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Fabrication and Evaluation of Herbal Soap Using Tomato, Aloe Vera, and Turmeric

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Abstract:

Background: Herbal cosmetics are increasingly preferred owing to their biocompatibility, minimal side effects, and therapeutic benefits. Soap remains one of the most widely used personal care products globally. The incorporation of plant based bioactive ingredients can enhance the functional and medicinal properties of soap formulations. Objective: This study aimed to formulate and evaluate herbal soap using tomato (*Solanum lycopersicum*), aloe vera (*Aloe barbadensis* Miller), and turmeric (*Curcuma longa*) extracts as active ingredients, with a focus on physicochemical properties, antimicrobial activity, and skin compatibility. Methods: Three formulations (F1, F2, F3) were prepared using the cold process saponification method with varying concentrations of tomato extract (5%, 10%, 15%), fixed concentrations of aloe vera gel (5%) and turmeric extract (1%, 2%, 3%). Formulations were evaluated for organoleptic properties, pH, moisture content, total fatty matter, foam height and stability, dirt dispersion, saponification value, skin irritation, and antimicrobial activity using agar well diffusion method. Results: All formulations exhibited satisfactory physicochemical parameters within accepted pharmacopoeial limits. Formulation F3, containing the highest concentrations of tomato (15%) and turmeric (3%) extracts, demonstrated superior foam stability (18 ± 0.8 min), lowest moisture content (11.2%), and the largest zones of inhibition against *Staphylococcus aureus* (18 ± 0.6 mm), *Escherichia coli* (16 ± 0.4 mm), *Candida albicans* (14 ± 0.5 mm), and *Pseudomonas aeruginosa* (13 ± 0.3 mm). None of the formulations induced skin irritation during patch testing. Conclusion: The herbal soap formulations prepared from tomato, aloe vera, and turmeric possess promising physicochemical, antimicrobial, and skin friendly properties. F3 was identified as the optimum formulation. These plant derived soaps offer a safe, cost effective, and eco-friendly alternative to synthetic commercial soaps.

Keywords: Herbal soap, Curcumin, Lycopene, Saponification, Antimicrobial activity, Physicochemical evaluation, Natural cosmetics.

1. INTRODUCTION

The global cosmetics and personal care industry has witnessed a paradigm shift toward herbal and natural formulations driven by growing consumer awareness of the potential risks associated with synthetic chemicals [1]. Soap, one of the oldest and most universally used cleansing agents, occupies a central position in daily hygiene. Conventional synthetic soaps, while effective in cleansing, often contain harsh surfactants, artificial dyes, and preservatives that may cause skin irritation, allergic reactions, and long-term dermatological complications [2]. Herbal soaps incorporate plant derived extracts, essential oils, and bioactive compounds to offer therapeutic benefits in addition to basic cleansing action. Such formulations harness the power of phytochemicals including polyphenols, flavonoids, terpenoids, and alkaloids that exhibit antioxidant, anti-inflammatory, antimicrobial, and skin-rejuvenating properties [3]. The use of medicinal plants in cosmetic preparations is well documented in Ayurvedic, Unani, and traditional medicine systems worldwide.

Tomato (*Solanum lycopersicum* L., family Solanaceae) is a rich source of lycopene, β -carotene, ascorbic acid, and tocopherol. Lycopene, a powerful antioxidant carotenoid, has demonstrated efficacy in protecting skin from UV induced oxidative damage, reducing melanin synthesis, and improving skin texture [4, 5]. Tomato extracts also possess antibacterial activity attributed to phenolic compounds such as chlorogenic acid and rutin [6]. Aloe vera (*Aloe barbadensis* Miller, family Asphodelaceae) is one of the most extensively researched medicinal plants for dermatological applications. Its gel contains acemannan, anthraquinones, vitamins (A, C, E, B12), amino acids, enzymes, and minerals that collectively exert moisturizing, wound healing, anti-inflammatory, and antimicrobial effects [7,8]. The high mucilage content forms a protective film on the skin, reducing transepidermal water loss and improving hydration. Turmeric (*Curcuma longa* L., family Zingiberaceae) contains curcumin as its principal bioactive constituent, which has been extensively studied for its potent anti-inflammatory, antioxidant, antibacterial, antifungal, and skin lightening activities [9, 10]. Curcumin inhibits melanin production by down regulating tyrosinase activity, making turmeric a sought after ingredient in skin care preparations aimed at managing hyperpigmentation and uneven skin tone [11].

The cold-process saponification method is widely employed in herbal soap preparation as it preserves the glycerin naturally produced during saponification and maintains the integrity of heat sensitive bioactive compounds [12]. Despite the increasing demand for herbal soaps, systematic scientific evaluation of formulations incorporating these three botanicals tomato, aloe vera, and turmeric in a single optimized product remains limited in the published literature. The present study was therefore undertaken to (i) Prepare herbal soap formulations at three concentration levels of tomato and turmeric extracts (ii) Evaluate the formulations for physicochemical, organoleptic, and functional parameters (iii) Assess antimicrobial efficacy against clinically relevant microorganisms (iv) Determine the safety of the formulations through skin patch testing.

2. MATERIALS AND METHODS

2.1. Collection and Authentication of Plant Material

Fresh ripe tomatoes (*Solanum lycopersicum* L.) were procured from a local certified organic farm in Solan. Aloe vera (*Aloe barbadensis* Miller) leaves were collected from the botanical garden of the Department of Pharmacy, LR Institute of Pharmacy, Solan. Turmeric rhizomes (*Curcuma longa* L.) were obtained from a approved herbal drug supplier.

2.2. Preparation of Plant Extracts

Tomato Extract: Fresh ripe tomatoes were washed thoroughly with distilled water, blanched at 85°C for 3 minutes, and pulped using a laboratory blender. The pulp was filtered through muslin cloth and centrifuged at 3000 rpm for 10 minutes. The supernatant was collected, lyophilized, and stored at 4°C until use. Lycopene content was determined spectrophotometrically at 503 nm and found to be 43.2 ± 2.1 $\mu\text{g/g}$ dry weight [4].

Aloe Vera Gel: Fresh aloe vera leaves were washed and the outer rind was removed with a sterile stainless steel knife. The clear inner gel was scooped, blended to a homogeneous consistency, centrifuged at 5000 rpm for 15 minutes to remove particulates, and used fresh for each batch of soap preparation.

Turmeric Extract: Dried turmeric rhizomes were powdered in a mechanical grinder and extracted with 70% ethanol using a Soxhlet apparatus at 60°C for 6 hours. The extract was filtered, concentrated under reduced pressure using a rotary evaporator, and the residual solvent removed under vacuum at 40°C. Curcumin content was determined by HPLC and expressed as $12.4 \pm 0.8\%$ w/w [11].

2.3. Preparation of Herbal Soap (Cold Process Method)

The soap was prepared by the cold process saponification method. Coconut oil, palm oil, and castor oil were weighed and mixed in a stainless steel vessel and gently heated to 40°C. Separately, sodium hydroxide (lye) was dissolved in distilled water (lye solution) and allowed to cool to approximately 40°C. The lye solution was slowly added to the oil blend with continuous stirring using a hand blender at low speed until light trace (a pudding like consistency) was achieved. At trace, tomato extract, aloe vera gel, and turmeric extract were incorporated in quantities corresponding to each formulation (Table 1). Glycerin and fragrance were added last. The soap batter was poured into silicone molds, covered, and allowed to saponify at room temperature for 48 hours. The soap bars were then unmolded, cut, and subjected to a 4 week cure at ambient temperature ($25 \pm 2^\circ\text{C}$, $45 \pm 5\%$ RH) before evaluation [12, 13].

Table 1: Formulation composition of herbal soap (F1, F2, and F3)

Ingredients	F1 (% w/w)	F2 (% w/w)	F3 (% w/w)	Role
Coconut oil	30	30	30	Base oil / emollient
Castor oil	10	10	10	Lathering agent
Palm oil	20	20	20	Hardening agent

Sodium hydroxide (NaOH)	12	12	12	Saponifying agent
Tomato extract	5	10	15	Antioxidant / skin brightening
Aloe vera gel	5	5	5	Moisturizer / soothing agent
Turmeric extract	1	2	3	Anti-inflammatory / antiseptic
Glycerin	5	5	5	Humectant
Distilled water	q.s.	q.s.	q.s.	Solvent
Rose fragrance (optional)	0.5	0.5	0.5	Fragrance

q.s. = quantity sufficient to 100% w/w; all extracts are dry weight equivalents

2.4. Physicochemical Evaluation

Organoleptic Properties: Colour, odour, texture, and surface appearance were assessed visually and by trained panel evaluation.

pH: A 1% w/v aqueous solution of each soap was prepared. pH was measured using a calibrated digital pH meter (Systronics, India) at room temperature. Measurements were taken in triplicate.

Moisture Content: Moisture content was determined by the gravimetric method. Accurately weighed soap samples (2 g) were dried in a hot air oven at 105°C until constant weight was achieved. Moisture % = [(initial weight – final weight) / initial weight] × 100 [14].

Total Fatty Matter (TFM): TFM was determined according to the method described in IS 2888:1993. Soap was dissolved in hot ethanol, acidified with hydrochloric acid, and the fatty acids extracted with petroleum ether. The solvent was evaporated and the residue weighed [14].

Foam Height and Stability: A 1% w/v soap solution (50 mL) was placed in a graduated cylinder, stoppered, and shaken vigorously for 1 minute (30 inversions). Foam height was measured immediately (t = 0) and after 5 minutes (t = 5 min). Foam stability was recorded as the time (minutes) for foam to collapse to half its original height [15].

Dirt Dispersion: A drop of standard carbon black dispersion was added to a soap solution. The dispersion pattern was observed and rated as Poor, Moderate, Good, Very Good, or Excellent by comparison with standard reference cards.

Saponification Value: Determined by the standard titrimetric method using alcoholic KOH, following AOAC Official Method 920.160.

Skin Irritation Test: A Draize patch test was performed on ten healthy human volunteers (aged 20–35 years) after obtaining written informed consent. Soap solution (2%, 0.1 mL) was applied on a patch (2 × 2 cm) on the inner forearm and occluded for 24 hours. Erythema, edema, and other reactions were scored according to the Draize scale [16].

2.5. Antimicrobial Activity

Antimicrobial activity was evaluated by the agar well diffusion method using Mueller-Hinton agar (bacteria) and Sabouraud Dextrose Agar (fungi). Test microorganisms *Staphylococcus aureus* (ATCC 25923), *Escherichia coli* (ATCC 25922), *Candida albicans* (ATCC 10231), and *Pseudomonas aeruginosa* (ATCC 27853) were obtained. A 10% w/v soap solution was used as the test solution. Wells (8 mm diameter) were bored in seeded agar plates, filled with 100 µL of test solution, and incubated at 37°C for 24 hours (bacteria) or 25°C for 48 hours (*C. albicans*). A commercially available antibacterial soap (Dettol® Original) served as positive control and distilled water as negative control. Zones of inhibition (ZOI) were measured in millimeters using a digital vernier calliper. All assays were performed in triplicate [17].

2.6. Statistical Analysis

Data are expressed as mean ± standard deviation (SD). One-way ANOVA followed by Tukey's post hoc test was used to compare means among formulations. A p-value < 0.05 was considered statistically significant. Statistical analysis was performed using GraphPad Prism 9.0 (GraphPad Software, USA).

3. RESULTS AND DISCUSSION

3.1. Organoleptic and Physicochemical Properties

All three herbal soap formulations were successfully prepared by the cold-process saponification method and demonstrated satisfactory organoleptic and physicochemical characteristics as summarized in Table 2. The soaps exhibited pleasant herbal odours and characteristic colour intensities that deepened with increasing concentrations of tomato and turmeric extracts, progressing from pale yellow (F1) to deep golden orange (F3). The progressive colour deepening is attributable to the cumulative contribution of lycopene (red orange pigment from tomato), β-carotene, and curcumin (yellow orange pigment from turmeric) [4, 9].

Table 2: Physicochemical evaluation parameters of herbal soap formulations

Parameter	F1	F2	F3	Standard Range
Appearance	Light yellow	Orange yellow	Deep orange	Uniform, appealing
Colour	Pale yellow	Golden	Deep golden	Uniform
Odour	Mild herbal	Mild herbal	Mild herbal	Pleasant
pH	9.2 ± 0.1	9.0 ± 0.1	8.9 ± 0.2	8.5–10.5
Moisture content (%)	12.4 ± 0.3	11.8 ± 0.2	11.2 ± 0.3	< 15%
Total fatty matter (%)	63.2 ± 0.5	64.1 ± 0.4	65.3 ± 0.6	≥ 60%
Foam height (cm)	8.5 ± 0.3	9.2 ± 0.2	9.8 ± 0.3	> 5 cm
Foam stability (min)	15 ± 1.0	17 ± 0.5	18 ± 0.8	> 10 min
Dirt dispersion	Good	Very Good	Excellent	Good to Excellent
Skin irritation	None	None	None	None
Hardness	Hard	Hard	Hard	Hard
Saponification value	182 ± 2	183 ± 2	184 ± 3	180–200

Values expressed as mean ± SD (n = 3); ZOI = zone of inhibition

pH

The pH values of F1, F2, and F3 were 9.2 ± 0.1, 9.0 ± 0.1, and 8.9 ± 0.2, respectively. All values fall within the acceptable pH range for toilet soaps (8.5–10.5) as per Bureau of Indian Standards (BIS) specifications [14]. Skin pH is normally slightly acidic (4.5–5.5); however, soap pH slightly above neutral is standard and does not compromise the soap's safety for normal skin. The slight decrease in pH with increasing herbal extract concentration is consistent with previous reports attributing the buffering capacity of organic acids present in tomato (ascorbic acid, citric acid) and turmeric extracts to moderating alkalinity [5,6]. This is advantageous as lower pH within the acceptable range minimizes the risk of skin irritation.

3.2. Moisture Content and Total Fatty Matter

Moisture content ranged from 12.4% (F1) to 11.2% (F3), all within the BIS permissible limit of less than 15% for milled toilet soaps [14]. Lower moisture content in F3 may be partly related to the higher dry extract concentration displacing water from the formulation matrix. Total fatty matter (TFM) values ranged from 63.2% to 65.3%, all exceeding the minimum requirement of 60% for Grade 2 toilet soaps. Higher TFM is associated with superior moisturizing ability and milder skin action, consistent with the oil composition (coconut, palm, and castor oils) selected for this study [12].

3.3. Foam Height and Stability

Foam generation and stability are critical consumer acceptance parameters for soap. F3 demonstrated the highest foam height (9.8 ± 0.3 cm) and foam stability (18 ± 0.8 min), significantly superior to F1 (8.5 cm; 15 min). Castor oil, a component of all formulations, is well known to produce creamy, stable lather owing to its high ricinolein content [12]. The saponins present in aloe vera are also reported to contribute to foam formation [7]. The incremental improvement in foam across formulations may reflect synergistic interactions between saponins from aloe vera and the polysaccharide matrix of aloe and tomato pectin stabilizing the foam bubbles [8, 15].

3.4. Dirt Dispersion

Dirt dispersion improved progressively from 'Good' (F1) to 'Excellent' (F3), indicating enhanced detergency with higher herbal extract concentration. This can be attributed to the amphiphilic nature of saponins and the surface active properties of organic acids in tomato and aloe vera, which aid in emulsifying and dispersing particulate dirt [7].

3.5. Antimicrobial Activity

The antimicrobial efficacy of the three formulations was evaluated against four clinically relevant microorganisms (Table 3). All formulations demonstrated dose dependent antimicrobial activity. F3 exhibited the largest zones of inhibition across all test organisms, significantly surpassing both F1 and the commercial positive control (Dettol® soap) in most cases.

Table 3: Antimicrobial activity zones of inhibition (mm) of herbal soap formulations

Microorganism	F1 (mm)	F2 (mm)	F3 (mm)	Standard soap (mm)
<i>Staphylococcus aureus</i>	12 ± 0.5	15 ± 0.4	18 ± 0.6	10 ± 0.3
<i>Escherichia coli</i>	11 ± 0.3	13 ± 0.5	16 ± 0.4	9 ± 0.2

<i>Candida albicans</i>	10 ± 0.4	12 ± 0.3	14 ± 0.5	8 ± 0.3
<i>Pseudomonas aeruginosa</i>	9 ± 0.3	11 ± 0.4	13 ± 0.3	8 ± 0.2

Values expressed as mean ± SD (n = 3); includes 8 mm well diameter

The antimicrobial activity of the formulations can be primarily attributed to curcumin in turmeric, which disrupts microbial cell membranes, inhibits cell division proteins (FtsZ), and generates reactive oxygen species [9,10]. Tomato extract contributes chlorogenic acid and other phenolics known to inhibit bacterial enzyme systems [6]. Aloe vera anthraquinones (aloin, barbaloin) exert direct bactericidal and fungicidal effects by intercalating with microbial DNA and disrupting membrane integrity [8]. The combined broad spectrum activity of these three botanicals indicates a synergistic antimicrobial mechanism, which is particularly advantageous against Gram-negative organisms such as *E. coli* and *P. aeruginosa*, which are inherently resistant to many antimicrobial agents due to their outer membrane permeability barrier [17].

3.6. Skin Irritation

None of the ten human volunteers exhibited any sign of primary skin irritation (erythema, edema, papules, or vesicles) at 24 hours or 72 hours post patch application for any of the three formulations (Draize score = 0). This confirms the dermal safety of the herbal soap preparations. The absence of irritation is consistent with the well documented skin soothing and anti-inflammatory effects of aloe vera acemannan and curcumin, and is attributed to the exclusion of synthetic preservatives, artificial fragrances, and sulfate surfactants from the formulations [8, 16].

3.7. Saponification Value

Saponification values (182–184 mg KOH/g) were within the standard range of 180–200, confirming complete saponification of the oil blend and absence of unsaponified matter that could lead to rancidity and product instability [14]. These values are consistent with the fatty acid composition of coconut oil (predominantly C12:0 lauric acid) and palm oil (C16:0 palmitic acid), which are known to saponify efficiently with NaOH.

Comparative Assessment and Optimal Formulation

Considering all evaluation parameters holistically, formulation F3 (containing 15% tomato extract, 5% aloe vera gel, and 3% turmeric extract) was identified as the optimal formulation. F3 demonstrated the most favourable pH (8.9), lowest moisture content (11.2%), highest TFM (65.3%), best foam performance, superior dirt dispersion, strongest antimicrobial activity, and full dermal compatibility. These findings align with prior investigations on herbal soaps incorporating individual or combinations of these botanicals [4, 8, 9,11] and demonstrate that combining three complementary plant extracts in a single matrix results in formulations with enhanced functional properties compared to mono herbal preparations. The present study provides quantitative scientific evidence for the preparation of a commercially viable herbal soap that integrates the antioxidant power of lycopene (tomato), the moisturizing and healing properties of aloe vera polysaccharides, and the antimicrobial and anti-inflammatory activity of curcumin. Such multi component herbal formulations are particularly relevant in the context of growing antimicrobial resistance and the global shift toward green and sustainable personal care products.

4. CONCLUSION

Three herbal soap formulations (F1, F2, and F3) were successfully fabricated using tomato extract, aloe vera gel, and turmeric extract by the cold-process saponification method. All formulations met the physicochemical and microbiological standards for toilet soaps. Formulation F3 (15% tomato, 5% aloe vera, 3% turmeric) was identified as the optimal formulation based on superior performance across all evaluation parameters including pH (8.9), TFM (65.3%), foam stability (18 min), and antimicrobial activity against both Gram-positive and Gram-negative bacteria and *Candida albicans*. Skin patch testing confirmed the safety and tolerability of all formulations. The synergistic combination of lycopene, acemannan, and curcumin confers multifunctional benefits encompassing antioxidant protection, deep moisturization, and broad-spectrum antimicrobial action. These herbal soaps represent a promising, eco-friendly, and evidence based alternative to conventional synthetic soaps. Future studies should investigate long term stability under accelerated and real time storage conditions, clinical evaluation of anti-acne and skin brightening efficacy, scale up feasibility, and potential incorporation of additional bioactive plant extracts to further broaden therapeutic activity.

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