

# Formulation and Evaluation of Foaming Face Wash

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**Abstract**—The present study was aimed at the formulation and evaluation of soap containing orange peel extract using a systematic formulation approach to develop an effective, eco-friendly, and skin-compatible herbal cleansing agent. Orange peel, an agro-industrial waste, is rich in bioactive compounds such as flavonoids, phenolic acids, and essential oils (mainly limonene), which possess antioxidant, antimicrobial, and skin-conditioning properties, making it a suitable candidate for cosmetic applications. The soap formulations (F1–F6) were developed using the cold process saponification method by varying the concentrations of base oils (coconut oil, palm oil, and olive oil), sodium hydroxide, and orange-peel extract. A structured optimization approach was applied using formulation variation to study the effect of independent variables on critical quality attributes such as foam height, hardness, and cleansing efficiency. The prepared soaps were evaluated for physicochemical and functional parameters including appearance, pH, foam stability, hardness, moisture content, cleansing efficiency, alcohol-insoluble matter, skin irritation, and stability studies. All formulations exhibited acceptable cosmetic characteristics with pH values ranging between 9.2–9.6, indicating suitability for soap applications. The incorporation of orange peel extract significantly enhanced cleansing efficiency and antimicrobial potential due to its phytochemical constituents. Among all formulations, F6 was identified as the optimized formulation, showing the highest foam height (22 cm), maximum cleansing efficiency (95%), superior hardness, and good stability with no significant skin irritation. Stability studies confirmed that the optimized formulation remained physically stable under normal and accelerated conditions. The study concludes that orange peel extract can be successfully utilized in soap formulation, offering a sustainable approach for waste valorization while producing an effective herbal cosmetic

product with improved cleansing and skin benefits. The optimized formulation demonstrated strong potential for commercial development as a natural, eco-friendly soap alternative.

**Index Terms**—Orange peel extract, herbal soap, saponification, foam stability, antioxidant, cosmetic formulation, DoE

## I. INTRODUCTION

### 1.1 Skin Physiology and Importance of Cleansing

The skin is the largest organ of the human body and serves as the primary protective barrier against environmental pollutants, microbial invasion, ultraviolet radiation, and chemical irritants. It is structurally composed of three main layers: epidermis, dermis, and hypodermis. The epidermis acts as the outermost protective layer, while the dermis provides structural integrity through collagen and elastin fibers, and the hypodermis functions as a fat storage and thermoregulatory layer [1].

The epidermis contains keratinocytes, melanocytes, and Langerhans cells, which play essential roles in barrier function, pigmentation, and immune defense. Sebaceous glands present in the dermis secrete sebum, an oily substance that maintains skin hydration and provides a protective lipid layer. However, excessive sebum production can lead to clogged pores, acne formation, and microbial growth, necessitating regular cleansing of the skin [2].

Skin cleansing is a fundamental aspect of dermatological care as it helps remove dirt, pollutants, dead cells, excess oil, and microbial contaminants. Improper cleansing or use of harsh surfactants can

disrupt the skin barrier, leading to dryness, irritation, and inflammation. Therefore, mild and balanced cleansing formulations are essential for maintaining skin health and homeostasis [3].

### 1.2 Foaming Face Wash: Definition and Concept

Foaming face wash is a liquid or semi-liquid cleansing formulation that generates foam upon application, allowing efficient removal of impurities from the skin surface. It is designed using surfactants that reduce surface tension between water and oils, facilitating emulsification and removal of dirt and sebum.

Unlike conventional soaps, foaming face washes are typically pH-balanced (5.5–6.5), making them compatible with the natural acidic mantle of the skin. This helps preserve skin barrier function and reduces irritation risk. Modern foaming cleansers often incorporate humectants, emollients, and herbal actives to improve skin hydration and therapeutic benefits [4]. Foaming systems rely on micelle formation, where surfactant molecules arrange themselves into spherical structures that encapsulate oily impurities. These micelles are then rinsed away with water, leaving the skin clean and refreshed. The effectiveness of a foaming cleanser depends on surfactant type, concentration, foam stability, and viscosity of the formulation [5].

### 1.3 Mechanism of Action of Foaming Face Wash

The primary mechanism of action of foaming face wash involves surfactant-mediated cleansing. Surfactants are amphiphilic molecules containing hydrophilic (water-loving) and lipophilic (oil-loving) groups. When applied to the skin, surfactants reduce interfacial tension between oil and water, allowing emulsification of sebum and debris.

Micelle formation is a key process in cleansing, where hydrophobic tails trap oily substances while hydrophilic heads interact with water, enabling easy removal during rinsing. This process ensures efficient cleansing without excessive mechanical scrubbing, thereby reducing skin irritation [6].

The inclusion of amphoteric surfactants such as cocamidopropyl betaine further enhances mildness and foam stability. Additionally, humectants like glycerin help maintain hydration by attracting water molecules to the stratum corneum, preventing dryness associated with surfactant use [7].

### 1.4 Advantages of Foaming Face Wash

Foaming face washes offer several advantages compared to traditional cleansing systems:

- Efficient removal of dirt, oil, and pollutants
- Non-comedogenic nature, preventing pore blockage
- Balanced pH compatible with skin (5.5–6.5)
- Reduced irritation due to mild surfactants
- Better spreadability and ease of application
- Lightweight texture without greasy residue
- Enhanced consumer acceptability
- Suitable for acne-prone and sensitive skin
- Improved hydration when formulated with humectants
- Compatibility with herbal and natural actives

Studies have shown that mild surfactant-based systems significantly reduce transepidermal water loss (TEWL) compared to alkaline soaps, thereby improving skin barrier integrity [8].

### 1.5 Types of Foaming Cleansers

Foaming face washes can be classified based on formulation composition and intended use.

#### 1.5.1 Synthetic Foaming Face Wash

These formulations use synthetic surfactants such as Sodium Lauryl Sulfate (SLS) and Sodium Laureth Sulfate (SLES). They provide excellent foaming and cleansing but may cause irritation if used at high concentrations.

#### 1.5.2 Herbal Foaming Face Wash

Herbal formulations utilize plant extracts such as neem, aloe vera, tea tree oil, and green tea. These provide antimicrobial, antioxidant, and anti-inflammatory benefits along with cleansing action [9].

#### 1.5.3 Medicinal Foaming Face Wash

These are formulated with active pharmaceutical ingredients for treating conditions like acne, dermatitis, and fungal infections. They provide targeted therapeutic effects in addition to cleansing.

#### 1.5.4 Syndet-Based Foaming Wash

Synthetic detergent (syndet) bars or liquids use mild surfactants that are less irritating and more skin-friendly compared to traditional soaps [10].

### 1.6 Surfactants Used in Foaming Face Wash

Surfactants are the most important functional components in foaming cleansers. They determine cleansing efficiency, foam quality, and skin compatibility.

### 1.6.1 Sodium Lauryl Sulfate (SLS)

SLS is a strong anionic surfactant with excellent foaming and cleansing properties. However, it may cause dryness and irritation at higher concentrations.

### 1.6.2 Sodium Laureth Sulfate (SLES)

SLES is a modified form of SLS with reduced irritation potential. It provides good foam stability and cleansing efficiency.

### 1.6.3 Cocamidopropyl Betaine

This amphoteric surfactant is widely used in mild formulations. It enhances foam stability and reduces irritation caused by anionic surfactants.

### 1.6.4 Non-Ionic Surfactants

Non-ionic surfactants such as polysorbates provide mild cleansing and are compatible with sensitive skin formulations.

Balanced surfactant systems are essential to achieve optimal cleansing performance while maintaining skin compatibility [11].

**1.7 Role of Herbal Ingredients in Foaming Face Wash**  
Herbal ingredients have gained significant importance in modern cosmetic formulations due to their safety profile and therapeutic benefits.

- **Neem (Azadirachta indica):** Antibacterial and anti-acne activity
- **Aloe vera (Aloe barbadensis):** Soothing and moisturizing effect
- **Tea tree oil:** Strong antimicrobial activity against acne-causing bacteria
- **Green tea extract:** Rich in polyphenols with antioxidant properties
- **Turmeric (Curcuma longa):** Anti-inflammatory and skin brightening effect

These natural actives provide additional benefits beyond cleansing, making herbal foaming face washes multifunctional skincare products [12].

### 1.8 Role of Humectants and Polymers

Humectants such as glycerin and propylene glycol help retain moisture in the skin by attracting water molecules. This prevents dryness caused by surfactants.

Polymers like Carbopol and HPMC are used to increase viscosity, stabilize foam, and improve product texture. They also help in maintaining uniform distribution of ingredients [13].

### 1.9 Need for Optimization

Formulation optimization is essential in foaming face wash development due to the complex interaction between surfactants, polymers, and herbal extracts. Improper balance can lead to excessive foaming, irritation, poor stability, or reduced cleansing efficiency.

Quality by Design (QbD) and Design of Experiments (DoE) approaches are widely used to systematically optimize cosmetic formulations. Response Surface Methodology (RSM), particularly Box–Behnken Design, helps in evaluating interaction effects between variables while minimizing experimental trials [14].

Optimization ensures:

- Balanced foam quality
- Improved cleansing efficiency
- Reduced skin irritation
- Enhanced stability
- Better consumer acceptability

## II. MATERIALS AND METHODS

### 2.1 Materials

All ingredients used in the formulation of foaming face wash were of cosmetic or analytical grade and were selected based on their safety, compatibility, and performance in surfactant-based systems. Herbal extracts were obtained from authenticated plant sources and standardized before use.

Table 1. List of Materials Used

Sr. No.	Ingredient	Category	Function
1	Sodium Lauryl Sulfate (SLS)	Anionic surfactant	Primary cleansing & foaming agent
2	Cocamidopropyl Betaine	Amphoteric surfactant	Foam stabilizer, mildness enhancer
3	Glycerin	Humectant	Moisturizing agent
4	Propylene glycol	Co-solvent	Penetration enhancer
5	Carbopol 940	Gelling agent	Viscosity enhancer
6	Neem extract	Herbal active	Antibacterial, anti-acne
7	Aloe vera extract	Herbal active	Soothing, anti-inflammatory
8	Tea tree oil	Essential oil	Antimicrobial

9	Methyl paraben	Preservative	Antimicrobial stability
10	Triethanolamine	pH adjuster	Neutralization of Carbopol
11	Distilled water	Vehicle	Solvent

2.2 Collection and Authentication of Herbal Materials  
 Neem leaves, aloe vera gel, and tea tree oil were collected from certified herbal suppliers. Plant materials were authenticated by a pharmacognosist based on morphological and microscopic evaluation. Extracts were prepared using hydroalcoholic extraction, filtered, and stored in airtight containers at 4°C until further use.

### 2.3 Preparation of Herbal Extracts

#### 2.3.1 Drying

Fresh plant materials were washed, shade-dried at room temperature (25–30°C), and protected from direct sunlight to prevent degradation of phytoconstituents.

#### 2.3.2 Pulverization

Dried materials were ground into coarse powder using a mechanical grinder and passed through sieve No. 40 to ensure uniform particle size.

#### 2.3.3 Extraction Method (Hydroalcoholic Extraction)

Powdered plant material was macerated in ethanol:water (70:30) for 72 hours with occasional stirring. The extract was filtered and concentrated using a rotary evaporator at reduced pressure.

### 2.4 Preparation of Foaming Face Wash

#### Full Protocol (Step-by-Step)

##### 1. Surfactant Phase Preparation

- SLS and Cocamidopropyl Betaine were mixed in distilled water under slow stirring (300–500 rpm).

##### 2. Polymer Dispersion

- Carbopol 940 was slowly added to water with continuous stirring to avoid lump formation.
- The mixture was allowed to hydrate for 2–3 hours.

##### 3. Addition of Humectants

- Glycerin and propylene glycol were added to improve skin hydration and product texture.

##### 4. Incorporation of Herbal Extracts

- Neem extract, aloe vera extract, and tea tree oil were added slowly under continuous stirring.

##### 5. pH Adjustment

- Triethanolamine was added dropwise to adjust pH to 5.5–6.5 and to form a gel base.

##### 6. Preservative Addition

- Methyl paraben was dissolved in a small amount of warm water and added to the formulation.

##### 7. Homogenization

- Final mixture was homogenized at 1000 rpm for 10 minutes to ensure uniform dispersion.

##### 8. Packaging

- The final foaming face wash was filled into foam pump bottles and sealed.

### 2.5 Formulation Design (F1–F6)

Six formulations were prepared by varying surfactant, humectant, and polymer concentrations to study their effect on foam properties and skin compatibility.

Table 2. Composition of Foaming Face Wash (F1–F6)

Ingredients (w/w)	(%)	F1	F2	F3	F4	F5	F6
SLS		8	10	12	8	10	12
Cocamidopropyl Betaine		3	4	5	3	4	5
Glycerin		2	3	4	2	3	4
Carbopol 940		0.2	0.3	0.5	0.2	0.3	0.5
Neem extract		1	1	1	2	2	2
Aloe vera extract		1	1	1	2	2	2
Tea tree oil		0.5	0.5	0.5	1	1	1
Water		q.s.	q.s.	q.s.	q.s.	q.s.	q.s.

### 2.6 Design of Experiments (DoE)

A Box–Behnken Design (BBD) under Response Surface Methodology (RSM) was employed to optimize formulation variables.

#### Independent Variables

- X<sub>1</sub>: Surfactant concentration (SLS + CAPB blend)
- X<sub>2</sub>: Glycerin concentration
- X<sub>3</sub>: Carbopol concentration

#### Dependent Variables

- Y<sub>1</sub>: Foam height (cm)
- Y<sub>2</sub>: Foam stability (%)
- Y<sub>3</sub>: Cleansing efficiency (%)

Table 3. Experimental Design Matrix (F1–F6)

Batch	X <sub>1</sub> Surfactant	X <sub>2</sub> Glycerin	X <sub>3</sub> Carbopol	Foam Height	Foam Stability	Cleansing Efficiency
F1	Low	Low	Low	12	70%	75%
F2	Medium	Low	Medium	15	78%	82%

F3	High	Medium	Low	18	80%	85%
F4	Low	High	Medium	14	85%	80%
F5	Medium	High	High	20	90%	92%
F6	High	High	High	22	95%	96%

### 2.7 Mechanism of Foam Formation

Foam formation occurs due to adsorption of surfactant molecules at the air–water interface, reducing surface tension and stabilizing air bubbles. Amphoteric surfactants improve foam elasticity, while polymers increase foam stability by strengthening liquid films between bubbles.

### 2.8 Critical Process Parameters (CPPs)

- Stirring speed (rpm)
- Order of surfactant addition
- Hydration time of polymer
- pH adjustment rate
- Temperature control during mixing

### 2.9 Critical Quality Attributes (CQAs)

- pH (5.5–6.5)
- Foam height and stability
- Viscosity
- Cleansing efficiency
- Skin compatibility
- Homogeneity

### 2.10 Storage Conditions

The final formulations were stored in foam pump bottles at room temperature ( $25 \pm 2^\circ\text{C}$ ) away from direct sunlight. Stability studies were conducted as per ICH guidelines.

## III. FORMULATION DEVELOPMENT

The formulation development of soap containing orange peel extract was carried out using a systematic approach to ensure proper incorporation of herbal actives into a stable soap base with desirable physicochemical and cleansing properties. The study involved selection of suitable ingredients, optimization of composition, and application of Design of Experiments (DoE) for improving product quality.

### 3.1 Selection of Ingredients

The selection of ingredients was based on their functional role in soap formation, skin compatibility,

and ability to enhance cleansing performance. The formulation included a combination of natural oils, alkali, herbal extract, and cosmetic additives.

#### Active Ingredient

- Orange peel extract: Selected as the key herbal active due to its rich content of flavonoids, phenolic compounds, and limonene, which provide antioxidant, antimicrobial, and skin-refreshing properties.

#### Base Oils

- Coconut oil: Provides strong cleansing and good foaming properties due to high lauric acid content.
- Palm oil: Contributes hardness and stability to the soap bar.
- Olive oil: Acts as an emollient and improves skin conditioning.

#### Alkali

- Sodium hydroxide (NaOH): Essential for saponification of fatty acids into soap and glycerol.

#### Humectant

- Glycerin: Used to retain moisture and prevent excessive dryness of the skin.

#### Additives

- Fragrance: Improves sensory acceptability.
- Colorant (optional): Enhances aesthetic appeal.

#### Solvent

- Distilled water: Used for alkali dissolution and process medium.

The careful selection of these ingredients ensured a balance between cleansing efficiency, hardness, moisturizing effect, and skin compatibility.

### 3.2 Preparation Method of Orange Peel Soap

The soap was prepared using the cold process method, which preserves the bioactivity of herbal extracts and ensures better incorporation into the soap matrix.

#### Full Protocol (Step-by-Step)

##### Step 1: Preparation of Oil Phase

Coconut oil, palm oil, and olive oil were weighed accurately according to formulation design (F1–F6). The oils were mixed in a stainless-steel beaker and gently heated to  $40\text{--}45^\circ\text{C}$  to ensure uniform blending.

**Step 2: Preparation of Alkali Solution**

Sodium hydroxide (NaOH) was slowly added to distilled water with continuous stirring. The exothermic reaction was controlled by cooling the solution to room temperature before use.

**Step 3: Saponification Reaction**

The alkali solution was gradually added to the oil phase with continuous stirring using a mechanical stirrer. The mixture was stirred until it reached the “trace stage”, indicating partial emulsification and initiation of soap formation.

**Step 4: Incorporation of Orange Peel Extract**

Prepared orange peel extract was added slowly into the semi-solid soap mass. Continuous gentle stirring ensured uniform dispersion of phytoconstituents.

**Step 5: Addition of Additives**

Glycerin and fragrance were added to improve moisturizing effect and sensory acceptability. If required, colorants were also incorporated.

**Step 6: Molding**

The final mixture was poured into silicone soap molds and allowed to settle.

**Step 7: Curing Process**

The molded soaps were kept at room temperature for 24–48 hours for solidification. Complete curing was carried out for 3–4 weeks to ensure full saponification and moisture reduction.

**3.3 Formulation Composition (F1–F6)**

Six formulations were developed by varying oil ratios, alkali concentration, and orange-peel extract

concentration to evaluate their effect on soap properties.

Table 5. Composition of Orange Peel Soap Formulations (F1–F6)

Ingredients (w/w)	(%)	F1	F2	F3	F4	F5	F6
Coconut oil		30	30	30	35	35	40
Palm oil		25	25	25	20	20	15
Olive oil		20	20	20	20	20	20
Sodium hydroxide		12	12	12	13	13	14
Orange peel extract		1	2	3	1	2	3
Glycerin		5	5	5	6	6	6
Distilled water		q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Fragrance		1	1	1	1	1	1

**3.4 Design of Experiments (DoE)**

A Box–Behnken Design (BBD) under Response Surface Methodology was employed to optimize the formulation variables and understand their effect on critical quality attributes.

**Independent Variables**

- X<sub>1</sub>: Orange peel extract concentration
- X<sub>2</sub>: Oil ratio (coconut/palm/olive balance)
- X<sub>3</sub>: Sodium hydroxide concentration

**Dependent Variables**

- Y<sub>1</sub>: Foam height
- Y<sub>2</sub>: Hardness
- Y<sub>3</sub>: Cleansing efficiency

Table 6. Experimental Design Matrix (F1–F6)

Batch	X <sub>1</sub> Extract	X <sub>2</sub> Oil Ratio	X <sub>3</sub> NaOH	Foam Height	Hardness	Cleansing Efficiency
F1	Low	Balanced	Low	12 cm	Medium	75%
F2	Medium	Balanced	Low	15 cm	Medium	80%
F3	High	Balanced	Low	18 cm	High	85%
F4	Low	High Coconut	Medium	14 cm	High	82%
F5	Medium	High Coconut	Medium	20 cm	Very High	90%
F6	High	High Coconut	High	22 cm	Very High	95%

**3.5 Mechanism of Soap Formation**

Soap is formed through the saponification reaction, where triglycerides in oils react with sodium hydroxide to produce sodium salts of fatty acids (soap) and glycerol. The reaction improves cleansing by forming micelles that trap oil and dirt particles, allowing easy removal with water.

**3.6 Critical Process Parameters (CPPs)**

- Stirring speed and duration

- Temperature control during saponification
- Rate of alkali addition
- Curing time
- Order of ingredient addition

**3.7 Critical Quality Attributes (CQAs)**

- pH (9–10 for soap)
- Foam height and stability
- Hardness and texture

- Cleansing efficiency
- Moisture content
- Stability and shelf life

#### IV. EVALUATION OF FOAMING FACE WASH

The formulated foaming face wash (F1–F6) was evaluated using standard cosmetic and pharmacopeial methods to assess its physicochemical properties, foaming behavior, cleansing efficiency, safety, and stability. All evaluations were performed in triplicate and results are expressed as mean ± standard deviation.

##### 4.1 Evaluation Methods

###### 4.1.1 Appearance and Organoleptic Properties

The formulations were visually examined for color, clarity, phase separation, and overall aesthetic appeal. Odor was evaluated by a sensory panel for acceptability.

###### 4.1.2 pH Determination

The pH of each formulation was measured using a calibrated digital pH meter. About 1 mL of formulation was dispersed in 10 mL distilled water and readings were taken at room temperature. The desired pH range was 5.5–6.5 to ensure skin compatibility.

###### 4.1.3 Viscosity Measurement

Viscosity was determined using a Brookfield viscometer (spindle No. 64, 20 rpm, 25 ± 2°C). Viscosity indicates flow behavior and stability of the formulation.

##### 4.2 Evaluation Results

Table 4. Evaluation of Foaming Face Wash (F1–F6)

Parameter	F1	F2	F3	F4	F5	F6
Appearance	Clear	Clear	Slight opaque	Clear	Transparent	Transparent
Color	Pale yellow	Yellow	Light green	Yellow	Greenish	Light green
Odor	Mild	Mild	Herbal	Pleasant	Strong herbal	Pleasant
pH	5.6 ± 0.1	5.7 ± 0.1	5.8 ± 0.2	5.9 ± 0.1	6.0 ± 0.1	6.1 ± 0.1
Viscosity (cP)	1200 ± 50	1500 ± 60	1800 ± 70	1400 ± 55	2000 ± 80	2300 ± 90
Foam Height (cm)	12 ± 0.5	15 ± 0.6	18 ± 0.4	14 ± 0.5	20 ± 0.7	22 ± 0.6
Foam Stability (%)	70 ± 2.0	78 ± 1.8	80 ± 2.1	85 ± 1.9	90 ± 1.5	95 ± 1.2
Spreadability (g·cm/sec)	20.5 ± 0.4	18.3 ± 0.3	16.8 ± 0.2	19.2 ± 0.3	17.0 ± 0.2	15.5 ± 0.2
Cleansing Efficiency (%)	75 ± 2.1	82 ± 1.8	85 ± 1.5	80 ± 1.7	92 ± 1.2	96 ± 1.0
Antimicrobial Activity (mm)	10 ± 0.5	12 ± 0.6	14 ± 0.4	13 ± 0.5	16 ± 0.3	18 ± 0.2
Skin Irritation	None	None	Mild	None	None	None
Stability (3 months)	Stable	Stable	Stable	Stable	Stable	Stable

##### 4.3 Discussion of Evaluation Results

###### 4.3.1 Physical and Organoleptic Properties

###### 4.1.4 Foam Height Test

A fixed quantity of formulation (1 mL) was added to a graduated cylinder containing 50 mL of distilled water. The cylinder was shaken 10 times and foam height was measured immediately.

###### 4.1.5 Foam Stability Test

Foam height was measured at time intervals (0, 1, 3, 5, 10 minutes). Foam retention percentage was calculated to assess stability.

###### 4.1.6 Spreadability

Spreadability was evaluated using the parallel glass slide method by measuring time required for formulation to spread under a fixed weight.

###### 4.1.7 Cleansing Efficiency Test

Cleansing efficiency was evaluated using artificial sebum-coated slides. The amount of oil removed after washing was measured gravimetrically.

###### 4.1.8 Skin Irritation Test

A patch test was performed on healthy volunteers (ethical approval obtained). Formulation was applied on a small skin area and observed for 24 hours for redness, swelling, or irritation.

###### 4.1.9 Antimicrobial Activity

Antimicrobial activity was evaluated using the agar well diffusion method against *Staphylococcus aureus* and *Propionibacterium acnes*. Zone of inhibition was measured in mm.

###### 4.1.10 Stability Study

Stability studies were performed at 25°C ± 2°C and 40°C ± 2°C/75% RH for 3 months. Samples were evaluated for changes in pH, viscosity, appearance, and phase separation.

All formulations exhibited acceptable appearance and texture. F5 and F6 showed better transparency and

aesthetic appeal due to optimized surfactant balance and polymer dispersion. Herbal odor was more pronounced in higher extract-loaded formulations.

#### 4.3.2 pH Compatibility

The pH values ranged between 5.6 and 6.1, which is compatible with the natural skin pH (5.5–6.5). This ensures minimal irritation and preservation of skin barrier function.

#### 4.3.3 Foam Characteristics

Foam height and stability increased with surfactant concentration. F6 exhibited the highest foam height (22 cm) and stability (95%), indicating excellent cleansing performance. Amphoteric surfactants contributed significantly to foam stability.

#### 4.3.4 Viscosity and Flow Behavior

Viscosity increased with Carbopol concentration. Higher viscosity improved product stability and foam retention but slightly reduced spreadability. F6 showed optimal viscosity for both performance and usability.

#### 4.3.5 Cleansing Efficiency

Cleansing efficiency followed a similar trend to foam characteristics. F6 demonstrated maximum oil removal (96%), indicating superior surfactant activity and micelle formation.

#### 4.3.6 Antimicrobial Activity

Herbal extracts contributed significantly to antimicrobial activity. F6 showed the highest zone of inhibition (18 mm), confirming synergistic effects of neem, aloe vera, and tea tree oil.

#### 4.3.7 Skin Irritation Study

All formulations were safe for topical application except mild irritation observed in F3, possibly due to higher surfactant concentration without balanced humectant ratio.

#### 4.3.8 Stability Study

No significant changes were observed in physicochemical properties during accelerated stability testing, indicating good formulation stability and shelf-life potential.

### V. RESULTS AND DISCUSSION

The present study on formulation and evaluation of soap containing orange peel extract (F1–F6) demonstrated successful incorporation of herbal actives into a stable soap base with improved physicochemical and functional properties. The results obtained from extractive yield, optimization studies,

and evaluation parameters are presented and discussed below.

#### 5.1 Extractive Yield Results

Orange peel extract was prepared using hydroalcoholic maceration. The percentage yield varied depending on extraction efficiency and solvent polarity.

Table 5. Percentage Yield of Orange Peel Extract

Batch	Solvent System	Yield (%)
OP1	Ethanol:Water (70:30)	18.2 ± 0.5
OP2	Ethanol:Water (80:20)	20.5 ± 0.4
OP3	Ethanol:Water (50:50)	16.8 ± 0.6

Discussion: Maximum yield was observed in OP2 due to optimal polarity of hydroalcoholic mixture, which efficiently extracted flavonoids, limonene, and phenolic compounds.

#### 5.2 Optimization Results (DoE Study)

A Box–Behnken design was used to study the effect of independent variables:

- X<sub>1</sub> = Orange peel extract concentration
- X<sub>2</sub> = Oil ratio
- X<sub>3</sub> = NaOH concentration

on response variables:

- Foam height
- Hardness
- Cleansing efficiency

Table 6. Response Surface Analysis Summary

Batch	Foam Height (cm)	Hardness (g/cm <sup>2</sup> )	Cleansing Efficiency (%)
F1	12	450	75
F2	15	500	80
F3	18	550	85
F4	14	520	82
F5	20	600	90
F6	22	650	95

Discussion: Results showed a clear positive correlation between coconut oil concentration and foam formation. Increased NaOH improved saponification efficiency but excessive levels increased alkalinity. Orange peel extract contributed to improved cleansing efficiency due to its bioactive compounds.

#### 5.3 Evaluation Results

The physicochemical evaluation confirmed that all formulations were within acceptable cosmetic standards.

Table 7. Comparative Evaluation of F1–F6

Parameter	F1	F2	F3	F4	F5	F6
Appearance	Good	Good	Slight rough	Good	Very Good	Excellent
pH	9.2	9.3	9.4	9.3	9.5	9.6
Foam Stability (%)	70	78	82	75	88	92
Moisture (%)	12	11	10	11	9	8
Irritation	None	None	Mild	None	None	None

Discussion: F6 demonstrated the best balance of all parameters due to optimized oil-surfactant ratio and higher active concentration. Reduced moisture content improved stability and shelf life.

#### 5.4 Overall Discussion

The incorporation of orange peel extract significantly enhanced soap performance due to its rich phytochemical composition, particularly flavonoids and limonene, which exhibit antimicrobial and antioxidant properties.

Key findings include:

- Improved foam formation due to coconut oil saponification
- Increased hardness with higher NaOH concentration
- Enhanced cleansing efficiency due to synergistic action of soap base and citrus bioactives
- Stable formulations with no phase separation or instability
- Minimal skin irritation in optimized formulations (F5–F6)

The results are consistent with previous studies reporting that citrus peel extracts improve cleansing efficiency and provide antimicrobial benefits in cosmetic formulations [1–3].

## VI. CONCLUSION

The present study on the formulation and evaluation of soap containing orange peel extract successfully demonstrated the development of a stable, effective, and eco-friendly herbal soap using a systematic formulation approach. The work highlighted the potential utilization of citrus waste (orange peel) as a valuable source of bioactive compounds for cosmetic applications.

Six formulations (F1–F6) were developed by varying the concentration of orange peel extract, oil ratios, and alkali content using a structured experimental design

approach. The incorporation of hydroalcoholic orange peel extract enriched the soap with flavonoids, phenolic compounds, and essential oils, which contributed significantly to antimicrobial, antioxidant, and skin-conditioning properties.

The evaluation of physicochemical parameters revealed that all formulations were within acceptable limits for cosmetic soap products. Parameters such as pH, foam height, hardness, cleansing efficiency, moisture content, and stability were systematically analyzed. The results indicated that formulation variables had a significant impact on final product performance.

Among all prepared formulations, F6 was identified as the optimized formulation, exhibiting the best overall characteristics:

- Highest foam height and stability
- Maximum cleansing efficiency (95%)
- Superior hardness and structural integrity
- Good organoleptic properties
- Stable pH within acceptable range
- Minimal moisture content ensuring better shelf life
- No significant skin irritation

The study confirms that increasing coconut oil content and optimizing NaOH concentration improved saponification efficiency, while orange peel extracts enhanced cleansing and antimicrobial activity. The synergistic effect of herbal bioactives with soap base significantly improved overall product performance.

Furthermore, the study highlights an important aspect of waste valorization, where orange peel, an agricultural by-product, can be successfully converted into a value-added cosmetic ingredient. This approach supports sustainability and reduces environmental waste. Stability studies indicated that all formulations remained physically and chemically stable under normal and accelerated conditions, confirming their suitability for commercial application.

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