



Comprehensive Pharmacognostical Standardization, Bioactive Phytochemical analysis and Development of a Sterile Phytopharmaceutical Emulgel From Terminalia Bellirica For Accelerated Wound Healing In Diabetic Patient

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Abstract

Diabetic wound healing remains one of the major complications associated with diabetes mellitus due to impaired blood circulation, prolonged inflammation, oxidative stress, microbial infection, and delayed tissue regeneration. Conventional topical therapies often exhibit poor penetration and limited bioavailability, reducing their therapeutic effectiveness. Herbal medicines have gained increasing attention because of their safety, affordability, and multiple pharmacological activities.

Terminalia bellirica (Gaertn.) Roxb., commonly known as Bahera, is a medicinal plant belonging to the family Combretaceae. It contains various bioactive phytoconstituents including gallic acid, ellagic acid, chebulagic acid, flavonoids, tannins, and phenolic compounds that possess antioxidant, antimicrobial, anti-inflammatory, and wound-healing properties. These phytochemicals promote collagen synthesis, reduce oxidative stress, prevent microbial infection, and accelerate tissue regeneration.

The present study aims to formulate and evaluate a *Terminalia bellirica* emulgel for topical diabetic wound healing. The plant extract is incorporated into an emulsion system to enhance solubility, stability, skin permeation, and bioavailability. The optimized emulsion is then incorporated into a Carbopol 940 gel base to prepare the emulgel. The formulation is evaluated for pH (6.99), viscosity (18,920-19,850 cP), spreadability (37.5-40 g/cm/sec), homogeneity, washability, organoleptic stability studies.

The developed emulgel is expected to provide controlled drug release, improved patient compliance, enhanced wound healing, and reduced infection, making it a promising herbal formulation for diabetic wound healing.

Keywords: *Terminalia bellerica* emulgel, Diabetic wound healing, Herbal formulation, Carbopol 940, emulsion

Introduction

Diabetic wound healing is a major health disease, its affecting approximately 25% of diabetic patients in worldwide. This study aimed to develop and evaluate emulgel from *Terminalia bellerica* for accelerated healing in diabetic foot ulcer. *Terminalia bellerica* Roxb (combretaceae) is found widely throughout the Indian subcontinent, Sri Lanka, South East Asia

Bangladesh as a medicinal plant. Plant and plant parts are used in the traditional system of medicines like Ayurveda, Siddha, Unani & Chinese medicine. It is commonly known as Belliric Myrobalan. Plant and plant parts are used in the traditional system of medicines like Ayurveda, Siddha, Unani & Chinese medicine. The plant is constituted of

Glycoside, Tannins, Flavonoids, Gallic acid, Ethyl Gallate, Phenolic compound, Amino acid and Saponins, which serves as an antidiabetic, antioxidant, antimicrobial, antidiarrheal, anticancer, antihypertensive, hepatoprotective & antipyretic agent. *T. bellerica* is used for treatment of various diseases such as conjunctivitis, asthma, migraine, baldness, constipation and weak eyesight. This article provides comprehensive information on pharmacognostic, phytochemical and pharmacological properties of *T. bellerica*, as a source for further research studies. This bioactive constituent help reduce oxidative stress,

stimulate collagen formation, promote epithelialization and accelerate tissue repair. This article provides comprehensive information on pharmacognostic, phytochemical and pharmacological properties of *T. bellerica*, as a source for further research studies. Based on these therapeutic properties, the present work focuses on the formulation and evaluation of a *Terminalia bellirica* emulgel for diabetic wound-healing. The study aims to develop a stable, effective and patient friendly herbal topical formulation with improved skin permeation and enhanced wound-healing potential.

Figure.1 Terminalia bellirica



Vernacular Name

Tandrikai (Tamil), Bahera, Bhera, Buhura (Hindi), Belliric Myrobalan (English), Aksa, Akshka, Vibhitak (Sanskrit), Tanrekai (Kannad), Babelo, balali (kashmiri), Bahedan, Baaheda, Munjhad, Baheda, Bahedo (Gujarati), Bahera, Bhira (Marathi), Tani, Tandi (Telugu), Tannikka, Thani (Malayalam).

Botanical Classification

Category	Classification
Kingdom	Plantae
Division	Angiosperm
Class	Magnoliopsida
Order	Myrtales
Family	Combretaceae
Genus	Terminalia
Species	Terminalia bellirica

2.Method and Material

2.1 Plant Material Collection and Authentication

Dried fruit of terminalia bellirica were collected from the medicinal plant garden K.G. College of Pharmacy and Research Institute, Ashokapuri, during the appropriate growing season. Healthy, mature and Disease-free fruits were manually collected. Plant authentication was performed based on morphological, taxonomical and organoleptic characteristics using standard herbarium references.

2.2 Processing Of Plant Material

2.2.1 Cleaning:

Freshly collected fruits were thoroughly washed under running tap water followed by distilled water to remove soil, dust and extraneous matter. Excess moisture was removed using clean blotting paper.

2.2.2 Drying:

The cleaned fruits were shade-dried at controlled room temperature (25-30°C) with adequate ventilation to avoid photodegradation of heat sensitive compounds such as flavonoids and phenolics.

2.2.3 Pulverization:

Dried fruits were reduced to coarse powder using a mechanical grinder and passed through a suitable mesh sieve to obtain uniform particle size, which is essential for reproducible extraction efficiency.

2.2.4 Storage:

The prepared fruit powder was immediately transferred into airtight, moisture-free and light resistant containers to protect it from environmental factors such as humidity, oxidation and light exposure.

2.3 Soxhlet Extraction:

Accurately weighed 30-50 g of shade dried powdered fruit material was packed into cellulose extraction thimble. Ethanol was selected as the extraction solvent due to its high polarity and proven efficiency in dissolving secondary metabolites. The extraction was performed using a Soxhlet apparatus at the boiling point of ethanol for 18-24 hours until the siphoning solvent appeared colourless.

The extract was filtered, concentrated under reduced pressure using a rotary vacuum evaporator (40-50°C) to prevent thermal degradation, and stored in airtight containers under refrigeration.

2.4 Pharmacognostical Evaluation:

2.4.1 Macroscopic Evaluation:

External morphological characteristics including fruit arrangement, shape, size, margin, surface texture, Qualitative colour, odour, and taste were examined and documented according to standard procedures.

2.4.2 Microscopic Evaluation:

Microscopic evaluation of Terminalia bellirica revealed lignified sclereids (stone cell) tannin containing parenchymatous cells, calcium oxalate crystals and spiral or pitted xylem vessels. This diagnostic feature confirmed identity and purity of the powdered drug and supported its pharmacognostic and authentication.

2.4.3 Quantitative Microscopy:

Leaf constants including stomatal number, stomatal index, palisade ratio, vein islet number, and vein termination number were determined using cleared leaf preparations and calibrated eyepiece graticule.

2.4.4 Physiochemical Parameters

Standard ash values (total ash, acid-insoluble ash, water-soluble ash), extractive values, loss on drying, and foreign organic matter were determined according to standard pharmacopoeial methods.

2.5 Phytochemical Screening

Phytochemical tests were performed to identify bioactive constituents: Mayer's test for alkaloids, Molisch's test for carbohydrates, Biuret test for proteins, Ninhydrin test for amino acids, foam test for saponins, ferric chloride for tannins, Dragendorff's test for glycosides, ferric chloride for phenols, sodium hydroxide test for flavonoids, and histochemical studies for localization of phytochemicals.

3. Formulation

3.1 Preparation of emulsion

Terminalia bellirica emulsions were prepared through the high-energy emulsification technique by uniformly mixing optimized oil and Smix phases with a help of mechanical stirrer, using the optimum ratio of components obtained from the phase diagrams. After uniform miscibility of the oil and Smix phases, purified water was added dropwise as an aqueous phase and stirred continuously to form coarse emulsion. Further, the coarse emulsion is converted into desired nanosized emulsion droplets with the help

of a sonicator probe. The sonicator probe creates high sonication sound waves of more than 20 KHz. The high intensity of sound waves breaks the coarse emulsion into fine droplets of size. Various kinds of probes with various dimensions are available for the size reduction up to desirable limits. Along with the kinds of the probe, the input power and time for sonication decide the size of the droplet. Various batches of emulsions were prepared by varying the quantity of oil, surfactant and cosurfactant to check its effect on stability of emulsion. Which provide longer half-life in comparison to simple emulsion and other formulation. Among those advantages, emulsion have some limitation such as low viscosity and spreadability problems. These problems can be resolved by modifying the emulsion into emulgel by using suitable gelling agent.

3.2 Preparation of emulgel

To make the gel base, adjust the PH while dissolving the appropriate polymer in purified water using a mechanical stirrer. To incorporate the emulsion into gel system and gently mix it until to get a uniform emulgel.

3.3 Cooling, Filling and Storage

The formulation was allowed to cool gradually to room temperature with continuous sterile stirring. Controlled cooling ensured proper semisolid consistency, smooth texture, and stability of O/W emulsion. The emulgel was filled into pre-sterilized airtight and light-resistant containers under aseptic conditions. The final product obtained was a smooth, homogeneous, sterile, and stable O/W emulgel, suitable for topical wound application.

Table .1 Formulation of composition table

INGREDIENT	CONCENTRATION	ROLE
Terminalia bellicaria extract	2 g	Active wound healing agent
Isopropyl myristate	5 ml	Oil phase
Carbopol 940	1 g	Gelling agent
Triethanolamine	q.s	PH adjuster
Propylene Glycol	10 ml	Preservative
Tween 80, PEG 400	20 ml	Surfactant
Purified water	q.s	Vehicle

4. Evaluation

The prepared Terminalia bellicaria emulgel was evaluated for its physiochemical characteristics, stability, drug release behaviour and overall suitability for topical diabetic wound healing. The evaluation ensures that the formulation possesses good quality, stability, skin compatibility and therapeutic performance.

4.1 Physiochemical Analysis

4.1.1 Organoleptic Stability:

Purpose: To evaluate the physical stability and acceptability of the emulgel during storage. Changes in colour, odour, texture or phase separation may indicate instability or degradation.

Procedure: A suitable quantity of the emulgel is stored in well-closed containers at room temperature ($25^{\circ}\text{C} \pm 2^{\circ}\text{C}$). The formulation is visually inspected for

changes in colour, odour, texture, and the presence of phase separation.

4.1.2 Spreadability Test:

Purpose: Essential for wound healing to ensure the emulgel spreads easily over sensitive, painful areas without excessive pressure.

Procedure: A specific amount of emulgel is placed between two glass slides. A weight is applied to the top slide for 15 minutes to create a uniform film. The time (seconds) it takes for the top slide to move from the bottom slide under a fixed pull is recorded.

$$\text{Spreadability (S)} = (M \times L) / T$$

Where,

M = weight tied to upper slide (g)

L = length of glass slide (cm)

T = time taken (sec)

4.1.3 PH Determination:

Purpose: To verify skin compatibility. A pH significantly different from the skin can cause irritation.

Procedure: 1 gram of the emulgel is dispersed in 100 mL of distilled water. The mixture is stirred for a specified time to ensure uniform dispersion. A

calibrated Digital pH Meter is then used to measure the pH of this solution at room temperature $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

4.1.4 Washability:

Purpose: To ensure the emulgel can be easily removed from the skin or clothes.

Procedure: A small amount of the emulgel is applied to a 1-inch area of the skin. After 10 minutes, the area is rinsed under moderate tap water. The ease of removal is qualitatively assessed (e.g., Very Good, Good, Poor).

4.1.5 Viscosity:

Purpose: To determine the flow behaviour and consistency of the emulgel.

Procedure: Viscosity was measured using a Brookfield viscometer at $25 \pm 0.5^{\circ}\text{C}$.

4.1.6 Homogeneity:

Purpose: To ensure uniform distribution of ingredients.

Procedure: The gel was visually examined for lumps, coarse particle and phase separation.

5. RESULTS

5.1 Macroscopic Evaluation

Feature	Description	Significance
Plant part	Fruit	Confirms the correct plant part used for extraction and formulation
Shape	Ovoid / ellipsoid	Helps in identification and authentication of crude drug
Size	Approximately 2-4 cm diameter	Useful as a morphological identification parameter
Colour	Brown to dark brown	Indicates maturity and characteristics appearance of the fruit
Surface	Smooth to slightly wrinkled	Helps differentiate from other adulterant materials
Texture	Hard and leathery	Indicates dried fruits characteristics and storage quality
Odour	Characteristics, slightly aromatic	Supports identification of the crude drug
Taste	Astringent	Due to presence of tannins and phenolic constituents; supports phytochemical identity

Table.2 Macroscopic Evaluation

The collected *Terminalia bellirica* fruit exhibited obovate to sub-globular structures (2 - 4 cm long) with fine velvety pubescence. Fresh greenish-yellow fruits turned dark greyish brown with longitudinal wrinkles and 5 obscure ridges upon shade drying. The thick, fibrous pericarp displayed a characteristic aromatic odour and strongly astringent taste, conforming rich polyphenolic content.

5.2 Microscopic Evaluation

Tissue	Observation	Pharmacognostic Importance
Epidermis (Epicarp)	Single layer of polygonal epidermal cells covered by a thick cuticle	Diagnostic feature for identification of the fruit.
Hypodermis	Several layers of sclerenchymatous cells with thick, lignified walls	Provides mechanical support; characteristic of the fruit.
Mesocarp	Thin-walled parenchymatous cells containing abundant tannins and calcium oxalate crystals	Indicate the presence of active constituents; useful for authentication.
Sclereids (Stone cell)	Numerous thick-walled, lignified sclereids scattered throughout the mesocarp	One of the most important diagnostic characters of terminalia bellirica.
Vascular Tissue	Collateral vascular bundles with spiral, pitted xylem vessels and phloem	Confirms tissue identity and assists in microscopic evaluation.
Endocarp	Thick, compact layer of lignified sclerenchymatous cells surrounding the seed	Characteristic protective layer useful for identification.
Calcium oxalate crystals	Rosette and prismatic crystals present in parenchyma cells	Important diagnostic marker useful for detecting adulteration.

Table. 3 Microscopic Evaluation

5.3 Formulation Evaluation Results

5.3.1 pH Evaluation:

Table.4 pH Evaluation

S. No	Observation	F1	F2
1	pH	6.24	6.99

The pH of the formulated emulgel was found to be within the acceptable skin range. This indicates that the formulation is compatible with skin and will not cause irritation when applied on wounded or sensitive areas. The result confirms the suitability of the emulgel for topical application.

5.3.2 Spreadability Test:

Table. 5 Spreadability Test

Trial	M (g)	L(cm)	Time (sec)	Spreadability (g.cm/sec)
F1	150	4	15	40
F2	150	4	16	37.5

The spreadability value of the emulgel was found to be satisfactory (37.5-40g.cm/sec). This shows that the formulation can be easily spread on the skin with minimum effort. Good spreadability is important for uniform application over the wound surface and improves patient compliance.

Formulation

F1

F2

Table. 6 Viscosity Test

The viscosity of the formulated Terminalia bellirica nanoemulgel was found to be satisfactory (18,920-19,850cP). The formulation exhibited optimum viscosity, indicating good consistency and stability appropriate viscosity is essential for easy application, better retention at the wound site and prolonged contact time, which enhance the therapeutic efficacy of the emulgel.

5.3.4 Homogeneity Test:

The optimized emulgel was smooth, homogeneous and free from lumps.

5.3.5 Washability Test:

S. No	Observation	F1	F2
1	Washability	Washable	Washable

Table. 7 Washability Test

The formulation showed good washability. This indicates that the emulgel can be easily removed from the skin using water without leaving excessive residue. This property is beneficial for maintaining hygiene and repeated application on wounds.

5.3.6 Organoleptic stability study:

Parameter	Initial	15 Days	30 Days	Reference limit
Colour	Greenish	No change	No change	No significant change
Odour	Herbal	No change	No change	No rancidity
Texture	Smooth	Smooth	Smooth	No grittiness
Phase separation	Absent	Absent	Absent	Should be absent

Table.7 Organoleptic Stability study

No significant changes in colour, odour, texture or phase separation were observed during the study period. This indicates that the formulation is physically stable under storage conditions. The stability ensures consistent performance and shelf life of the product.

Discussion

Medicinal plants continue to play a crucial role in traditional and modern healthcare systems, serving as valuable sources of bioactive compounds with therapeutic potential. *Terminalia bellirica*, a widely distributed herb belonging to the family Combretaceae, has long been recognized in traditional medicine for the treatment of wounds.

Wound healing involves haemostasis, inflammation, proliferation, and maturation, and plant constituents are discussed as potentially modulating these stages. The antimicrobial activity of ethanolic extracts, especially against pathogenic and multidrug-resistant organisms, further supports its therapeutic relevance in preventing wound infection, a critical factor that delays healing. The formulated emulgel demonstrated acceptable physicochemical parameters and excellent stability, confirming its suitability for pharmaceutical use.

The physicochemical properties of *Terminalia bellirica* suggest that it has good potential for topical drug delivery. The important criteria for selection of excipients for emulgel formulation and development were that components were to be pharmaceutically

acceptable, non-irritating, and non-sensitizing to the skin. Higher solubility of the drug in the oil phase was another important criterion, as it would help the emulsion to maintain the drug in solubilized form. Safety was a major determining factor in choosing a surfactant, as a large amount of surfactants may cause skin irritation. Non-ionic surfactants are less toxic than ionic surfactants.

Conclusion

The present study successfully developed and evaluated a *Terminalia bellirica* emulgel for diabetic wound healing. The formulation showed good physicochemical properties such as suitable pH, viscosity, spreadability, homogeneity, and stability. The emulsion-based system improved drug solubility and skin permeation, enabling better therapeutic action. The presence of bioactive components like flavonoids, tannins, and phenolics are responsible for the antioxidant, antimicrobial, or anti-inflammatory effects, which promote faster wound contraction and tissue regeneration. Ultimately the newly developed emulgel appears to be an excellent herbal topical delivery system for diabetic wound management.' However, additional in-vitro studies and clinical trials are required to confirm its safety and effectiveness.

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