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Research Article

Formulation and Evaluation of Polyherbal Face Serum Incorporating *Moringa oleifera* and *Aegle marmelos* Leaves

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ABSTRACT

The aim of this research was to create a stable polyherbal face serum and evaluate it thoroughly, using the synergistic qualities of Moringa oleifera leaves and Aegle marmelos (Bael) leaves encapsulated in a biomimetic lipid matrix. The temperature-controlled hot infusion method < 50oC was used in the preparation of the formulation, consisting of Jojoba oil (8 ml), Sweet Almond oil (4 ml), and Olive oil (1.7 ml) as the main carrier vehicles to prevent thermal degradation of bioactive flavonoids and coumarins. Physicochemical assessment revealed an ideal skin-compatible pH of 5.4, optimal viscosity of 13, 759 Pa.s facilitating deep dermal penetration, and a non-greasy skin feel. Stability studies conducted as per ICH Q1A(R2) for 6 months have confirmed that the formulation remains as it is and a shelf life of 24 months can be guaranteed at ambient storage conditions. Evaluation results indicated a uniform homogeneity, good spreadability, and absence of rancidity throughout the test period. Safety validations including the USP <61>/<62> microbial enumeration tests indicated no microbial growth, while 24-hour human patch tests confirmed the serum's complete non-irritation. These findings demonstrate that the developed polyherbal serum is a safe, effective and nutrient rich natural alternative to synthetic skin care for rejuvenation and antioxidant protection.

INTRODUCTION

Background of Herbal Cosmetics.

The term "cosmetics" is derived from the Greek word Kosmetikos, which means the art of adornment or arrangement [34]. The modern market and consumer behavior hold a significant shift to "clean beauty," which avoids synthetic additives such as parabens, sulfates, and artificial fragrances due to sensitivity in some skins and the long-term toxicity of these compounds [24,30]. As such, the herbal beauty market is pegged at $94.11 billion in 2024 and is expected to rise above $323

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billion by 2033. Modern herbal cosmetics or "cosmeceuticals" are a hybrid where the traditional ethnobotanical wisdom is standardized through modern pharmaceutical mediums to positively influence the skin physiology through bio-active delivery [24,33].

Benefits of Face Serum over Creams Serums.

Benefits of Face Serum over Creams Serums are a more advanced form of skincare products that aim to penetrate the dermal layers instead of occluding the skin surface [3,34]. Serums are highly concentrated formulas that contain ten times more biologically active molecules than standard creams with heavy occlusive agents and waxes that stay on the stratum corneum [35]. A critical technical advantage of serums is their compliance with the 500 Dalton Rule. A critical technical advantage of serum lies in its strict adherence to the 500 Dalton Rule, with most active compounds possessing molecular weight within the limit for natural penetration by the skin lipid barrier (Vitamin C - ~176 Da, Retinol (~286 Da) [30]. Their tiny molecular makeup combined with their relatively lightweight, fluid consistency makes for quick absorption at the cellular level to better address issues like skin hydration, reducing pores, and boosting skin firmness than traditional high-viscosity emulsions [34,36].

Role of Primary Herbal Actives and Ingredients.

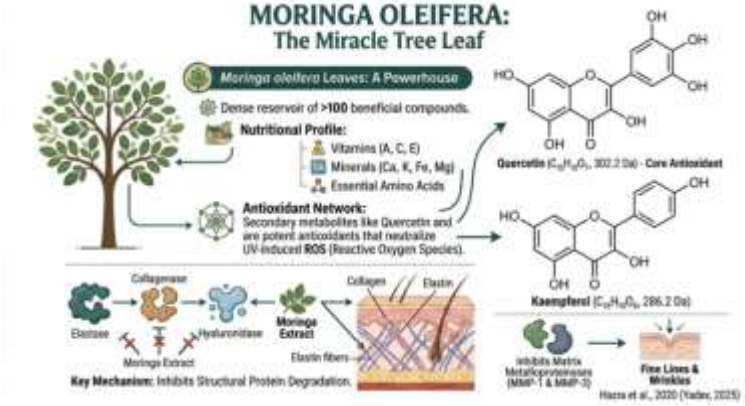


Moringa Oleifera Leaves

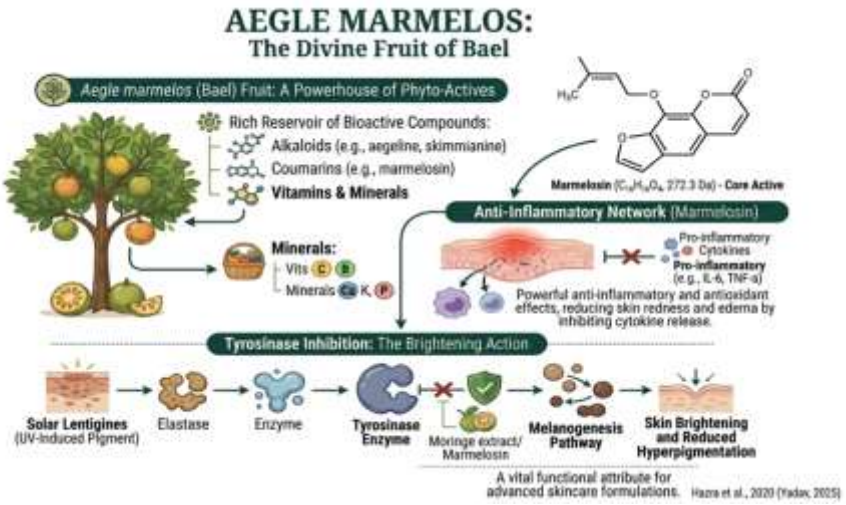


Aegle Marmelos (Bael) Fruit

Moringa oleifera Leaves: Leaves are densely packed with more than 100 beneficial components which include vitamins (A, C, E) minerals (Ca, K, Fe, Mg) and all the required amino acids [16,18]. Quercetin (302.2 Da) and Kaempferol (286.2 Da), are the main secondary metabolites and act as potent antioxidants that quench UV-imposed reactive oxygen species (ROS) [17,28]. The anti-elastase, anti-collagenase, and anti-hyaluronidase activities of Moringa extracts preclude the degradation of structural proteins and consequently inhibit Matrix Metalloproteinases (MMPs), specifically MMP-1 and MMP-3 to abate fine lines and wrinkles [7,16].



Aegle marmelos (Bael) Fruit: Known as the 'Divine Tree' in Ayurveda, Bael fruit and its peel are rich in alkaloids (aegeline, skimmianine), and coumarin derivatives like marmelosin [15,25]. Marmelosin provides potent anti-inflammatory and antioxidant action, reducing skin redness and oedema by inhibiting pro-inflammatory cytokines [27,39]. A vital functional attribute of Bael in skincare is tyrosinase inhibition, by modulating the melanogenesis pathway that provides a natural brightening agent to reduce hyperpigmentation and solar lentigines [15,26].



Carrier Lipid Matrix (Jojoba, Almond, and Olive Oils):

- **Jojoba Oil:** This "liquid wax ester" is chemically made up of 97% long-chain, monounsaturated fatty acids and alcohols that closely resemble the wax esters found in up to 30% of human sebum [21]. This biomimicry allows Jojoba oil to play the function of a natural regulator, fooling the skin into cutting down on excess oil production, and penetrating the hair follicles to dissolve hardened sebum deposits [22].
- **Sweet Almond Oil:** Categorized as a mid-weight carrier, it is valued for its high concentrations (62–86%) of oleic acid, which provides glide and new nourishment. It is a powerful emollient that is capable of strengthening the lipid ratio of the stratum corneum, thus helping in the recovery of the barrier function of the skin in individuals who have dry or sensitive skin [23].
- **Olive Oil:** Rich in squalene and phenolic antioxidants, Olive oil facilitates skin repairing and moisture locking. Its high concentration of unsaturated fatty acids ensures that it can work as a natural cleanser that dissolves oily residue on the skin surface, while also offering long-term hydration [14].





- **Stabilizers & Fragrance (Vitamin E and Essential Oils):**

  - **Vitamin E (Alpha-Tocopherol):** Vitamin E has a dual role of product Stabilizer and biological active. As a stabilizer, it prevents oxidation of the polyunsaturated fatty acids (PUFAs) in the lipid phase, preventing rancidity. Biologically, it acts as a humectant, and a potent antioxidant that protects skin cells against UV induced oxidative damage and premature skin aging [11,14].

  - **Sandalwood Oil:** In addition to the characteristic pleasant odour, Sandalwood offers considerable antimicrobial properties, demonstrating efficacy against the proliferation of pathogens such as Staphylococcus aureus. Its anti-inflammatory profile helps soothe irritated skin, ideal for managing redness caused by acne or eczema [12].

  - **Rose Oil:** Obtained through steam distillation, Rose oil acts as a natural skin toner and has excellent pH-balancing properties. Its inclusion omits synthetic fragrances and adds therapeutic aromatic effects and is known to counterbalance excess skin fat while optimizing skin glow [13].







Ingredient Benefit Mapping (Table). **This table summarizes the functional roles of each component in the polyherbal matrix.**

Benefit	Source	Dermatological Role	Citations
Moisturizing	Jojoba, Almond, & Olive Oils	Barrier repair and TEWL reduction	[21, 23]
Antioxidant	Vitamin E and *Moringa oleifera*	ROS neutralization and UV protection	[11, 16]
Soothing	*Aegle marmelos* and Sandalwood	Anti-inflammatory action on sensitive skin	[27, 38]
Skin Glow	*Moringa* + Bael	Tyrosinase inhibition & nutrient replenishment	[15, 39]
Protection	Preservative + Antioxidant	Microbial stability and lipid anti-oxidation	[11, 12, 13]

AIM AND OBJECTIVE

The main target of this research is to come up with a natural, polyherbal face serum to fully optimise skin health so as to ensure it stays radiant and glows with health, combating the prevailing characteristics that hamper healthy skin like oxidative stress and dehydration.

Key objectives are:

1. Preparation of a stable herbal infusion using Moringa oleifera and Aegle marmelos.

2. Evaluation of the prepared serum on different physicochemical, and safety parameters such as pH, viscosity, and irritancy.

3. Comparing the quality of the product against standard requirements for cosmetics to guarantee safety and effectiveness.

3. Ancient Use

The use of medicinal plants in skin care measures can be traced back more than five millennia in the book of history regarding the earliest beauty routines of the earliest known civilizations [38].

Moringa in the Ancient Mediterranean.

Moringa oleifera was greatly treasured by the ancient Egyptian, Greek, and Roman civilizations for its extreme stability and moisturizing factors [18,19].

Ancient Egyptian Storage Jars: Evidence from the 18th dynasty (1550–1292 B.C.) supplies concrete proof of its dominance, with ten specialized storage jars or amphorae containing "Sweet Moringa oil" discovered in ancient Egyptian tomb KV63 by archaeologists. They served personal skincare and royal beauty rituals, and were often placed within funeral processions to accompany the body for the afterlife. While larger amphorae were used for trade, smaller pottery and stone jars were the standard for preserving royal "Ben oil" [18].





Roman Glass Unguentaria: The Romans were the first to use Moringa oil as a premier carrier of their complex luxury perfumes. These were dispensed from specialized unguentaria–slim, pear-shaped or bulbous blown-glass vessels with long necks that were meant to regulate the dispensing of precious oils during daily dressing or funerary rituals. Moringa's lightweight nature made it able to absorb scents effectively, making it a staple in the Roman bathhouses and pharmacies [19].



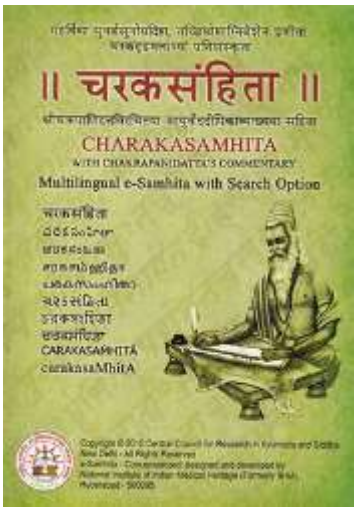


Aegle marmelos in the Vedic Era.

The Aegle marmelos (Bael) fruit has a long and deep history in the Southeast Asian traditional

medicinal history, even in the old Vedic times of 2000 B.C [38,39].

Historical Manuscript Documentation (Charaka Samhita): Documented by the Sage Charaka (1500 B.C.) in the Charaka Samhita, the Bael tree is officially acknowledged as necessary item for preparing restorative tonics and managing skin infections. Known as "Bilva" or "Shivaduma" (the Tree of Shiva), every part of the plant was considered sacred and therapeutically active [38].



Ayurvedic Khalva Yantra (Mortar and Pestle): In traditional uses, Bael leaves crushed were put as a poultice on skin infections and wounds (antimicrobial activity). This was done with the help of a Khalva Yantra (or a Kharal)—a grinding device usually made out of granite, black stone, or marble. This was the ancient method of trituration, mixing and pounding the herbal ingredients to release their bioactive secondary metabolites before administering them for healing [39].



MATERIALS AND METHODS.

Collection of Ingredients.

The carrier oils and the main herbal powders (Moringa oleifera and Aegle marmelos) were procured from authenticated providers or local markets.

In specialized laboratory settings, plant materials are authenticated by botanical experts, and are deposited within herbaria under specific voucher numbers to ensure constant phytochemical quality [5,10].

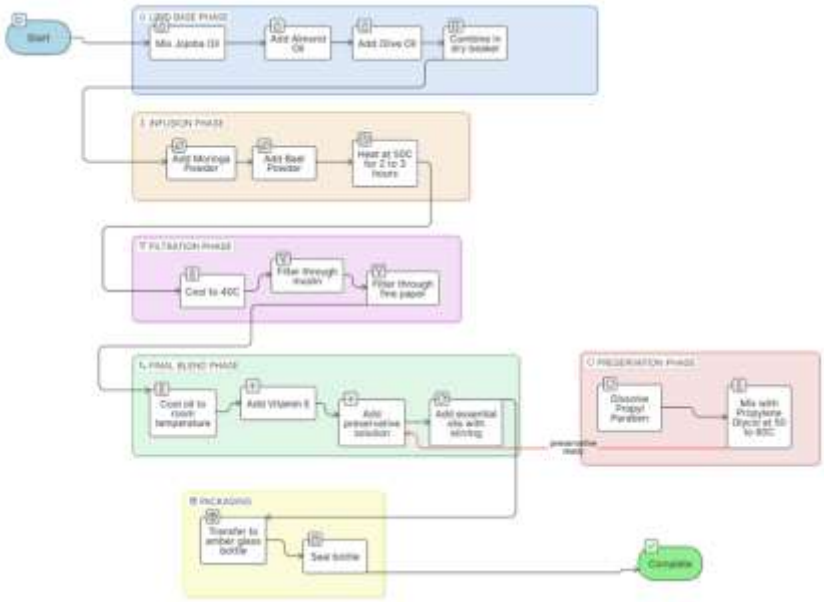
Preparation of Herbal Infusion.

The formulation method employed is hot infusion (heat-assisted maceration). The herbal powders (Moringa and Bael) were added to the oil base which include Jojoba, Almond and Olive oils. The mixture was heated in a water bath at temperatures not to exceed 50ºC for 2–3 hours. This controlled heating allows diffusion of the oil soluble bioactive constituents such as flavonoids and coumarins into the lipid phase without causing thermal degradation of the liable molecules [34,35].

Formulation Table (15 ml).

Ingredient	Quantity	Role	Citations
Jojoba Oil	8 ml	Base/Vehicle; Sebum Balancer	[21, 22]
Almond Oil	4 ml	Nourishment; Barrier Repair	[23]
Olive Oil	1.7 ml	Moisture Lock; Antioxidant	[14]

Moringa Powder	0.7 g	Active (Antioxidant)	[16, 28]
Bael Powder	0.7 g	Active (Soothing/Anti-inflammatory)	[15, 27]
Vitamin E	0.2 ml	Antioxidant/Stabilizer	[11, 14]
Propyl Paraben	4.5 mg	Preservative	[12]
Sandalwood Oil	2 drops	Fragrance; Antimicrobial	[34]
Rose Oil	1 drop	Fragrance/Toner	[34]



Mixing Procedure (Step-by-Step).

The preparation follows a standardized protocol for non-aqueous polyherbal formulations to ensure maximum phytochemical yield [34,35].

1. Oil Blending: Mix Jojoba, Almond, and Olive oils in a clean, dry beaker. This creates a biomimetic base that facilitates the solubility of lipophilic herbal actives [9,21].

2. Infusion: Add *Moringa* and Bael powders; heat on a water bath at $\leq$ 50°C for 2–3 hours. This temperature is critical to prevent the thermolabile degradation of Quercetin and Marmelosin [6,40].

3. Filtration: Cool the mixture to 40°C and filter through a muslin cloth followed by Whatman No. 1 filter paper to obtain a clear infused oil [1,10].

4. Preservative Solution: Dissolve Propyl paraben in 0.5–1 ml of propylene glycol (heated at 50-60°C until clear [11,12].

5. Final Addition: Allow the infused oil to cool to room temperature. Add Vitamin E, the preservative solution, and essential oils with continuous stirring to ensure uniform distribution [14,36].

6. Packaging: Transfer the serum into amber-colored glass bottles to protect against photo-oxidation of the polyunsaturated fatty acids (PUFAs) [11,20].

EVALUATION PARAMETERS.

Organoleptic Evaluation.

The serum was visually assessed for color (yellowish/ brownish), odor (pleasant/

sandalwood), and overall appearance (clear/ uniform).

pH Determination.

A 1 ml sample was diluted with 50 ml of distilled water. The pH was measured using a calibrated pH meter and test strips to ensure it fell within the skin-compatible range of 4.1 to 6.7 [3,36].

Stability Studies.

The formulation was subjected to stress tests in accordance with ICH Q1A(R2) guidelines, involving storage at (25°C ± 2°C) (Long-term) and (40°C ± 2°C) (Accelerated) for up to 6 months [11].

Patch Test / Irritancy Test.

A 24-hour patch test was conducted on human volunteers to monitor for any signs of redness, edema, or swelling; no irritation was observed [24,32].

Shelf Life Prediction.

Accelerated stability data at elevated temperatures were used to predict a two-year shelf life under ambient conditions [11,31].

Viscosity.

26 ± 1°C using a Labman LMDV60 viscometer at 120 rpm. The recorded value was 13,759 mPa·s (cP), ensuring optimal flow for topical uptake. [34].

Antioxidant Assay (DPPH): The serum's ability to scavenge 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals was measured spectrophotometrically at 517 nm to determine the IC_{50} value. [33].

Homogeneity.

Tested by visual inspection on a glass slide to ensure even dispersion of extracts and the absence of particulate matter or phase separation [10,37].

Spreadability.

Determined by the time taken for two glass slides to separate under a 20g weight; the serum showed "good" spreadability, essential for uniform facial coverage [29,34].

Absorption.

The rate of penetration into the stratum corneum was assessed; high-quality carrier oils like Almond oil provide a slow, nourishing absorption [8,23].

Centrifugation.

The serum was centrifuged at 3000-4000 rpm for 10-30 minutes to check for physical instability or phase separation [10,36].

Rancidity of Oil.

The serum was assessed for "Absent" rancidity by testing for lipid peroxides and organoleptic changes over time [Image 3] [14,20].

Specific Gravity.

Determined using a pycnometer or relative density methods as per USP to ensure consistency in batch weight and volume.

Acid Value Test.

The number of milligrams of Potassium hydroxide (KOH) required to neutralize free fatty acids in 1g of the sample was calculated using:

$$\text{Acid Value} = \frac{56.1x\ VxN}{W}$$

A low acid value indicates the freshness of the lipid matrix [14,22].

Microbial Test.

Tested for Total Aerobic Microbial Count (TAMC) and Total Combined Yeast and Mold Count (TYMC) as per USP and . Results showed "No microbial growth" [12,13].

RESULTS

Observations from All Tests.

The organoleptic properties of the polyherbal serum remained unchanged throughout the evaluation. The viscosity and spreadability stayed within the appropriate levels for topical delivery, resulting in a skin feel that was not greasy, but nourishing.

Parameter	Initial Value	After 3 Months (RT)	After 6 Months (40∘C)
pH	5.4	5.4	5.3
Appearance	Clear Yellow	No Change	No Change
Homogeneity	Uniform	Uniform	Uniform

Physical Changes.

This is to say that significant phase separation, precipitation, or discoloration was not observed during the 6-month stability study which confirms the efficacy of the preservative and the stability of the hot infusion.

CONCLUSION

Summary of Findings.

The developed polyherbal serum has integrated the antioxidant benefits of Moringa and Bael in a biomimetic lipid delivery system. Also the developed polyherbal serum exhibited high physicochemical stability and absolute safety for topical application [10,36].

Final Remarks on Safety and Effectiveness.

The serum offers a natural alternative to synthetic products and can provide a high concentration of bioactive molecules, without relying on harsh chemicals. The pH factor in the serum ensures that it supports the acid mantle (Weisenseel & Brown, 2020).

Suggested Storage and Shelf Life.

The serum should be stored in amber-colored glass bottles, in a cool and dry place, away from direct sunlight. Predicted shelf life on accelerated stability tests stands at 24 months [11].

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