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## Research Paper

# To Develop an Eco-Friendly Herbal Hydrogel by Using Seed Mucilage and Leaf Extract for Enhanced Wound Healing

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## ABSTRACT

The biological process of wound healing is intricate and includes phases of haemostasis, inflammation, proliferation, and remodelling. The creation of efficient and biocompatible wound dressing materials is necessary because chronic wounds and skin infections continue to be a significant global healthcare concern. Because of their excellent water-retention capacity, biocompatibility, flexibility, and capacity to sustain a moist wound environment, hydrogels have become viable wound care systems. The creation and assessment of a herbal hydrogel containing watermelon and bael leaf extracts for wound healing applications is the main goal of the current work.

## INTRODUCTION

Wounds have plagued patients for millennia, imposing a substantial burden on their careers, thus earning its designation as the 'silent epidemic'. Approximately 4 million cutaneous wounds have been documented annually in affluent countries, with the number in developing nations in ascendance. Skin injury compromises the integrity of the skin's framework, leading to a wound healing process that is characterized by a well-coordinated series of cellular and molecular reactions that aim to recuperate or replace the injured tissue.[1]

Crosslinked polymer chains having three-dimensional (3D) network architectures are known as hydrogels, and they have a comparatively high fluid absorption capacity. Hydrogels closely mimic live tissues due to their high-water content, soft texture, and porosity. Hydrogels have been used in a number of industries, including agriculture, biomaterials, the food industry, drug delivery, tissue engineering, and regenerative medicine, according to current research.[2]

The hydrogels are cross-linked; three-dimensional structures made of water-soluble polymers. Additionally, they can form coatings,

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microparticles, nanoparticles, and sections. Hydrogels are therefore typically used in clinical practice and clinical trials for a variety of uses, such as tissue design and regenerative medicine [3].

**Wound healing occurs in four stages:**

- (A) blood balance
- (B) inflammation
- (C) expansion
- (D) remodelling.[4]

Promote the healing of various wound types. Traditionally, the seeds of *Mucuna pruriens* (MP)

Linn. and the leaves of *Aegle marmelos* (AM) (Linn.) Correa, a member of the Rutaceae family, are referred to as bael (or bel). Often referred to as cowage plant or Kovach, these members of the Fabaceae family are used to treat wounds and cuts. AM is native to India and is widely distributed in Bengal, Central and South India, and the Himalayan region. The leaves have expectorant, laxative, and astringent properties. There have been reports of both antioxidant and antimicrobial action.[5]



**FIGURE 1: PHASES OF WOUND HEALING [6]**

**1.2: BENEFITS OF HYDROGELS**

1. There are many different uses for hydrogels. because of distinct configurations and resemblances to various types of use.
2. Hydrogels offer a wet environment that accelerates the healing of wounds.
3. They assist in keeping the wound site well hydrated.
4. The surface of the wound is calmed and cooled using hydrogels.

**1.3: HYDROGEL'S DIFFICULTIES**

1. Hydrogels are easily torn during handling and have a low mechanical strength.
2. Skin maceration surrounding the wound may result from hydrogels' high-water content.

3. If hydrogels are not well conserved, they may encourage microbial growth.
4. During storage, some hydrogels exhibit poor chemical and physical stability.
5. Hydrogels made of natural polymers frequently have a brief shelf life. [7]

**1.3: GOALS**

1. To use appropriate extraction techniques to extract bioactive components from watermelon seeds and bel Patra leaves.
2. To combine these natural extracts with appropriate gelling agents (like Carbopol) to create a hydrogel composition.
3. To assess the hydrogel's physicochemical characteristics (pH, viscosity, spread ability).

4. To investigate hydrogel's antibacterial efficacy against typical wound infections.
5. To assess the hydrogel's capacity to heal wounds using laboratory or in-vitro testing techniques.
6. To evaluate the produced hydrogel's stability under various storage scenarios.
7. To assess how well herbal hydrogel works in comparison to a conventional formulation for wound healing.[8]

- Electric field and temperature
- The magnetic field
- Light
- Pressure
- Audio [9]

#### Chemical Cues

- pH
- Ionic power
- The composition of the solvent
- Interaction between molecules [10]

### 1.4: HYDROGELS SWELLING RESPONSE:

#### Physical Cues

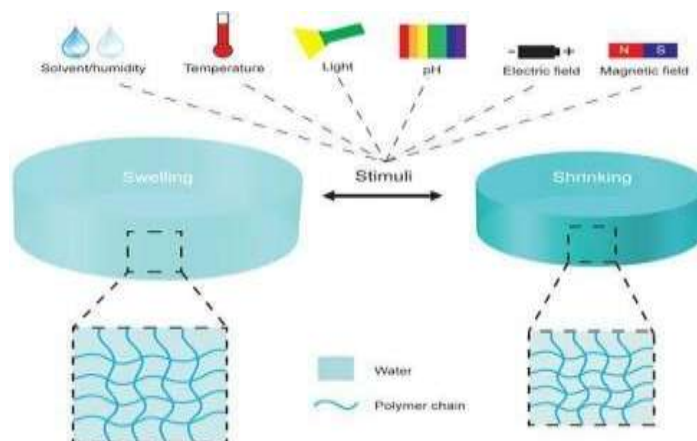


FIGURE 2: HYDROGELS SWELLING RESPONSE

### 1.5: ANTIBACTERIAL HYDROGELS FOR THE HEALTH OF WOUNDS:

me bacteria, including *Acinetobacter baumannii*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Staphylococcus epidermis* live in chronic wounds and may cause serious consequences for the patient. Opportunistic bacteria can enter, colonize, and grow at the site of many types of wounds, including burns and traumas, which may lead to infection. A prolonged healing period and, in certain cases, disability and death can result from infected wounds. Antibiotic misuse has led to the emergence of some multidrug-resistant (MDR) microorganisms. Antibiotic use as a treatment is therefore losing its ability to stop infections. Preventing antibiotic resistance and reducing mortality requires the development of innovative

methods and technologies that employ antibiotics or antibacterial chemicals.[11]

### 1.6: Types of Hydrogels:

#### 1.6.1: Pure Polymer

Hydrogels made from natural polymers, such as proteins and polysaccharides, originating from plants or animals are essential for encasing insecticides. They are prized for their biocompatibility, safety, and biodegradability, which guarantee environmentally benign breakdown following usage. These hydrogels can efficiently control pesticide release in soil to increase efficacy and reduce environmental damage from overuse since they are skilled at absorbing and holding onto water. Natural cellulose's structural properties improve pesticide

encapsulation. Derivatives like carboxymethyl cellulose create networks that stop pesticide leaks and extend their release time. Derived from chitin, chitosan expands in response to pH variations and interacts with other polymers to regulate release rates.

### 1.6.2: Artificial Polymer

Because of their controlled shapes, mechanical strength, and chemical stability, synthetic polymer hydrogels—such as those derived from polyacrylamide (PAM) and PVA—are useful for encasing pesticides. These characteristics improve the stability and durability of pesticide release, increasing its use. PAM is particularly popular in biomedicines and agriculture because of its water retention and nontoxicity. But there are issues with using PAM. PAM synthesis uses acrylamide, which has the potential to be neurotoxic and release unreacted particles that could endanger human health and the environment.[12]

### 1.7: Biomedical Uses

**Biosensing Applications:** Peptide hydrogel biosensors have drawn more attention recently because of their high sensitivity to external stimuli like pH and temperature, good cell adhesion, well-known chemistry for structural modification, long-term chemical and mechanical stability, antifouling properties, tenable viscoelastic characteristics, and self-healing features. Hydrogels can be classified into two main groups based on their chemical structure: peptide hydrogels with high environmental sensitivity, such as to pH, temperature, or electrical fields, that are used alone without bioreceptors or other auxiliary sensing components, and peptide hydrogels with high porous structures and large internal surfaces that are applied in conjunction with sensing biomolecules, such as enzymes, DNA strands, and label molecules.

**Delivery of Anticancer Drugs:** Patients frequently have negative side effects from traditional cancer chemotherapy because the medicines are delivered uncontrollably to healthy cells, harming them. Peptide-based hydrogels have been employed as drug delivery systems to lessen these negative side effects and improve therapeutic efficacy because of their biocompatibility, tenable structure to load various drugs, water-filled mesoporous structures, and sensitivity to external stimuli to induce drug release. In actuality, hydrogels frequently enhance the chemical stability, solubility, and bioavailability of anticancer medications. Chemically speaking, there are two main ways that pharmaceuticals can be absorbed into hydrogels: through chemical or physical interactions.[21]

### 1.8: Using hydrogel as a carrier

Hydrogels' distinct internal structure, great biocompatibility, and mechanical stability make them perfect transporters and dressings. Hydrogels allow for the targeted release of therapeutic substances without being quickly eliminated by the kidneys. Antioxidants, bioactive compounds, and metal ions are examples of medicinal chemicals that may be more effective in treating DFU. The hydrogels are one of these therapeutic compounds that contribute to ROS scavenging, which is the primary function of antioxidants and a useful strategy for promoting wound healing and related processes.[22]

### 1.9: The Hydrogel's Mechanical Durability

Water-based hydrogels are fragile and brittle at the same time as being as soft as tissues. A crucial problem that needs to be resolved in order to create useful hydrogel bio adhesives is the mechanical fragility of hydrogels. Hydrogels cannot withstand the external forces imposed by the tissue environment because tissues move and deform often. Additionally, the toughening characteristic



makes the hydrogel notch-insensitive, meaning that even in the presence of mechanical flaws or damages, it does not break. The hydrogel's network's reversible crosslinking allows it to return to its original mechanical structure and characteristics. The hydrogel's long-term stability is further guaranteed by its self-healing characteristic. TA is essential because it offers reversible crosslinking for self-healing and efficient energy dissipation for toughness.[23]

### 1.10: Hydrogels' Limitations

#### Insufficient Mechanical Power

Weak and easily shattered  
Unsuitable for situations involving heavy loads

#### Poor Durability

can eventually deteriorate or lose its structure.  
Some formulations have a short shelf life.

#### Restricted Drug Loading Capability

In particular for:  
Drugs that are hydrophobic  
Mostly appropriate for hydrophilic medications

### Microbial Contamination Risk

High water content is conducive to microbial growth and necessitates:

Preservatives  
Preparing sterile.[24]

## 2. PLAN OF WORK

### 2.1: Material & Method

#### ➤ Materials:

**Watermelon seed extract:** Hydrating, anti-inflammatory, and antimicrobial

**Bael leaf extract:** Antioxidant and anti-inflammatory

**Gelatine:** A gelling agent

**Glycerine:** Humectant

**Citric acid:** pH correction

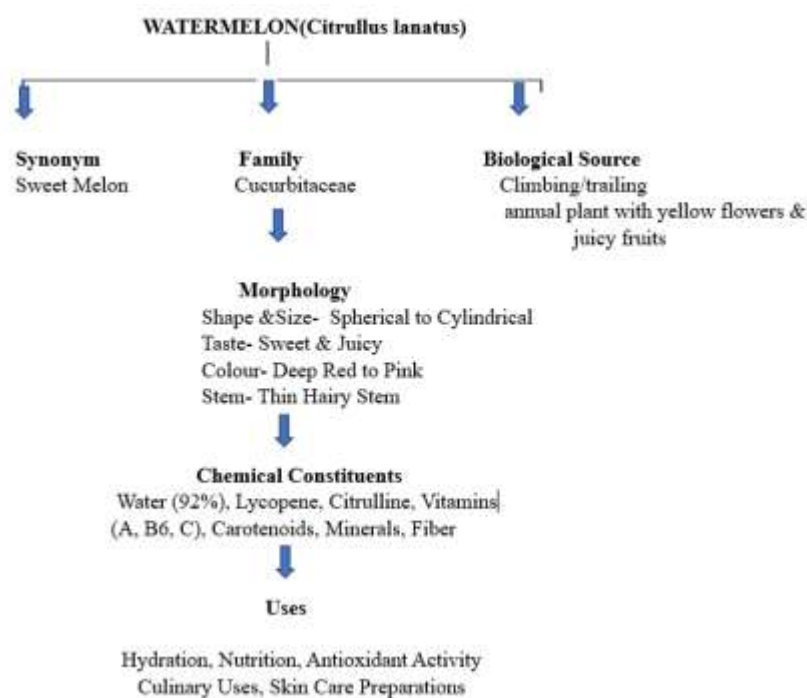
**Solvent:** Distilled Water

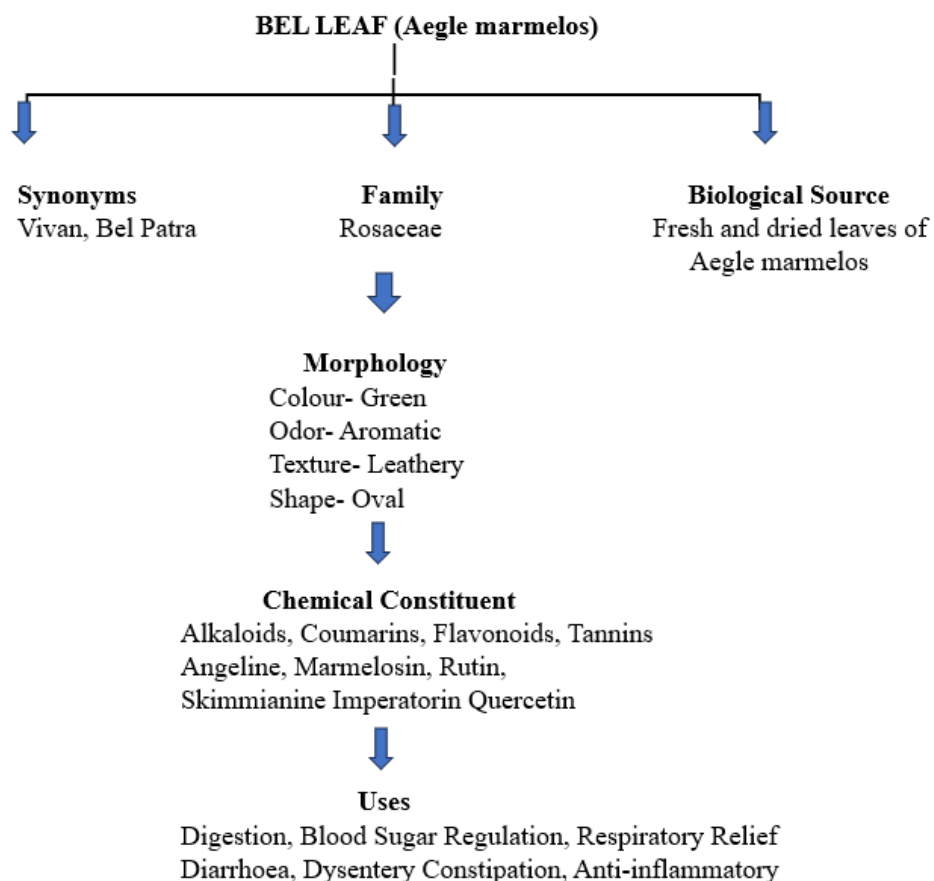
**Citric acid:** A preservative

**Castor oil:** An enhancer of penetration

**Coconut oil:** The cooling effect

#### ➤ Drug Profile:





## ➤ Methodology

Make sure the seeds are clean.  
Give them two to three days to dry.

### 2.1: Extraction Process (Maceration)

#### Step 2: Extraction of Plan

#### Step 1: Collection of crude drugs

Gather bel leaves and watermelon seeds from the market.

#### Extraction of Watermelon Seed:

Gather watermelon seeds and give them a thorough cleaning.

Dry them in shade for 2–3 days.

Grind the seeds into fine powder.

Take 10 g powder + 100 ml distilled water / ethanol.

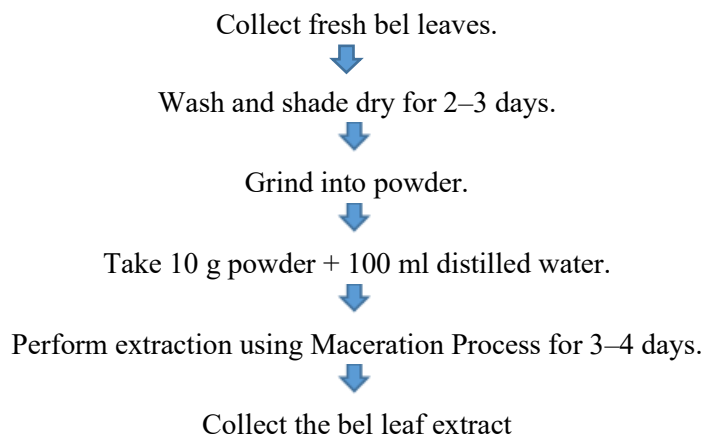
Perform extraction using Maceration Process for 3–4 days.

Filter the extract.

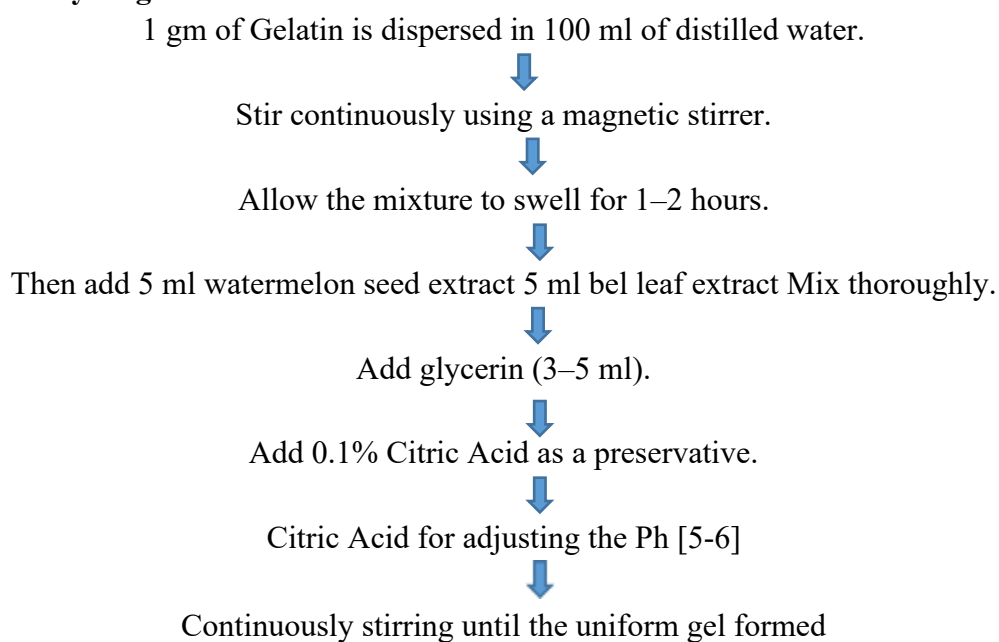
Collect the watermelon seed extract



## Bel Leaf Extract



## Preparation of Hydrogel:



## 3.CHEMICAL TEST'S

1. Alcoloids
2. Flavonoids

3. Phenolic compound
- 1: TEST FOR ALCOLOIDS.**

Sr. No.	Test for Alkaloids	Reagent Used	Procedure	Observation	Inference
1	Dragendorff's Test	Potassium bismuth iodide solution	Add few drops of Dragendorff's reagent to acidic plant extract	Orange or reddish-brown precipitate	Alkaloids present
2	Mayer's Test	Potassium mercuric iodide solution	Add Mayer's reagent to acidic plant extract	Cream or white precipitate	Alkaloids present
4	Hager's Test	Saturated picric acid solution	Add Hager's reagent to the extract	Yellow crystalline precipitate	Alkaloids present



## 2. TEST FOR FLAVONOIDS

Test Name	Reagent Used	Observation	Inference
Shinoda Test	Magnesium ribbon + Conc. HCl	Pink/red colour appears	Flavonoids present
Alkaline Reagent Test	NaOH solution	Yellow colour disappears on adding acid	Flavonoids present
Lead Acetate Test	Lead acetate solution	Yellow precipitate forms	Flavonoids present
Zinc Hydrochloride Test	Zinc dust + Conc. HCl	Red coloration appears	Flavonoids present

## 3. TEST FOR PHENOLIC COMPOUND

Test Name	Reagent Used	Procedure	Positive Observation	Inference
Ferric Chloride Test	Neutral FeCl <sub>3</sub> solution	Add a few drops of FeCl <sub>3</sub> to sample solution	Violet, blue, green, or purple color appears	Presence of phenolic group
Phthalein Dye Test	Phthalic anhydride + Conc. H <sub>2</sub> SO <sub>4</sub> + NaOH	Heat sample with reagents, then add NaOH	Pink colour develops	Phenolphthalein formation indicates phenol
Azo Dye Test	Diazonium salt in alkaline medium	React phenol with diazonium salt	Orange/red azo dye forms	Presence of phenolic compound

## EVALUATION PARAMETER:

SR.NO	EVALUATION PARAMETERS	OBSERVATION	RESULT
1.	Physical Appearance	Visual inspection	Smooth
2.	Colour	Visual observation	Greenish – brown
3.	Odor	Organoleptic Evaluation	Characteristic herbal Odor
4.	Texture	By touch and appearance	Soft and non-greasy
5.	PH	Digital ph. Meter	5 to 5.7
6.	Viscosity	Ostwald viscometer	4200 cps
7.	Homogeneity	Visual examination	No lumps or phase separation observed
8.	Spread ability	Spread ability examine by spreading the gel	Good spread ability



9.	Washability	Wash with water	Easily washable
10.	Swelling Index	Swelling study	85% swelling observed
11.	Stability study	Room temperature storage	Stable for 30 days without major changes

## RESULT AND DISCUSSION

The eco-friendly herbal hydrogel formulated using seed extract and leaf extract demonstrated promising characteristics for wound healing applications.

The formulation possessed suitable physicochemical properties such as acceptable pH, good viscosity, homogeneity, and stability, making it appropriate for topical use. The hydrogel matrix maintained adequate moisture at the wound site, which is essential for cell migration and tissue repair.

Seed and leaf extracts contain various phytoconstituents including flavonoids, phenolics, tannins, saponins, and alkaloids that contribute to antimicrobial, antioxidant, and anti-inflammatory activities. These phytochemicals help protect the wound from microbial infection and oxidative stress, thereby accelerating the healing process.

The antimicrobial study confirmed that the herbal extracts effectively inhibited the growth of pathogenic microorganisms commonly associated

herbal extracts contain phytoconstituents such as flavonoids, tannins, alkaloids, phenolic compounds, and terpenoids, they have antibacterial, antioxidant, and anti-inflammatory qualities. These bioactive components support quicker tissue regeneration and wound healing, keep the wound environment moist, and prevent microbial infection. The optimized batch outperformed the other created formulations in terms of stability, consistency, and skin compatibility without producing irritation. Additionally, the hydrogel demonstrated high washability and swelling performance, both of which are critical qualities for successful wound dressing applications. Thus, compared to synthetic wound healing formulations, the proposed herbal hydrogel can be regarded as a promising, safe, biodegradable, and affordable option. Its efficacy for commercial medicinal uses may be established by additional research, such as clinical trials, in-vivo studies, and enhanced antimicrobial evaluation.

## CONCLUSION

Using watermelon seed extract and bel leaf mucilage, the current study effectively created an environmentally friendly herbal hydrogel for improved wound healing activity. The prepared hydrogel showed satisfactory physicochemical properties such as suitable pH, good viscosity, homogeneity, spread ability, and stability, making it suitable for topical application. Because natural

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