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Research Article

FORMULATION AND EVALUATION OF HERBAL GEL FOR WOUND HEALING

¹Dipali .D. Kale, ²Mr.Nandkishor B. Deshmukh, ³Swati P. Deshmukh

¹Student of Bachelor of Pharmacy,

Shraddha Institute of Pharmacy, Kondala Zambre, Washim 444-505.

² Associate Assistant Professor Department of Pharmaceutics, Shraddha Institute of Pharmacy, Washim 444-505.

³ Professor Department of Pharmacology, Shraddha Institute of Pharmacy, Kondala Zambre, Washim 444505.

Abstract:

The present study focuses on the formulation and evaluation of a herbal gel for wound healing using medicinal plant extracts. Wound healing is a complex biological process involving phases such as hemostasis, inflammation, proliferation, and remodeling. Conventional treatments may cause side effects and delayed healing, creating the need for safer and more effective alternatives. Herbal medicines, rich in bioactive compounds like flavonoids, tannins, and alkaloids, offer antimicrobial, anti-inflammatory, and antioxidant properties that promote faster tissue regeneration.

In this study, selected medicinal plants such as Aloe vera, Azadirachta indica (Neem), Curcuma longa (Turmeric), and Phyllanthus emblica (Amla) were used due to their wellknown wound healing properties. The herbal extracts were prepared and incorporated into a gel base using Carbopol 934 as a gelling agent. The formulated gel was evaluated for various physicochemical parameters including appearance, pH, viscosity, spreadability, extrudability, and stability.

The results showed that the formulated gels were homogeneous, non-irritant, and stable, with pH values suitable for skin application. The gel exhibited good spreadability and appropriate viscosity, ensuring ease of application and effective drug delivery. Stability studies confirmed that the formulation remained stable under different storage conditions.

Overall, the developed herbal gel demonstrated promising characteristics for wound healing, offering a safe, effective, and patient-friendly alternative to synthetic formulations. The study supports the potential use of herbal-based topical formulations in modern wound management.

Corresponding author:

Dipali .D. K,

Student of Bachelor of Pharmacy,

Shraddha Institute of Pharmacy,

Kondala Zambre, Washim 444-505.

QR CODE



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1. INTRODUCTION:

1. Skin and Its Functions

The skin is the largest and one of the most complex organs of the human body, forming a dynamic interface between the internal physiological environment and the external surroundings. It accounts for nearly 15–20% of total body weight and plays a crucial role in maintaining homeostasis. Beyond serving as a simple covering, the skin is an active organ involved in protection, regulation of body temperature, sensory perception, immune defense, and prevention of water loss. Its multifunctional nature is attributed to its well-organized layered structure, consisting of the epidermis, dermis, and hypodermis, each contributing uniquely to overall skin function and health.

1.1 Structure of Skin

1.1.1 Epidermis

The epidermis is the outermost layer of the skin and serves as the primary barrier against environmental insults. It is composed of stratified squamous epithelium and lacks blood vessels, relying on diffusion from underlying layers for nutrient supply.

1.1.2 Dermis

Beneath the epidermis lies the dermis, a thick and fibrous layer composed primarily of connective tissue. It provides structural integrity, elasticity, and mechanical strength to the skin. The dermis is richly supplied with blood vessels, lymphatics, and nerve endings, making it essential for nourishment, thermoregulation, and sensory functions.

1.1.3 Hypodermis (Subcutaneous Tissue)

The hypodermis, also known as the subcutaneous layer, lies beneath the dermis and consists mainly of adipose tissue and loose connective tissue. Although it is not always considered a true part of the skin, it is functionally significant in supporting the upper layers.

1.2 Functions of Skin

1. Protective Function
2. Sensory Function
3. Barrier Function
4. healing ability

2. Wound Healing Process

Wound healing is a complex, multi-phase process that is essential for restoring the integrity of the skin and underlying tissues following an injury. The

process can be broadly divided into four overlapping phases: haemostasis, inflammation, proliferation, and remodeling.

Haemostasis Phase:

The wound healing process begins immediately after an injury with the haemostasis phase. The primary goal during this phase is to stop bleeding. Blood vessels at the site of the injury constrict, and platelets aggregate to form a clot.

Inflammation Phase:

Following haemostasis, the inflammatory phase begins. This phase is characterized by the recruitment of immune cells to the wound site. Neutrophils are the first responders, arriving within hours to phagocytize bacteria and debris.

Proliferation Phase:

The proliferation phase is marked by the formation of new tissue. This phase involves several key processes, including angiogenesis, collagen deposition, granulation tissue formation, and re-epithelialization. Fibroblasts, which are attracted to the wound site by growth factors, synthesize collagen and extracellular matrix components that form the structural framework for new tissue.

Remodelling Phase:

The final phase of wound healing is remodelling, which can last for months or even years. During this phase, the wound undergoes extensive tissue remodelling to restore tensile strength and functional integrity.

3. Factors Affecting Wound Healing

Wound healing is a complex and dynamic biological process influenced by multiple internal and external factors. These factors can significantly alter the rate and quality of tissue repair.

Infection

Infection is one of the most critical factors that delay wound healing. The presence of pathogenic microorganisms such as bacteria leads to prolonged inflammation, tissue damage, and delayed epithelialization.

Oxygenation

Adequate oxygen supply is essential for cellular metabolism, collagen synthesis, and angiogenesis during wound healing. Oxygen supports the production of adenosine triphosphate (ATP), which fuels cellular activities such as fibroblast proliferation and epithelial cell migration.

Moisture Balance

Maintaining an optimal moisture environment at the wound site is crucial for efficient healing. A moist

wound environment promotes cell migration, enhances growth factor activity, and prevents tissue dehydration.

Diabetes

Diabetes mellitus is a major systemic condition that significantly delays wound healing. Elevated blood glucose levels impair leukocyte function, reduce immune response, and increase susceptibility to infections.

Age

Age plays an important role in determining the efficiency of wound healing. In elderly individuals, cellular proliferation, collagen deposition, and angiogenesis are reduced.

Nutrition (Vitamins A, C, and Zinc)

Proper nutrition is essential for optimal wound healing. Specific nutrients play crucial roles:

- **Vitamin A** enhances epithelialization, supports immune function, and promotes collagen formation.

- **Vitamin C** is essential for collagen synthesis and acts as a potent antioxidant, protecting tissues from oxidative damage.

- **Zinc** is involved in DNA synthesis, cell division, and protein synthesis, all of which are vital for tissue regeneration.

Deficiency of these nutrients can lead to impaired wound healing, reduced tensile strength of the repaired tissue, and increased risk of infection.

4.Role of Medicinal Plants in Wound Healing

Medicinal plants have been extensively used across cultures and generations for managing various types of wounds, ranging from minor cuts and abrasions to chronic ulcers and burns. The healing process of a wound is a complex physiological event that involves a series of steps including hemostasis, inflammation, cell proliferation, collagen formation, and tissue remodeling. Medicinal plants play a vital role at different stages of this process through their rich phytochemical profile, which includes flavonoids, tannins, alkaloids, saponins, glycosides, and terpenoids.

Table 1: Plants commonly used in wound healing

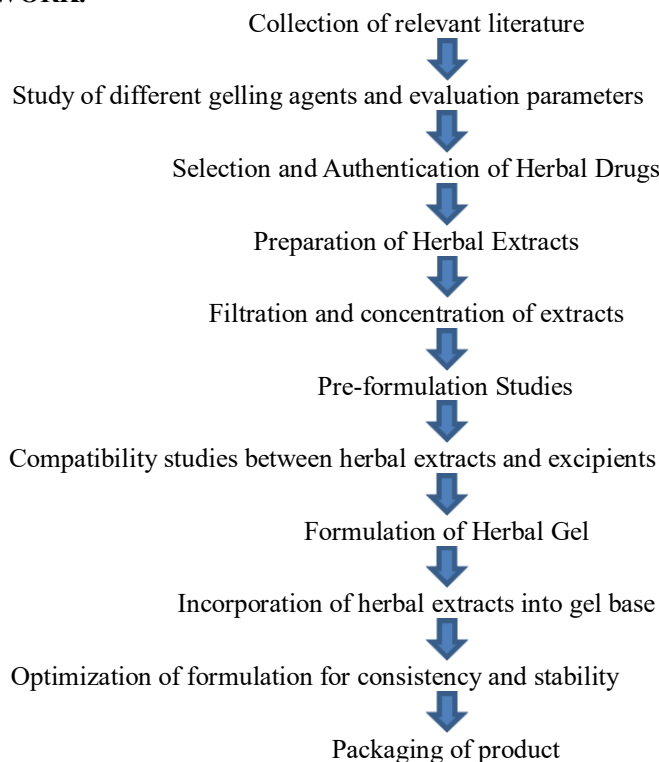
Plant Name	Family	Key Bioactive Compounds	Reported Activity
<i>Aloe vera</i>	Asphodelaceae	Anthraquinones, Polysaccharides	Anti-inflammatory, promotes cell proliferation
<i>Achillea millefolium</i> (Yarrow)	Asteraceae	Flavonoids, Sesquiterpene lactones	Astringent, promotes hemostasis and wound contraction
<i>Allium cepa</i> (Onion)	Amaryllidaceae	Quercetin, Sulfur compounds	Antimicrobial, enhances collagen synthesis
<i>Phyllanthus Emblica</i> (Amla)	Apiaceae	Triterpenoids, Asiaticoside	Enhances collagen synthesis, wound contraction
<i>Cassia alata</i> (Ringworm bush)	Fabaceae	Anthraquinones, Flavonoids	Antifungal, antimicrobial, promotes healing
<i>Calendula officinalis</i>	Asteraceae	Flavonoids, Carotenoids	Antiseptic, stimulates epithelialization
<i>Lantana camara</i>	Verbenaceae	Flavonoids, Triterpenes, Essential oils	Antimicrobial, antioxidant, antiinflammatory
<i>Curcuma longa</i> (Turmeric)	Zingiberaceae	Curcumin	Antioxidant, antiinflammatory, promotes tissue repair

<i>Azadirachta indica (Neem)</i>	Meliaceae	Nimbidin, Nimbin, Azadirachtin	Antibacterial, antifungal, wound healing
<i>Tulsi</i>	Lamiaceae	Eugenol, Ursolic acid	Anti-inflammatory, antibacterial, enhances tissue regeneration
<i>Lawsonia inermis (Henna)</i>	Lythraceae	Lawsonic acid, Flavonoids	Antimicrobial, cooling, helps in wound healing
<i>Punica granatum (Pomegranate)</i>	Lythraceae	Ellagic acid, Gallic acid	Antioxidant, promotes granulation tissue formation
<i>Ficus benghalensis (Banyan)</i>	Moraceae	Flavonoids, Tannins, Glycosides	Anti-inflammatory, astringent, accelerates healing
<i>Terminalia arjuna</i>	Combretaceae	Tannins, Flavonoids, Arjunolic acid	Astringent, antioxidant, anti-inflammatory
<i>Tridax procumbens</i>	Asteraceae	Flavonoids, Alkaloids, Carotenoids	Antimicrobial, enhances fibroblast proliferation and wound contraction
<i>Vitex negundo</i>	Lamiaceae	Flavonoids, Iridoid glycosides	Anti-inflammatory, antibacterial, relieves pain
<i>Emblica officinalis (Amla)</i>	Phyllanthaceae	Ascorbic acid, Tannins, Flavonoids	Promotes collagen synthesis, antioxidant
<i>Moringa oleifera</i>	Moringaceae	Ascorbic acid, Zeatin, Flavonoids	Antioxidant, promotes epithelialization
<i>Hyssopus officinalis (Comfrey)</i>	Boraginaceae	Allantoin, Rosmarinic acid	Promotes cell proliferation, anti-inflammatory
<i>Cissus quadrangularis</i>	Vitaceae	Ketosteroids, Flavonoids	Promotes tissue regeneration, enhances wound healing

Table 2: Mechanisms of Phytochemicals in Wound Healing

Mechanism	Role in Wound Healing	Phytochemicals Involved
Free Radical Scavenging	Reduces oxidative stress and tissue damage	Flavonoids, Phenolics
Angiogenesis Enhancement	Promotes blood vessel formation and nutrient supply	Flavonoids, Terpenoids
Fibroblast Proliferation	Increases extracellular matrix and granulation tissue formation	Alkaloids, Terpenoids
Epithelialization	Accelerates skin cell migration and wound closure	Flavonoids, Glycosides
Collagen Maturation	Increases skin strength and tissue remodeling	Vitamin C, Tannins

1. PLAN OF WORK.



2. BOTANICAL AND PHYTOCHEMICAL PROFILE

Medicinal plants have been an integral part of healthcare systems since ancient times and continue to play a crucial role in modern therapeutics, particularly in the management of wounds and skin-related disorders. Traditional systems such as Ayurveda, Unani, and Siddha have extensively documented the use of plant-based remedies for enhancing wound healing, preventing infections, and restoring skin integrity. The growing interest in herbal medicine is primarily due to its safety, cost-effectiveness, and multi-target therapeutic action, which often surpasses the limitations associated with synthetic drugs.

In the present research work, medicinal plants with well-documented wound healing properties have been selected, including Aloe vera, Azadirachta indica (Neem), Curcuma longa (Turmeric), and Phyllanthus Emblica (Amla).

2.1 ALOE VERA



Part Used

Fresh leaf gel (inner mucilage)

Pharmacological Importance

Aloe vera gel is widely recognized for its wound healing, anti-inflammatory, antimicrobial, and moisturizing properties. It plays a significant role in accelerating wound healing by stimulating fibroblast proliferation, enhancing collagen synthesis, and promoting angiogenesis.

2.2 AZADIRACHTA INDICA (NEEM)



Part Used

- Leaves
- Bark

Pharmacological Importance

Neem exhibits a broad spectrum of pharmacological activities, particularly antibacterial, antifungal, anti-inflammatory, and antioxidant effects. The presence of active constituents such as azadirachtin, nimbidin, and quercetin contributes to its potent antimicrobial

action against various pathogens commonly associated with wound infections.

1. 3 CURCUMA LONGA (TURMERIC)

Curcuma longa, commonly known as turmeric, is a perennial rhizomatous herbaceous plant extensively cultivated in tropical and subtropical regions, particularly in India. The plant is characterized by large oblong leaves, yellow flowers, and underground rhizomes, which are the primary source of its medicinal and culinary value.



Part Used

Dried and fresh rhizome

Pharmacological Importance

The pharmacological efficacy of *Curcuma longa* is mainly attributed to its principal active constituent, curcumin, along with other curcuminoids such as demethoxycurcumin and bisdemethoxycurcumin. Curcumin exhibits potent anti-inflammatory, antioxidant, and antimicrobial activities, which play a crucial role in wound healing.

5.4 PHYLLANTHUS EMBLICA (AMLA)

Phyllanthus Emblica (Amla), known as Amla or Indian gooseberry, is a small to medium-sized

deciduous tree widely distributed in tropical and subtropical regions, especially in India. The plant is characterized by feathery, light green leaves, greenish-yellow flowers, and nearly spherical fruits that are light greenish-yellow in color with a smooth and hard appearance.

Part Used

Fresh And dried fruits



Pharmacological Importance

The pharmacological activity of *Phyllanthus emblica* is mainly attributed to its high content of vitamin C, along with other bioactive compounds such as tannins, flavonoids, gallic acid, and ellagic acid. These constituents contribute to its strong antioxidant, anti-inflammatory, and antimicrobial properties.

3. MATERIAL AND METHODS:

Materials Herbal Materials

The selected medicinal plants with established wound healing properties were procured from authenticated sources and identified by a qualified botanist.

Table 3: Materials used for research study

Plant Name	Biological Source	Part Used	Purpose
<i>Aloe vera</i>	Leaves	Gel	Moisturizing, healing
<i>Azadirachta indica</i>	Neem	Leaves	Antimicrobial
<i>Curcuma longa</i>	Turmeric	Rhizome	Anti-inflammatory
<i>Phyllanthus Emblica (Amla)</i>	Whole plant	Whole plant	Tissue regeneration

Chemicals and Excipients

All chemicals used were of analytical grade.

Table 4: Chemicals and Excipients

Ingredient	Role
Carbopol 934	Gelling agent
Hydroxypropyl methylcellulose (HPMC)	Thickening agent
Propylene glycol	Humectant and penetration enhancer
Methyl paraben	Preservative
Propyl paraben	Preservative
Triethanolamine	Neutralizer
Distilled water	Vehicle

Collection and Authentication of Plant Material
Preparation of Herbal Extract
Phytochemical Screening
Formulation of Herbal Gel

Method of Preparation

Initially, an accurately weighed quantity of Carbopol 934 was gradually dispersed in a measured volume of distilled water with continuous stirring to prevent lump formation. The dispersion was then allowed to stand for sufficient time to ensure complete hydration and swelling of the polymer, resulting in a uniform viscous base.

In a separate container, the required quantity of herbal extract was dissolved in propylene glycol, which acts as a humectant as well as a penetration enhancer, facilitating better permeation of active constituents through the skin. To this solution, methyl paraben and propyl paraben were added as

preservatives to inhibit microbial growth and enhance the shelf life of the formulation.

The prepared extract solution was then slowly incorporated into the hydrated polymer dispersion under continuous stirring to achieve uniform distribution of the active ingredients within the gel matrix. Care was taken to avoid air entrapment during mixing.

Subsequently, triethanolamine was added dropwise to the formulation with gentle stirring. This step resulted in neutralization of the Carbopol dispersion, leading to an increase in viscosity and formation of a clear, homogeneous gel. The pH of the formulation was carefully adjusted to fall within the physiological skin pH range (approximately 5.5–7.0) to ensure compatibility and minimize irritation upon application.

Table 5: Composition of Herbal Gel Formulation

Ingredient	F1	F2	F3	F4
Carbopol 934 (Gelling Agent)	0.15 gm	0.20 gm	0.25 gm	0.30 gm
Herbal extract (API)	1.5 gm	2 gm	2.5 gm	3 gm
Propylene glycol (Penetration Enhancer)	1 gm	1.5 gm	2 gm	2.5 gm
Methyl paraben (Preservative)	0.03 gm	0.04 gm	0.05 gm	0.6 gm
Triethanolamine (pH adjuster)	q.s	q.s	q.s	q.s
Distilled water (Vehicle)	upto 15 gm	upto 20 gm	upto 25 gm	upto 30 gm

The selection of Carbopol 934 as a gelling agent is justified by its ability to form stable, non-greasy, and easily spreadable gels, which are ideal for topical drug delivery. The inclusion of propylene glycol improves drug permeation and hydration of the skin, thereby enhancing therapeutic efficacy. Neutralization with triethanolamine ensures the formation of a stable gel network, while maintaining a skin-compatible pH.

Evaluation of Herbal Gel

The prepared herbal gel formulations were subjected to a series of physicochemical evaluation parameters to assess their quality, stability, and suitability for topical

application. These evaluations are essential to ensure uniformity, consistency, efficacy, and patient acceptability of the formulation.

Physical Evaluation

The formulated gels were initially examined for their organoleptic and physical characteristics, which play a crucial role in determining patient compliance and product acceptability.

The appearance of the gel was observed for clarity, smoothness, and absence of particulate matter, indicating proper formulation and dispersion of ingredients. Homogeneity was assessed by visual inspection and by applying a small quantity of gel on the skin to check for the presence of lumps,

aggregates, or phase separation. A homogeneous gel indicates uniform distribution of the active ingredients within the formulation.

pH Measurement

The pH of the formulated gel was determined using a calibrated digital pH meter to ensure compatibility with the physiological pH of the skin.

For this purpose, a known quantity of gel was dispersed in distilled water, and the electrode of the pH meter was immersed into the sample. The reading was recorded after stabilization. Maintaining the pH within the range of 5.5 to 7.0 is essential to avoid skin irritation and ensure safe topical application.

Viscosity

The viscosity of the gel formulations was measured using a Brookfield viscometer at predetermined rotational speeds (rpm) using an appropriate spindle.

Viscosity is a critical parameter that influences the spreadability, stability, and drug release behavior of the gel. The measurements were carried out at room temperature, and readings were recorded once the system reached equilibrium. Proper viscosity ensures ease of application and retention of the gel at the site of action.

Spreadability

Spreadability is an important parameter that determines the ease of application of the gel on the skin surface. It was evaluated using the glass slide method.

A fixed amount of gel was placed between two glass slides, and a specific weight was applied on the upper slide. The time required for the upper slide to slip over the lower slide was recorded. Spreadability was calculated using the following relation:

$$S = M \times L / T$$

Where:

S = Spreadability

M = Weight applied (g)

L = Length moved by the glass slide

(cm) T = Time taken (sec)

Higher spreadability values indicate better application properties and uniform distribution over the skin.

Extrudability

Extrudability was determined to evaluate the ease with which the gel can be extruded from a collapsible tube, which is an important parameter for patient convenience.

A known quantity of gel was filled into a collapsible tube, and the force required to extrude the gel was measured. The amount of gel extruded under applied pressure was recorded. Good extrudability ensures that the gel can be easily dispensed without excessive force, indicating appropriate consistency and viscosity.

Stability Studies

Stability studies of the formulated herbal gel were conducted in accordance with International Council for Harmonisation (ICH) guidelines to evaluate the effect of environmental conditions on the formulation over time. The prepared formulations were stored under different temperature conditions, namely room temperature ($25^{\circ}\text{C} \pm 2^{\circ}\text{C}$) and accelerated conditions ($40^{\circ}\text{C} \pm 2^{\circ}\text{C}$) for a period of three months. During the study, samples were periodically evaluated for changes in physical appearance, pH, viscosity, and homogeneity.

Statistical Analysis

All experimental data obtained from the evaluation studies were expressed as mean $\pm$ standard deviation (SD) to represent the variability and reliability of the results. Statistical analysis was performed using appropriate software tools, and comparisons between different formulations were carried out using Analysis of Variance (ANOVA). A value of $p < 0.05$ was considered statistically significant. This analysis ensures the validity, reproducibility, and scientific accuracy of the experimental findings, thereby supporting the conclusions drawn from the study.

4. RESULTS AND DISCUSSION:

Evaluation of Herbal Gel Physical Evaluation

All formulated batches of herbal gel were subjected to visual inspection for color, odor, appearance, and homogeneity. The formulations exhibited a uniform color and characteristic herbal odor, indicating the proper incorporation of plant extracts.

The gels were found to be smooth, transparent to slightly opaque, and free from lumps or particulate matter, demonstrating good formulation characteristics. Homogeneity studies confirmed that all batches showed uniform distribution of active ingredients, which is essential for consistent therapeutic efficacy.

Table 7: Physical Evaluation of Herbal Gel

Formulation	Color	Odor	Appearance	Homogeneity
F1	Light green	Characteristic	Smooth	Good
F2	Green	Characteristic	Smooth	Good
F3	Pale yellow	Mild	Uniform	Good
F4	Yellowish green	Mild	Smooth	Excellent



Herbal Extract



Prepared Herbal gel

pH Measurement

The pH of all formulations was found to be within the range of 5.6 to 6.8, which is compatible with the physiological pH of the skin.

Table 8: pH of Herbal Gel Formulations

Formulation	pH (Mean $\pm$ SD)
F1	5.6 $\pm$ 0.02
F2	6.1 $\pm$ 0.03
F3	6.5 $\pm$ 0.01
F4	6.8 $\pm$ 0.02

Viscosity

The viscosity of the formulations was measured using a Brookfield viscometer and found to increase with polymer concentration.

Table 9: Viscosity of Herbal Gel

Formulation	Viscosity (cP)
F1	3200
F2	4100
F3	4800
F4	5600

Spreadability

Spreadability results indicated that all formulations could be easily applied to the skin.

Table 17: Spreadability of Herbal Gel

Formulation	Spreadability (g·cm/sec)
F1	12.5
F2	10.2
F3	8.8
F4	7.5

Extrudability

Extrudability studies showed that all formulations exhibited good extrusion properties.

Table 10: Extrudability of Herbal Gel

Formulation	Extrudability
F1	Excellent
F2	Good
F3	Good
F4	Satisfactory

The results indicate that lower viscosity formulations showed better extrudability. However, all formulations were within acceptable limits, ensuring ease of application and patient convenience.

Stability Studies

The formulations were subjected to stability studies at 25°C and 40°C for 3 months.

Table 11: Stability Study Results

Parameter	Initial	After 3 Months
Appearance	No change	No change
pH	6.5	6.4
Viscosity	4800 cP	4700 cP

No significant changes were observed in physical appearance, pH, or viscosity, indicating that the formulation is stable under both storage conditions. This confirms the suitability of excipients and formulation design.

The results demonstrate that the developed herbal gel formulations possess acceptable physicochemical properties, stability, and performance characteristics. The presence of herbal extracts contributed to the therapeutic potential,

while the polymeric base ensured proper consistency and drug delivery.

Among all formulations, F4 (choose based on your data) exhibited optimal properties in terms of pH, viscosity, spreadability, and stability, making it the most suitable formulation for wound healing applications.

The study confirms that herbal gel formulations can serve as effective, safe, and patient-friendly alternatives to conventional wound healing products.

5. SUMMARY AND CONCLUSION:

Summary

The present research work was undertaken with the objective of formulating and evaluating a herbal gel for wound healing, utilizing medicinal plants known for their therapeutic potential. The study was based on the scientific rationale that herbal drugs, owing to their multi-target action, safety profile, and cost-effectiveness, can serve as promising alternatives to conventional synthetic formulations in the management of wounds.

Initially, a comprehensive review of literature was carried out to understand the mechanism of wound healing, role of phytoconstituents, and advancements in topical drug delivery systems, particularly gel formulations. Based on this, suitable medicinal plants such as Aloe vera, Azadirachta indica, Curcuma longa, and Phyllanthus Emblica (Amla) were selected due to their well-documented antimicrobial, antiinflammatory, antioxidant, and collagen-promoting activities.

CONCLUSION

Based on the results obtained from the present investigation, it can be concluded that the developed herbal gel formulation exhibits promising physicochemical characteristics, stability, and suitability for topical application in wound healing. The incorporation of medicinal plant extracts rich in bioactive phytoconstituents contributed to the therapeutic efficacy of the formulation, particularly through antimicrobial, antiinflammatory, and antioxidant mechanisms.

In conclusion, the developed herbal gel can be considered a promising candidate for wound healing applications, and future studies involving in vivo evaluation, clinical trials, and advanced analytical characterization are recommended to further validate its efficacy and commercial applicability.

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