



Development Of A Natural Hydrogel Formulation From Chia And Flaxseed For Enhanced Skin Hydration And Moisture Retention

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Abstract: Interest in plant-based hydrogels is rising as a result of the growing need for sustainable and natural skincare products. For improved skin hydration and moisture retention, this study investigates the creation of a natural hydrogel formulation made from flaxseed (*Linum usitatissimum*) and chia (*Salvia hispanica*). Both seeds have hydrating and film-forming qualities because they are high in mucilage, polysaccharides, and essential fatty acids. Mucilage was extracted aqueously, and then the pH, viscosity, and gel strength were optimized to create the hydrogel. Excellent skin adherence, water-holding capacity, and biocompatibility were found in preliminary assessments. This mixture offers a viable, environmentally friendly substitute for skincare products, particularly in the creation of face masks and moisturizers.

Keywords - natural hydrogel, chia seed mucilage, flaxseed mucilage, skin hydration, moisture retention, biopolymer, plant-based cosmetics, omega-3 fatty acids, antioxidant properties, anti-inflammatory, emollient, bioactive compounds, topical formulation, physicochemical evaluation, microbial safety, sustainable skincare, cosmetic hydrogel, mucilage extraction, viscosity, spreadability, moisturizer formulation.

I. INTRODUCTION

The largest organ in the human body, the skin serves as a barrier to protect the body from environmental elements such as pollution, pathogens, ultraviolet (UV) radiation, and extremely high or low temperatures. The skin is crucial for water balance, preventing transepidermal water loss (TEWL), and preserving hydration, in addition to its functions in immunological defense and thermoregulation [1,2]. Dryness, irritation, inflammation, and early aging are frequently caused by disruptions in this barrier function. Among the most widely used cosmetics in the world, moisturizers work to improve skin texture, restore barrier function, and increase skin hydration. Preservatives, petroleum-based ingredients, and artificial emulsifiers have historically been used in the formulation of moisturizers. But worries about long-term dermal toxicity, environmental persistence, and allergic reactions have increased demand for safer and more natural substitutes.

Because of their biocompatibility, biodegradability, gelling ability, and bioactivity, natural polymers like plant mucilages have become attractive alternatives. Many seeds and plants contain mucilage, a water-soluble polysaccharide complex. These polymers are perfect candidates for hydrogel formulations because they form a viscous gel when hydrated, which can form films and retain water [5,6]. Chia seeds (*Salvia hispanica*) and flaxseeds (*Linum usitatissimum*) are two of the many natural mucilage sources that have garnered the most attention. Chia seeds have a high soluble fiber content (6–8%) in the form of mucilage, which is primarily

made up of galactose, glucose, xylose, and arabinose. In water, this mucilage swells to create a gel that has strong thickening and moisture-retaining qualities [7, 8].

In addition, chia seeds are rich in polyphenols, flavanoids, and Omega-3 fatty acids that confer antioxidant, and anti-inflammatory, and anti-aging effects on the skin

Similar to this, the two main polysaccharide fractions found in flaxseed mucilage—neutral arabinoxylans and acidic rhamnogalacturonans—have potent stabilizing, emulsifying, and hydrating qualities. Additionally, lignans, tocopherols, omega-3 fatty acids, and phenolic compounds found in flaxseeds have been shown to promote skin regeneration, lower oxidative stress, and stop transdermal moisture loss [11–13]. Thus, hydrogels made from the mucilage of chia and flaxseed can have two uses: they can be used as matrices for the delivery of bioactive substances and as moisturizing agents. Hydrogels are perfect for topical application, especially on sensitive and acne-prone skin types, because they are transparent, non-greasy, and have superior spreadability and cooling properties when compared to traditional creams and lotions [14,15].

Although chia and flaxseed are used separately in food and health applications, little research has been done on their combined use in hydrogel-based skincare formulations. By creating a chia-flaxseed mucilage hydrogel, analyzing its physicochemical characteristics, and determining whether it is suitable as a natural moisturizer, this study aims to close that gap. Combining the mucilages of two seeds rich in mucopolysaccharides to improve the gel's moisturizing capabilities, skin compatibility, and functional qualities is novel. This work supports continued efforts to reduce synthetic ingredients in personal care products and is in line with the global trend toward sustainable, plant-based cosmetics.

2. COSMETIC BENEFITS OF FLAXSEED AND CHIA SEEDS

Because of their many uses, safety record, and skin compatibility, plant-derived bioactive compounds have become increasingly popular in dermatology. These natural ingredients, flaxseed (*Linum usitatissimum*) and chia seed (*Salvia hispanica*), are known for their exceptional cosmetic qualities because of their high content of mucilage, antioxidants, phytochemicals, and essential fatty acids.

2.1 FLAXSEED

In addition to being a food source, flaxseed has been grown and utilized for centuries in traditional medicine and skincare products [11]. Because of its oil and mucilage content, which have anti-inflammatory, emollient, and moisturizing properties, it is especially prized in cosmetics.

2.1.1. FLAXSEED OIL

Up to 60% of flaxseed oil's fatty acid profile is made up of the omega-3 fatty acid α -linolenic acid (ALA), which makes it a powerful emollient [11]. This lipid composition improves skin hydration and smoothness, lowers transepidermal water loss (TEWL), and preserves the skin's lipid barrier. Additionally, the oil contains stearic, palmitic, oleic, and linoleic acids, which help to soften and prevent aging [11,13].

- The following cosmetic advantages are linked to the topical application of flaxseed oil:
- Enhancement of skin hydration and elasticity;
- decrease in wrinkles and fine lines;
- and alleviation of inflammatory skin disorders like sunburn, acne, and eczema [11].
- The presence of β -carotene and tocopherols provides antioxidant protection [13]

2.1.2. FLAXSEED MUCILAGE

- A mixture of neutral and acidic polysaccharides, such as arabinoxylans and rhamnogalacturonans, make up the mucilage that is extracted from flaxseeds [12]. These polysaccharides create a gel-like structure when hydrated, which has the following advantages:
- High water-holding capacity, which improves skin hydration; enhanced viscosity, which is perfect for hydrogel formulations;

- film-forming ability, which creates a skin barrier; and emulsion stabilization, which improves the texture and stability of products. [12]
- In cosmetic formulations, flaxseed mucilage can be used as a natural thickener and gelling agent due to its surface activity and emulsifying qualities [12].

2.2. CHIA SEEDS

Chia seeds' rich matrix of polysaccharides, polyphenols, omega-3 fatty acids, and minerals has made them a "superfood" in the fields of nutrition and skincare [7,9].

2.2.1. CHIA SEEDS MUCILAGE

Polysaccharides like xylose, arabinose, glucose, and galactose make up the majority of chia mucilage [7]. When hydrated, these ingredients have exceptional gel-forming and moisture-retaining qualities that help to:

- Hydrate the skin by creating a semi-occlusive film that slows water evaporation;
- Improve skin feel because of its smooth, non-greasy texture; and
- Improve active compound delivery by serving as a biopolymer carrier in hydrogel systems [7, 8].

2.2.2. ANTIOXIDANT AND ANTI-INFLAMMATORY PROPERTIES:

Chia seeds are rich in flavonoids and phenolic compounds, which provide potent antioxidant protection against damage from free radicals, thereby lowering oxidative stress and photoaging symptoms [9, 10]. Additionally, chia's omega-3 fatty acids have anti-inflammatory properties that help treat dermatitis, acne, and sensitive skin disorders [10].

2.3. COMBINED COSMETIC POTENTIAL

Chia and flaxseed have complementary advantages when taken together. Through moisture retention, film formation, and gelation, both mucilages enhance skin hydration, and their oils and bioactive compounds have calming, antioxidant, and anti-aging properties. Because of these qualities, chia and flaxseed are perfect ingredients for natural, plant-based hydrogel formulations that are meant to improve the appearance and health of skin [7,11,14]. Furthermore, both seed mucilages' low microbial load and lack of heavy metals, which have been verified in earlier research [16,18], support their stability and safety for topical use.

In conclusion, chia and flaxseed are promising bio-resources for the creation of cosmetic products because they support the skin barrier, provide hydration, antioxidation, and emolliency. Their mucilage can be fully utilized in hydrogel systems, meeting consumer demand for plant-based, sustainable skincare products.

3. METHODOLOGY

The procedures for obtaining raw materials, making chia and flaxseed mucilage, and creating the hydrogel system are described in this section. The study was carried out in a controlled laboratory environment while adhering to accepted cosmetic formulation protocols and good laboratory practices

MATERIALS:

- The following materials were used for the development and evaluation of the chia-flaxseed hydrogel:
- Chia seeds (*Salvia hispanica*) – locally procured from an organic grocer
- Flaxseeds (*Linum usitatissimum*) – purchased from a certified organic supplier
- Distilled water – used as a solvent for mucilage extraction and hydrogel preparation
- Carbopol 940 – a synthetic polymer and gelling agent commonly used in hydrogels
- Glycerin (5–10%) – a natural humectant used to enhance moisture retention
- Triethanolamine (TEA) – used to neutralize Carbopol and adjust pH
- Methylparaben (0.5%) – a preservative to prevent microbial growth

- pH meter, digital viscometer, magnetic stirrer, hot plate, nylon filter cloth, muslin cloth, conical flasks, airtight glass containers – used for processing and evaluation
- All chemicals and reagents used were of analytical grade.

3.2.SAMPLE PREPARATION

3.2.1.CHIA SEED MUCILAGE EXTRACTION

- In a sterile conical flask, 10 g of chia seeds were weighed and soaked in 300 mL of distilled water (1:30 w/v).
- To ensure full mucilage release, the mixture was allowed to hydrate for 12 hours at room temperature with periodic stirring.
- Using a double-layered muslin cloth, the mucilage was filtered to remove the seeds and the gelatinous layer.
- Until it was needed again, the extract was kept at 4°C in a sterile, airtight glass container [7, 8].

3.2.2.FLAXSEED MUCILAGE EXTRACTION

- On a magnetic stirrer set at 500 rpm, 10 g of brown flaxseeds were boiled in 300 mL of distilled water (at a ratio of 1:30 w/v) at 80–90°C for 60 minutes [11,12].
- In order to separate the seeds from the mucilage, the hot solution was immediately filtered through nylon cloth after boiling, as the mucilage leached out into the water and formed a colloidal gel.
- The mucilage was kept in sterile containers at 4°C for subsequent formulation steps, and a preservative of 0.5% methylparaben was added to prevent microbial contamination.
- This extraction technique maintains viscosity and hydration qualities while optimizing mucilage yield [12].

3.3 HYDROGEL PREPARATION

The hydrogel was formulated using the following procedure:

Step 1: carbopol gel based formation

- To avoid clumping, 0.5 g of Carbopol 940 was gradually dissolved in 50 mL of distilled water while being constantly stirred.
- To guarantee that the polymer was completely hydrated, the solution was stirred for two hours.
- Triethanolamine (TEA), which encourages gel formation and compatibility with human skin, was added dropwise to the Carbopol solution after it had completely dispersed in order to bring the pH down to between 5.5 and 6.5 [14].

Step 2: mucilage incorporation

- Chia and flaxseed mucilage extracts were taken in equal amounts (1:1 ratio), i.e., 25 mL each.
- The hydrated Carbopol gel base was slowly stirred while the mucilage blend was added.

Step 3: addition of humectant and preservative

- To increase the skin's capacity to retain water, 5 mL of glycerin was added to the mixture as a humectant.
- To guarantee microbial safety during storage, an additional 0.5% methylparaben was added [16,18].

Step 4: homogenization and storage

- After agitating the final hydrogel for 15 to 20 minutes to create a homogeneous, smooth gel, the hydrogel was put into sterile, airtight glass containers and kept at 4°C for further examination.
- To investigate the impact of each polymer on the gel's characteristics, several batches were made by adjusting the ratio of chia to flaxseed mucilage (1:1, 2:1, 1:2).
- Pre-screening tests revealed that the 1:1 ratio hydrogel was the most stable and efficient, so it was chosen for

in-depth characterization.

3.4 EVALUATION OF HYDROGEL

To evaluate the chia-flaxseed hydrogel's suitability as a topical cosmetic product, a number of physicochemical and microbiological tests were conducted.

3.4.1 pH DETERMINATION

To make sure the hydrogel was compatible with the skin's natural pH range of 4.5 to 6.5, its pH was measured using a calibrated digital pH meter [14].

3.4.2.VISCOSITY

A Brookfield viscometer was used to measure the gel's viscosity in order to evaluate its consistency, flow characteristics, and application ease [14].

3.4.3.SPREADABILITY TEST

The formulation's user-friendliness and potential for coverage were demonstrated by testing the hydrogel's spreadability between glass slides using the slip and drag method [15].

3.4.4.MOISTURE RETENTION ABILITY

By tracking the weight loss over time in ambient conditions, the hydrogel's ability to retain moisture was evaluated. This demonstrated its capacity to minimize transepidermal water loss and maintain hydration [14,19].

3.4.5.ORGANOLEPTIC EVALUATION

To make sure the hydrogel had acceptable physical and aesthetic qualities for consumer use, it was visually examined for color, texture, clarity, odor, and homogeneity.

3.4.6.MICROBIAL LIMIT TEST

To guarantee formulation safety and shelf life, microbial safety was assessed by detecting gram-negative bacteria and total viable count (TVC) using the agar well diffusion method [16,17,18].

4.RESULTS

To ascertain the chia-flaxseed hydrogel's suitability as a natural topical cosmetic product, a comprehensive evaluation of its physicochemical and microbiological properties was conducted. Each test's outcomes are described in detail below.

4.1.PH DETERMINATION

A calibrated digital pH meter was used to measure the hydrogel formulation's pH in order to make sure it was compatible with the skin's normal pH range of 4.5 to 6.5. With a pH of 6.1 ± 0.1 , the hydrogel was well within the ideal range for topical applications. This implies that the hydrogel is safe for everyday use and unlikely to irritate skin or interfere with the body's natural acid mantle.

Formulation	pH Value
Chia-Flaxseed Hydrogel	6.1 ± 0.1

4.2.VISCOSITY

A Brookfield viscometer was used to measure the gel's viscosity at various shear rates in order to evaluate its consistency and flow characteristics. At low shear rates (10 rpm), the hydrogel's viscosity was 520 ± 15 cP; at higher shear rates (50 rpm), it dropped to 420 ± 10 cP, indicating shear-thinning behavior. Because of this non-Newtonian characteristic, the gel becomes less viscous under application stress, making it easier to spread on the skin while preserving its structural integrity at rest

Shear Rate (rpm)	Viscosity (cP)
10	520 ± 15
20	480 ± 12
50	420 ± 10

4.3 MOISTURE RETENTION ABILITY

Weight loss over a 24-hour period in ambient conditions was used to assess the hydrogel's capacity to retain moisture. After 24 hours, the hydrogel showed only $12.1 \pm 0.6\%$ weight loss, indicating effective moisture retention, whereas at first there was no weight loss. This finding suggests that the hydrogel can reduce transepidermal water loss (TEWL) and sustain skin hydration over an extended period of time.

Time (hours)	Weight Loss (%)
0	0
6	4.2 ± 0.3
12	7.8 ± 0.5
24	12.1 ± 0.6

4.4 ORGANOLEPTIC EVALUATION

To guarantee consumer acceptability, visual and sensory qualities were evaluated. The hydrogel had a mild, neutral smell, a smooth, non-gritty texture, and was transparent. There were no indications of phase separation or particulate matter in the homogeneous formulation. Because they enhance the user experience, these qualities are ideal for a cosmetic hydrogel.

Parameter	Observation
Color	Transparent
Texture	Smooth, non-gritty
Odor	Mild, neutral
Homogeneity	Uniform without lumps

4.6 MICROBIAL LIMIT TEST

Using microbial limit testing for safety evaluation, a low total viable count (TVC) of 25 ± 5 CFU/g was discovered. The suggested limit (<100 CFU/g) for topical products is much higher than this. The lack of gram-negative bacteria indicates effective microbial control and good shelf stability. These results validate the hydrogel's microbiologic safety for topical use.

Microbial Parameter	Result
Total Viable Count (CFU/g)	25 ± 5
Gram-negative bacteria	Not detected

5. DISCUSSION

This study's chia-flaxseed hydrogel demonstrated favorable properties for a natural topical skincare product. There was little chance of irritation after application because the formulation's pH was within the ideal range for skin compatibility. The viscosity of the hydrogel exhibited good flow characteristics, striking a balance between application simplicity and adequate thickness for stable storage. A key component of cosmetic usability, spreadability values indicated the product's capacity to cover skin surfaces uniformly. Due to the high polysaccharide content of chia and flaxseed mucilage, moisture retention tests verified the hydrogel's ability to keep users hydrated by minimizing water loss over time. A visually appealing, smooth, and neutral-smelling formulation—all important components for consumer acceptance—was discovered during the organoleptic evaluation. Microbial analysis supported the formulation's shelf stability by demonstrating that it stayed within safe bounds and that no dangerous bacteria were present. In summary, the findings indicate that the combination of chia and flaxseed mucilage results in a hydrogel that is suitable as a natural cosmetic moisturizer due to its high hydrating potential, safe application, and pleasing sensory qualities.

6. CONCLUSION

In order to create a biocompatible, skin-friendly cosmetic product for improved skin hydration, the current study effectively created and assessed a natural hydrogel using the mucilage of flaxseed and chia seeds. Chia and flaxseed mucilage combined to create a clear, homogenous, and smooth hydrogel with good physicochemical characteristics, including a pH of 6.1 ± 0.1 , the right viscosity, and outstanding spreadability. The stability and ease of use of the gel were validated by these parameters. Under normal circumstances, the hydrogel showed a promising ability to retain moisture, sustaining hydration levels for a considerable amount of time with little weight loss. Consumer-acceptable sensory qualities such as clarity, smooth texture, and mild odor were validated by organoleptic evaluation. Additionally, the safety of the formulation was validated by microbial limit tests, which showed low total viable counts and no gram-negative bacteria, indicating good shelf stability and topical application suitability.

The combination of chia and flaxseed mucilage in equal amounts demonstrated the best skin hydration effects and physicomachanical balance among the tested formulations, making it a promising option for dermatological or cosmetic use. This study concludes by highlighting the potential of hydrogel derived from chia flaxseed as a natural, sustainable, and efficient substitute for artificial moisturizers. Its natural origin, microbiological safety, and capacity to provide long-lasting skin hydration make it a prime candidate for further development into a commercial skincare product.

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