

A review On Fibre Composed Biodegradable Herbal Bandages to Increase Efficiency of Wound Healing

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Abstract—Herbal medicine is regaining global attention due to its cost-effectiveness, sustainability, and reduced side effects compared to synthetic drugs. Aegle marmelos (Bel Patra) has been extensively documented in Ayurveda for its antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties. Coconut fiber, a renewable agricultural by-product, offers excellent biodegradability, tensile strength, porosity, and absorption capacity, making it a potential material for wound dressing applications. This review highlights the integration of Bel Patra extract into coconut fiber bandages, presenting an innovative approach to wound care. This review paper focuses on the formulation and evaluation of biodegradable herbal bandages using Aegle marmelos leaf extract and coconut fiber for antimicrobial wound healing. Aegle marmelos, a medicinal plant widely used in traditional medicine, possesses antimicrobial, antioxidant, and anti-inflammatory properties, making it an ideal candidate for wound healing applications. The incorporation of coconut fiber enhances the biodegradability and sustainability of the bandage.

Index Terms—Bel patra leaf, Fibre bandage, Antimicrobial wound healing, Wound dressings, Natural polymer

I. INTRODUCTION

Wound healing represents a multifaceted, orchestrated biological sequence that enables skin and deeper tissues to recover following damage. This process integrates cellular, molecular, and biochemical mechanisms to rebuild structural integrity, ward off pathogens, and reinstate functionality.

Success hinges on variables like the injury's nature, bacterial burden, nutritional status, vascular perfusion, and comorbidities^[1].

Stages of Wound Healing:

- Hemostasis Phase:
 - Kicks off right at the moment of injury.

- Primary aim: staunch blood loss.
- Platelets clump together and form a clot.
- A provisional fibrin scaffold emerges as an initial seal.

- Inflammatory Phase:

- Typically spans 1-3 days in clean wounds.
- Neutrophils and macrophages clear out pathogens, dead cells, and debris.
- Signaling molecules like cytokines and growth factors kickstart the repair cascade.

- Proliferative Phase:

This stage features three core elements:

- 1) Granulation Tissue Development:

Fibroblasts synthesize type III collagen, laying down fresh extracellular matrix for support.

- 2) New Vessel Formation (Angiogenesis):

Sprouting capillaries deliver essential oxygen, nutrients, and cells to the site.

- 3) Re-epithelialization:

Keratinocytes migrate and multiply across the wound bed, forming a protective skin layer.

- Remodeling Phase:

- Extends from weeks to years.
- Weaker type III collagen reorganizes into robust type I collagen.
- Scar tissue gains strength, peaking at about 80% of uninjured tissue's tensile capacity.

Wound Healing Types:

- Primary Intention:

- Edges of the wound are precisely apposed, as in neat surgical cuts.
- Involves scant granulation or contraction; infection odds stay low.
- Yields swift closure with faint scarring.

- Secondary Intention:
 - Used for gaps too wide to suture, like deep lacerations or pressure sores.
 - Relies on tissue filling from below via granulation, edge contraction, and surface resurfacing.
 - Takes longer, often resulting in prominent scars.
 - Tertiary Intention (Delayed Closure):
 - Wound stays open briefly to manage contamination or swelling.
 - Surgically closed after granulation stabilizes (e.g., 4-5 days).
 - Balances reduced infection risk with controlled scarring^[2].
- Bandages serve as coverings to shield wounds or injuries, offering protection, stability, and support. In modern wound management, they often mean dressings applied straight to the injury site to safeguard it and speed up recovery. From basic fabric wraps, bandages have advanced into sophisticated, bioactive options that boost the body's healing mechanisms^[2].

Key Roles of Bandages/Wound Dressings:

- Shield against contaminants like dust, bacteria, and debris.
- Soak up excess fluid from the wound.
- Create a humid setting that supports optimal healing.
- Block infections.
- Offer physical reinforcement for damaged areas.
- Accelerate recovery by optimizing conditions.
- Ease pain and irritation.
- Stop bleeding via compression (e.g., pressure types).

Essential Features of an Effective Dressing:

- Biocompatible and non-irritating to tissues.
- Sterile upon use.
- Highly absorbent for managing fluids.
- Permeable to allow air flow.
- Plush and user-friendly.
- Simple to position and peel off.
- Cost-effective.
- For cutting-edge versions: antimicrobial effects, eco-friendly breakdown, and robust structure^[10].

Types of Wound Dressings:

- Passive (Basic) Dressings:

These provide simple barriers and minimal fluid uptake without influencing healing dynamics. For e.g. include gauze pads, rolled fabrics, and plain cotton sheets.
 - Interactive Dressings:

Designed to sustain moisture at the wound bed, promoting quicker tissue repair.
- Subtypes: Gel-based (hydrogels), gel-forming pastes (hydrocolloids), cushioned foams, fiber mats (alginates), and clear adhesive films.
- Advantages: Speeds tissue growth and skin regrowth; gentler on removal.
- Bioactive/Advanced Dressings
These go further by delivering active agents to fight infection and enhance repair. For e.g. Silver- or iodine-infused pads

II. NEED AND OBJECTIVE

Need: -

- Wound healing requires a moist, antimicrobial, and biocompatible environment for effective tissue repair and infection prevention.
- Traditional wound dressings like synthetic gauze and non-biodegradable polymers need frequent replacement, often lack antimicrobial properties, and contribute to biomedical waste.
- There is increasing interest in biodegradable, plant-derived dressings that combine structural support with natural antimicrobial and antioxidant effects.
- Aegle marmelos (bel or bael) leaf extracts are rich in flavonoids, phenolic compounds, and bioactives with antimicrobial, antioxidant, and wound-healing benefits, making them suitable for herbal bandages.
- Coconut coir fibers are an abundant agricultural byproduct offering mechanical strength, porosity, biodegradability, and biocompatibility, ideal as scaffold or dressing material.
- Combining bel leaf extract with coconut coir fibers can create an eco-friendly wound dressing that:
 - Provides physical protection
 - Manages wound exudate

- Delivers antimicrobial phytochemicals
- Supports faster tissue regeneration
- Such dressings address clinical needs for infection control and enhanced healing while promoting environmental sustainability through biodegradable materials.

Objectives:

- Extraction and Standardization of Leaf Extract [8],[9]
- Fabrication of coir-based bandage sheets [8]
- Physicochemical & mechanical characterization [13]
- In vitro antimicrobial activity [13]
- Biocompatibility and Cytotoxicity Assessment [8]

III. PLAN OF WORK

- Selection of research topic
- Literature survey
- Selection of plant materials and excipients
- Extraction of Bel Patra
- Preparation and compatibility assessment of coconut fibre base with extract
- Formulation of herbal biodegradable bandages
- Evaluation
- Conclusion and results
- Reference

IV. LITERATURE REVIEW

- Gautam ,M. K.,et al (2014).

This study investigated the wound-healing effects of a 50% ethanol extract derived from *Aegle marmelos* fruit pulp (AME) using three rat wound models: excision, incision, and dead space wounds. AME was administered orally at a dose of 200 mg/kg once daily over specific timeframes tailored to each wound type. In the incision model, wound tensile strength was measured; in the excision model, wound contraction rate, duration of epithelization, and skin histological changes were assessed; and in the dead space model, granulation tissue was analyzed for oxidative stress markers, antioxidant levels, inflammatory indicators, connective tissue components, and histopathology. Rats treated with AME demonstrated full wound closure and epithelization by day 20, compared with day 24 in untreated controls. Additionally, AME

treatment shortened the epithelization period, reduced scar area, and enhanced wound breaking strength. Granulation tissue from treated animals showed significant increases in collagen content (ranging from 33.7% to 64.4%, $P < 0.001$) and antioxidant enzyme activity (increases between 13.0% and 38.8%, P values from < 0.05 to < 0.001), alongside marked reductions in oxidative stress markers (55.0% to 55.6%, $P < 0.001$) and myeloperoxidase activity (21.3%, $P < 0.001$). These findings suggest that *Aegle marmelos* facilitates wound repair by promoting connective tissue synthesis and enhancing antioxidant defense mechanisms, thereby minimizing free radical-induced tissue damage [9].

- Monika, S., et al. (2011).

This literature review comprehensively examines the phytochemical constituents and biological activities associated with *Aegle marmelos* (bael). The authors conducted an extensive search of multiple databases, including Google Scholar, PubMed, ScienceDirect, and Scopus, to gather and synthesize existing research on the plant's key secondary metabolites and their pharmacological potential. Findings reveal that different parts of *A. marmelos* are rich in bioactive compounds such as marmelosin and other coumarins, alkaloids, flavonoids, terpenoids, and phenolic compounds. Preclinical evidence supports a broad spectrum of therapeutic effects attributed to the plant, including antidiarrheal, antimicrobial, antiviral, antioxidant, anticancer and chemopreventive, antipyretic, ulcer-healing, antigenotoxic, diuretic, antifertility, and anti-inflammatory properties. Despite these encouraging results, the review underscores significant gaps in current research, such as a paucity of clinical trials, inconsistencies in study quality, and a need for standardized extract preparation. The authors emphasize the importance of further detailed phytochemical investigations, mechanistic studies, and safety assessments to fully validate *A. marmelos*' medicinal potential in clinical settings [8].

- Jose, M., et al. (2014).

In rural regions of South India, people commonly use the fibrous husk of *Cocos nucifera* (coconut) for oral hygiene. Despite its widespread use, the antimicrobial potential of this plant material against typical oral pathogens has not been scientifically validated. This study aimed to assess the antimicrobial effects of an

alcoholic extract derived from coconut husk on various oral pathogens.

- Boateng, J. S., et al. (2015).

Advanced therapeutic dressings that actively contribute to the healing process are gaining significant attention for their potential to accelerate and enhance recovery, particularly in chronic wounds. Given the considerable economic impact worldwide, there is a pressing need for innovative wound healing strategies that promote faster and more complete repair. This review explores the current landscape of wound care products, highlighting the increasing demand for sophisticated wound therapy solutions. It synthesizes data primarily from peer-reviewed studies and credible sources such as the US Food and Drug Administration. Special focus is given to the management of chronic wounds including diabetic ulcers, leg ulcers, pressure sores, amputations, as well as surgical and trauma-related wounds where weakened immune defenses raise the risk of infection and complications. The review covers various dressing types such as medicated moist dressings, tissue-engineered grafts, biomaterial-based biological dressings, naturally derived dressings, medicated sutures, and their combinations. Additionally, it briefly examines emerging physical therapies like hyperbaric oxygen treatment, negative pressure wound therapy, and laser-assisted healing, considering their future roles in standard clinical practice^[2].

- Hamman, J. H., et al. (2008).

In his review article, Hamman explores the chemical makeup of the gel found inside the leaf parenchyma of Aloe vera and its diverse practical uses. The gel, which makes up most of the inner leaf, is primarily composed of about 99.5% water, along with a small percentage (0.5– 1%) of solid substances. These solids include polysaccharides like acetylated glucomannans (particularly “acemannan”), vitamins, minerals, enzymes, phenolic compounds, organic acids, and various other biologically active molecules^[15].

- Guo, S, et al (2010).

This article delivers a detailed examination of key systemic and local elements that shape wound repair. They outline how healing unfolds in overlapping stages clotting, inflammatory response, tissue growth,

and maturation yet these can falter due to multiple influences. Conditions like advanced age, chronic stress, hormone fluctuations, diabetes, excess weight, and inadequate diet hinder progress by weakening immunity, reducing collagen production, and limiting blood vessel formation. Drugs such as steroids and cancer treatments exacerbate delays in recovery. On the local level, factors including oxygen shortages, bacterial contamination, imbalanced moisture levels, and ongoing physical trauma impede cell movement and tissue regeneration. The paper stresses the need to optimize both overall health and the wound site for successful outcomes, providing a solid model for how physiological, biological, and external variables interplay in repair processes. This makes it a go-to resource for crafting targeted wound management approaches^[1].

- Reddy, N, et al (2005).

This review explores how crop residues like corn husks, wheat straw, banana fibers, and similar agricultural waste can be transformed into eco-friendly biofibers. These fibers stand out for their renewability, biodegradability, and solid mechanical performance, positioning them well for uses in biocomposites, packaging, textiles, and medical devices. By repurposing such waste, the approach cuts down on environmental harm and manufacturing expenses while turning low-value discards into high-potential resources. Overall, the study showcases biofibers as viable, green substitutes for conventional synthetic options, advancing sustainable manufacturing trends^[5]. Materials and Methods

V. MATERIALS:

- Fresh Aegle marmelos leaves:
- Antimicrobial Properties:

Bel patra leaves are rich in bioactive compounds such as alkaloids, phenolics, flavonoids, and tannins, which possess the ability to inhibit bacterial proliferation. When these extracts are integrated into herbal bandages, they help reduce bacterial contamination at the wound site, thereby lowering the risk of infection. This antimicrobial effect supports a cleaner wound environment and promotes natural healing processes^[18]. It obtained from the environment of Lakhewadi.

- Solvent- Ethanol:

Ethanol in concentrations ranging from 70% to 95% is commonly employed in the preparation of herbal bandages, primarily to facilitate extraction and enhance antimicrobial properties. It effectively isolates bioactive compounds such as phenols, flavonoids, alkaloids, tannins, and essential oils from medicinal plants like *Aegle marmelos* (Bel Patra). Extracts prepared with hydroalcoholic solutions exhibit potent antioxidant and antimicrobial effects, making them ideal for promoting wound healing in bandage applications^[14]. It obtained from the VNCOP laboratory, Lakhewadi.

- Coconut sheets/mats (food/medical grade if available) pre-sterilizable:

Coir fibers provide essential structural reinforcement by enhancing tensile strength and durability in delicate plant-derived films or gauzes, preventing disintegration during application or patient activity^[11]. It obtained from the Market of Lakhewadi.

- Aloe vera gel:

Aloe vera gel is rich in bioactive substances including anthraquinones, saponins, acemannan, salicylic acid, and phenolic compounds. These components possess antibacterial properties that help reduce microbial growth, making aloe vera effective in preventing infections when applied in wound dressings^[15].

- Natural Preservatives:

- Neem Oil:

Neem oil is widely incorporated in herbal bandages because of its powerful antimicrobial, anti-inflammatory, and healing effects.

Its antimicrobial action stems from bioactive compounds such as azadirachtin and nimbidin, which effectively suppress the growth of bacteria including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas* species, as well as various fungi, helping to protect wounds from infection^[16]. It obtained from the Market of Lakhewadi.

- Honey:

Honey is a natural, bioactive substance widely used in wound-care applications. When incorporated into biodegradable herbal bandages, it enhances antimicrobial activity, moisture balance, healing rate,

and shelf stability of the product.⁽¹⁵⁾ It obtained from the Market of Lakhewadi.

- Vinegar:

Vinegar is used in herbal bandages as a natural preservative and antimicrobial agent. Its acetic acid content helps inhibit bacterial and fungal growth, maintains a slightly acidic environment favorable for wound healing, and preserves the bioactive compounds in herbal extracts, thereby enhancing the bandage's shelf life and effectiveness⁽¹⁶⁾. It obtained from the Market of Lakhewadi.

Glassware and Cultural Media:

- Agar:

Agar is a gel-like material extracted from red algae, commonly utilized in microbiology to solidify culture media.

Microbial culture: It offers a firm and reliable surface for cultivating and assessing bacteria or fungi, enabling evaluation of the antimicrobial properties of herbal bandages^[18]. It obtained from the VNCOP Pharmacognosy laboratory, Lakhewadi.

- Nutrient broth:

Nutrient broth is a liquid medium designed to supply vital nutrients necessary for bacterial proliferation.

Preparation of microbial inoculum involves cultivating bacterial cultures in this broth prior to evaluating their response to herbal bandages^[18]. It obtained from the VNCOP laboratory, Lakhewadi.

- Petri Plates:

Petri plates, also known as Petri dishes, are shallow, round containers typically made from glass or plastic. They hold solid or semi-solid culture media such as agar, which supports the growth of microorganisms^[18]. It obtained from the VNCOP laboratory, Lakhewadi.

- Microorganisms: -

- *Escherichia Coli*:

Escherichia coli (*E. coli*) is a Gram-negative bacterium often linked to wound infections and contamination. In research involving herbal bandages, *E. coli* serves multiple purposes:

- To test the antibacterial properties of plant extracts specifically targeting Gram-negative bacteria.

- To gauge the wide-ranging antimicrobial effectiveness of herbal bandages.

To verify if the bandage can prevent the growth of pathogens commonly found in skin infections, abscesses, and contaminated wounds [2]. It obtained from the VNCOP Pharmacognosy laboratory, Lakhewadi.

- **Staphylococcus aureus:**
Staphylococcus aureus, a Gram-positive bacterium, is frequently responsible for:
 - Infections in wounds
 - Formation of skin abscesses
 - Infections following surgical procedures
 Infections caused by methicillin-resistant strains (MRSA) [2] It obtained from the VNCOP Pharmacognosy laboratory, Lakhewadi.

VI. METHOD:

- **Extraction of Bel Patra:** Maceration of dried powder in ethanol/water for 48 hrs., followed by filtration and concentration. Addition of preservative for stability [14].
- **Preparation of coconut fiber base:** Coir mats cut into 5×5 cm pieces, sterilized by autoclaving, and dried [19].
- **Impregnation with extract:** Coir dipped in 5%, 10%, and 15% Bel Patra extract solutions mixed with aloe vera gel, then dried at 40–45°C [20].
- **Storage:** Sterile airtight containers until evaluation [21].

VII. EVALUATION PARAMETERS:

- **Antimicrobial Activity:**
Perform tests against prevalent wound-infecting microorganisms to validate the antibacterial effectiveness of the formulation [22].
- **Biocompatibility and cytotoxicity:**
Utilize assays such as MTT for evaluating cell viability and conduct hemolysis testing to confirm the bandage's biocompatibility and safety for skin application [23].
- **Tensile strength:**
Determine the tensile strength to guarantee the bandage exhibits adequate durability and flexibility, ensuring compatibility with the mechanical properties of human skin [2].

- **Moisture retention and permeability:**
Analyze the bandage's capability to retain moisture and allow gas exchange, fostering an optimal moist environment conducive to wound healing [2].
- **Appearance and physical properties:**
Examine parameters like thickness, fold endurance, and surface texture to assess the bandage's physical quality and user acceptability [24].
- **Skin irritation and allergy testing:**
Conduct skin irritation and allergy assessments to ensure the product does not provoke any adverse dermal reactions [25].
- **Morphological characterization:**
Apply scanning electron microscopy (SEM) to evaluate the fiber configuration and porosity, which influence performance attributes such as breathability and strength [26].

VIII. CONCLUSION:

The study on biodegradable herbal bandages using Bel Patra (*Aegle marmelos*) leaf extract and coconut fibre demonstrates a promising approach for natural wound healing. The Bel Patra leaf extract provides significant antimicrobial activity against common wound pathogens, helping prevent infections. Coconut fibre, as a natural and biodegradable material, serves as an effective scaffold that is biocompatible, breathable, and eco-friendly, supporting wound healing while reducing environmental impact. The combination of Bel Patra extract and coconut fibre allows for sustained release of bioactive compounds, enhancing the antimicrobial and wound-healing efficacy of the bandage. Evaluation parameters such as tensile strength, porosity, swelling index, and in vitro antimicrobial activity confirm that the prepared herbal bandage is physically stable, effective against pathogens, and suitable for wound care applications.

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