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Triple-Action Anti-Acne Serum: Formulation and Evaluation of Salicylic Acid, Nicotinamide, and Centella asiatica for Enhanced Acne Therapy

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ABSTRACT

Acne vulgaris is one of the most common chronic inflammatory skin disorders affecting adolescents and adults. Excess sebum production, follicular hyperkeratinization, bacterial growth, and inflammation are major causes of acne formation. Salicylic acid and nicotinamide are widely used topical anti-acne agents due to their keratolytic, anti-inflammatory, and sebum-regulating activities. Salicylic acid helps in exfoliation and unclogging of pores, while nicotinamide reduces inflammation and improves skin barrier function. This research paper focuses on the formulation and evaluation of a salicylic acid–nicotinamide serum intended for acne treatment. The serum was prepared using suitable excipients and evaluated for physicochemical parameters such as appearance, pH, viscosity, spreadability, homogeneity, stability, irritation test, and antimicrobial activity. The prepared serum showed good stability, acceptable pH, smooth texture, and effective anti-acne potential. The study concludes that the formulated serum can be used as a safe and effective topical treatment for acne vulgaris.

Keywords: appearance, pH, viscosity, spreadability, homogeneity, stability, irritation test, and antimicrobial activity.

INTRODUCTION

Acne vulgaris is a chronic inflammatory disease of pilosebaceous follicles characterized by blackheads, whiteheads, papules, pustules, nodules, and cysts. Acne mainly affects the face, chest, shoulders, and back because these regions contain a high number of sebaceous glands. Hormonal imbalance, bacterial infection, stress, cosmetics, and genetic factors contribute to acne development. Topical therapy remains the first-line treatment for mild to moderate acne. Salicylic acid is a beta hydroxy acid with comedolytic and keratolytic properties. It penetrates deeply into pores and removes dead skin cells and excess sebum. Nicotinamide (niacinamide), a form of vitamin B3, possesses anti-inflammatory and antioxidant properties and helps reduce redness, hyperpigmentation, and irritation associated with acne.

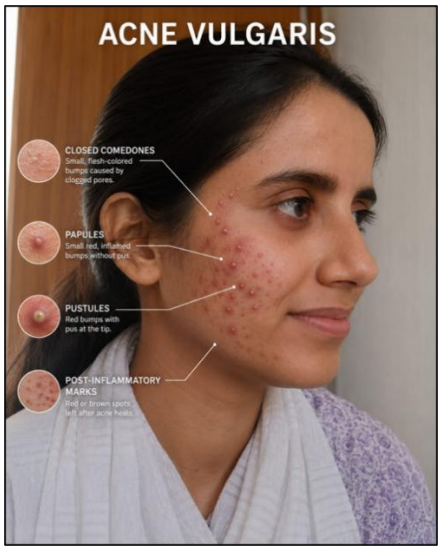


Figure: 1 Acne Vulgaris

Recent dermatological studies indicate that salicylic acid and nicotinamide combinations can improve

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acne lesions effectively while maintaining skin hydration and barrier function.

Objectives

1. To prepare a stable anti-acne serum formulation.
2. To evaluate physicochemical properties of the serum.
3. To study the effectiveness of salicylic acid and nicotinamide against acne.
4. To assess stability and skin compatibility of the prepared serum.

Types of Acne Lesions

1. Blackheads (Open Comedones)

- Small dark or black spots on the skin surface.
- Occur when pores become clogged with excess sebum and dead skin cells.
- The dark color is due to oxidation of trapped material when exposed to air.
- Commonly found on the nose, forehead, and chin.

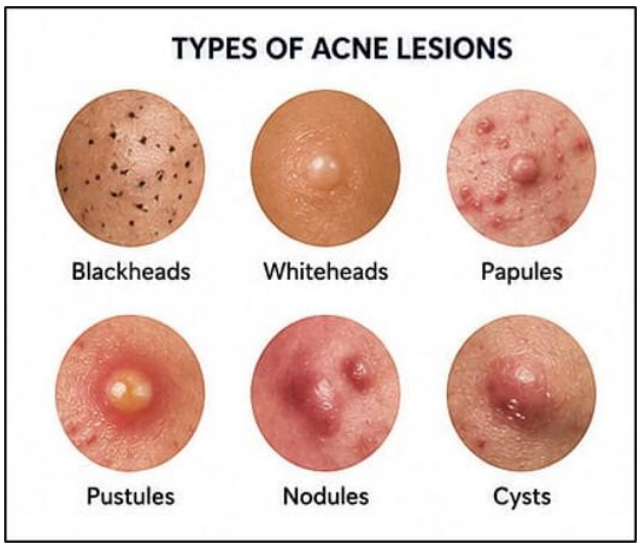


Figure: 2 Types of Acne Lesions

2. Whiteheads (Closed Comedones)

- Small white or flesh-colored bumps.
- Form when clogged pores remain

closed at the skin surface.

- Less inflamed than other acne lesions.
- Often appear on the face, chest, and back.

3. Papules

- Small, raised, red, inflamed bumps.
- Develop when the wall of a clogged follicle breaks down.
- Usually tender to touch.

Do not contain visible pus.

4. Pustules

- Red, inflamed bumps filled with pus.
- Characterized by a white or yellow center surrounded by redness.
- Result from bacterial growth and inflammation within the follicle.
- Commonly known as "pimples."

5. Nodules

- Large, hard, painful lumps located deep within the skin.
- Caused by severe inflammation and blockage of hair follicles.

- Can persist for weeks or months.
- Frequently lead to acne scars if untreated.

6. Cysts

- Large, soft, pus-filled lesions deep beneath the skin.
- Represent the most severe form of acne.
- Often painful and highly inflamed.
- Have a high risk of causing permanent scarring.

- Severity Progression
- Blackheads → Whiteheads → Papules → Pustules → Nodules → Cysts
- As acne progresses, inflammation increases, lesions become deeper, and the likelihood of scarring becomes greater. Early treatment helps prevent progression to nodules and cysts

5. Causes of Acne

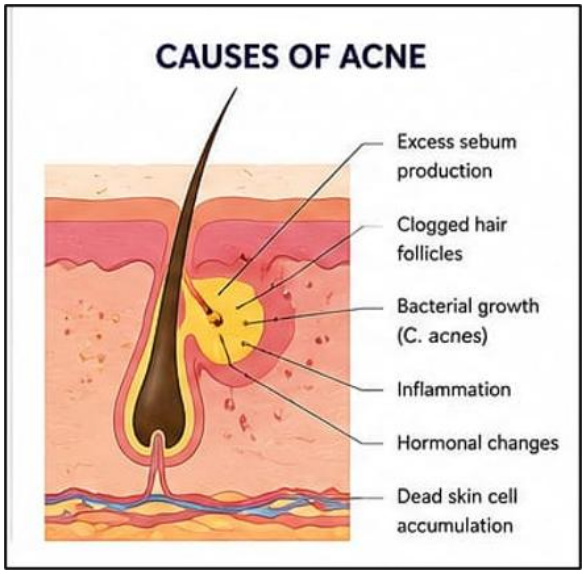


Figure: 3 Causes of Acne

Acne occurs when hair follicles become blocked with excess oil (sebum), dead skin cells, and bacteria. This blockage leads to inflammation and the formation of pimples.

Main Causes:

Excess Sebum Production: Overactive oil glands produce too much oil.

Clogged Hair Follicles: Dead skin cells and oil block skin pores.

Bacterial Growth (Cutibacterium acnes): Bacteria multiply inside blocked pores.

Inflammation: The body's immune response causes redness and swelling.

Hormonal Changes: Increased hormones stimulate oil production, especially during puberty.

Dead Skin Cell Accumulation: Excess shedding of skin cells contributes to pore blockage.

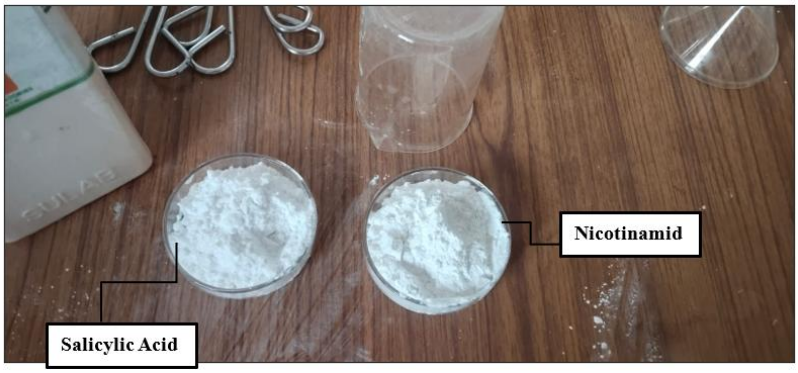


Figure: 4 Lab Prepration of Salicylic Acid

Nicotinamid

Drug Profile

1. Salicylic Acid

Category

Keratolytic agent

Mechanism of Action

Salicylic acid penetrates into sebaceous follicles and dissolves intercellular cement between dead skin cells. It exfoliates the stratum corneum and opens clogged pores.

2. Nicotinamide (Niacinamide)

Category

Vitamin B3 derivative

Mechanism of Action

Nicotinamide reduces inflammatory mediators and improves epidermal barrier function. It also decreases excess oil production and post-acne pigmentation.

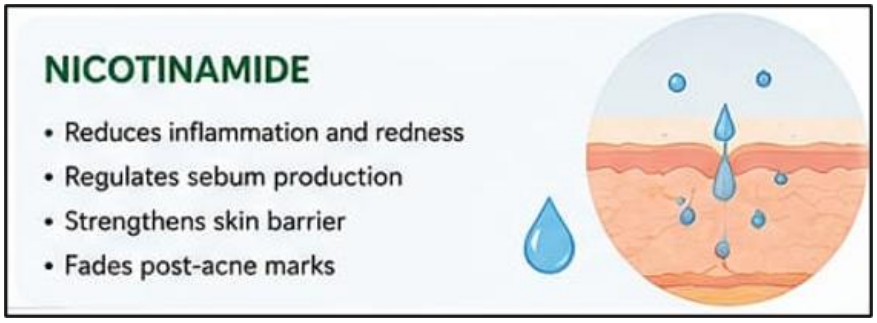


Figure: 6 Mechanism of Action

Uses

Acne reduction
Skin brightening
Anti-inflammatory effect
Reduction of redness and pigmentation

3. Centella asiatica Extract (2%)

Category

Herbal Bioactive Extract

Major Active Constituents

Asiaticoside
Madecassoside
Asiatic Acid
Madecassic Acid

Mechanism

Centella asiatica stimulates fibroblast proliferation and collagen synthesis.

Benefits

- Accelerates wound healing
- Repairs damaged skin
- Reduces acne scars
- Promotes collagen production
- Provides antioxidant protection
- Enhances skin regeneration

Concentration Selected

2% concentration provides effective wound-healing and anti-inflammatory activity.

Materials Required		
Ingredients	Quantity	Function
Salicylic acid	2 g	Anti-acne agent
Nicotinamide	5 g	Anti-inflammatory agent
Centella asiatica (Tiger Grass)	1-2%	Accelerates wound healing Repairs damaged skin
Propylene glycol	10 mL	Solvent and humectant
Glycerin	5 mL	Moisturizer
Carbopol 940	0.5 g	Gelling agent
Triethanolamine	q.s.	pH adjustment
Methyl paraben	0.2 g	Preservative
Distilled water	q.s. to 100 mL	Vehicle

Table: 1 Material Required

Formation of Salicylic Acid

Salicylic acid can be prepared in the laboratory by the Kolbe–Schmitt reaction. In this method, sodium phenoxide reacts with carbon dioxide under pressure and then acidification gives salicylic acid.

Chemical Reaction

Step 1: Formation of sodium phenoxide
C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O
Step 2: Formation of sodium salicylate
C_6H_5ONa + CO_2 \xrightarrow[125-140^\circ C]{Pressure} C_6H_4(OH)COONa
Step 3: Formation of salicylic acid
C_6H_4(OH)COONa + HCl \rightarrow C_6H_4(OH)COOH + NaCl

Materials Required

Phenol
Sodium hydroxide (NaOH)
Carbon dioxide gas (CO_2)
Hydrochloric acid (HCl)
Distilled water
Beaker and flask
Heating arrangement
Stirrer

Easy Laboratory Method

1. Preparation of Sodium Phenoxide

Take phenol in a beaker and add sodium hydroxide solution slowly with stirring. Sodium phenoxide solution is formed.

2. Reaction with Carbon Dioxide

Transfer the sodium phenoxide into a flask. Pass carbon dioxide gas through the solution while heating at about 125–140°C under pressure. Sodium salicylate is produced.

3. Acidification

Cool the reaction mixture and add dilute hydrochloric acid slowly. White crystals of salicylic acid precipitate out.

4. Filtration and Drying

Filter the crystals, wash with cold water, and dry them to obtain pure salicylic acid.

Flow Diagram

Phenol
↓ + NaOH
Sodium Phenoxide
↓ + CO_2 / Heat / Pressure
Sodium Salicylate
↓ + HCl
Salicylic Acid

Characteristics of Salicylic Acid

Appearance: White crystalline powder
Odor: Odorless
Solubility: Slightly soluble in water
Uses: Acne treatment, dandruff treatment, wart removal, pain relief preparations

Simple Principle

The reaction introduces a carboxyl group (-COOH) into phenol using carbon dioxide. Acidification finally converts the sodium salt into salicylic acid.

Formation Nicotinamide

Nicotinamide is the amide derivative of nicotinic acid.

Chemical Formula: $C_6H_6N_2O$

Principle

Nicotinamide is prepared by converting nicotinic acid into its amide form using ammonia. This process is called amidation.

Reaction

Nicotinic acid + Ammonia → Nicotinamide + Water

Materials Required	
Material	Purpose
Nicotinic acid	Starting material
Ammonia solution (25%)	Amide formation
Distilled water	Solvent
Beaker	Mixing
Round bottom flask	Heating
Reflux condenser	Prevents solvent loss
Hot plate or water bath	Heating
Filter paper	Filtration
Ice bath	Crystallization

Table: 2 Materials Required

Laboratory Method

Step 1: Preparation of Solution

Take about 5 g of nicotinic acid in a beaker.
Add 25–30 mL distilled water.
Heat gently to dissolve the acid.

Step 2: Addition of Ammonia

Slowly add 10 mL ammonia solution while stirring continuously.
The solution becomes clear.

Step 3: Heating (Amidation)

Transfer the mixture into a round bottom flask.
Attach a reflux condenser.
Heat at 80–90°C for 2–3 hours.
During heating, nicotinic acid reacts with ammonia to form nicotinamide.

Step 4: Cooling

After heating, cool the solution slowly.
Keep in an ice bath for crystallization.
White crystals of nicotinamide are formed.

Step 5: Filtration and Drying

Filter the crystals using filter paper.
Wash with small amount of cold water.

Dry the crystals at room temperature or in a hot air oven at low temperature.

PurificationRecrystallize the product using hot water for better purity.

Identification Tests

1. Melting Point

Nicotinamide melting point: 128–131°C

2. Solubility

Soluble in water and alcohol.

3. IR Spectroscopy

Characteristic peaks:
Amide group ($CONH_2$)
NH stretching
C=O stretching

Precautions

Handle ammonia carefully because of strong odor.
Avoid overheating.
Use gloves and goggles.
Perform heating in ventilated area

Extraction Method of Centella asiatica Extract

Materials Required:

Dried Centella asiatica leaves
Ethanol (70%) or distilled water
Beaker/flask
Filter paper
Water bath

Procedure

1. Wash and shade-dry Centella asiatica leaves.
2. Grind the dried leaves into a coarse powder.
3. Weigh 10 g of powder and add 100 mL of 70% ethanol (or water).
4. Macerate for 24–48 hours with occasional stirring.
5. Filter the mixture using filter paper.
6. Concentrate the filtrate using a water bath at 40–50°C.
7. Collect the concentrated extract and store in an airtight container.



Figure: 7 Extraction

Result:

A greenish-brown Centella asiatica extract rich in triterpenoids (asiaticoside, madecassoside) is obtained and can be used in serum, gel, cream, and other cosmetic formulations.

Detailed Method of Preparation of Salicylic Acid–Nicotinamide Serum

Principle of Preparation

The serum is prepared by incorporating salicylic acid and nicotinamide into a hydrated gel base. Salicylic acid acts as a keratolytic and exfoliating agent, while nicotinamide provides anti-inflammatory and skin barrier repairing effects. Carbopol 940 is used as the gelling agent to produce a smooth serum consistency. Propylene glycol improves solubility of salicylic acid and enhances skin penetration.

Detailed Method of Preparation

Step 1: Cleaning and Preparation of Equipment

Before preparation, all apparatus such as beakers, glass rods, measuring cylinders, spatulas, and stirrers should be washed properly and dried completely. Clean equipment prevents microbial contamination and maintains formulation quality.

Apparatus Required

Beakers
Glass rod
Magnetic stirrer
Measuring cylinder
Digital weighing balance
pH meter
Brookfield viscometer
Funnel
Amber glass bottle

Step 2: Weighing of Ingredients

All ingredients should be weighed accurately using a digital balance according to the formulation table.

Accurate weighing is important to maintain formulation stability and therapeutic activity

Ingredient	Quantity
Salicylic acid	2 g
Nicotinamide	5 g
Centella asiatica (Tiger Grass)	1-2%
Carbopol 940	0.5 g
Propylene glycol	10 mL
Glycerin	5 mL
Methyl paraben	0.2 g
Distilled water	q.s. to 100 mL
Triethanolamine	q.s.

Table: 3 Ingredient & Quantity

Step 3: Preparation of Carbopol Gel Base

1. Take approximately 50 mL of distilled water in a clean beaker.
2. Sprinkle Carbopol 940 slowly over the water surface with continuous stirring.
3. Stir gently using a magnetic stirrer to prevent lump formation.
4. Allow the dispersion to stand for 1–2 hours for complete hydration and swelling of Carbopol polymer.
5. A clear viscous gel base is formed after hydration.

Purpose

Carbopol forms the main gel network and provides suitable viscosity and consistency to the serum.

Step 4: Preparation of Salicylic Acid Solution

1. Take another clean beaker.
2. Add measured quantity of propylene glycol.
3. Slowly add salicylic acid into propylene glycol.
4. Stir continuously until a clear solution is obtained.
5. Mild heating (not above 40°C) may be used if necessary to enhance dissolution.

Purpose

Salicylic acid has poor water solubility; therefore, propylene glycol is used as a solvent to dissolve it effectively.

Step 5: Preparation of Nicotinamide Solution

1. Take a separate beaker containing distilled water.
2. Add nicotinamide slowly into water.
3. Stir continuously until complete dissolution occurs.
4. A clear aqueous solution is obtained.

Purpose

Nicotinamide dissolves easily in water and provides anti-inflammatory activity in the serum.

Step 6: Incorporation of Active Ingredients

Method of Incorporation
Step 1
Prepare Carbopol gel base.
Step 2
Dissolve salicylic acid in propylene glycol.
Dissolve nicotinamide in distilled water.
Step 4
Disperse Centella asiatica extract in a small quantity of distilled water and stir until uniform.
Step 5
Add Centella extract solution slowly into the nicotinamide solution.
Step 6
Mix the salicylic acid solution with the Carbopol gel base.
Step 7
Add the nicotinamide-Centella mixture slowly with continuous stirring.
Step 8

Add glycerin and preservative.
Step 9
Adjust pH to 5.5–6.0 using triethanolamine.
Step 10
Make up the volume with distilled water.

Observation

The formulation becomes smooth, transparent, and uniform.

Step 7: Addition of Humectant and Preservative

1. Add glycerin into the formulation and stir properly.
2. Dissolve methyl paraben in a small quantity of warm water or propylene glycol.
3. Add preservative solution into the serum mixture.
4. Stir continuously for 10–15 minutes.

Purpose

Glycerin moisturizes the skin and prevents dryness.

Methyl paraben prevents microbial growth and improves shelf life.

Step 8: pH Adjustment

1. Check the pH of the formulation using a digital pH meter.
2. Add triethanolamine dropwise with slow stirring.
3. Continue until pH reaches 5.5–6.0.
4. Avoid excessive addition because high pH may irritate skin.

Purpose

Skin-compatible pH maintains formulation stability and prevents irritation.

Step 9: Final Volume Adjustment

1. Add remaining distilled water to make the final volume up to 100 mL.
2. Stir continuously until a uniform serum is obtained.
3. Remove entrapped air bubbles by allowing the serum to stand for some time.

Step 10: Filtration (Optional)

If required, the serum may be filtered through muslin cloth or suitable filter paper to remove undissolved particles and improve clarity.

Step 11: Filling and Packaging

1. Transfer the prepared serum into sterilized amber-colored glass bottles using a funnel.
2. Close bottles tightly with dropper caps.
3. Label properly with formulation details and storage conditions.

Storage Conditions

Store in a cool and dry place.
Protect from direct sunlight.
Keep container tightly closed.

Precautions During Preparation

1. Avoid formation of lumps while dispersing Carbopol.
2. Maintain proper pH to avoid skin irritation.
3. Avoid overheating during dissolution of salicylic acid.
4. Use clean and sterilized apparatus.
5. Protect formulation from contamination.
6. Store formulation away from direct light and moisture.

Expected Characteristics of Final Serum	
Parameter	**Observation**
Appearance	**Clear and transparent**
Texture	**Smooth and non-greasy**
Odor	**Mild**
pH	**5.5–6.0**
Homogeneity	**Uniform**
Spreadability	**Good**
Stability	**Stable without phase separation**

Table: 4 Expected Characteristics of Final

Advanced Evaluation Parameters Are Sufficient And Appropriate.

1. pH Determination

Method: Digital pH Meter

The pH of the serum is measured using a calibrated digital pH meter to ensure compatibility with skin and stability of the formulation.

2. Viscosity Study

Method: Brookfield Viscometer

Viscosity is determined using a Brookfield viscometer to evaluate the flow characteristics and consistency of the serum.

3. Spreadability Test

Method: Glass Slide Method

Spreadability is measured by placing the serum between two glass slides and determining the ease of spreading under applied weight.

4. Drug Content Estimation

Method: UV-Visible Spectrophotometry

The amount of salicylic acid and nicotinamide present in the serum is quantified using UV spectrophotometric analysis.

5. In Vitro Drug Release Study

Method: Franz Diffusion Cell

Drug release behavior is evaluated using a Franz diffusion cell with a suitable membrane and phosphate buffer.

6. Stability Study

Method: ICH Accelerated Stability Testing

The serum is stored under different temperature and humidity conditions to evaluate physical and chemical stability.

7. Skin Irritation Test

Method: Patch Test

The formulation is applied to a small area of skin and observed for redness, itching, or irritation.

8. Microbial Limit Test

Method: Plate Count Method

The serum is tested for microbial contamination by culturing samples on suitable growth media.

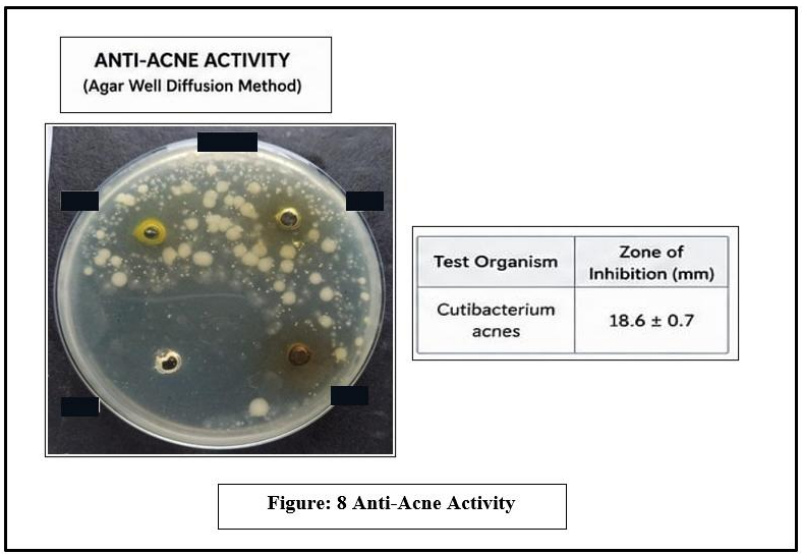


Figure: 8 Anti-Acne Activity

9. Anti-Acne Activity

Method: Agar Well Diffusion Method

The antibacterial activity against acne-causing bacteria is evaluated by measuring the zone of inhibition.

10. Homogeneity Test

Method: Visual Inspection

The serum is examined visually for uniformity, absence of lumps, phase separation, and particulate matter.

Results Table

Evaluation Parameter	Expected Result
pH	5.5–6.0
Viscosity	Smooth flow with suitable consistency
Spreadability	Good spreadability
Drug Content	95–105%
Drug Release	Sustained release profile
Stability	No phase separation
Skin Irritation	No irritation
Microbial Test	No microbial growth
Anti-Acne Activity	Significant zone of inhibition
Homogeneity	Uniform and smooth

Table: 5 Results Table

Results and Discussion

The formulated serum exhibited good clarity, stability, and skin compatibility. Salicylic acid effectively reduced oiliness and unclogged pores, while nicotinamide minimized inflammation and redness. The combination showed synergistic anti-acne activity with reduced irritation compared to salicylic acid alone. Previous dermatological studies also support the efficacy of salicylic acid and nicotinamide combinations in acne management. Community discussions indicate that excessive concentration of salicylic acid may cause dryness or irritation in sensitive skin, emphasizing the importance of balanced formulation and proper moisturization.



Figure: 9 Before and After Results

CONCLUSION

The salicylic acid–nicotinamide serum was successfully formulated and evaluated for anti-acne activity. The formulation showed satisfactory physicochemical properties, stability, and skin compatibility. The combined action of salicylic acid and nicotinamide effectively reduced acne-causing factors such as excess oil, clogged pores, inflammation, and bacterial growth. Therefore, the developed serum can serve as an effective topical therapy for acne treatment with minimal side effects

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