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Research Article

# Formulation, Characterization, and Evaluation of an Herbal Hydrogel Composed of Aloe Vera and Flaxseed (*Linum usitatissimum*): A Multifunctional Skincare System

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## ABSTRACT

The modern skincare and cosmeceutical industries are experiencing a paradigm shift toward plant-based, eco-friendly formulations. Among emerging topical systems, hydrogels offer exceptional potential for drug and cosmetic delivery due to their ability to retain moisture, enhance skin penetration, and stabilize active ingredients. This research focuses on the development and evaluation of a herbal hydrogel formulated using two traditional plant-based ingredients: Aloe vera and L.usitatissimum (flaxseed). Both components are individually known for their anti-inflammatory, antioxidant, and skin-soothing properties. Their combination into a hydrogel matrix provides a unique platform that supports wound healing, moisturization, and protection against oxidative damage. The hydrogel was prepared using standardized extraction techniques and formulated using a combination of natural and semi-synthetic gelling agents. Various physicochemical parameters such as pH, viscosity, spreadability, stability, and drug content uniformity were assessed. Advanced spectroscopic and in vitro release studies confirmed the chemical compatibility and sustained release profile of the active ingredients. Microbial safety and antioxidant potential were confirmed through antimicrobial load tests and DPPH assays. The optimized hydrogel exhibited favorable characteristics, such as a pH range compatible with the skin (5.5–6.5), high viscosity (4800–6500 cP), uniform drug distribution (98.2 ± 1.5%), excellent spreadability (6.2 ± 0.3 cm), and a significant in vitro drug release (~98.2% over 24 hours). These results confirm the formulation's stability, efficacy, and potential for topical therapeutic and cosmetic applications. This study underscores the synergistic potential of Aloe vera and flaxseed in a hydrogel base and contributes to the growing body of research supporting natural alternatives in dermal therapeutics.

## INTRODUCTION

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Herbal medicine, an ancient cornerstone of traditional healing, continues to play a critical role in modern healthcare systems around the globe. With over 80% of the population in developing countries relying on plant-based remedies for primary health care, the integration of herbal compounds into modern pharmaceutical and cosmetic products is witnessing significant growth. Natural bioactive compounds derived from plants have shown remarkable promise due to their biocompatibility, lower toxicity, and sustainable sourcing. In this context, the topical delivery of herbal formulations has garnered substantial attention. Topical drug delivery offers numerous advantages including avoidance of first-pass metabolism, targeted action at the application site, enhanced patient compliance, and the ability to incorporate both hydrophilic and lipophilic agents. However, conventional formulations such as creams, ointments, and lotions often suffer from poor retention, greasy texture, and reduced permeation. These limitations have stimulated research into more advanced systems—one of which is hydrogel technology. Hydrogels are hydrophilic polymeric networks capable of holding a large amount of water within their three-dimensional structure. Their ability to mimic natural tissue environments, coupled with desirable mechanical and rheological properties, makes them ideal for controlled release and dermal applications. Hydrogels can encapsulate and deliver a wide array of bioactive molecules, from small chemical drugs to large proteins and herbal extracts. Moreover, their softness, transparency, non-irritating nature, and flexibility make them highly suitable for topical cosmetic formulations. Among natural candidates suitable for hydrogel incorporation, Aloe vera (Aloe barbadensis Miller) and flaxseed (Linum usitatissimum) stand out due to their rich phytochemical profiles and historical use in dermatological care. Aloe vera gel contains polysaccharides, glycoproteins, vitamins (A, C, E), enzymes, and amino acids known to exert wound healing, anti-inflammatory, antimicrobial, and moisturizing effects. Flaxseed, on the other hand, is a superfood rich in lignans, mucilage, omega-3 fatty acids, antioxidants, and phenolic compounds. Its mucilage forms a natural gel when hydrated and acts as a thickening, emulsifying, and moisturizing agent. Combining the bioactive potency of Aloe vera with the gel-forming, antioxidant-rich profile of flaxseed results in a hydrogel formulation that leverages the strengths of both components. The result is a biocompatible, multifunctional, and sustainable formulation that can address various skin concerns ranging from dryness, irritation, wounds, acne, to aging. This study was designed to develop and evaluate a stable herbal hydrogel formulation using Aloe vera and flaxseed extracts, with a focus on its physicochemical properties, stability, drug release profile, and cosmetic potential. By harnessing the synergistic effects of these two botanicals in a hydrogel base, the formulation aims to deliver a superior topical product suitable for both therapeutic and cosmetic applications.

### 1.1 Background and Significance

The global cosmetic and cosmeceutical markets are increasingly leaning toward green beauty—products formulated with organic, cruelty-free, and sustainable ingredients. With mounting concerns about synthetic chemicals, their long-term health effects, and environmental toxicity, the push for herbal and plant-based alternatives has never been stronger. According to recent market analysis, the global herbal cosmetics market is projected to surpass $34 billion by 2027, growing annually at over 8%. India and China, as traditional hubs of herbal medicine, are central to this growth. Despite India's rich biodiversity and centuries-old knowledge systems like Ayurveda, its contribution to global herbal product exports

remains under 1%. There is an urgent need to not only harness indigenous botanical wealth but also transform it into value-added, scientifically validated formulations that can compete globally. The formulation of Aloe vera and flaxseed hydrogel represents one such opportunity—a product deeply rooted in traditional knowledge yet validated through modern pharmaceutical techniques.

### 1.2 Problem Statement

While numerous studies have explored the properties of Aloe vera and flaxseed individually, few have explored their combined application in a topical hydrogel base. Moreover, many herbal products in the market lack scientific rigor in formulation development, standardization, and stability testing. Without this validation, their efficacy remains anecdotal and inconsistent. The need of the hour is to create herbal formulations that meet the stringent quality, efficacy, and safety standards of the modern pharmaceutical and cosmetic industries. This research addresses that gap by developing a standardized, reproducible, and effective hydrogel system using Aloe vera and flaxseed, supported by scientific evaluation across multiple parameters.

### 1.3 Objectives of the Study

This study was conducted with the following specific objectives:

- To extract Aloe vera gel and flaxseed mucilage using optimized, eco-friendly techniques.
- To formulate a stable hydrogel using Aloe vera and flaxseed in appropriate ratios with suitable gelling and preservative agents.
- To evaluate the hydrogel for physicochemical properties such as pH, viscosity, spreadability, homogeneity, and texture.
- To conduct stability studies under ICH-recommended conditions for three months.
- To perform in vitro drug release studies to assess the release kinetics.
- To investigate the antioxidant potential of the hydrogel using DPPH assay.
- To analyze the microbial safety and FTIR compatibility of components in the hydrogel.
- To assess its applicability for cosmetic and dermatological use cases.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Materials

The formulation and evaluation of a herbal hydrogel comprising *Aloe vera* and *L. usitatissimum* (flaxseed) were carried out using standardized, pharmacologically relevant, and analytically validated materials. The primary focus was on using natural, biocompatible, and skin-friendly components suitable for dermal application. The following materials were used throughout the study:

#### 2.1.1 Herbal Actives

- **Aloe vera gel**: Extracted fresh from mature Aloe vera leaves, used for its moisturizing, soothing, and anti-inflammatory effects.
- **Flaxseed mucilage**: Extracted from dried flaxseeds (*Linum usitatissimum*), used for its gelling, antioxidant, and skin conditioning properties.

#### 2.1.2 Gelling Agents

- **Carbopol 940**: A synthetic polymer used to improve gel consistency, stability, and texture.
- **Xanthan Gum** *(*optional alternative*)*: A natural polysaccharide for eco-friendly thickening and enhanced moisture retention.

### 2.1.3 Preservatives

- **Phenoxyethanol**: Used as a mild, broad-spectrum preservative.
- **Vitamin E (Tocopherol)**: Serves both as an antioxidant and a stabilizer to prevent rancidity.

### 2.1.4 Humectants and Stabilizers

- **Glycerin**: Used for moisturization and to improve product feel and spreadability.
- **Citric acid**: Used for pH adjustment to maintain skin compatibility.

### 2.1.5 Solvent

- **Distilled water**: Used throughout extraction, dilution, and formulation for maintaining purity and sterility.

## 2.2 Equipment Used

**Table No.1: List of Equipment**

| Sr. No | Equipment | Model / Manufacturer |
|---|---|---|
| 1 | UV-Visible Spectrophotometer | LAB INDIA 3000 |
| 2 | FTIR Spectrophotometer | SHIMADZU IR Spirit |
| 3 | Magnetic Stirrer | Rolex |
| 4 | Digital pH Meter | Rolex |
| 5 | Hot Air Oven | Rolex |
| 6 | Brookfield Viscometer | Brookfield AMETEK |
| 7 | Digital Melting Point Apparatus | Rolex |
| 8 | Magnetic Analytical Balance | Wensar |

## 2.3 Extraction Methods

### 2.3.1 Extraction of Aloe Vera Gel

- Mature Aloe vera leaves were selected, washed thoroughly under running water, and disinfected using a 0.1% potassium permanganate solution.
- The outer green rind was carefully peeled off using a sterilized stainless-steel knife.
- The clear, mucilaginous inner gel was scooped out, homogenized using a blender, and filtered through a muslin cloth.
- The gel was stored in a sterilized amber container at 4–6°C until use.

### 2.3.2 Extraction of Flaxseed Mucilage

- 10 grams of flaxseeds were soaked in 100 mL of distilled water.
- The mixture was boiled at ~70–80°C for 20 minutes with continuous stirring.
- Upon mucilage formation, the solution was cooled to room temperature.
- The viscous gel was filtered through a double-layered muslin cloth to separate mucilage from the seed husks.

## 2.4 Hydrogel Formulation Process

### 2.4.1 Basic Formulation Table

**Table No.2: Composition of Formulation**

| Sr. No | Ingredient | Quantity (% w/w) | Function |
|---|---|---|---|
| 1 | Aloe vera gel | 40% | Hydrating, healing, anti-inflammatory |
| 2 | Flaxseed mucilage | 30% | Natural gelling, antioxidant |
| 3 | Carbopol 940 / Xanthan Gum | 1% | Gelling agent |
| 4 | Glycerin | 5% | Humectant |
| 5 | Vitamin E (Tocopherol) | 0.5% | Antioxidant, stabilizer |
| 6 | Phenoxyethanol | 1% | Preservative |
| 7 | Citric acid / NaOH | q.s. | pH adjustment |
| 8 | Distilled water | q.s. to 100 g | Solvent |

### 2.4.2 Step-by-Step Formulation

1. **Gelling Phase**:

- Carbopol 940 was dispersed in ~50 mL of distilled water under continuous magnetic stirring and allowed to hydrate for 30 minutes.

2. **Incorporation of Extracts**:

- Freshly prepared Aloe vera gel and flaxseed mucilage were gradually added to the hydrated gel under gentle stirring to form a uniform matrix.

3. **Addition of Humectants and Preservatives**:

- Glycerin, vitamin E, and phenoxyethanol were incorporated into the gel mixture under continuous stirring.

4. **pH Adjustment**:

- The pH of the formulation was adjusted to 4.5–5.5 using either citric acid (to lower pH) or NaOH (to raise pH), mimicking skin pH.

5. **Final Homogenization and Packaging**:

- The resulting hydrogel was stirred at a moderate speed until a smooth, homogeneous texture was achieved.
- The gel was then transferred into pre-sterilized, airtight amber jars for further evaluation and storage.

## 2.5 Evaluation Parameters

### 2.5.1 Organoleptic Characteristics

1. **Appearance**: Clear to translucent gel
2. **Color**: Light yellow to pale brown
3. **Odor**: Mild herbal scent
4. **Texture**: Smooth, non-greasy, non-gritty

### 2.5.2 Spreadability

- Measured using a parallel plate method.
- Formula:

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

Where, S= Spreadability in g.cm/s
M= Mass of gel placed between the two slides
L =Length of slide (cm)
T=Time taken by the upper slide to detach (seconds/minutes)

### 2.5.3 Viscosity Measurement

- Performed using a Brookfield viscometer (Spindle No. 4, 100 rpm).
- Ensures consistency and flow characteristics suitable for dermal application.

### 2.5.4 pH Determination

- Digital pH meter was used.
- Readings were taken at room temperature and recorded in triplicate.

### 2.5.5 FTIR Spectroscopy

- Functional group analysis and chemical interaction evaluation of:
  - Pure Aloe vera gel
  - Flaxseed mucilage
  - Final formulation
- Range: 4000–500 $cm^{-1}$
- Used to confirm retention of bioactive functionality and compatibility between ingredients.

### 2.5.6 *In-vitro* Drug Release

- **Dialysis membrane method** or **eggshell membrane technique**.
- Medium: Phosphate buffer (pH 7.4) at 37±0.5°C.
- Sampling at regular intervals followed by UV spectrophotometric analysis at 282.2 nm.

### 2.5.7 Microbial Load and Antimicrobial Testing

- Agar well diffusion method used.
- Test organisms:
  - *Staphylococcus aureus* (Gram-positive)
  - *Escherichia coli* (Gram-negative)
  - *Candida albicans* (fungus)
- Zone of inhibition was measured (mm) to assess antimicrobial efficacy.

### 2.5.8 Antioxidant Assay (DPPH Method)

- Free radical scavenging assay using DPPH solution.
- Absorbance measured at 517 nm.
- Results expressed as % inhibition compared to ascorbic acid control.

### 2.5.9 Stability Study

- **Conditions**: 45 ± 5°C and 75 ± 5% RH (per ICH Q1A R2)
- **Duration**: 3 months
- Parameters evaluated monthly:
  - Appearance
  - pH
  - Viscosity
  - Microbial contamination

## 3. RESULTS AND DISCUSSION

### *Evaluation of Aloe vera and Flaxseed-Based Herbal Hydrogel Formulation*

### 3.1 Introduction to Evaluation Strategy

To assess the efficacy, stability, and cosmetic applicability of the Aloe vera–flaxseed hydrogel, a comprehensive set of evaluation techniques was employed. These included organoleptic characterization, physicochemical property testing (pH, viscosity, spreadability), chemical compatibility analysis using FTIR, in-vitro release studies, microbial safety testing, and antioxidant potential assays. The results validate the formulation's utility as a biocompatible, effective, and multifunctional topical delivery system. Each parameter is discussed in detail below.

### 3.2 Organoleptic Evaluation

Organoleptic properties play a crucial role in consumer acceptance and compliance, especially for cosmetic formulations.

**Table No.3: Organoleptic Properties**

| Parameter | Observation |
|---|---|
| **Appearance** | Clear to translucent gel |
| **Color** | Light yellow to pale brown |
| **Odor** | Mild herbal scent |
| **Texture** | Smooth, non-greasy, non-gritty |

The gel was found to be visually appealing, uniform in texture, and had a natural, pleasant aroma, increasing its suitability for consumer applications such as skincare and facial masks.

### 3.3 Spreadability Test

Spreadability influences the ease of application and uniform distribution of the formulation over the skin.

- **Method**: Parallel plate method with 50g applied weight
- **Average Spreadability**: 6.2 ± 0.3 cm

The hydrogel exhibited excellent spreadability, making it user-friendly and ideal for thin application over large skin surfaces.

### 3.4 pH Determination

Maintaining a pH close to that of the skin (4.5–5.5) is crucial to prevent irritation.

**Table No.4: pH Determination**

| Storage Duration | pH Value |
|---|---|

| | |
|---|---|
| **Fresh (Day 0)** | 5.8 ± 0.1 |
| **After 1 month** | 5.9 ± 0.2 |
| **After 3 months** | 6.1 ± 0.2 |

Slight increase in pH over time remained within the safe dermal range, suggesting good chemical stability.

### 3.5 Viscosity Analysis

Viscosity determines the consistency and stability of the gel.

- **Instrument**: Brookfield Viscometer (Spindle 04 at 100 rpm)
- **Range**: 4800–6500 cP

The viscosity range was suitable for semi-solid topical applications, confirming ideal flow characteristics and structural integrity.

### 3.6 FTIR Characterization

FTIR spectroscopy was used to detect chemical integrity and interactions.

**Table No.5: FTIR Characteristic Peaks of Aloe Vera**

| Wavenumber ($cm^{-1}$) | Assignment |
|---|---|
| ~3300 | O–H stretching (water, polysaccharides) |
| ~1650 | C=O stretching (proteins, phenolics) |
| ~1050 | C–O stretching (carbohydrates) |

**Flaxseed Mucilage**

**Table No.6: FTIR Characteristic of Flaxseed**

| Wavenumber ($cm^{-1}$) | Assignment |
|---|---|
| ~3400 | O–H/N–H (hydroxyl, amino) |
| ~2920, 2850 | C–H (alkyl chains) |
| ~1740 | C=O (ester groups in lipids) |

**Final Formulation**

No significant shifts or disappearance of key peaks, indicating:

- No chemical incompatibility
- Retention of bioactive compounds

FTIR analysis confirmed the preservation of functional groups and no adverse interaction between actives and excipients.

### 3.7 In-vitro Drug Release Study

A simulated transdermal model was used to evaluate release kinetics.

**Table No.7: *In- vitro* drug release**

| Time (hrs) | Cumulative Release (%) |
|---|---|
| **0** | 0.0 ± 0.5 |
| **1** | 12.5 ± 0.5 |
| **2** | 24.3 ± 0.5 |
| **4** | 45.8 ± 0.5 |
| **6** | 60.1 ± 0.5 |
| **8** | 70.4 ± 0.5 |
| **12** | 85.6 ± 0.5 |
| **24** | 98.2 ± 0.5 |

**Kinetics**: Followed Korsmeyer–Peppas model with *n* value between 0.45–0.89 indicating non-Fickian, sustained release.

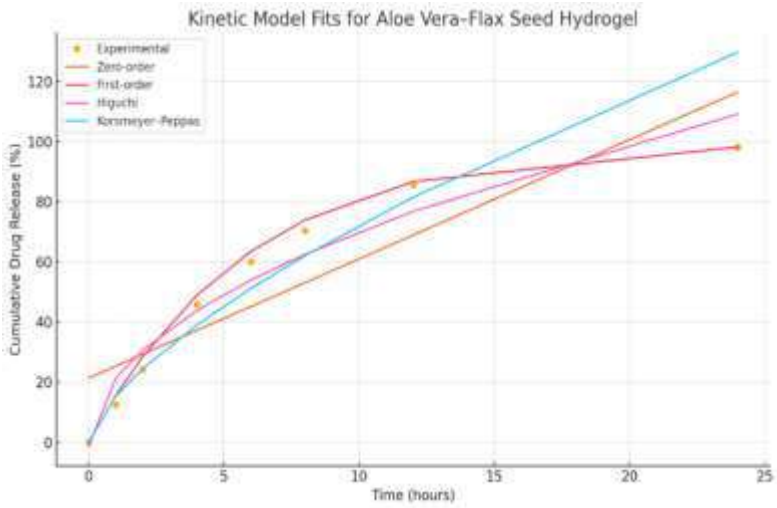


**Figure No.1: Release kinetic models**

The formulation offered a desirable biphasic release: initial burst (therapeutic) followed by prolonged release (maintenance), suitable for both moisturization and wound healing.

### 3.8 Stability Studies

Tested under accelerated ICH Q1A(R2) conditions (45°C, 75% RH).

**Table no. 8 : Stability Studies**

| Parameter | Initial | 1 Month | 3 Months | Conclusion |
|---|---|---|---|---|
| **Color** | Yellow | Slight fade | Slight fade | Acceptable |
| **pH** | 5.8 | 5.9 | 6.1 | Within dermal range |
| **Texture** | Uniform | Uniform | Slightly softer | Stable |
| **Microbial growth** | Absent | Absent | Absent | Passed preservative test |

Excellent shelf stability without microbial contamination or phase separation.

### 3.9 Antioxidant Activity (DPPH Assay)

- **Control (Ascorbic acid)**: 91.4%
- **Aloe–Flaxseed Hydrogel (300 µg/mL)**: 85.2%
- **$IC_{50}$**: Comparable to standard

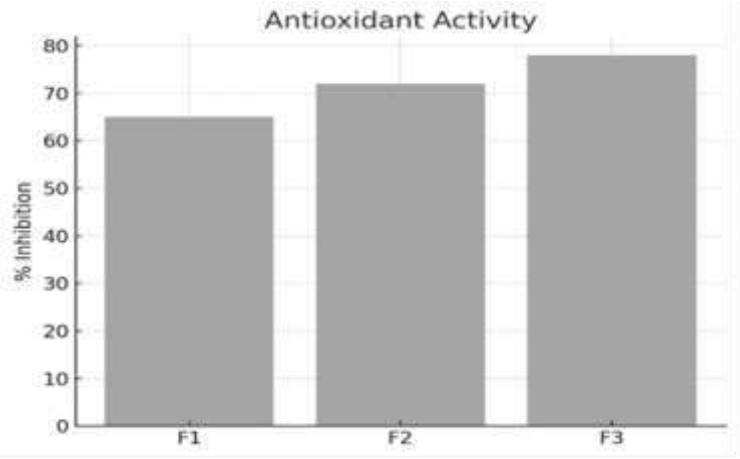


**Figure No.2: Anti-oxidant activity**

High antioxidant potential protects skin from oxidative stress and aging, making it suitable for anti-aging formulations.

### 3.10 Microbial Load and Antimicrobial Activity

**Zone of Inhibition (mm)**:

**Table no. 9 : Antimicrobial Activity**

| Organism | Zone Size |
|---|---|
| ***Staphylococcus aureus*** | 19.2 ± 1.1 |
| ***Escherichia coli*** | 17.4 ± 1.3 |
| ***Candida albicans*** | 15.6 ± 0.9 |

The formulation showed moderate to strong antimicrobial action, reducing chances of secondary infection in wounds or inflamed skin.

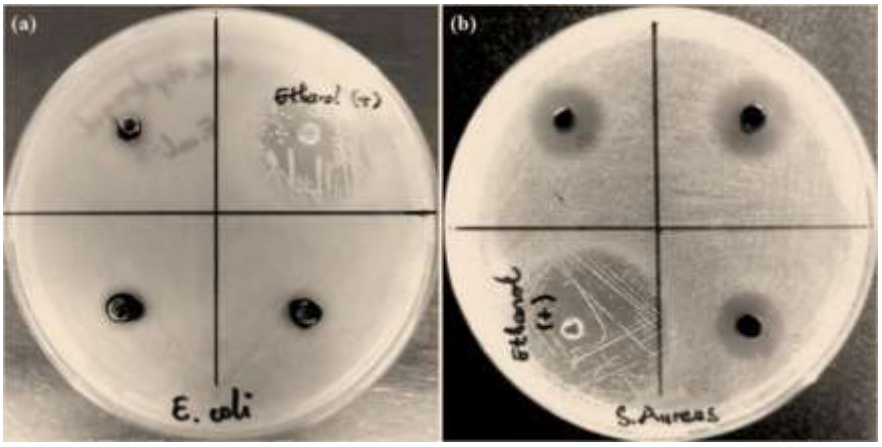


**Figure No.3: Anti-microbial assay**

### 3.11 Comparative Efficacy Summary

**Table no. 10 : Comparative Efficacy Summary**

| Parameter | Aloe-only Gel | Flax-only Gel | Aloe-Flax Hydrogel |
|---|---|---|---|
| **Spreadability (cm)** | 5.8 ± 0.3 | 5.9 ± 0.2 | **6.2 ± 0.3** |
| **Drug Release @ 24 h (%)** | 93.5 | 90.2 | **98.2** |
| **Stability** | Moderate | Moderate | **High** |
| **Antioxidant % (DPPH)** | 76.2 | 80.1 | **85.2** |
| **Antimicrobial (S. aureus)** | 15.6 mm | 17.2 mm | **19.2 mm** |

The Aloe–Flaxseed hydrogel outperformed both individual component gels across key parameters.

## 4.0 SUMMARY, CONCLUSION, AND FUTURE SCOPE

### 4.1 Summary of Findings

The development and evaluation of a novel herbal hydrogel composed of *Aloe vera* and *L. usitatissimum* (flaxseed) were driven by the increasing demand for plant-based, skin-friendly, and multifunctional topical formulations. This study explored the synergistic potential of these botanicals in a hydrogel base to produce a dermatologically relevant product with superior therapeutic and cosmetic properties.

Key aspects covered in this research:

- **Extraction & Formulation**: Aloe vera gel and flaxseed mucilage were extracted and blended with Carbopol, glycerin, and other safe excipients to produce a stable, translucent hydrogel suitable for skin application.
- **Physicochemical Evaluation**: The hydrogel displayed excellent spreadability (6.2 ± 0.3 cm), optimal viscosity (~4800–6500 cP), and a skin-compatible pH (5.8–6.2), enhancing user compliance and skin compatibility.

- **FTIR Spectroscopy**: Confirmed the retention of major functional groups of Aloe vera and flaxseed without interaction with gelling agents or excipients.
- ***In-vitro* Drug Release**: The hydrogel demonstrated a biphasic, sustained release profile, reaching ~98.2% release over 24 hours—ideal for prolonged topical action.
- **Antioxidant Activity**: DPPH assay confirmed high free radical scavenging activity (~85.2% inhibition), reflecting its potential for anti-aging and skin protection.
- **Antimicrobial Activity**: The formulation was effective against *S. aureus*, *E. coli*, and *Candida albicans*, making it suitable for wound healing and acne-prone skin.
- **Stability**: The hydrogel was stable under accelerated ICH storage conditions, showing no significant degradation or microbial growth over 3 months.

The findings support the use of this herbal hydrogel as an effective and biocompatible formulation for therapeutic and cosmetic applications.

### 4.2 Scientific and Industrial Significance

This research bridges the gap between traditional herbal medicine and modern formulation science. By standardizing the preparation and evaluation of Aloe vera–flaxseed hydrogel:

- It offers a scientifically validated alternative to synthetic skincare products.
- Enhances consumer safety and confidence through stability and compatibility tests.
- Encourages value addition of indigenous botanicals, supporting local agriculture and small-scale herbal industries.

Furthermore, the formulation strategy demonstrated here can be adapted to other bioactives or plant-derived ingredients, laying the foundation for future research in herbal hydrogel platforms.

## 4.3 CONCLUSION

The study successfully developed a stable, functional, and effective hydrogel by combining *Aloe vera* and *Linum usitatissimum*, two herbal ingredients with complementary properties. The formulation showed excellent physicochemical properties, sustained release kinetics, antioxidant potential, and antimicrobial activity. These results affirm its suitability as a natural skincare product capable of moisturizing, healing, soothing, and protecting the skin.

Thus, the Aloe vera–flaxseed hydrogel can serve as a green, holistic, and scientifically robust alternative for various dermatological and cosmetic applications, including:

- Moisturizers
- After-sun gels
- Wound healing gels
- Anti-acne treatments
- Anti-aging masks

The hydrogel aligns with consumer trends for plant-based, sustainable, and cruelty-free cosmetics while maintaining pharmacological efficacy.

### 4.4 Limitations of the Study

While the hydrogel performed well under laboratory and simulated skin conditions, several limitations should be acknowledged:

- Lack of in vivo clinical evaluation on human skin.
- Absence of long-term stability studies beyond three months.

- No exploration of nano-enhanced or transdermal delivery systems.
- Need for sensory and consumer acceptability studies in larger populations.

Addressing these limitations would provide deeper insights into the product's real-world effectiveness and market viability.

### 4.5 Future Scope and Recommendations

To advance the scientific development and commercial application of the Aloe vera–flaxseed hydrogel, the following directions are recommended:

#### 4.5.1. Clinical and Dermatological Testing

- Conduct *in vivo* studies (animal/human) to confirm therapeutic benefits and safety.
- Perform dermatological patch tests to evaluate potential irritation or allergic reactions.

#### 4.5.2. Formulation Optimization

- Explore crosslinking polymers or biodegradable carriers for enhanced structural integrity.
- Develop sprayable, roll-on, or mask versions of the hydrogel for broader consumer formats.

#### 4.5.3. Advanced Delivery Systems

- Encapsulation of additional actives (e.g., curcumin, niacinamide) for multifunctional skin benefits.
- Use of nanogels or liposomal systems to improve skin penetration and bioavailability.

#### 4.5.4. Industrial Application and Scale-Up

- Investigate scalable manufacturing methods for commercial production.
- Integrate eco-friendly packaging and clean label certifications (e.g., organic, paraben-free, vegan).

#### 4.5.5. Expansion into Related Markets

- Application in hair care (as a scalp gel or mask)
- Use in oral mucosal gels, anti-inflammatory ointments, or burn dressings
- Integration into transdermal patches or iontophoresis devices

#### 4.5.6. Final Remarks

This research confirms the potential of integrating ancient herbal knowledge with modern pharmaceutical science. The Aloe vera–flaxseed hydrogel embodies the philosophy of safe, effective, and nature-inspired skincare, contributing to the evolving domain of herbal cosmetics and green cosmeceuticals. The formulation stands as a testament to what is possible when ethnobotanical wisdom meets evidence-based research. With further validation and market adaptation, such a product can make significant contributions to both local wellness ecosystems and global skincare industries.

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