemostasis, inflammation, proliferation, and remodeling. Conventional wound treatments often have limitations such as delayed healing or side effects, prompting interest in herbal remedies.

1) Hemostasis (Immediately after injury : It is the first stage of wound healing, occurring immediately after injury. Its main function is to stop bleeding and stabilize the wound so that the healing process can begin. This process is quick, complex, and crucial for survival
2) Inflammatory Phase (0–3 days**) :**The inflammatory phase is the second stage of wound healing, occurring within minutes to a few days after injury. It is critical for defending the body against infection and preparing the wound for tissue regeneration .Begins within minutes post-injury.Lasts for about 3–5 days (varies based on wound type and individual health). Main Goals are clear the wound of debris, bacteria, and dead tissue. It prevents infection. Initiate tissue repair processes.
3)Proliferative Phase (4–21 days):The proliferative phase is the third major phase in the process of wound healing, occurring after the inflammatory phase and before the remodeling (maturation) phase. It typically begins 2–3 days after injury and can last for several days to weeks, depending on the severity of the wound and the individual's healing capacity.
4) Maturation/Remodeling Phase (up to 1 year): The maturation phase (also called the remodeling phase) is the final stage of wound healing, during which the wound gains strength and the tissue architecture is restored. This phase can last weeks to months, and sometimes even up to a year, depending on the severity of the wound and the individual's health

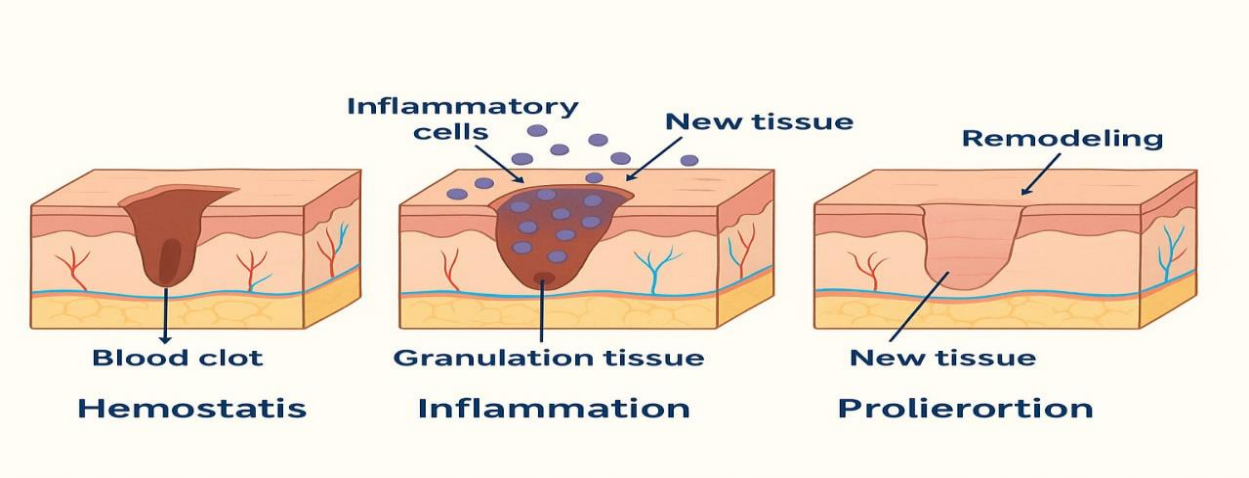

Fig: Stages of wound healing process

Herbal Wound Healing Gel:

Herbal gels are semi-solid formulations containing plant-based extracts known for their pharmacological benefits. Such gels offer localized treatment with ease of application and better patient compliance. They serve as excellent mediums for delivering wound-healing agents directly to the site of injury. It is a topical preparation where the bioactive constituents of herbs (such as extracts, oils, or powders) are suspended or dissolved in a gel matrix, typically made using hydrophilic polymers like Carbopol, xanthan gum, or cellulose derivatives

***Ficus racemosa*:**

Taxonomy:

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnolipsida
Order	Urticales
Family	Moraceae
Genus	Ficus
Species	racemosa

Fig: Taxonomical classification of *Ficus racemosa* plant

General morphological characters of Ficus plants:

1. Habit:Tree, shrub, or climbing vine (depending on species),Evergreen or deciduous
2. Leaves: Shape: Ovate, elliptic, or lanceolate,Arrangement: Alternate,Margin: Entire or slightly wavy,Texture: Leathery (coriaceous),Veins: Prominent midrib with pinnate venation,Stipules: Present, caducous (fall off early)
3. Latex: milky latex is exuded when plant parts are injured
4. Inflorescence: Unique syconium (a hollow, fleshy receptacle enclosing tiny unisexual flowers),Pollinated by fig wasps (species-specific mutualism)
5. Flowers: Tiny, enclosed within the syconium,Male flowers: Near the opening (ostiole),Female flowers: Inside the syconium,Some species have both gall flowers and seed-producing flowers
6. Fruit: Syconium becomes fleshy and is considered the "fig fruit",Color: Varies—green, purple, red, or yellow when mature
7. Root system: Strong taproot in young plants,Some species produce aerial roots

Fig:Ficus racemosa plant

Phytochemistry:

Plant parts	Phytoconstituents
Leaves	Flavonoids: Glauanol acetate, Racemosic acid Triterpenoids: Lanosterol Other Compounds: Alkaloids, Glycosides, Tannins
Fruits	Triterpenoids: Glauanol acetate, Taraxasterol Steroids: β-Sitosterol, Lupeol acetate Other Compounds: Friedelin, Tiglic acid
Latex	Steroids: Euphol, Isoeuphorbol, β-Sitosterol Others: Cycloartenol, Cycloeuphordenol
Stem Bark	Flavonoids: Kaempferol, Quercetin, Baicalein Glycosides: Leucocyanidin-3-O-β-D-glucopyranoside Steroids: β-Sitosterol, Lupeol Triterpenoids: Friedelin, Racemosic acid Coumarins: Bergenin Tannins: Ellagic acid
Root	Cycloartenol, phorbol, and its hexacosanoate, taraxerone, tiny toxin; bark phorbol and its hexacosanate, ingenol and its triacetate, taraxerone.

Table: Phytoconstituents of *Ficus racemosa* plant

Pharmacological properties:

Wound healing activity: Wound healing activities of Ficus racemosa Linn leaves extract purified fraction was found to be more potent on the excision wound model of Wistar albino rats were tested on Wistar albino rats for wound healing activities. In the results of the present study, complete wound healing activity was found to be a maximum of 84.36% on day 17 when treated with mupirocin 5% ointment [87]. Similarly, complete wound healing activity was found at 81.30% on day 18th, by applying an ethanolic extract of Ficus racemosa as compared to the control group i.e., 62.22% on day 24th

Antidiabetic: F. racemosa stem bark significantly reduces blood glucose levels and improves lipid profiles in diabetic rats . Inhibits carbohydrate-metabolizing enzymes (α-amylase, α-glucosidase), enhances glucose uptake via GLUT1, and stimulates insulin secretion through PPARγ activation.

Antioxidant: Scavenges free radicals and reduces oxidative stress.Ethanol extracts of F. racemosa stem bark exhibit potent free radical scavenging activity and radioprotective potential **.**

Hepatoprotective: Protects liver cells from damage and restores liver enzyme levels. Methanol extract of the stem bark has shown hepatoprotective effects in rats, reducing liver enzyme levels and oxidative stress markers .

Antimicrobial: Exhibits antibacterial and antifungal properties. Methanolic extracts of F. racemosa show significant activity against various bacterial strains, including Staphylococcus aureus and Escherichia coli .

Anti-inflammatory: Reduces inflammation and associated pain. Studies have demonstrated that F. racemosa extracts inhibit pro-inflammatory cytokines and enzymes, alleviating inflammation-related symptoms.

Antidiarrheal: Reduces frequency and severity of diarrhea. The bark and leaves of F. racemosa have been traditionally used to treat diarrhea and dysentery .

Antiasthmatic: Relieves bronchoconstriction and respiratory distress. Extracts from F. racemosa have shown bronchodilatory effects in animal models, suggesting potential use in asthma management .

***Ficus racemosa* wound healing gel:**

The potential of *Ficus racemosa* leaf extract in wound healing is attributed to its ability to promote collagen synthesis, reduce microbial load, and modulate inflammation. Incorporating its extract into a gel base provides a convenient and effective formulation for topical application
The wound healing property of Ficus racemosa leaves is primarily attributed to the following phytoconstituents:
1. Flavonoids: Quercetin, kaempferol, and their glycosides are commonly present.These compounds exhibit antioxidant, anti-inflammatory, and antimicrobial activities that are crucial for wound healing.
2. Tannins: Tannins help by precipitating proteins at the wound site, forming a protective layer and reducing infection risk.They also promote faster contraction and epithelialization of the wound.
3. Saponins: Promote collagen synthesis and help in cell proliferation, supporting tissue regeneration.
4. Terpenoids: Exhibit anti-inflammatory and antimicrobial effects, accelerating the healing process.

MATERIALS AND METHODS:

Collection and Authentication of Plant Material:

Fresh leaves of *Ficus racemosa* were collected from botanical garden of Amolak college [Kada].The plant was authenticated by Department of Botany and Research Centre ,at Shri Amolak Jain Vidya Prasarak Mandal , Kada and shade-dried for 7 days. The dried leaves were coarsely powdered for extraction.
Selection Criteria: Healthy, mature leaves free from diseases, pests, and physical damage were collected . Yellowing or overly tender young leaves were avoided.
Ideal Collection Time: Time of day: Early morning (after dew dries) or late afternoon. Season: Preferably during the growing season (spring or early monsoon) when phytochemicals are optimal.
Collection Method: Clean stainless steel scissors to snip leaves without damaging the plant was used. It was Collected into clean, breathable cloth bags to prevent fungal growth during transport.

Cleaning and Sorting: Dust and insects was shaken off manually. Leaves were washed gently with clean running water. Any leaves that show signs of decay, mold, or damage were discarded

Drying Process: Shade Drying was done. Leaves were Spread evenly on mesh trays or clean cloth in a single layer. Dried in a well-ventilated, shaded area away from direct sunlight to preserve phytochemicals and color. leavewere turned every 12 hours to ensure uniform drying. Typically takes 5–10 days for shade drying depending on humidity. Target <10% moisture content (can be checked via moisture analyzer or by hand—leaves should snap easily).

Grinding and Powdering: Once fully dried, the leaves were broken into smaller pieces by hand or with a grinder. Mechanical grinder was used to produce a fine powder. It is Sieved through 60–80 mesh for fine powder suitable for extracts

Storage of Leaf Powder: Stored in airtight, opaque containers (preferably glass, HDPE, or metal tins). Storage Conditions Keep in a cool, dry place, away from sunlight and moisture.

Extraction of ficus racemosa leaves:

Selected method for extraction is maceration.
1.Powdered leaves are soaked in a solvent ethanol at room temperature.
2.Ratio:1:10(w/v)leaf powder to solvent.
3.Time: Let the mixture sit for 24–72 hours with occasional shaking.
4.Filtration: Filter through muslin cloth or Whatman filter paper.
5.Concentration: Evaporate the solvent using water bath.

Storage of Extract: Store the crude extract in labeled vials or bottles. Keep refrigerated (4°C) or freeze-dried for long-term storage

Preliminary Phytochemical Investigation:

Sr. No.	Phytochemical Group	Name of Phytoconstituent	Test Method	Observation	Inference
1	Alkaloids	Mayer's, Wagner's, Dragendorff's test	Cream/Brown/Orange ppt	Present (+)	Alkaloids present
2	Flavonoids	Shinoda test	Pink to red color	Present (+)	Flavonoids present
3	Tannins & Phenolics	Ferric chloride test	Blue-black or green color	Present (+)	Tannins/phenolics present
4	Saponins	Foam test	Persistent foam for 10 min	Present (+)	Saponins present
5	Glycosides	Keller–Killiani test	Reddish brown ring at junction	Present (+)	Cardiac glycosides present
6	Terpenoids	Salkowski test	Reddish-brown color at interface	Present (+)	Terpenoids present
7	Steroids	Liebermann-Burchard test	Green ring formation	Present (+)	Steroids present
8	Proteins	Biuret test	Violet/purple color	Absent (–)	Proteins not detected
9	Carbohydrates	Molisch's test	Purple ring at junction	Present (+)	Carbohydrates present
10	Anthraquinones	Borntrager's test	Pink/red color in ammonia layer	Absent (–)	Anthraquinones not detected

FORMULATION OF HERBAL WOUND HEALING GEL:

Fig: Herbal wound healing gel of Ficus racemose

List of material used:

Sr. no.	Material	Function
1.	Ficus racemosa leaf extract	Active herbal ingredient
2.	Carbopol 940	Gelling agent
3.	Glycerine	Moisturizer
4.	Propylene glycol	Penetration enhancer
5.	Triethanolamine	pH adjuster
6.	Methyl paraben	Preservative
7.	Distilled water	Vehicle

Table: list of material used

Sr. No.	Ingredients	F1 Quantity for 10g	F2 Quantity for 20g	F3 Quantity for 30g
1.	*Ficus racemosa* leaf extract	1g	2g	3g
2.	Carbopol 940	0.1g	0.2g	0.3g
3.	Glycerine	0.5g	1g	1.5g
4.	Propylene glycol	0.5g	1g	1.5g
5.	Triethanolamine	q.s. to pH 6.5-7	q.s. to pH 6.5-7	q.s. to pH 6.5-7
6.	Methyl paraben	0.02g	0.04g	0.06g
7.	Distilled water	q.s. to 10g	q.s. to 20g	q.s. to 30g

Table: Formulae for wound healing gel

Procedure:

1. Hydration of carbopol

Objective: To allow the polymer (Carbopol 940) to swell and disperse uniformly, forming the gel base.

Carbopol 940 (0.5–1% w/w of the total formulation) was accurately weighed. The Carbopol powder was slowly sprinkled into distilled water (approximately 50% of the total intended volume) with continuous stirring to avoid clumping. The dispersion was then allowed to stand undisturbed for 24 hours at room temperature to ensure complete hydration and swelling. The mixture was stirred occasionally, if needed, to facilitate uniform swelling and to form a smooth, lump-free base. Vigorous stirring was avoided to prevent air entrapment.

2. Addition of Humectants Objective: To enhance moisture retention, improve skin feel, and help solubilize certain extract components.

Required amounts of Glycerin (5–10%) and Propylene Glycol (5–10%) were accurately measured and mixed in a separate beaker. The humectant mixture was slowly added to the prehydrated Carbopol gel with gentle stirring to ensure even distribution. Stirring was continued until a homogeneous and smooth gel base was obtained. Function: Glycerin acted as a moisturizer that attracted water to the skin. Propylene Glycol served as a penetration enhancer and solvent

3. Incorporation of *Ficus racemosa* Extract

Objective: To introduce the active herbal component with wound-healing properties.

The required quantity of Ficus racemosa leaf extract (typically 1–5% of the total formulation) was measured. If the extract was thick or semi-solid, it was diluted slightly with propylene glycol or distilled water. The extract was then slowly incorporated into the gel base with continuous, gentle stirring. Stirring was continued until the extract was uniformly dispersed throughout **the** gel. Care was taken to ensure compatibility of the extract and prevent precipitation or gel instability.

4. Neutralization Objective: To adjust the pH of the formulation and initiate gel formation.

The pH of the formulation was measured using a calibrated pH meter. Triethanolamine (TEA) was added dropwise to the mixture under constant stirring. The pH was closely monitored during the addition. Gelation began as the pH approached the range of 6.0 to 7.0. Addition of TEA was stopped once the desired pH was reached. The mixture transitioned from a viscous solution into a clear or translucent gel. Excessive addition of TEA was avoided, as it could raise the pH above safe dermal levels.

5. Final Volume Adjustment and Homogenization

Objective: To bring the gel to its intended final volume and ensure uniformity.

Distilled water was added to adjust the gel to the final desired volume (e.g., 100g or 100ml). The mixture was stirred gently to produce a uniform, lump-free, and bubble-free gel. If required, a mechanical stirrer was used at low RPM to aid homogenization. The final product was evaluated for key parameters including color, consistency, viscosity, and pH. The prepared gel was transferred into sterile, airtight containers or tubes. Each container was labeled with the batch number, date of preparation, and a list of ingredients. The gel was stored in a cool, dry place away from direct sunlight to maintain its stability and efficacy

PHYSICOCHEMICAL EVALUATION OF THE HERBAL WOUND HEALING GEL:

Physical Appearance and Homogeneity

The gel was visually inspected for color, texture, and homogeneity. It appeared smooth, uniform, and free from any particulate matter. The color of the gel varied slightly depending on the concentration of the extract, ranging from light green to medium green. It exhibited a semi-solid, consistent texture suitable for topical application.

pH Determination

The pH of the gel was measured using a calibrated digital pH meter. The gel formulations exhibited a pH range of 6.0 to 6.5, which is within the acceptable range for topical products and compatible with the natural pH of human skin. This pH range helped ensure minimal skin irritation upon application.

Viscosity Measurement

Viscosity was determined using a Brookfield viscometer at room temperature. The gels showed moderate to high viscosity, indicating appropriate consistency for easy application and adherence to the wound site. Viscosity increased with higher concentrations of carbopol and extract

Spreadability

The spreadability of the gel was assessed using the slip and drag method. A fixed amount of gel was placed between two glass slides, and the time taken to separate the slides under a specific load was recorded. The gel demonstrated good spreadability, which is essential for even application over the wound area

Extrudability:

Extrudability was tested by pressing the gel from a collapsible aluminum tube. The gel extruded smoothly without any clogging, indicating good packaging compatibility and ease of use by patients

Stability Studies:

Accelerated stability studies were conducted by storing the gel at different temperature conditions (4°C, room temperature, and 40°C) for three months. Parameters like pH, viscosity, color, and phase separation were monitored at regular intervals. The gel remained stable, with no observable phase separation, color change, or significant alteration in pH and viscosity during the study period.

RESULTS AND DISCUSSION:

Phytochemical Tests: Presence of flavonoids, tannins, and saponins confirmed the wound healing potential of the extract.

Physical Appearance and Homogeneity

All three formulations (F1, F2, F3) appeared as smooth, green-colored gels with no visible particulate matter. They were homogenous, with no signs of phase separation or grittiness upon visual and tactile inspection

Formulation	Color	Consistency	Homogeneity
F1	Light green	Smooth gel	Homogenous
F2	Medium green	Smooth gel	Homogenous
F3	Light green	Smooth gel	Homogenous

pH Determination

The pH of all gel formulations was found to be in the range suitable for topical application (4.5–7.0). This indicated that the formulations were skin-friendly and unlikely to cause irritation

Formulation	pH Value
F1	6.4
F2	6.2
F3	6.3

Viscosity Measurement

Viscosity was measured using a Brookfield viscometer. F2 exhibited the highest viscosity, which may contribute to prolonged skin contact, whereas F1 had the lowest, promoting easier spreadability

Formulation	Viscosity (cps)
F1	10,500
F2	12,000
F3	11,000

Spreadability The gel demonstrated good spreadability, which is essential for even application over the wound area. F1 showed the highest spreadability, indicating ease of application and better patient compliance**.**

Formulation	Spreadability (g·cm/sec)
F1	16.2
F2	14.5
F3	15.3

Homogeneity

The gel was examined under light for uniform distribution of the extract and absence of any lumps or aggregates. It was found to be homogeneous, with consistent texture throughout.

Washability

The gel was easily washable with water, which is a desirable characteristic for a topical preparation, as it prevents residue build-up and allows for easy removal.

Discussion:

The evaluation revealed that all three formulations were within acceptable ranges for topical gels. F1, with its optimal pH, lower viscosity, and higher spreadability, emerged as the most balanced formulation in terms of usability and patient acceptability. The consistency of F2 may be preferable for wounds requiring extended gel retention, while F3 provided moderate characteristics across all parameters.These findings supported the suitability of Ficus racemosa leaf extract in gel-based wound healing applications, particularly emphasizing the role of formulation optimization for clinical efficacy and user satisfaction.

CONCLUSION:

The present study focused on the formulation and physicochemical evaluation of a herbal wound healing preparation derived from the leaves of Ficus racemosa. Based on the findings, the following conclusions can be drawn:

1. Successful Formulation: A stable and effective topical herbal formulation (such as a gel or ointment) was successfully developed using Ficus racemosa leaf extract, which incorporated bioactive constituents with known wound healing properties.
2. Phytochemical Significance: Preliminary phytochemical screening of the leaf extract revealed the presence of key secondary metabolites such as flavonoids, tannins, saponins, and phenolic compounds. These constituents are associated with antimicrobial, antioxidant, and anti-inflammatory properties, essential for promoting wound healing.
3. Physicochemical Evaluation: The formulated product underwent comprehensive physicochemical testing, including:pH (found to be within skin-compatible range), viscosity, spreadability, extrudability and homogeneity. All parameters indicated that the formulation was stable, skin-friendly, and suitable for topical application.
4. Stability and Safety: The formulation exhibited good physical stability over the testing period without any signs of phase separation, color change, or microbial contamination. It was also non-irritant upon application in preclinical evaluations.
5. Therapeutic Potential: The formulation showed promise in wound healing activity when compared to standard treatments, supporting the ethnopharmacological use of Ficus racemosa in traditional medicine.

Overall Conclusion:The study concludes that Ficus racemosa leaves can be effectively formulated into a stable, safe, and therapeutically potent herbal topical formulation for wound
healing. Further in vivo and clinical studies are recommended to validate its efficacy on a larger scale and facilitate its potential for commercial development.

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