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Formulation and Evaluation of an Antioxidant-Rich Foundation Stick Incorporating *Aegle marmelos* Fruit Extract

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A B S T R A C T

Background: The development of formulations with both medicinal and aesthetic effects has been accelerated by the growing demand for multipurpose cosmetics based on herbs. The plant *Aegle marmelos* (Bael), which is abundant in bioactive chemicals and has been shown to have antioxidant properties, holds great promise for use in dermatology.

Objective: *Aegle marmelos* fruit extract was used in this study's formulation and evaluation of an antioxidant-rich medicated foundation stick. Its physicochemical properties, phytochemical components, antioxidant activity, and microbiological stability were all evaluated.

Methods: Standardised fruit extract from *Aegle marmelos* was combined with appropriate excipients to create a medicated foundation stick. The formulation underwent a thorough evaluation that included physicochemical analyses (pH determination, melting point analysis, spreadability testing), phytochemical screening, organoleptic assessment, antioxidant evaluation using the DPPH free radical scavenging assay, and testing for microbial contamination.

Results: The optimised formulation demonstrated favourable organoleptic characteristics, including a consistent texture, a herbal scent, and a visually appealing look. A pH of 6.2 and a melting point of 55°C were found by physicochemical examination, suggesting good thermal stability and skin compatibility. The presence of flavonoids, tannins, and phenolic substances was verified by phytochemical analyses. Antioxidant investigation showed a synergistic boost of antioxidant capability upon formulation, with DPPH % inhibition values of 13.41% for the pure extract, 27.95% for the placebo formulation, and 33.80% for the *Aegle marmelos*-loaded stick. Microbial testing validated the product's microbiological stability and safety by confirming the lack of bacterial and fungal development.

Conclusion: The *Aegle marmelos*-enriched medicinal foundation stick offers strong antioxidant advantages together with good physicochemical and microbiological stability, effectively combining therapeutic efficacy with aesthetic appeal. This study emphasises how *Aegle marmelos* can be an active participant in the

Keywords: *Aegle marmelos*, Foundation stick formulation, Antioxidant activity, Phytochemical screening, Herbal cosmetics

1. Introduction

1.1 General Background

The cosmetic business has seen a significant change in recent years towards natural, plant-based formulations, which has led to the growth of the cosmeceuticals market—products that combine therapeutic benefits with aesthetic appeal. Customers are favouring solutions that use the bioactivity of herbal substances to improve skin health in addition to attractiveness.

Aegle marmelos (also called Bael), a member of the Rutaceae family, has attracted a lot of interest among the wide variety of medicinal plants investigated for cosmetic uses. Flavonoids, coumarins, tannins, alkaloids, and essential oils are among the many bioactive components found in *Aegle marmelos* fruit. These components work together to provide anti-ageing, anti-inflammatory, and antioxidant qualities.

Because oxidative stress is a major factor in the pathophysiology of accelerated skin ageing, Bael's antioxidant action is very noteworthy. Bael leaf extracts have been successfully included in topical formulations such as lotions and moisturisers in previous research, indicating their potential to improve skin hydration and protection.

Concurrently, the idea of stick-based cosmetic delivery systems—like foundation sticks—has become more well-liked because of their portability, hygienic use, and efficient administration of active ingredients. Multifunctionality—products that provide both medicinal and aesthetic benefits—is emphasised by current cosmeceutical trends.

Nevertheless, in spite of these developments, there is still a significant study gap regarding the use of *Aegle marmelos* fruit extract in a firm foundation stick formulation.

1.2 Aegle marmelos

Aegle marmelos Linn., commonly referred to as Bael in Hindi, is a perennial tree native to the sub-Himalayan tract, Central India, and Southern India. It belongs to the family Rutaceae and subfamily Aurantioideae, taxonomically classified as follows:

Table 1 – Taxonomic Classification of *Aegle Marmelos*

Taxonomic Rank	**Classification**
Kingdom	Plantae
Family	Rutaceae
Subfamily/Subclass	Aurantioideae
Genus	*Aegle*
Species	*Aegle marmelos*
Common Name	Bael / Bengal Quince

In India, *Aegle marmelos* is known by a variety of colloquial names. Sanskrit names it Adhararutha, Asholam, Atimangaliya, and Bilva; Telugu names it Sandiriyam, Srifalam, Sailsham, Birvam, Marlam, and Maredu; Hindi names it Bel, Bili, Sirphal, and Bela; and Tamil names it is Aluvigam, Kuvilam, Mavilangai, Vilwam, and Villvam. Other names for it include Bella or Bilba in Kannada, Biri in Gujarati, Kubalam or Bilwam in Malayalam, Bello in Odia, and Bael in Bengali (Gavali SD, Jagtap PA, Kunjir YA, Pakhare MK, Hake K, 2023).

Botanical Description of *Aegle marmelos* Fruit

The fruit has a pale orange, fibrous pulp inside a woody, smooth, and firm pericarp. With a diameter of up to 20 cm and an oval to oblong form, it can take up to a year to mature (Kale AB, Gaikwad NB, Rajendra K 2024).

Chemical Constituents

The fruit is rich in bioactive components and nutrients:

Bioactive Components: Carbohydrates, volatile oils, minerals, vitamins, coumarins, phenolic acids, alkaloids, flavonoids, organic acids, and antioxidants.

Nutritional Composition (per 100g):

Carbohydrates: 31.80 g

Fibre: 2.90 g

Minerals: 1.70 g

Fats: 0.39 g

Vitamins: 0.05 mg

Riboflavin (Vitamin B2): 1.20 mg

Thiamine (Vitamin B1): 0.13 mg

Beta-Carotene: 55.0 mg (Gavali SD, Jagtap PA, Kunjir YA, Pakhare MK, Hake K, 2023), (Karale MA, More RA, 2024), (Patil AR, Patil AR, Lovhare RB, 2023).

Notably, the fruit has high concentrations of marmelosin and phenolic acids, which both support its strong antioxidant qualities.

Reported Biological and Therapeutic Activities

Numerous pharmacological actions, such as antioxidant, antiulcer, antidiabetic, anticancer, antihyperlipidemic, anti-inflammatory, antibacterial, and antispermatogenic effects, have been shown for extracts from *Aegle marmelos*. Bael fruit extract is perfect for anti-ageing cosmetic formulations because of its high vitamin C concentration, which promotes collagen formation, lowers oxidative stress, and increases skin firmness and elasticity. (Gavali SD, Jagtap PA, Kunjir YA, Pakhare MK, Hake K, 2023), (Karale MA, More RA, 2024).

Mechanism of Antioxidant Activity

Aegle marmelos's antioxidant potential is ascribed to its capacity to scavenge free radicals, suppress lipid peroxidation, and boost endogenous antioxidant enzyme activities, all of which help to prevent oxidative damage linked to ageing and a number of chronic illnesses (Mohan M, Gupta D, Bhatt A, Verma R, Pathak N, Singh M, 2021).

1.3 Cosmetic Foundation

One of the most popular types of cosmetics for the face is foundation. Their main purposes include balancing out skin tone, hiding flaws including redness, pores, scars, and blemishes, and producing a flat surface for more makeup application. Contemporary foundation formulas aim to provide a natural-looking finish along with supplementary skincare advantages including sun protection, hydration, and skin care (Kanda N, Martindale S, Varcin M, Searing C, Tamburic S, 2015).

1.4 Foundation Stick

Like a big lipstick, a foundation stick is a solid foundation in the shape of a twist-up tube. This format has a number of benefits.

- Convenience and portability for fast touch-ups.
- Application accuracy for contouring or focused coverage.
- Compared to liquid foundations, this method is more hygienic and less contaminated.

Particularly for customers who are constantly on the go, foundation sticks are preferred because of their simplicity and mess-free application.

1.5 Medicated Cosmetics / Cosmeceuticals

By offering both medicinal advantages and aesthetic enhancement, medicated cosmetics, commonly referred to as cosmeceuticals, fill the gap between conventional cosmetics and pharmaceuticals.

Advantages of Medicated Cosmetics/Cosmeceuticals:

- Targeted Treatment: Medicated cosmetics can address specific skin concerns like acne, pigmentation, or aging.
- Dual Benefits: They combine the benefits of skincare and medication, saving time and effort.
- Improved Compliance: Patients are more likely to use products that enhance appearance while treating skin conditions.

Disadvantages of Medicated Cosmetics/Cosmeceuticals:

- Skin Irritation: Some formulations may cause irritation or allergic reactions due to active ingredients.
- Cost: Medicated cosmetics are often more expensive than regular skincare products.
- Limited Efficacy: Not all products deliver the promised results, and their effectiveness can vary (Patil AR, Patil AR, Lovhare RB, 2023), (Gautam MK, Purohit V, Agarwal M, Singh A, Goel RK, 2014).

1.6 Medicated Foundation

In addition to providing decorative covering, a medicated foundation is a cosmetic product made with active therapeutic chemicals that address underlying skin conditions. These formulas are intended to provide a smooth, even skin tone while treating rosacea, acne, hyperpigmentation, or early ageing symptoms. Medicated foundations are becoming more and more well-liked among consumers who are concerned about their health due to the growing demand for skincare and cosmetic items.

As previously described, no research has looked into creating a medicated foundation stick that contains Bael extract, despite the potential advantages of *Aegle marmelos* and the ease of use of stick-based cosmetic formulations.

In order to provide a multipurpose solution with both therapeutic antioxidant advantages and cosmetic coverage, the goal of this study is to develop and test a medicated foundation stick utilising *Aegle marmelos* fruit extract.

2. Materials and Methodology

2.1 Materials

Table 2 – Ingredients

Category	Ingredients	Function

Oil Phase Components	Beeswax, White Paraffin, Cocoa Butter, Carnauba Wax, Teel (Sesame) Oil, Cetostearyl Alcohol	Emollients, structural matrix, moisturizers
Powder Phase Components	Talcum Powder, Titanium Dioxide, Rice Powder, Sandalwood Powder	Opacifiers, bulking agents, skin-soothing agents
Humectants	Glycerin, Propylene Glycol	Moisture retention, powder dispersion
Heat-Sensitive Additives	Vitamin E (Tocopherol), Lavender Essential Oil	Antioxidant, fragrance, therapeutic effect

The following ingredients were carefully selected and used in the formulation of the medicated foundation stick, considering both functional and therapeutic properties:

Beeswax: Beeswax (Cera alba) solidifies oils and creates a breathable, moisture-locking barrier. Beeswax (Cera alba) was used to give the formulation structure, firmness, and smooth application. This is especially advantageous for dry and sensitive skin types (Gawande, Patel, Shaikh, 2023).

Fig. 1 – Beeswax

Carnauba Wax: Carnauba wax (Copernicia prunifera wax) has a high melting point and stiff consistency; carnauba wax (Copernicia prunifera wax) was added to improve firmness, spreadability, water resistance, and product stability (Gujar, Umekar, Kale, 2023).

Fig. 2 – Carnauba wax

Cocoa Butter: As a rich natural emollient, cocoa butter (Theobroma cacao seed butter) was added to the product to provide deep moisturisation, increase skin elasticity, and give it a creamy texture that makes application simple (Thaker, Patel, Maru, 2024).

Fig.3 – Cocoa Butter

White Paraffin: White soft paraffin (petroleum jelly) creates a protective layer on the skin's surface to stop transepidermal water loss and guarantee improved spreadability and smoothness. White soft paraffin (petroleum jelly) serves as an occlusive emollient (Kukudkar, Anasane, Mokashi, 2023).

Fig. 4 – White soft paraffin

Cetostearyl Alcohol: A fatty alcohol mixture, cetostearyl alcohol functioned as a viscosity enhancer and emulsifying agent, giving the emulsion stability and a silky texture (Rowe, Sheskey, Quinn, 2009).

Fig. 5 – Cetostearyl alcohol

Teel (Sesame) Oil: Used for its moisturising effects and natural antioxidant qualities, sesame oil (Sesamum indicum oil) helps hydrate the skin, rebuild the barrier, and protect against oxidative stress (Gupta, Sharma, 2017).

Fig. 6 – Teel oil

As an oil absorber, lubricant, and adhesive, **talc (hydrated magnesium silicate)** helped create a matte, smooth surface and made it easier for colours to be evenly distributed throughout the skin (Telange-Patil, Bhise, Kanase, 2022).

Glycerine: Glycerine, also known as glycerol, maintained skin hydration, enhanced texture, and extended the formulation's shelf life by acting as a strong humectant and successfully attracting moisture into the skin's layers (Harshad, Surana, Chavan, 2024).

Propylene Glycol: Propylene glycol improved moisture retention, improved active solubilisation, and facilitated improved skin absorption by acting as a humectant and a solvent (Khairnar, Gujarathi, Pathan, 2024).

Titanium Dioxide: Because of its potent light-scattering capabilities, titanium dioxide (TiO_2) was used as a natural white pigment, offering opacity, even skin tone coverage, and broad-spectrum ultraviolet (UV) protection (Trivedi, Murase, 2017).

Sandalwood Powder: The formulation included sandalwood powder (Santalum album) because of its anti-inflammatory, antibacterial, and calming properties for the skin, as well as its ability to provide a subtle, pleasant scent (Pratibha, Sanghavi, Kadam, 2023).

Rice Powder: Rice powder (Oryza sativa) provided oil-control qualities and a matte, smooth finish while acting as a natural absorbent, antioxidant, and skin texture enhancer. (Madne, Chaudhari, Khadabadi, 2022).

As a strong antioxidant that helps neutralise free radicals, shields the skin from oxidative damage, enhances skin texture, and aids in skin hydration, **vitamin E (α-tocopherol)** was included (Thaker, Patel, Maru, 2024).

Fig. 7 – Vitamin E

Lavender Oil: The use of lavender essential oil (Lavandula angustifolia) was intended to improve the entire experience of product application due to its soothing scent, moderate antibacterial qualities, and sensory augmentation (Sabara, Kunicka-Styczyńska, 2009).

Fig. 8 – Lavender oil

To guarantee uniformity and safety throughout the formulation process, all components utilised were of pharmaceutical or cosmetic quality and employed without additional purification (Rowe, Sheskey, Quinn, 2009).

2.2 Apparatus and Equipment

The medicated foundation stick was developed and tested using a variety of tools and equipment. For preparation and measurement procedures, glassware including borosilicate beakers (Borosil®), measuring cylinders, pipettes, test tubes, volumetric flasks, glass rods, and sieves (mesh size #120) were utilised. Powders were blended and their sizes reduced using a mortar and pestle (Borosil®). Foundation stick moulds. A digital pH meter for measuring pH, a UV-Visible Spectrophotometer (Jasco V-730, Japan) for spectrophotometric analysis, and a Triple Stability Chamber (Thermolab TX0000310G, India) for stability tests at regulated humidity and temperature were among the analytical tools. The melting point was determined using a capillary melting point device (Labline®, India). To evaluate firmness and spreadability, a Brookfield Texture Analyser (Brookfield) was used for texture analysis. Powders were sonicated using a computerised ultrasonic cleaner (Oscar Ultrasonics, India). A precision digital weighing scale was used to weigh the ingredients. An electric water bath was used to heat and melt the components, and a normal mercury thermometer was used to record the temperatures.

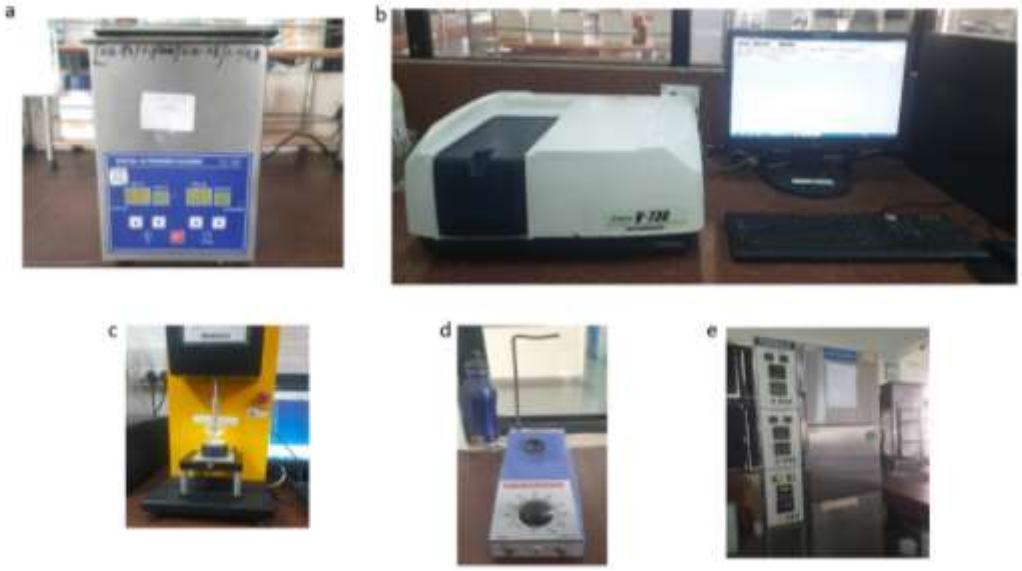

Fig. 9 - (a) Digital Ultrasonic Cleaner; (b) UV spectrophotometer (Jasco V 730); (c) Texture Analyser (Brookfield); (d) Capillary Based Melting point Apparatus; (e) Triple stability chamber (Thermolab TX0000310G)

2.3METHODOLOGY / PROCEDURE:

Step 1: Preparation and Pre-weighing

Fig. 10 – Weighing of Ingredients

- Calibrate the weighing balance.
- Weigh each raw material accurately according to the specified formulation batch size.
- Separate ingredients into four formulation phases: oil phase, powder phase, humectant phase, and heat-sensitive phase.

Step 2: Formation of the Oil Phase (Lipophilic Matrix)

- In a borosilicate beaker, combine: Beeswax, White paraffin, Cocoa butter, Carnauba wax, Teel (Sesame) oil, Cetostearyl alcohol
- Place the beaker in a thermostatically controlled water bath.
- Heat gradually to **60 ± 2°C** with continuous stirring until all solids are completely liquefied and homogeneously blended.

Step 3: Powder Dispersion Preparation

Fig. 11 – Trituration of Powders

- In a mortar, combine: Talcum powder, Titanium dioxide, Rice powder, Sandalwood powder
- Triturate manually until a fine, uniform dry blend is achieved (approximately 3–5 minutes).
- Gradually incorporate **glycerin** and **propylene glycol** into the dry mix while continuing trituration.
- Continue mixing until a smooth, cohesive, lump-free paste is formed. This serves as the *pre-dispersed solid phase*.

Step 4: Emulsification and Dispersion.

Fig. 12 – Emulsification and Dispersion

- Slowly add the molten oil phase to the powder-humectant dispersion in the mortar in small aliquots.
- Triturate continuously during addition to facilitate proper wetting, dispersion, and emulsification of the powder in the lipid matrix.
- Ensure complete homogenization to form a semi-solid emulsion with uniform particle distribution.
- Final mixture should be free from phase separation or visible agglomerates.

Step 5: Cooling and Incorporation of Heat-Sensitive Additives

- Allow the emulsion to cool to **40 ± 2°C**.
- Add: Vitamin E (Tocopherol), Lavender essential oil
- Stir gently and thoroughly with a glass rod or mechanical stirrer to avoid volatilization or oxidation of active components.

Step 6: Moulding and Solidification

- Pour the warm emulsion into pre-sanitized silicone or metal moulds.
- Tap the moulds lightly to remove trapped air bubbles and ensure even filling.
- Allow to cool and solidify at ambient room temperature (**25–28°C**) for 4–6 hours.
- For accelerated setting, place moulds under refrigeration (4–8°C) for 30–60 minutes.

Step 7: Demoulding and Finishing

- Once fully solidified, gently remove the bars from the moulds.
- Visually inspect for defects (air bubbles, surface cracks, oil sweating).
- Weigh and document individual product units (if needed).
- Store in clean, airtight containers to prevent from oxidation and fragrance loss.

Fig. 13 – Demolding and Finishing

2.4 Formulation Composition

Table 3: Composition of Medicated Foundation Stick (Formulation F16)

Ingredient	**Percentage (%)**
Beeswax	10%

White Paraffin	15%
Cocoa Butter	5%
Teel (Sesame) Oil	20%
Cetostearyl Alcohol	10%
Carnauba Wax	5%
Sandalwood Powder	3%
Talc	1%
Glycerin	1%
Propylene Glycol	1%
Rice Powder	5%
Titanium Dioxide	2%
Vitamin E	3%
Lavender Oil	5%
Shimmer (Colorant/Effect Agent)	q.s (quantity sufficient)

2.5 Evaluation Parameters

2.5.1 Organoleptic Characteristics

The direct examination of the formulation's sensory qualities through sight, touch, and smell is known as organoleptic evaluation. For cosmetic acceptability, it is a crucial factor.

The qualities listed below were assessed:

Physical Appearance: The formulation's homogeneity, the existence of any phase separation, and the lack of air bubbles or granules were examined visually. The ideal stick appearance was thought to be smooth, homogeneous, and free of bumps or splits.

Colour: The stick's consistency and suitability for the desired shade were examined. Any colour instability, patchiness, or discolouration suggested possible formulation problems.

Texture: The stick's texture was evaluated by lightly touching its surface and applying it to the skin. When applied, a good stick formulation should feel non-greasy, non-gritty, and smooth. Any stickiness or roughness was viewed as undesirable.

2.5.2 Melting Point Determination – Capillary Tube Method

To evaluate the foundation stick's stability and thermal behaviour, the melting point analysis was carried out.

A capillary tube with a closed end was filled with a tiny amount of the formulation. The tube was submerged in a melting point device that contained a liquid media (such as liquid paraffin) and connected to a thermometer. At a regulated pace of about 1°C per minute, the temperature was raised steadily. The melting point was defined as the temperature at which the stick material started to melt.

The test helps establish the formulation's capacity to survive temperature fluctuations during storage and use, assuring consumer safety and product integrity (Poucher WA, 1993).

2.5.3 Hardness – Texture Analyser

The force needed to penetrate or deform the stick is determined by hardness, a crucial mechanical attribute that influences the application experience. A texture analyser equipped with a cylindrical stainless steel probe (usually 5–10 mm in diameter) was used to measure the hardness. After calibrating the device, the probe was permitted to pierce the stick sample at a predetermined speed (for example, 1 mm/s) until it fractured or reached a fixed distance.

The hardness value was determined by measuring the maximal force (in Newtons) needed to penetrate.

A stick that is too hard can be challenging to use, while one that is too soft can readily melt or distort (Tai A, Bianchini R, Jachowicz J, 2014).

2.5.4 Spreadability – Texture Analyser

Spreadability affects both product efficacy and consumer impression by indicating how easily the formulation distributes on the skin. Spreadability was assessed using the Texture Analyser by sandwiching a certain amount of the stick between two glass plates and applying a predetermined weight or compressive force. The force-distance curve was created, or the spread diameter was measured.

Lower force and higher spread distance imply better spreadability, which makes it easier to apply the formulation evenly without pulling on the skin (Tai A, Bianchini R, Jachowicz J, 2014).

2.5.5 Water Resistance

Water resistance, which is important for long-wear formulations, controls the stick's capacity to withstand being washed off by perspiration or moisture. A predetermined amount of the stick was evenly placed on a designated skin area (such as the forearm) in this test, and it was let to dry naturally. In order to replicate actual water exposure, a continuous stream of distilled water was then applied to the application site for a predetermined amount of time (for example, five minutes).

Following exposure to water, the area was gently blotted without rubbing using filter paper. Good water resistance was determined by the degree of colour retention and the lack of smearing (Barel AO, Paye M, Maibach HI, 2014).

2.5.6 pH Determination

In addition to preventing skin irritation, the foundation stick's pH guarantees compatibility with the pH of the skin, which is normally between 4.5 and 6.5.

The stick was dissolved in distilled water to create a 1% w/v dispersion. A calibrated digital pH meter was used to measure the pH at room temperature following two to three minutes of stabilisation.

Extreme pH formulations were deemed inappropriate for topical use because they could cause irritation or disrupt the skin's protective layer.

2.5.7 Qualitative Phytochemical Analysis

The presence of the main bioactive groups from the *Aegle marmelos* extract used in the formulation was found using qualitative phytochemical screening. Typical phytochemical analyses comprised:

Fehling's solutions A and B were cooked in a boiling water bath and combined with 5 mL of filtrate to test for reducing sugars. The presence of **reducing sugars** was detected by the formation of an orange-red precipitate.

Tannin Test: The extract was mixed with a few drops of a 10% lead acetate solution. The presence of tannins was verified by a white precipitate.

Flavonoids were detected by treating 5 mL of extract with diluted NaOH, which caused a yellow tint that vanished when diluted HCl was added. **Phenolic Compound Test**: Two to three drops of 5% ferric chloride were added to five millilitres of extract. Phenolic chemicals were suggested by a strong violet-blue or green colouring (Behera P, Raj VJ, Basavaraju R, 2014).

2.5.8 Quantitative Phytochemical Evaluations

Total Flavonoid Content (TFC) – Aluminium Chloride Colorimetric Method

The aluminium chloride technique was used to quantify the flavonoid content.

Quercetin standards at known quantities (usually 10–100 µg/mL) were used to create a calibration curve.

A UV-Visible spectrophotometer was used to detect absorbance at 510 nm following a 30-minute incubation period at room temperature in which the sample extract and standard solutions were treated with a 2% aluminium chloride solution.

Quercetin equivalents per gramme of extract (mg QE/g) were used to express the flavonoid content (Vishwakarma A, Ahmad SS, Bakoriya D, 2024).

Total Phenolic Content (TPC) – Folin-Ciocalteu Assay

Folin-Ciocalteu's reagent was used to measure the phenolic content.

Diluted Folin-Ciocalteu reagent was combined with the sample and gallic acid standard solutions, and the mixture was then incubated. The mixture was let to stand after the sodium carbonate was added, and the absorbance at 738 nm was measured.

Gallic acid equivalents per gramme extract (mg GAE/g) were used to express the results (Sharma P, Sharma V, Agarwal N, 2023).

2.5.9 Antioxidant Activity – DPPH Radical Scavenging Assay

The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay was used to assess the formulation extract's antioxidant capacity.

To put it briefly, a 0.1 mM DPPH solution was made in methanol. After mixing a predetermined amount of extract with DPPH solution, the mixture was left to incubate for half an hour in the dark. Using spectrophotometry, the absorbance drop at 517 nm was observed.

The following formula was used to determine the DPPH radical's % inhibition:

%Inhibition = (A0 − A1 / A0) × 100

Where A0 = Absorbance of the DPPH control (without sample) & A1 = Absorbance of the sample (with extract). This formula calculates the percentage of DPPH radical scavenged by the antioxidant compound in the sample. A higher % inhibition indicates stronger antioxidant activity. (Singh A, Koundal V, Bhardwaj K, 2024).

2.5.10 Microbial Studies

To make sure the formulation was safe and stable against microbial contamination, a microbiological investigation was done. A predetermined amount of the stick was aseptically diluted and plated on Sabouraud's dextrose agar for fungus and nutritional agar for bacteria. In order to measure colony-forming units (CFU), plates were incubated at the proper temperatures (30–35°C for bacteria and 20–25°C for fungus). For topical treatments, the microbiological load was contrasted with pharmacopeial acceptability limits.

2.5.11 Animal Testing – Skin Irritation Test

Albino rats were used to investigate the possibility of skin irritation (with prior ethics committee approval).

A measured quantity of formulation was applied under occlusion for a full day after the dorsal side's hair was shaved.

The test areas were examined for indications of irritation, oedema, or erythema following patch removal. A conventional Draize scoring system was used to rate the results, and the Primary Irritation Index (PII) was determined.

5.2.12 Stability Studies

The following criteria were used to evaluate the medicated foundation stick's stability:

Environment (25 ± 2 °C, 60% relative humidity) circumstances that were accelerated during a one-month period (40 ± 2°C, 75% RH). Formulations were kept in tightly sealed containers and assessed once a week for: Physical appearance, Colour and odor changes, Texture alterations, pH variation, Hardness, Spreadability.

3. Results

3.1 Organoleptic Characteristics

The foundation stick from batch F16 exhibited a skin-toned colour, a smooth texture, good hardness, an opaque appearance, and a pleasant, distinct foundation fragrance. These characteristics indicate a successful formulation achieved with the appropriate excipients.

Table 4: Organoleptic Characteristics of Foundation Stick (Batch F16)

Sr. No.	Parameter	Inference
1	Physical Appearance	Opaque
2	Colour	Skin coloured
3	Texture	Smooth
4	Hardness	Good
5	Odour	Pleasant, characteristic

3.2 Melting Point

Using the capillary method, the melting point of Batch F16 was determined to be 50°C, which indicates adequate thermal stability.

3.3 Hardness

Hardness according to the texture analyser assessment, Batch F16 exhibited the ideal firmness for stick application, with a measured hardness value of 31.60 g.

3.4 Spreadability

With a measured spreadability force of 31.60 g, Batch F16 demonstrated facile application and moderate resistance.

3.5 Water Resistance

When exposed to water and blotted, batch F16 showed moderate water resistance with slight fading and smearing.

3.6 pH Determination

Dermal compatibility was ensured by the foundation stick's neutral pH of 7.0.

3.7 Qualitative Phytochemical Analysis

The foundation stick retained key phytoconstituents including flavonoids, phenols, tannins, and reducing sugars, post formulation.

Table 5: Phytochemical Analysis of Foundation Stick and Pure Extract

Sr. No.	Test	Pure Extract Observation	Foundation Stick Observation	Inference
1	Flavonoids	Yellow to colourless	Yellow to colourless	Present
2	Phenols	Violet colour	Violet colour	Present
3	Tannins	White precipitate	White precipitate	Present
4	Reducing Sugar	No red precipitate	No red precipitate	Present

3.8 Quantitative Evaluations

Total Phenolic Content (TPC)

The TPC of the pure extract was 2835 mg GAE/g extract, while the F16 foundation stick displayed 90.9 mg GAE/g extract.

Table 6: Total Phenolic Content (TPC) Results

Sample	Absorbance	Concentration (µg/ml)	TPC (mg GAE/g extract)
Pure Extract (0.7 g)	1.4637	28.35	2835
Foundation Stick	0.8500	0.4545	90.9

Total Flavonoid Content (TFC)

The TFC of the foundation stick was significantly higher (3947.61 mg QE/g extract) than the pure extract (419.1 mg QE/g extract).

Table 7: Total Flavonoid Content (TFC) Results

Sample	Absorbance	Extract Used	TFC (mg QE/g extract)
Pure Extract (0.7 g)	0.8801	0.7 g	419.1
Foundation Stick	0.0829	0.007 g	3947.61

3.9 Antioxidant Activity (DPPH Assay)

The antioxidant assay revealed 33.80% inhibition for the drug-loaded stick compared to 13.41% for pure extract and 27.95% for placebo.

Table 8: Antioxidant Activity (DPPH Assay) Results

Sample	Absorbance (A1)	% Inhibition
Control	0.2787	-

Pure Extract	0.2413	13.41%
Placebo	0.2008	27.95%
Drug Stick	0.1845	33.80%

3.10 Microbial Studies

Minimal microbial growth was observed, indicating good antimicrobial preservation due to natural agents like lavender oil and sandalwood oil.

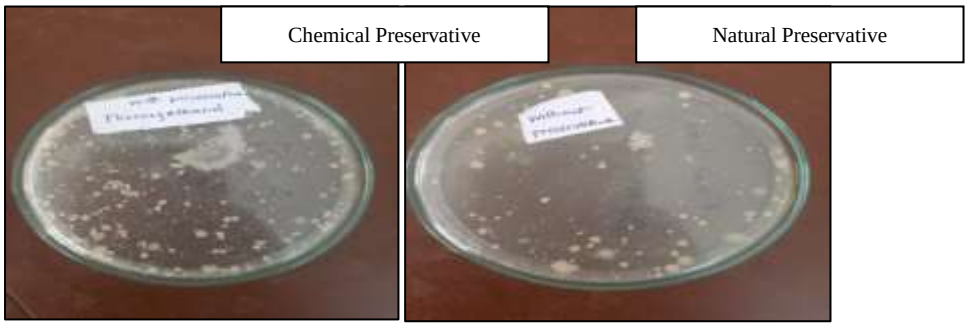

Fig14. Microbial Studies

3.11 Skin Irritation Test

Application of the formulation on Albino rats did not cause any erythema, oedema, or visible irritation, confirming dermal safety.

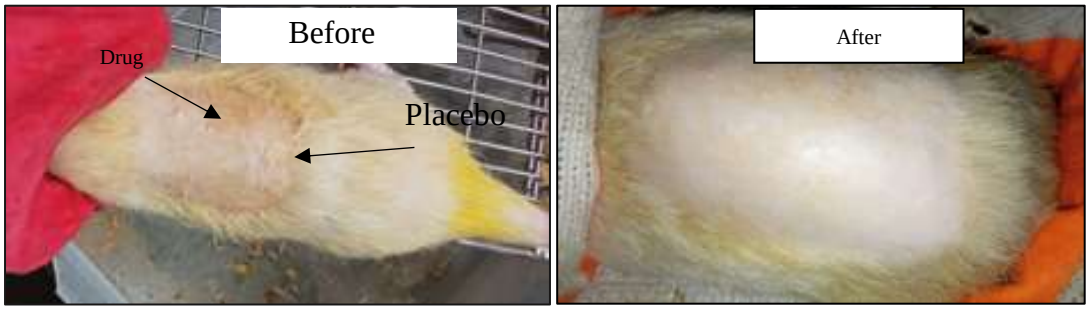

Fig15. Skin Irritation Studies

3.12 Stability Studies

Stability testing at room and accelerated conditions over one month showed no significant changes, confirming product stability.

Fig16. Stability Studies

Table 9: Stability Study Results for Foundation Stick (Batch F16)

Evaluation Parameter	**After 15 Days**	**After 30 Days**
Physical Appearance	Opaque	Opaque
Colour	Skin coloured	Skin coloured
Texture	Smooth	Smooth
Hardness (g)	31.60	30.97
Odour	Pleasant, characteristic	Pleasant, characteristic
Melting Point (°C)	50°C	49°C
pH Value	7.0	6.9
Water Resistance	Moderate smudging and fading	Slightly increased smudging
Spreadability (g)	31.60	30.97
Antioxidant Activity (% inhibition)	33.80%	33.12%

4. Discussion

The smooth texture, good hardness, and nice scent of the foundation stick (Batch F16) were all desirable organoleptic traits. These characteristics can be ascribed to the appropriate choice and ratio of excipients, including cocoa butter, beeswax, lavender oil, and sandalwood oil (Wenninger JA, McEwen GN Jr, 1997). Successful pigment dispersion, which is essential for aesthetic appeal, is shown by the opacity and even pigmentation. The formulation will stay stable in tropical regions without softening during handling or storage because of its melting point of 50°C. A key factor in reaching this stability was the inclusion of waxes with high melting points, such as beeswax and carnauba.

The formulation's proper balance between firmness and ease of application was shown by the hardness and spreadability numbers. Glycerin and sesame oil improved the spreading experience by lowering friction without making the stick too soft.

The stick's neutral pH of 7.0 guarantees that it won't irritate sensitive skin type. For items meant for daily use, this pH compatibility is essential. The retention of flavonoids, phenols, tannins, and reducing sugars after formulation was validated by qualitative phytochemical analysis. An intriguing finding emerged from the quantitative TPC and TFC estimations: the TFC significantly increased upon formulation, whilst the TPC marginally decreased. The synergistic increase of flavonoids by plant-based excipients such as rice powder and sandalwood powder may help to explain this.

These results were corroborated by antioxidant experiments, which showed that the drug-loaded stick had more radical scavenging activity (33.80%) than the pure extract and placebo, suggesting that the formulation enhanced the antioxidative capability.

According to microbiological tests, the antibacterial activity of the included essential oils is responsible for the good stability against contamination. The dermatological safety of the foundation stick was confirmed by skin irritation testing conducted on albino rats, which revealed no obvious allergic reactions or irritation. Under accelerated storage circumstances, stability testing showed that the formulation retained its functional, chemical, and physical integrity, indicating shelf stability for commercial usage.

All things considered, the foundation stick effectively blended physical stability, antioxidant capabilities, phytochemical retention, microbiological safety, and aesthetic features, making it a viable option for cosmeceutical applications.

5. Conclusion

As a multipurpose cosmetic formulation, the produced medicated foundation stick containing extract from *Aegle marmelos* (Bael fruit) showed encouraging promise. Batch F16 was chosen as the optimal formulation because it had the desired organoleptic properties, including a neutral pH that is suitable for skin application, a smooth and uniform texture, and a pleasing fragrance. Its formulation resilience was supported by physicochemical assessments that verified its stability for 30 days in both ambient and accelerated conditions, with no discernible changes in colour, texture, or spreadability. Easy application and structural stability were guaranteed by mechanical property evaluations that showed moderate stiffness (hardness of 31.60 g) and an acceptable melting point (50°C). Spreadability testing revealed an optimal glide, enhancing the sensory attributes important for user acceptance. Water resistance studies showed moderate smudging and fading, indicating acceptable durability upon skin application.

Phytochemical analysis revealed a high total phenolic content (90.9 mg GAE/g) and total flavonoid content (3947.61 mg QE/g), suggesting the effective retention of antioxidant bioactives from *Aegle marmelos*. The antioxidant potential was further substantiated by DPPH radical scavenging assay results (33.80% inhibition), indicating strong free radical neutralisation capacity, essential for protecting skin against oxidative stress. Microbial studies confirmed the effectiveness of incorporated natural preservatives in maintaining microbiological safety. Furthermore, dermal irritation studies conducted on animal models reported no signs of erythema or oedema, confirming the biocompatibility and safety of the formulation.

Overall, the *Aegle marmelos*-based foundation stick successfully combines therapeutic skin benefits with desirable cosmetic attributes, offering a natural, safe, and effective alternative to conventional synthetic-based products.

Future investigations may focus on extending the stability testing over six months to one year, conducting large-scale clinical trials to assess efficacy and consumer acceptance, and exploring the incorporation of advanced drug delivery systems such as nanoemulsions or liposomal carriers to enhance the bioavailability of active phytoconstituents. Additionally, examining synergistic formulations with other herbal extracts and expanding the antimicrobial efficacy against a wider spectrum of skin pathogens could further establish its position as a next-generation cosmeceutical product.

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