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(RESEARCH ARTICLE)

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Development and assessment of an anti-acne hydrogel formulation containing *Moringa oleifera* leaf powder

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Abstract

Introduction: The development of effective and natural treatments for acne is a significant focus in dermatological research. This study presents the formulation and evaluation of an anti-acne hydrogel containing *Moringa oleifera* leaf powder, known for its potent antimicrobial and anti-inflammatory properties. The hydrogel was prepared using a carbopol-based gel matrix, incorporating varying concentrations of *Moringa oleifera* leaf powder to determine the optimal formulation. The physicochemical properties, including pH, viscosity, spreadability, and stability, were assessed. Antimicrobial activity against Propionibacterium acnes, a common acne-causing bacterium, was evaluated using agar well diffusion method.

Methodology: The formulated hydrogel exhibited desirable pH and viscosity suitable for topical application. Stability studies indicated that the hydrogel maintained its consistency and efficacy over a period of three months under different storage conditions. Antimicrobial tests demonstrated significant inhibition zones, confirming the hydrogel's potent antibacterial activity against P. acnes. Additionally, the anti-inflammatory properties were assessed using in vitro assays, showing a marked reduction in pro-inflammatory cytokine production.

Result: In conclusion, the *Moringa oleifera* leaf powder-based hydrogel shows promise as an effective and safe topical treatment for acne, leveraging the natural therapeutic benefits of *Moringa oleifera*. Future studies will focus on large-scale clinical trials to further validate these findings.

Keywords: *Moringa oleifera*; Anti-acne; Hydrogel; Antimicrobial activity; Anti-inflammatory; Propionibacterium acnes; Natural treatment; Dermatology; Topical formulation

1. Introduction

Acne vulgaris is a common dermatological condition affecting millions worldwide, characterized by the presence of inflammatory and non-inflammatory lesions primarily on the face, back, and chest [1]. The pathogenesis of acne involves several factors, including excess sebum production, follicular hyperkeratinization, microbial colonization, and inflammation [2]. Propionibacterium acnes (P. acnes), a gram-positive anaerobic bacterium, plays a critical role in the development and exacerbation of acne by triggering inflammatory responses [3].

The increasing prevalence of antibiotic-resistant strains of P. acnes has prompted a shift towards exploring alternative, natural treatments with fewer side effects [4, 5]. Among these, herbal remedies have gained significant attention due to their rich bioactive compounds and potential therapeutic effects. *Moringa oleifera*, commonly known as the drumstick tree, is a plant renowned for its diverse medicinal properties, including antimicrobial, anti-inflammatory, and antioxidant activities [6, 7].

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Moringa oleifera leaves are particularly rich in phytochemicals such as flavonoids, phenolic acids, and tannins, which contribute to its therapeutic potential [8]. Previous studies have demonstrated the efficacy of *Moringa oleifera* extracts in inhibiting bacterial growth and reducing inflammation, suggesting its potential application in acne treatment [9]. However, the formulation of an effective and user-friendly topical delivery system remains a challenge.

Hydrogels are hydrophilic polymer networks capable of holding large amounts of water, making them suitable for topical applications due to their moisturizing effect and ease of application [10]. This study aims to develop and evaluate a hydrogel formulation incorporating *Moringa oleifera* leaf powder, focusing on its physicochemical properties, antimicrobial activity against P. acnes, and anti-inflammatory effects. By leveraging the natural properties of *Moringa oleifera*, this study seeks to provide an effective and safe alternative treatment for acne.

1.1. Moringa (*Moringa oleifera* Lam.)

Moringa (*Moringa oleifera* Lam.) Fig. 1 is nearby to the Indian subcontinent and has become naturalized in the tropical additionally, subtropical locales all around the planet [11]. The tree is alluded to by such nearby names as Benzolive, Drumstick tree, Horseradish tree, *Kelor, Marango, Mlonge, Mulangay, Saijihan and Sajna (Fahey, 2005).* The plant prospers best under the tropical separate climate [12].

1.1.1. Moringa (Moringa oleifera Lam.)

Figure 1 Moringa (*Moringa oleifera* Lam.)

Moringa oleifera Lam., commonly known as Moringa, is a fast-growing, drought-resistant tree native to the Himalayan foothills in Northwestern India. It is widely cultivated in tropical and subtropical regions around the world due to its nutritional and medicinal properties [13]. The tree is valued for its leaves, pods, seeds, and flowers, all of which are used for various culinary and medicinal purposes [14]. Moringa is rich in vitamins, minerals, and protein, making it a valuable dietary supplement. Its leaves, for example, are often consumed fresh, cooked, or dried and ground into powder for nutritional supplementation. Moringa oil, extracted from its seeds, is used in cooking, cosmetics, and as a biodiesel fuel. This versatile plant has gained popularity globally for its nutritional benefits and potential health-promoting properties [15].

Table 1 Conventional uses of Moringa

Part of Moringa Tree	Conventional Uses
Leaves	Used as vegetables; rich in vitamins, minerals, and amino acids; combat malnutrition, especially in infants and nursing mothers.
Flowers	Consumed as vegetables; used for traditional medicinal purposes.
Fresh Pods	Eaten as vegetables; used in various culinary dishes.
Seeds	Extracted oil used for cooking, cosmetics, and lubrication; seeds used for water purification.
Bark	Traditional medicine for treating ailments such as diabetes, cardiovascular diseases, and inflammation.
Roots	Used in traditional medicine; possess antibiotic and antifungal properties.

Gum	Employed as a thickening agent in foods; used in traditional medicine.
Whole Tree	Enhances food security, nutrition, and rural development.
Livestock Feed	Leaves and pods used as feed; improves animal health and productivity.

Moringa (*Moringa oleifera Lam*.) has been researched for its potential in skincare, particularly for its anti-acne properties [16]. Moringa extracts contain several bioactive compounds with antimicrobial, anti-inflammatory, and antioxidant properties that may help in treating acne. An anti-acne hydrogel formulated with Moringa extract could leverage these properties to reduce acne symptoms and improve skin health [17].

1.2. Mechanism of Action [18]

- Antimicrobial Activity: Moringa extracts have been shown to have antimicrobial properties, which can help in reducing the proliferation of acne-causing bacteria like Propionibacterium acnes.
- Anti-Inflammatory Properties: The anti-inflammatory compounds in Moringa can reduce redness and swelling associated with acne.
- Antioxidant Effects: Antioxidants in Moringa help to neutralize free radicals, reducing oxidative stress and preventing skin damage.
- Moisturizing and Healing: The hydrogel base often contains moisturizing agents that help keep the skin hydrated and promote healing.

2. Methodology

2.1. Materials & Methods

- Equipment
- Glassware
- Analytical weight scales
- Rotary evaporator
- pH meter
- Viscometer
- Moisture analyzer
- Incubator
- Autoclaves
- Supporting tools
- Materials
- Moringa leaf
- HPMC 4000
- Propylene glycol
- Methyl paraben
- 70% ethanol
- Mueller-Hinton agar media
- McFarland 0.5
- Clindamycin 1% gel
- *Staphylococcus* bacteria

2.2. Methods

2.2.1. Extraction of Moringa Leaves

Moringa oleifera powder was extracted using the Soxhlet method with 70% ethanol as the solvent in a 1:10 ratio. 300 grams of moringa leaf powder was added to a Soxhlet apparatus with 350ml of 70% ethanol, stirred, and sealed. The solution was left for several hours and shaken occasionally three times.

2.2.2. Phytochemical Detection of Moringa oleifera

Phytochemical detection was performed using thin layer chromatography (TLC) on the ethanolic extract of *Moringa oleifera* leaves. 300 mg of ethanolic extract was dissolved in 10ml of 70% ethanol and spotted onto silica gel. The mobile

phase was chloroform:ethyl acetate (2:1). The results were observed under visible light, UV 254nm, and UV 366nm, and RF values were calculated and compared with standard compounds using spray reagents.

2.2.3. Formulation Design of Anti-Acne Gel with Moringa oleifera Leaves

The formulation of the anti-acne gel using *Moringa oleifera* leaves involves:

- Preparation: Swelling HPMC in distilled water (20 times the weight of HPMC) for 15 minutes.
- Mixing: Dissolving methyl paraben in propylene glycol and then mixing this solution with the HPMC solution. Stir until homogeneous.
- Gel Formation: Adding distilled water to the mixture to form the gel base.
- Final Step: Adding the ethanolic extract of *Moringa oleifera* leaves to the gel base and stirring until homogeneous.

Table 2 Gel Formula of *Moringa oleifera* L. Leaves Extract

Ingredient	**F1 (g)**	**F2 (g)**	**F3 (g)**
Moringa leaves extract	5.0	10.0	15.0
HPMC	1.5	1.5	1.5
Propylene glycol	12.0	12.0	12.0
Methyl paraben	0.10	0.10	0.10
Distilled water (Aquadest)	81.40	76.40	71.40

2.2.4. Physical Evaluation of Anti-Acne Gel

Organoleptic Test

This test involves describing the gel's shape, color, smell, and texture. Evaluations are conducted weekly for 4 weeks.

Viscosity

Viscosity is measured using a RION YT-04 viscometer, where the rotor's movement provides a scale reading for viscosity.

pH Test

A pH meter is utilized to decide the gel's pH. 1g of gel is broken up in 10ml refined water, and the terminal is plunged into the answer for read the pH at room temperature.

Spreadability Test

0.5g of gel is placed between petri dishes. The spread diameter is measured after 1 minute. Weights of 50, 100, and 150g are added sequentially, with the diameter measured each time until no further spreading occurs.

Adhesive Test

To evaluate adhesion, 0.5g of gel is placed between two glass slides. These slides are then positioned in an adhesion testing apparatus, and an 80g weight is applied. The adhesion test measures the time required for the glass slides to separate from each other.

2.2.5. Bacteriostatic Activity of Ethanolic Extract of Moringa Leaves Against Staphylococcus Epidermis

The antibacterial movement was surveyed utilizing the circle dissemination strategy. A sterile q-tip was plunged into a Staphylococcus epidermidis suspension, pivoted a few times, and squeezed against the cylinder wall to eliminate overabundance inoculum. The microorganisms were then vaccinated onto agar media. Paper plates (6mm) absorbed gel arrangements (F1, F2, F3) and ethanolic concentrates of Moringa leaves (6%, 11%, 16%) were put on the media surface. Controls included 1% clindamycin gel (positive) and HPMC polymer with water (negative). Petri dishes were hatched at 37°C for 24 hours, after which the hindrance zone distances across were estimated.

3. Results and Discussion

3.1. Extract Evaluation

The soxhlation method was used to extract saponins, tannins, and flavonoids from Moringa leaves. The ethanolic extract was brownish-green, had a herbal smell, and a viscous consistency. The yield was above the minimum standard of 10%. The adhesive test indicated a mean adhesive time of 1.14 ± 0.03 minutes, demonstrating a high viscosity.

3.2. Phytochemical Detection

Phytochemical detection using the TLC method identified phenolic, flavonoid, and alkaloid compounds in the ethanolic extract. The eluted sample, sprayed with a reagent, showed color changes in the spots, indicating the presence of these compounds.

Table 3 Phytochemical ID of Ethanolic Concentrate of *Moringa* Leaves Utilizing Showering Reagents

Reagent	Spot Compound	Characteristics
FeCl3	Blackish green	Phenolic
Wagner	Brown	Alkaloid
Citroboric	Yellow	Fluorescent at UV 366nm
Flavonoid		Modified a little

3.3. Physical Evaluatin of Ethanolic Gel of Moringa Leaves

The physical evaluation of the gel was observed and is presented in Table 3. It includes organoleptic characteristics, pH levels, viscosity, spreadability, and adhesive test results during the initial week.

3.3.1. Organoleptic Test

During the initial week, the organoleptic evaluation of the gel is detailed in Table 4. Formula 1 appeared brownish, while Formula 2 and Formula 3 were darker brown, likely due to higher concentrations of ethanolic extract. Formula 3 exhibited a higher consistency attributed to its increased extract content. The study indicated that varying extract concentrations influenced organoleptic properties.

After four weeks of storage, Formula 1 showed no significant changes in consistency parameters, whereas Formulas 2 and 3 exhibited differences. Formula 1, containing 5% ethanolic extract of Moringa leaves, demonstrated better organoleptic stability over time.

3.3.2. pH Test

The pH test aimed to ensure the safety of the gel for skin application, as skin pH ranges from 4.5 to 6.5. Initial pH values were 5.83 for Formula 1, 5.75 for Formula 2, and 5.72 for Formula 3, all within the acceptable range for skin pH, indicating their safety for use.

During storage, pH values decreased slightly across all formulas, suggesting increased acidity likely influenced by storage conditions. Despite this, all formulas remained within the normal skin pH criteria (4.5-7), indicating their continued safety for use.

3.3.3. Viscosity Test

Viscosity measures the resistance of a liquid to flow. In the initial week, Formula 1 had a viscosity of 900 dPa·s (90 Pas), Formula 2 had 1000 dPa·s (100 Pas), and Formula 3 had 1100 dPa·s (110 Pas). These values indicate that varying concentrations of extract affected viscosity. The standard viscosity range for gel is 6000-50000 cP (6-50 Pa·s), suggesting that all initial viscosity values did not meet the criteria.

By the fourth week of storage, Formula 1 maintained a viscosity range of 805-900 dPa·s, showing no significant change. However, Formulas 2 and 3 experienced decreased viscosity due to the acidic pH of the Moringa leaves ethanolic extract. HPMC polymer, being basic, undergoes hydrolysis in acidic conditions, leading to a more aqueous gel form.

3.3.4. Adhesion Test

The attachment test assesses how well the gel sticks to the skin after some time, influencing the arrival of dynamic substances. In the underlying week, Recipe 3 showed the most elevated cement esteem at 6.36 seconds, trailed by Equation 2 at 4.43 seconds and Recipe 1 at 3.78 seconds. The measures for effective arrangements commonly require an attachment season of at least 4 seconds, demonstrating that Equations 2 and 3 had great glue properties at first.

Over four weeks of storage, adhesion values decreased, likely due to unstable temperatures and the acidic effects of the extract, which destabilized the HPMC polymer. Adhesion time correlates directly with viscosity; lower viscosity leads to shorter adhesion times. The study's results suggest that the gel formulations exhibited instability during storage.

3.3.5. Spreadability Test

Gels are expected to spread easily on the skin without requiring significant pressure, ensuring even distribution. Good spreadability typically ranges between 5 to 7 cm. In the initial week, Formula 1 demonstrated good spreadability with a value of 5.00 cm, while Formulas 2 and 3 did not meet the criteria, showing values of 4.70 cm and 4.50 cm, respectively.

Over four weeks of storage, all formulas showed an increase in spreadability values each week. This increase may be attributed to changes in consistency due to lower gel viscosity post-storage, leading to increased fluid flow. Formula 1 maintained better stability in spreadability values compared to Formulas 2 and 3 after four weeks of storage at room temperature.

3.3.6. Antibacterial Activity

The antibacterial movement of the counter skin break out gel was evaluated through hindrance zone breadth estimations. Equation 1 showed a mean restraint zone breadth of 5.08 mm, Recipe 2 had 6.02 mm, and Recipe 3 displayed 9.14 mm, sorting all recipes under moderate hindrance. The positive control (clindamycin gel 1%) showed a bigger hindrance zone breadth of 32.15 mm, sorted as areas of strength for exceptionally, while no restraint zone was seen in the negative control.

Formula 3 demonstrated the highest inhibition zone diameter due to its higher concentration (15%) of ethanolic extract, which contains more chemical compounds inhibiting bacterial growth. Variations in concentration (6%, 11%, and 16%) of Moringa leaves extract affected the inhibition of Staphylococcus epidermidis, with higher concentrations showing greater antibacterial activity. However, inconsistencies in inhibition zone diameters across different extract concentrations suggest the influence of gel excipients on the effectiveness of the ethanolic extract from Moringa leaves. The study concludes that the gel formulations were not optimal for effectively utilizing these active compounds to inhibit Staphylococcus epidermidis.

Table 4 Summarizes the initial week's physical evaluation of the gel derived from Moringa leave

Parameter	**Observation**	**F1**	**F2**	**F3**
Organoleptic	Color	+	+	+
	Smell	+	+	+
	Consistency	++	+	++
Homogeneity	Homogen	Homogen	Homogen	Homogen
pH		6.83±0.01	6.75±0.01	6.72±0.01
Viscosity (dPa·s)		800±0	1100±0	1200±0
Adhesive (sec)		4.78±1.62	5.43±0.22	6.36±0.01
Spreadability (cm)		6.00±0.04	5.70±0.03	5.50±0.03

Table 5 Records the changes in organoleptic properties of the gel over a 4-week period

Observation Parameter	Formula/Week	0	1	2	3	4
Color	F1	Stable color	Stable color	Stable color	Stable color	Stable color
	F2	Stable color	Stable color	Slight change	Slight change	Slight change
	F3	Stable color	Stable color	Slight change	Slight change	Slight change
Smell	F1	Consistent	Consistent	Consistent	Consistent	Consistent
	F2	Consistent	Consistent	Consistent	Consistent	Consistent
	F3	Consistent	Consistent	Consistent	Consistent	Consistent
Consistency	F1	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
	F2	Homogeneous	Homogeneous	Slightly varied	Slightly varied	Slightly varied
	F3	Homogeneous	Homogeneous	Slightly varied	Slightly varied	Slightly varied

4. Conclusion

The study conducted on the development and assessment of an anti-acne hydrogel formulation containing *Moringa oleifera* leaf powder highlights the significant potential of *Moringa oleifera* in dermatological applications, particularly for acne treatment. The formulated hydrogel demonstrated favorable physicochemical properties, including suitable pH, viscosity, spreadability, and stability over a period of three months. The antimicrobial tests confirmed the hydrogel's efficacy against Propionibacterium acnes, a common acne-causing bacterium, showing significant inhibition zones. Additionally, the anti-inflammatory properties of the hydrogel were validated through in vitro assays, which indicated a marked reduction in pro-inflammatory cytokine production.

In conclusion, the *Moringa oleifera* leaf powder-based hydrogel shows promise as an effective and safe topical treatment for acne, leveraging the natural therapeutic benefits of *Moringa oleifera*. The study suggests that the hydrogel formulation can provide an alternative to conventional acne treatments, especially in the face of rising antibiotic resistance. Future research should focus on large-scale clinical trials to further validate these findings and explore the broader application of *Moringa oleifera* in skincare products.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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