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DEVELOPMENT AND EVALUATION OF A WATER-BASED FOOT CRACK GEL USING CHIA SEED AND ALOE VERA EXTRACTS

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ABSTRACT

This study aimed to develop and evaluate a herbal-based gel formulation for treating cracked heels, utilizing chia seed extract and aloe vera extract as key active ingredients. Chia seed extract, rich in omega-3 fatty acids, provides excellent skin hydration and antimicrobial properties, while aloe vera extract is known for its moisturizing, anti-inflammatory, and antimicrobial effects. Three formulations (F1, F2, and F3) were prepared using varying concentrations of Carbopol 934 as a gelling agent. The formulations were evaluated for organoleptic properties, homogeneity, pH, spreadability, viscosity, moisture absorption, and antimicrobial activity against Staphylococcus aureus and Escherichia coli. Results demonstrated that all formulations possessed optimal pH, homogeneity, viscosity, and spreadability, with F2 showing the most effective antimicrobial activity and overall performance. The findings suggest that the herbal-based gel formulation, particularly F2, offers a promising alternative for treating foot cracks, with further in vivo studies recommended to validate its therapeutic efficacy.

INTRODUCTION

Cracked heels, a common foot problem, are often caused by dry skin and can lead to discomfort, pain, and even infections if not treated properly. While typically considered a minor cosmetic issue, severe cases of cracked heels can result in deeper fissures, bleeding, and a higher risk of infection, particularly among individuals with chronic health conditions like diabetes. The lack of oil glands on the heels and exposure to environmental factors such as dry weather, prolonged standing, or unsuitable footwear contribute to the thickening and drying of the skin, making it prone to cracking.

Traditional treatments for cracked heels include emollients, moisturizing agents, and exfoliants. However, there is a growing interest in natural and herbal-based remedies due to their perceived safety, lower risk of side effects, and additional therapeutic benefits. Plants have long been a source of medicinal compounds, and their extracts have been used in treating various skin conditions, including cracked heels. Chia seed (*Salvia hispanica L.*) and aloe vera (*Aloe barbadensis Miller*) are two such plants with notable dermatological benefits.

Chia seeds are rich in omega-3 fatty acids, which are essential for maintaining skin barrier function and hydration. The fatty acids help reduce inflammation and enhance skin hydration, making them ideal for treating dry, cracked skin. Aloe vera, on the other hand, is widely recognized for its moisturizing, wound healing, anti-inflammatory, and antimicrobial properties. It helps lock moisture into the skin, promotes collagen synthesis, and offers a soothing effect, all of which are beneficial in managing cracked heels.

This study aims to develop and evaluate a water-based gel formulation incorporating chia seed and aloe vera extracts to treat cracked heels. The formulation combines the hydrating and healing properties of these extracts in a gel base that is easy to apply and provides good skin adherence. The gel's physical properties, such as pH, viscosity, spreadability, and antimicrobial activity, were assessed to determine its suitability and effectiveness in managing foot cracks. By focusing on natural ingredients, this research seeks to offer a safer, effective alternative to conventional treatments for cracked heels, catering to the growing demand for herbal-based skincare products.

As per the D&C act 1940, Cosmetics means, “any article intended to be rubbed, poured, sprinkled or sprayed on, or introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance, and includes any article intended for use as a component of cosmetic.[1]

The various functions of skin are

- It creates a layer of protection that is waterproof and serves as a barrier against environmental agents, toxins, injuries, and microbial invasion.
- Thermoregulation.
- Blood reservoir.
- Sensation medium.
- Excretion of Sodium chloride and some metabolites like urea.
- Vitamin D and melanin synthesis.
- Maintains water and electrolyte balance.
- Secretes sebum and sweat that softens the skin.
- Storage of fats, water, salts and sugars.[19,36]
- It gives the proper effector cells in the lymphatic tissues the immunological information acquired during antigen processing.
- It acts as the route for various drug delivery systems.[36]

Often overlooked, feet are a crucial part of the body responsible for movement, such as walking, running, and jumping, and require proper care. Heel cracks, a common foot issue, occur due to the absence of oil glands on the heels, leading to the thick, dry skin splitting and cracking. Typically, small cracks are merely a cosmetic nuisance, but if left untreated, they can deepen, causing pain and potentially leading to infections. Although cracked heels usually do not result in serious issues, severe cases can become infected, potentially leading to cellulitis, a skin infection.[5]

Fig. 2: Cracked feet.

Causes and risk factors of foot crack are as follows

- Being on your feet for long periods of time, especially on hard floors.
- Hard and unsupportive footwear, like open-back sandals, shoes and thongs.
- Walking around barefoot as this provides no support for your feet.
- Obesity.
- Taking long, hot showers.
- Chronic conditions such as diabetes.[4]
- Using harsh soaps.
- Having cold, dry skin.
- Dry, cold weather.[5]
- Lacking moisture.
- Lack of vitamins, minerals & zinc in your diet can adversely affect your heel health.
- Ageing skin.
- Disorders like Athlete's foot, Psoriasis, Eczema, Thyroid disease, diabetes and some other skin conditions.
- Failing to keep your feet adequately clean.[6]

Some of the symptoms of foot crack are

- Calluses, or dry, hard skin that forms around the heel, are the first indication.
- Pain and discomfort, especially while standing.
- Itchiness in the area.
- Bleeding from the cracks.
- Flaky skin.
- Warmth, redness & swelling may be present if there is an infection.[4]

There are various treatments available for foot crack

- Use heel balms or thick moisturizers containing urea, salicylic acid, alpha - hydroxy acids and saccharide isomerate.
- Soak feet in lukewarm water up to 20 minutes and exfoliate feet using pumice stone, foot scrubber or loofah and then apply heel balms.
- Honey may be used as a natural remedy for foot crack due to antibacterial properties as well as for its moisturizing, cleansing and wound healing properties.
- Coconut oil is very good for dry skin.[7]

Since ancient times, plants have served as inspiration for new medicinal molecules, benefiting human health and well-being with plant-derived medicines. Numerous plants have been used to treat various diseases such as diabetes, skin infections, and heart failure. Salvia hispanica L. (Chia) offers several clinical benefits, including cardioprotection, weight loss, and improvements in metabolic disorders. Research has shown that chia seed extracts are rich in omega-3 and omega-6 fatty acids, which are crucial for normal skin function, making them effective for treating pruritus, xerosis, and enhancing skin hydration. Chia seed extract also exhibits antimicrobial activity against microorganisms such as P. gingivalis, F. nucleatum, A. actinomycetemcomitans, S. aureus, E. coli, and B. subtilis.

Aloe barbadensis miller (Aloe vera) is widely used in cosmetology due to its numerous properties, including wound healing, skin protection against UV and gamma radiation, moisturizing, anti-inflammatory, antiviral, antitumor, anti-aging, and antiseptic effects. It is effective in treating conditions like psoriasis vulgaris, alopecia, skin burns, and various infections. Aloe vera is an excellent moisturizer and skin hydrator, locking moisture into the skin and enhancing collagen synthesis, making it ideal for treating cracked heels. It also demonstrates significant antimicrobial activity against microorganisms such as S. aureus, K. pneumoniae, E. coli, Candida, and A. niger.

Gels are uniform, semi-solid mixtures made from one or more medicinal solutions or dispersions in suitable hydrophilic and hydrophobic bases. Gel formulations offer various benefits over other skin formulations.

- It is light weight, absorbs very quickly through the skin and is non-sticky [14].
- Easy to prepare.
- It is pleasant and non-slippery.
- It shows good binding property on the applied site.
- It is environment-friendly and can tolerate stressful conditions [15].

MATERIALS AND METHODS

Plant profile

1. Chia seeds

Fig. 3: Chia seeds.

Classification
Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Order: Lamiales
Family: Lamiaceae
Genus: Salvia
Species: S. hispanica.[17]

Description
Chia seed (Salvia hispanica L.) is an annual plant with opposing leaves that are 5-8 cm long and 3-5 cm broad. It can reach a height of 1.75 metres. At the tip of every stalk, it bears spike-shaped, multi-cluster purple or white flowers.Mexico, Guatemala, Bolivia, Ecuador, Colombia, Nicaragua, northwest Argentina, sections of Australia, and the southwestern United States are among the countries where chia is grown and consumed for commercial purposes. Commercial chia is raised for its seed, containing α-linolenic acid and is rich in omega-3 fatty acids, yielding 25–30% extractable oil.[18]

2. Aloe vera

Fig. 4: Aloe vera.

Classification
Kingdom: Plantae
Phyllum: Tracheophyta
Class: Liliopsida
Order: Asparagales
Family: Asphodelaceae
Genus: Aloe
Species: Aloe barbadensis Mill[20]

Description
The genus Aloe has more than 650 species of succulent plants that flower.[21,22] Large, thick, fleshy leaves form a rosette on the majority of Aloe species. Aloe flowers are tubular, generally yellow, orange, pink, or red, and they dangle densely in bunches at the top of simple or branched, leafless stems.[21,23] Aloe vera is applied topically and internally to people as a traditional or complementary therapy.[21,24] It is widely recognized for its therapeutic and aesthetic uses.[21,25]

Chemicals and Instruments
The chemicals used are Carbopol 940, triethanolamine, methyl paraben, Propyl paraben, Rose oil, distilled water, Muller Hinton agar. The bacteria used are S. aureus and E.coli. The instruments used are Glass wares, Magnetic stirrer, pH meter, micropipette, autoclave and incubator.

Plant material Collection and Extraction

1. Chia seed

Chia seed was purchased from the market and 10g of chia seeds were weighed soaked in 100 ml distilled water and kept in cool dark place for 24 hours. Then it is filtered using a muslin cloth.[26]

2. Aloe vera

Aloe vera leaves were collected from. The fresh leaves were washed thoroughly and the margin and spikes were removed from it. The fillets were taken and washed thoroughly with distilled water to remove the surface exudates. Fresh aloe fillets were obtained. These are crushed in a mixer grinder and then stirred well. It is then filtered with muslin cloth and stored.[2,6,12,27]

Phytochemical screening

1. Test for carbohydrates

- **Molisch's test**

2-3 ml of aqueous extract was taken and a few drops of molisch's reagent were added and shaken. Then we add Conc. H_2SO_4 from the sides of the test tube. Violet ring will be formed at the junction of two liquids.[28]

- **Fehling's test**

1ml of Fehling's A and 1ml of Fehling's B solution was mixed together in a test tube and boiled for 1 minute. To this solution add the test solution and boil in water bath for 5-10 minutes. Yellow color followed by brick red precipitate is obtained.[28]

- **Benedict's test**
- **Barfoed's test**

Barfoed's reagent and Test solution are mixed in equal volumes and heated for 1-2 minutes. Then cool the solution and red precipitate is obtained.[28]

2. Test for proteins

- **Biuret test**

3ml of test solution is taken and 4% NaOH and few drops of 1% $CuSO_4$ were added. Violet or pink color appearance occurs.[28]

3. Test for amino acids

- **Ninhydrin test**

3ml test solution and 3 drops of 5% Ninhydrin solution were mixed together and boiled in water bath for 10 minutes. Appearance of bluish or purple color occurs.[28]

4. Test for anthraquinone glycosides

- **Borntrager's test**

Take 3ml of test solution and add dil. H_2SO_4. Boil the solution and filter it. To the filtrate, add equal amount of chloroform or benzene and shake well. Separate the organic layer. To this organic layer, add few drops of ammonia. Pink or red color is observed in the ammoniacal layer.[28]

5. Test for Phenolic Compounds and Tannins

- **Ferric chloride test**

To 2-3ml of aqueous or alcoholic extract add 2 drops of 5% $FeCl_3$ solution and a deep blue or green color is obtained.[28]

6. Test for flavonoids

- **Alkaline reagent**

After adding a few drops of sodium hydroxide to two ml of extract, the extract turned a deep yellow color, but when a few drops of diluted HCL were added, the color gradually turned colorless, showing the presence of flavonoids.[29]

Gel formulation

Gels are uniform, semi-solid mixtures that are often made of one or more medication solutions or dispersions in appropriate hydrophilic and hydrophobic base materials.[30] It penetrates through skin very quickly and produces greater bioavailability compared to creams or lotions. Here, Carbopol is used, as it is a better gelling agent than any other. It also causes less irritation to skin and not absorbed into body.[31,32] As carbopol is anionic cross linked polymer, it must be neutralized using triethanolamine. Triethanolamine contains carboxylic groups which neutralizes carbopol resulting in a stable gel.[33] It is used as a pH adjuster in the formulation. Preservative used in this formulation is Methyl paraben, as the gel is made using water medium, it may be susceptible to the development of microbes. Rose water is used as fragrance in the gel formulation.

Table 1: Formula of Foot crack gel.

Sl. No.	Ingredients	F1	F2	F3
1.	Chia seed extract	2g	2g	2g
2.	Aloe vera gel extract	1g	1g	1g
3.	Carbopol 934	0.5g	0.75g	1g
4.	Glycerin	4g	4g	4g
5.	Triethanolamine	0.2g	0.2g	0.2g
6.	Methyl paraben	0.2g	0.2g	0.2g
7.	Rose water	0.3g	0.3g	0.3g
8.	Distilled water	100ml	100ml	100ml

F1 – Gel with 0.5g Carbopol. F2 – Gel with 0.75g Carbopol. F3 – Gel with 1g Carbopol.

Procedure

- The chemicals and extract are weighed as per the formula.
- Take a dry mortar and pestle and put carbopol 934.
- Pour hot water into it and crush it properly.
- Then add methyl paraben and crush it well until dissolved.
- Add glycerin to the resultant gel base and mix well.
- Add the aloe vera and chia seed extracts and mix it well till it become homogenous mixture.
- Then add triethanolamine to the mixture and mix well and finally, add rose water to the formulation.
- The resultant gel is transferred to the container.

Evaluation of gel

1. Organoleptic evaluation

The gel formulation was tested for its color, odour and appearance.[33]

2. Homogeneity

Two transparent glass plates were taken. Spread 1g of the gel on one of the glass plates and put the second glass plate over it. Observe whether the gel spreads uniformly without lumps or particles.[34]

3. Measurement of pH

The pH meter calibration was done by using a standard buffer solution. Then weigh 0.5g of gel and dissolve in 50 ml distilled water and the pH was measured.[6]

4. Spreadability

A 1g sample of each gel was put in the middle of a 20 cm by 20 cm glass plate. After that, the sample was covered with glass plates and a weight of 100g was placed and kept for 1 minute. The sample's spreading areas in millimeters were measured. With reference to the applied weight, the results were represented using the equation in terms of the spreading area. d is the sample's mean diameter (mm), and S is the spreading area (mm2) as a result of applied weight a (g).

$S = d^2\Pi / 4$ [35].

5. Viscosity

The sample was placed in the beaker and spun at spindle number 64 for 20 and 30 rpm, respectively. The reading was recorded at each speed. Three readings were averaged.[2]

6. Moisture absorption studies

Without using any adsorbent, 100 ml of water were added to a beaker, set within a desiccator, and allowed to become saturated. After measuring out 100 mg of the crack gel in a watch glass or glass slide, it was put in the desiccator. For a full day, the watch glass or glass slide with the prepared gel within was kept in the desiccator. Moisture absorption was observed after 24 hours.[2]

7. Antimicrobial activity

The extract's dilution was made ready for screening. This involved weighing 0.2 grams of gel and adding 0.8 ml of sterile distilled water to it. By using the cup plate method to analyze the zone of inhibition, the antimicrobial activity of the gel was shown against a variety of bacteria, specifically S. aureus and E.coli. A suitable agar media was used to cultivate the microorganisms. The formulation was diluted and then added to the wells. The plates were incubated for 48 hours at 37 °C. A distinct zone of inhibition that surrounds the wells and has been documented indicates the activity of the gel.[6]

RESULTS AND DISCUSSION

1. Phytochemical screening

Chia seed extract

Table 2: Phytochemical screening of chia seed extract.

Phytoconstituent	Inference
Phenolic compounds & Tannins	+++
Flavonoids	++

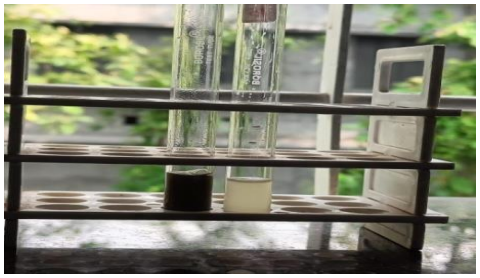

Fig. 5: Phytochemical screening of chia seed extract.

Aloe vera extract

Table 3: Phytochemical screening of aloe vera extract.

Phytoconstituent	Inference
Carbohydrates	+
Proteins	+
Amino acids	++
Anthraquinone glycosides	+++

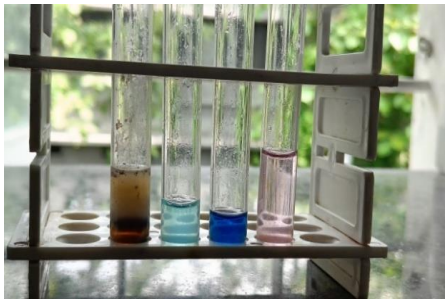

Fig. 6: Phytochemical screening of aloe vera extract.

2. Organoleptic evaluation

Property	F1	F2	F3
Color	Colorless	Colorless	Colorless
Odour	Characteristic smell	Characteristic smell	Characteristic smell
Appearance	Clear	Clear	Clear

3. Homogeneity

F1	Homogenous
F2	Homogenous
F3	Homogenous

4. Measurement of pH

The pH of all formulations was measured and all the formulations was found to have optimum pH.

Formulation	pH
F1	5.91
F2	4.56
F3	4.77

Fig. 7: pH of F1.

Fig. 8: pH of F2.

Fig. 9: pH of F3.

5. Spreadability

Formulation	Spreadabilitty
F1	13.8474
F2	15.8962
F3	12.56

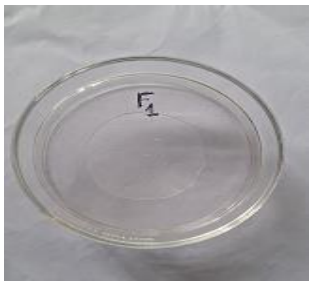

Fig. 10: F1 Spreadability.

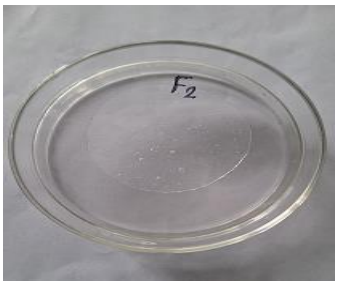

Fig. 11: F2 Spreadability.

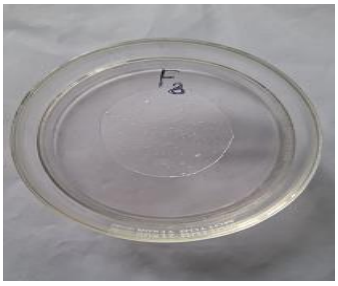

Fig. 12: F3 Spreadability.

6. Viscosity

The viscosity was determined for all the formulations and all the formulations showed optimum viscosity.

Formulation	Viscosity
F1	36mPa.s
F2	39mPas.s
F3	40mPa.s

7. Moisture absorption

The moisture absorption was tested for all the formulations and no formulations absorbed moisture.

Formulation	Moisture absorption
F1	No moisture absorbed
F2	No moisture absorbed
F3	No moisture absorbed

Fig. 13: Moisture absorption test of all the formulations.

8. Antimicrobial activity

The antimicrobial activity of all the formulations was tested using Muller Hinton agar media. The formulation F2 showed better zone of inhibition in in S.aureus and E.coli, compared to other formulations.

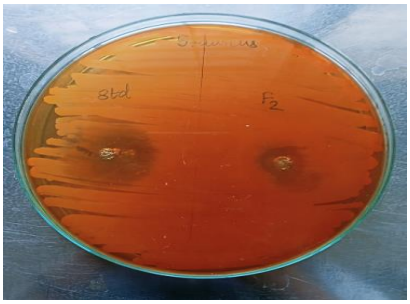

Fig. 14: Zone of inhibition of F2 in S.aureus.

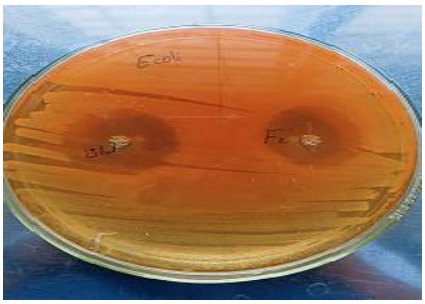

Fig. 15: Zone of inhibition of F2 in E.coli.

CONCLUSION

The herbal-based foot crack gel developed in this study exhibited promising characteristics for treating cracked heels, particularly the second formulation (F2). All formulations demonstrated optimal spreadability, pH balance, viscosity, and moisture absorption properties, crucial for effective skin application and treatment. The inclusion of chia seed extract and aloe vera extract provided substantial benefits in terms of skin hydration, moisture retention, and antimicrobial properties. Notably, F2 showed the most significant antimicrobial activity against S. aureus and E. coli, indicating its potential effectiveness in preventing and treating infections associated with foot cracks. These initial findings are encouraging and suggest that the herbal-based gel could serve as a safe and effective alternative for managing foot cracks. However, further in vivo investigations are necessary to fully establish its efficacy and safety profile for widespread use.

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