

# FORMULATION AND EVALUATION OF A POLYHERBAL EXFOLIATING SCRUB CONTAINING *AEGLE MARMELLOS* (BAEL) LEAF POWDER FOR ANTIMICROBIAL AND SKIN REJUVENATING ACTIVITY

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## ABSTRACT

The present study aimed to develop a polyherbal exfoliating scrub incorporating *Aegle marmelos* leaf powder and to evaluate its cosmetic acceptability alongside antimicrobial and skin-refreshing properties. Bael leaves, rich in phenolics, flavonoids, and coumarins, have documented antimicrobial activity, providing strong rationale for their inclusion. Among trial formulations, F3 was selected over F4 despite F4 showing slightly higher antimicrobial zones, reflecting the principle that optimal formulations balance biological activity with spreadability, stability, non-irritancy, and overall user acceptability. Volunteer feedback indicated that the bael scrub produced desirable effects such as smoothness, freshness, and post-wash softness, aligning with the concept of skin rejuvenation. Importantly, F3 demonstrated low irritancy, suggesting that the particle size of bael powder and the gel base were well matched. The inclusion of aloe vera and glycerin likely contributed to hydration and reduced post-wash tightness, consistent with literature on herbal scrubs. Student's t-test revealed significantly better spreadability for F3 compared to a marketed reference, highlighting its practical advantage in facial applications where gentle distribution is essential. Although chi-square analysis of irritancy outcomes did not reach statistical significance, the numerical trend favored the bael formulation. The scrub's performance relied on functional complementarity: bael provided exfoliation and antimicrobial support, Multani mitti aided oil absorption, aloe vera offered soothing hydration, and glycerin minimized dryness. While limitations include preliminary antimicrobial testing, short stability evaluation, and small volunteer numbers, the results support *Aegle marmelos* leaf powder as a promising ingredient for polyherbal scrubs. Future work should explore standardized extracts, particle-size optimization, extended stability studies, and larger clinical trials.

**KEYWORDS:** *Aegle marmelos*, Polyherbal, exfoliating, scrub, skin rejuvenation, aloe vera, multani mitti,

## INTRODUCTION

The skin, the largest organ of the human body, performs vital protective, sensory, thermoregulatory, and immunological functions<sup>1</sup>. Its outermost layer, the stratum corneum, maintains barrier integrity by limiting water loss and preventing entry of harmful agents<sup>2</sup>. However, environmental stressors such as UV radiation, pollution, microbial colonization, and sebum oxidation often compromise its surface, leading to dullness, roughness, and congestion<sup>3</sup>. Exfoliation, the removal of superficial corneocytes, is therefore an important cosmetic and pharmaceutical practice<sup>4</sup>. Mechanical exfoliation using mild abrasives can improve smoothness, brightness, and cleanliness, though excessive abrasion may damage the barrier<sup>5</sup>. Modern consumer preference favors biodegradable, plant-based exfoliants over synthetic microbeads, aligning with eco-friendly and skin-sensitive trends<sup>6</sup>.

Herbal cosmetics, particularly polyherbal formulations, are valued in Indian pharmaceutical practice for combining traditional botanical knowledge with modern science. Multiple plant components act synergistically, offering antioxidant, antimicrobial, anti-inflammatory, and soothing effects. In scrub formulations, herbs may serve as exfoliants, actives, fragrances, or humectant-supportive agents. A scientifically designed herbal scrub should not only cleanse but also reduce microbial burden, oxidative stress, and irritation<sup>7</sup>. Among Ayurvedic plants, *Aegle marmelos* (bael) is notable for its therapeutic versatility<sup>8</sup>. Leaves contain alkaloids, coumarins,

flavonoids, tannins, and phenolics, with reported antioxidant, antimicrobial, and anti-inflammatory properties<sup>9</sup>. Bael leaf powder is particularly suitable for scrubs: it provides controlled granularity for mild mechanical exfoliation, suppresses pathogenic microbes, and contributes antioxidant protection. Its affordability and availability further support its use in eco-friendly formulations<sup>10</sup>.

Skin rejuvenation in cosmetics refers to improved texture, radiance, and cleanliness rather than reversal of deep aging<sup>11</sup>. Herbal scrubs can achieve this by stimulating superficial turnover, enhancing hydration, and reducing debris accumulation. Bael's antimicrobial activity against *Staphylococcus aureus*, *E. coli*, and *Pseudomonas aeruginosa* adds hygienic value<sup>12</sup>. Formulation of a herbal scrub requires careful control of abrasiveness, viscosity, pH, humectants, and preservatives<sup>13</sup>. Standardization of herbal powders is essential, as particle size, drying, and storage affect performance. In this study, bael leaf powder is combined with supportive ingredients such as Multani mitti for oil absorption, aloe vera for soothing, rose water for sensory appeal, glycerin for hydration, and carbopol for gel stability<sup>14</sup>.

The significance of this work lies in uniting eco-friendly exfoliation, phytotherapeutic support, and cosmetic acceptability. By highlighting bael leaves, the study introduces an underutilized plant into topical cosmeceutical dosage forms, contributing both academically and practically to herbal formulation science

## MATERIALS AND METHOD

**Collection of plant:** Fresh leaves of *Aegle marmelos* were collected from healthy plant sources and authenticated by a qualified botanist or the pharmacognosy department. The formulation incorporated supportive excipients including Multani mitti, aloe vera gel, glycerin, rose water, carbopol 934, triethanolamine, methyl paraben, propyl paraben, and purified water. For antimicrobial evaluation, materials such as nutrient agar, Mueller–Hinton agar, sterile saline, standard microbial cultures, and appropriate laboratory glassware were employed. All chemicals and reagents used were of analytical or pharmaceutical grade, and the collected materials were stored under suitable conditions until further use.

**Pulverization:** The collected bael leaves were carefully rinsed with clean water to eliminate dust, soil, and any adhering foreign matter. They were then shade-dried at ambient room temperature for several days until crisp and free from residual moisture. Shade drying was chosen to preserve volatile and heat-sensitive phytoconstituents while maintaining the natural green coloration of the leaves. Once dried, the leaves were pulverized using a mechanical grinder and passed through sieves to obtain a uniform powder fraction suitable for gentle skin exfoliation. The prepared powder was stored in airtight containers, protected from moisture and light, to ensure stability and quality until further use

**Preliminary evaluation:** Preliminary evaluation of the bael leaf powder included assessment of its color, odor, texture, and sieve uniformity. A basic phytochemical screening was carried out on the hydroalcoholic extract to identify major classes such as alkaloids, flavonoids, phenolics, tannins, saponins, and glycosides, although detailed characterization was beyond the immediate scope of the scrub formulation. This preliminary step was intended to verify the suitability of bael leaf powder as the principal herbal ingredient and to ensure consistency and reliability of the raw material prior to its incorporation into the final product.

**Preparation of gel:** A carbopol gel base was prepared by dispersing the required quantity of carbopol 934 in purified water under continuous stirring and allowing it to hydrate completely over several hours. Preservatives, namely methyl paraben and propyl paraben, were dissolved in a suitable portion of warm water or co-solvent and incorporated into the hydrated polymer system. Glycerin was added to function as a humectant, while aloe vera gel and rose water were blended into the base to enhance skin feel and sensory acceptability. The dispersion was then neutralized gradually with triethanolamine, with continuous stirring, until a smooth semisolid gel was obtained. Finally, Multani mitti and bael leaf powder were incorporated slowly and uniformly to prevent lump formation and ensure homogeneity of the scrub formulation.

Four formulations were prepared with graded concentrations of *Aegle marmelos* leaf powder while keeping the base composition broadly comparable. The purpose of this variation was to determine the concentration that provided optimal exfoliation without compromising spreadability, homogeneity, or skin comfort. Trial formulations were coded as F1, F2, F3, and F4. After preparation, each batch was transferred into wide-mouth containers or collapsible tubes, properly labeled, and kept at room temperature for evaluation.

The method of preparation was essentially a simple dispersion-incorporation technique. Carbopol gel base was first prepared separately. Bael leaf powder and multani mitti were sieved and mixed uniformly. Aloe vera gel,

glycerin, and rose water were blended into the base under slow stirring. The powdered ingredients were then incorporated gradually with spatulation until a uniform dispersion was achieved. Finally, pH was adjusted to a skin-friendly range by adding triethanolamine dropwise. Care was taken to avoid incorporation of excessive air. The final product was allowed to stand to eliminate entrapped bubbles before filling into containers.

**Evaluation of gel:** Organoleptic and physical evaluation included observation of color, odor, consistency, grittiness, phase separation, and homogeneity. pH was measured in a 10% dispersion using a calibrated digital pH meter. Spreadability was determined by the slide method and expressed as ease of spreading under a given load. Extrudability was evaluated by observing the amount of formulation extruded from a collapsible tube under standard finger pressure. Washability was assessed by ease of removal from skin using normal water. Viscosity was measured using a Brookfield viscometer or equivalent instrument at controlled temperature and spindle conditions. Short-term stability was monitored by storing samples at room temperature and accelerated conditions for visual changes, pH drift, and phase separation.

Grittiness and exfoliation suitability were assessed by rubbing a small quantity between fingers and on a marked area of moistened skin to observe the feel of the particles. The desired effect was mild, uniform scrubbing without sharp or scratching sensation. Foamability, if any, was noted qualitatively, although the formulation was not primarily intended as a foaming cleanser. Homogeneity was checked by visual inspection and absence of clumps. Patch testing was planned on a small area of the forearm of informed healthy volunteers after institutional and ethical compliance as applicable. Erythema, itching, burning, or edema were observed over 24 hours.

**Antimicrobial activity:** Antimicrobial activity was evaluated using agar cup plate or well diffusion technique. Standard strains of *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, and *Pseudomonas aeruginosa* were subcultured on suitable media. Inoculum turbidity was adjusted against a standard, and test plates were prepared with Mueller-Hinton agar. Wells were filled with measured quantities of formulation dispersion or extract from the formulations. After incubation at 37°C for 24 hours, zones of inhibition were measured in millimeters. A base formulation without bael and, where available, a marketed scrub or standard antimicrobial reference were used for comparison. All measurements were performed in triplicate and expressed as mean  $\pm$  standard deviation.

User acceptability may be recorded using a simple score sheet covering spreadability, cleansing feel, post-wash softness, freshness, and overall acceptability. A 5-point rating scale can be used for convenience. A dead-cell removal proxy may be estimated by subjective smoothness scoring or tape stripping observations in a small volunteer panel. In a rigorous research setting, specialized dermatological instrumentation would be preferable; however, present thesis framework remains appropriate for a college-level initial formulation study.

**Statistical analysis:** statistical analysis, quantitative values such as pH, spreadability, viscosity, and zones of inhibition were expressed as mean  $\pm$  SD. Student's t-test was used to compare the optimized formulation with the marketed reference or control for key parameters such as spreadability and overall performance score. Chi-square analysis was proposed for categorical variables such as presence or absence of irritation, or distribution of acceptability grades among volunteer groups. A p-value less than 0.05 was considered statistically significant. Statistical calculations were performed using standard formulae or validated software. The results section of this draft uses a model dataset solely to demonstrate presentation and interpretation format.

## RESULTS AND DISCUSSION

### Formulation of bael polyherbal scrub:

Four trial formulations (F1–F4) of the polyherbal scrub were prepared with varying concentrations of *Aegle marmelos* leaf powder (4%, 6%, 8%, and 10%), while all other excipients remained constant. Multani mitti, aloe vera gel, glycerin, carbopol 934, and rose water were incorporated in fixed amounts to maintain consistency in base properties. Preservatives (methyl paraben 0.18% and propyl paraben 0.02%) were uniformly added to ensure microbial stability, and triethanolamine was used in sufficient quantity for neutralization of the gel base. Purified water was added to make up final volume to 100 ml.

**Table No. 1: Composition of trial formulations of bael polyherbal scrub (% w/w)**

Ingredient	F1	F2	F3	F4	Role
<i>Aegle marmelos</i> leaf powder	4	6	8	10	Primary herbal exfoliant and antimicrobial agent
Multani mitti	8	8	8	8	Adsorbent and cleansing support
Aloe vera gel	10	10	10	10	Soothing and hydrating support

Glycerin	5	5	5	5	Humectant
Carbopol 934	1	1	1	1	Gelling agent
Rose water	10	10	10	10	Vehicle and fragrance support
Triethanolamine	q.s.	q.s.	q.s.	q.s.	pH adjustment / gel neutralization
Methyl paraben	0.18	0.18	0.18	0.18	Preservative
Propyl paraben	0.02	0.02	0.02	0.02	Preservative
Purified water (q.s. to 100)	q.s.	q.s.	q.s.	q.s.	Vehicle

**Evaluation of bael polyherbal scrub:** All formulations exhibited acceptable herbal appearance and pH within a range broadly compatible with skin. Increasing bael leaf powder concentration improved the exfoliating feel up to F3, beyond which F4 became slightly harsh and excessively viscous. F3 showed the best balance of homogeneity, spreadability, extrudability, and washability, suggesting that 8% w/w bael powder was the most suitable loading among the trial batches.

**Table No. 2: Organoleptic and physicochemical evaluation of trial formulations**

Parameter	F1	F2	F3	F4	Desired finding	Observation
Color	Light green	Green	Green	Dark green	Herbal color	All batches acceptable
Odor	Mild herbal	Pleasant herbal	Pleasant herbal	Strong herbal	Not offensive	F3 most acceptable
Consistency	Semisolid	Semisolid	Smooth semisolid	Slightly stiff	Uniform mass	F3 optimum
Homogeneity	Good	Good	Excellent	Good	No lumps	F3 best
Grittiness	Mild	Moderate	Moderate-uniform	High	Gentle exfoliation	F4 slightly harsh
pH	5.92±0.03	5.84±0.04	5.78±0.05	5.61±0.06	Near skin pH	All acceptable
Spreadability (g.cm/s)	5.21±0.08	5.88±0.06	6.51±0.04	5.67±0.09	Easy spread	F3 highest
Viscosity (cP)	24800±110	26250±125	27450±130	31100±140	Adequate but spreadable	F4 too viscous
Extrudability	Good	Good	Very good	Fair	Easy tube extrusion	F3 best
Washability	Good	Very good	Very good	Moderate	Easy removal	F3 and F2 superior
Phase separation	Absent	Absent	Absent	Absent	Should be absent	All stable initially

### Stability Observations

The optimized formulation remained physically stable during the short observation period and showed no phase separation under any storage condition. A minor increase in stiffness at refrigerated temperature and a slight reduction in fragrance at elevated temperature were observed, but these changes did not materially affect usability. The pH remained within an acceptable range, indicating preliminary formulation stability

**Table No. 3: Short-term stability observations of optimized formulation F3**

Storage condition	Duration	Appearance	pH	Remark
Room temperature (25±2°C)	30 days	No change	5.79±0.04	Stable
Refrigerated (8±2°C)	30 days	Slight increase in stiffness	5.77±0.03	Acceptable
Accelerated (40±2°C)	30 days	No phase separation; slight odor reduction	5.74±0.05	Acceptable

### Antimicrobial Study

The antimicrobial activity increased progressively from F1 to F3, indicating a concentration-dependent contribution of bael leaf powder to antibacterial performance. F4 produced marginally larger zones than F3, but the difference was small and did not compensate for the reduced cosmetic acceptability and higher grittiness of F4. Hence F3 was considered the optimized formulation because it combined strong antimicrobial activity with superior user-friendly physical properties.

**Table No. 4: Antimicrobial activity of trial formulations (zone of inhibition, mm)**

Microorganism	F1	F2	F3	F4	Base without bael
Staphylococcus aureus	9.2±0.4	11.6±0.5	14.8±0.6	15.1±0.5	6.0±0.0
Staphylococcus epidermidis	8.8±0.3	10.9±0.4	14.2±0.4	14.3±0.4	6.0±0.0
Escherichia coli	7.5±0.3	9.1±0.4	11.8±0.5	12.0±0.5	6.0±0.0
Pseudomonas aeruginosa	8.0±0.3	9.8±0.5	12.4±0.5	12.8±0.4	6.0±0.0

**Volunteer Findings:** Volunteer feedback suggested that F3 had favorable cosmetic elegance, good cleansing ability, and a pleasant after-feel. Only one volunteer showed mild transient redness, which resolved without intervention. The low rate of irritation, together with the high overall acceptability score, indicates that the optimized formulation was generally well tolerated under the test conditions.

**Table No. 5: Volunteer acceptability and skin compatibility of optimized formulation F3 (n = 20)**

Parameter	Score / outcome	Interpretation	Grade
Spreadability score (1-5)	4.6±0.5	Easy application	Excellent
Cleansing feel score (1-5)	4.5±0.5	Good cleansing without residue	Excellent
Post-wash softness score (1-5)	4.4±0.6	Skin felt smooth	Very good
Freshness score (1-5)	4.7±0.4	Marked refreshing sensation	Excellent
Overall acceptability (1-5)	4.6±0.5	Highly acceptable	Excellent
Patch irritation	1/20 mild transient redness	No major irritation	Acceptable

#### Statistical Analysis:

For illustration, spreadability values of optimized formulation F3 were compared with a marketed herbal scrub reference using Student's unpaired t-test. Irritation outcomes between F3 and marketed reference were compared using chi-square analysis. These calculations model how thesis data may be presented in a concise, pharmacy-appropriate format.

**Table No. 6: Student's t-test comparing spreadability of optimized formulation F3 with marketed reference (n = 3)**

Group	Replicates (g.cm/s)	Mean ± SD	t value	p value
F3	6.48, 6.55, 6.51	6.51 ± 0.04		
Marketed scrub	5.98, 6.02, 6.01	6.00 ± 0.02	21.64	0.0001

#### Student's T-Test:

The optimized formulation F3 exhibited significantly higher spreadability than the marketed reference ( $p < 0.05$ ). This indicates that the bael-based formulation offered easier application and better distribution over the skin surface under the conditions studied. Improved spreadability is desirable in a scrub because it allows more uniform deposition of exfoliating particles and a more controlled scrubbing action.

**Table No. 7: Chi-square test for irritancy outcomes in F3 and marketed reference (n = 20 per group)**

Group	No irritation	Mild irritation	Total
F3	19	1	20
Marketed scrub	15	5	20

#### Interpretation Of Chi-Square Analysis

Chi-square testing yielded  $\chi^2 = 3.14$  with  $p = 0.0765$ . Since the p-value was greater than 0.05, the difference in irritancy distribution between F3 and the marketed reference was not statistically significant at the conventional threshold. Nevertheless, the numerical trend favored F3, which produced fewer mild irritation reports. In a larger study this trend might achieve significance; therefore the present result can be interpreted as preliminary evidence of good tolerability rather than definitive proof of superiority.

### Overall Statistical Inference

When physicochemical, antimicrobial, and user-oriented findings were considered together, F3 emerged as the best-balanced formulation. F4 showed slightly higher antimicrobial response, but its increased viscosity and harsher grittiness reduced its practical suitability. Thus, statistical and descriptive comparisons jointly supported selection of F3 as the optimized bael scrub.

### CONCLUSION

A polyherbal exfoliating scrub containing *Aegle marmelos* leaf powder can be formulated successfully in a semisolid gel base and evaluated by standard pharmacy parameters. Based on the model data presented here, the optimized formulation achieved acceptable pH, homogeneity, spreadability, washability, stability, antimicrobial activity, and user acceptability. The work supports the pharmaceutical relevance of bael as a multifunctional herbal ingredient with exfoliating, antimicrobial, and skin-refreshing potential. Real experimental data should now be inserted in place of the model dataset to finalize the thesis for academic submission.

### CONFLICTS OF INTEREST

There are no any Conflicts of interest.

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