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Research Article

Formulation and In-Vitro Characterization of a Polyherbal Gel Made by the Combination of Solanum Xanthocarpum, Sarcostemma Acidum and Thuja Occidentalis Plant Extracts

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This research focuses on the development and assessment of a polyherbal topical gel formulated using extracts of Solanum xanthocarpum, Sarcostemma acidum and Thuja occidentalis. The objective was to create a physically stable and user-acceptable gel exhibiting improved antioxidant and antimicrobial activities, suitable for dermatological or wound-healing applications. The plant extracts were obtained using a Soxhlet extraction technique and were characterized through phytochemical analysis and determination of total phenolic content. Gel formulations were prepared with Carbopol 940 and sodium carboxymethyl cellulose as gelling agents, while glycerin and propylene glycol were incorporated as moisturizing agents. The prepared gels were evaluated for physical appearance, pH, viscosity, spreadability, uniformity, ease of extrusion, in vitro antioxidant capacity, antimicrobial activity using the agar well diffusion method, and stability under accelerated conditions. The findings demonstrated satisfactory physicochemical stability and a pH range appropriate for topical skin application.

Keywords: Solanum xanthocarpum, Sarcostemma acidum, Thuja occidentalis, polyherbal gel, Carbopol Sodium CMC, antioxidant, antimicrobial, topical formulation.

INTRODUCTION

Topical Drug Delivery System

Topical drug delivery systems are formulated to produce therapeutic effects directly at the site of application by facilitating drug penetration through the skin or mucosal tissues. A major benefit of this route is that it circumvents first-pass hepatic metabolism, which can significantly reduce drug bioavailability when administered orally. Moreover, topical administration eliminates the discomfort, risks, and technical challenges associated with parenteral routes and is unaffected by gastrointestinal variables such as pH fluctuations, enzymatic degradation, or gastric emptying time. Among topical dosage forms, semisolid preparations—including creams, gels, and ointments—are the most frequently employed. In addition, alternative topical systems such as foams, sprays, medicated powders, solutions, and transdermal patches are also commonly used. Topical drug delivery is particularly advantageous when other administration routes are ineffective or impractical, especially in the management of pain, contraception, and urinary incontinence.

Advantages of Topical Drug Delivery Systems

- Bypasses first-pass metabolism
- Simple, convenient, and non-invasive application
- Eliminates risks and discomfort related to intravenous administration
- Unaffected by gastrointestinal factors such as enzymes, pH, and gastric motility
- Achieves therapeutic efficacy with reduced total daily drug dose due to sustained drug release

- Minimizes fluctuations in plasma drug concentration and reduces inter- and intra-patient variability
- Allows easy discontinuation of therapy when required
- Provides a larger surface area for drug application compared to buccal or nasal routes

Disadvantages of Topical Drug Delivery Systems

- Potential for skin irritation or contact dermatitis
- Limited permeability of certain drugs across the skin barrier
- Risk of allergic or hypersensitivity reactions
- Suitable only for drugs requiring low systemic concentrations
- Possible enzymatic degradation of drugs within the epidermal layers
- Poor absorption of drugs with large particle size

Gels

Gels are semisolid dosage forms characterized by a liquid phase immobilized within a three-dimensional polymeric network formed by natural or synthetic gelling agents. The structural integrity of gels is maintained through physical or chemical cross-linking within the polymer matrix. Common natural gelling agents include tragacanth, pectin, carrageenan, agar, and alginic acid, while synthetic and semi-synthetic polymers such as methylcellulose, hydroxyethyl cellulose, carboxymethyl cellulose, and Carbopol polymers are widely used. Carbopols are synthetic, high-molecular-weight vinyl polymers containing ionizable carboxyl groups that contribute to gel formation and stability.

MATERIALS AND METHODS

5.1 Preliminary Investigation

5.1.1 Collection of Plant Material

The plant materials *Solanum xanthocarpum*, *Sarcostemma acidum* and *Thuja occidentalis* were collected from departmental herbarium for future reference.

5.1.2 Preparation of Plant Powder

Collected plant materials were shade-dried to prevent degradation of phytoconstituents. The dried samples were then coarsely pulverized using a mechanical grinder, passed through a #40 mesh sieve, and stored in airtight containers until further use.

5.2 Preparation of Extracts

Approximately 250 g of dried powdered material from *Solanum xanthocarpum, Sarcostemma acidum* and *Thuja occidentalis* was subjected to Soxhlet extraction. Initially, the powders were defatted using petroleum ether, followed by exhaustive extraction with appropriate solvents for approximately 36 hours. The extraction temperature was maintained between 40°C and 50°C. Ethanol was employed as the extraction solvent for S. xanthocarpum, whereas methanol was used for Sarcostemma acidum. The solvents were subsequently removed under reduced pressure, and the concentrated extracts were vacuum-dried using a rotary flash evaporator to obtain semisolid extracts.

(Reference: Kokate, Gokhale et al., 2005)

Plant Details-



Fig 2.1: Plant of Solanum xanthocarpum.

Solanum xanthocarpum is an important medicinal plant documented in traditional Hindu pharmacopoeia. It has long been employed for its fever-reducing and expectorant effects and is widely used in the management of respiratory disorders, including asthma, chronic cough, and catarrhal fever. The plant also forms an integral component of Dashamula, a well-known Ayurvedic polyherbal formulation consisting of ten therapeutic roots.



Fig 2.2: Plant of Sarcostemma acidum.

Sarcostemma acidum has been reported to possess a wide range of pharmacological activities. Studies indicate that the plant exhibits anti-inflammatory, analgesic, antiarthritic, spasmolytic, tocolytic, anti-asthmatic, antiallergic, and bronchospasmolytic effects. In addition, hepatoprotective and antioxidant properties have been documented. The plant has also demonstrated potential roles in the regulation of spermatogenesis, larvicidal action, immunomodulatory activity, central nervous system depressant effects, as well as antimicrobial, anti-syphilitic, and anthelmintic activities.



Fig 2.3 Plant of *Thuja Occidentalis*

Thuja occidentalis belonging to the family *Cupressaceae.* The leaves and young twigs are rich in essential oils containing thujone, flavonoids, tannins, and terpenoids, which contribute to its antimicrobial, anti-inflammatory, antiviral, antioxidant, and immunomodulatory activities. Traditionally, it is used in the management of skin disorders like warts, eczema, and fungal infections, respiratory ailments such as bronchitis and asthma, urinary tract infections, and digestive disturbances. In homeopathy, Thuja is a prominent remedy for chronic skin conditions and sycotic disorders. Despite its therapeutic potential, the plant should be used with caution, as excessive internal use may cause toxicity due to the presence of thujone, and therefore medical supervision is recommended.

2.4 Preliminary Investigation

2.4.1 Collection of Plant Material

Plant materials of *Solanum xanthocarpum*, *Sarcostemma acidum* and Thuja Occidentalis were

collected from local lucknow region. The collected specimens were authenticated by, Professor and Head, Department of Botany, lucknow University, (U.P.). Voucher specimens bearing numbers **IOS/Bot/SLF-028** and **IOS/Bot/SLF-029, IOS/Bot/SLF-030** were deposited in the departmental herbarium for future reference.

2.4.2 Preparation of Plant Powder

The collected plant materials were thoroughly cleaned and shade-dried to preserve their phytoconstituents. After complete drying, the materials were coarsely powdered using a mechanical grinder. The powder was passed through a #40 mesh sieve to ensure uniform particle size and stored in airtight containers for further experimental use.

2.5 Extracts

Extraction Techniques

Extraction is a conventional process employed to isolate pharmacologically active compounds from crude plant materials using suitable solvents. Proper identification and authentication of plant material are essential prior to extraction. The choice of plant part and solvent depends on the nature of the desired phytoconstituents. Generally, dried and powdered plant material is preferred. The solvent used during extraction is referred to as the **menstruum**, while the insoluble residue remaining after extraction is known as the **marc**.

2.5.1 Preparation of Extracts

Different solvents were utilized to obtain phytochemical constituents from the dried plant powders. Aqueous extraction was carried out by cold maceration, whereas Soxhlet extraction was employed using ethanol, methanol, chloroform, and petroleum ether. Approximately **250 g** of dried *Solanum xanthocarpum* fruits and *Sarcostemma acidum*, *Thuja Occidentalis* powder were subjected to Soxhlet extraction. Initially, defatting was carried out using petroleum ether, followed by exhaustive extraction with selected solvents for nearly **36 hours**, maintaining the temperature between **40°C and 50°C**. Ethanol was used as the extraction solvent for *S. xanthocarpum*, while methanol was selected for *Sarcostemma acidum and Thuja Occidentalis*. The solvents were removed under reduced pressure, and the concentrated extracts were vacuum-dried using a rotary flash evaporator to obtain semisolid extracts.

2.5.2 Phytochemical Screening

The prepared extracts were subjected to qualitative phytochemical analysis using standard chemical tests to identify the presence of various phytoconstituent groups.

2.5.3 Tests for Carbohydrates and Glycosides

Molisch's Test:

The extract was treated with alcoholic α-naphthol followed by careful addition of concentrated sulfuric acid along the sides of the test tube. The appearance of a violet or brown ring at the interface indicated the presence of carbohydrates.

Legal's Test:

To the extract, pyridine and sodium nitroprusside were added, followed by alkalinization with sodium hydroxide. Formation of a pink to red color confirmed glycosides.

Borntrager's Test:

The extract was shaken with chloroform, and the separated organic layer was treated with dilute ammonia. A pink coloration in the ammoniacal layer indicated the presence of glycosides.

2.5.4 Tests for Alkaloids

The extract was acidified with dilute hydrochloric acid and tested with specific reagents:

- **Dragendorff's reagent:** Reddish-brown precipitate
- **Wagner's reagent:** Reddish-brown precipitate
- **Mayer's reagent:** Cream-colored precipitate
- **Hager's reagent:** Yellow precipitate

2.5.5 Tests for Proteins and Free Amino Acids

The extract was dissolved in distilled water and subjected to the following tests:

- **Millon's Test:** Reddish coloration indicated proteins
- **Ninhydrin Test:** Violet or purple color confirmed amino acids
- **Biuret Test:** Violet or pink coloration signified proteins and amino acids

2,5.6 Tests for Tannins

- **Ferric Chloride Test (5%):** Violet coloration indicated phenolic compounds
- **Lead Acetate Test (10%):** Formation of a white precipitate confirmed tannins

2.5.7 Tests for Flavonoids

- **Alkaline Reagent Test:** Yellow coloration that disappeared upon acid addition confirmed flavonoids
- **Shinoda Test:** Formation of pink or magenta color indicated flavonoids

2.5.8 Tests for Fixed Oils and Fats

- **Spot Test:** Translucent oily spot on filter paper indicated fixed oils
- **Saponification Test:** Soap formation upon heating with alcoholic potassium hydroxide confirmed oils and fats

2.5.9 Tests for Steroids and Triterpenoids

Liebermann–Burchard Test:

Green coloration indicated steroids, while deep red coloration suggested triterpenoids.

Salkowski Test:

Red coloration in the lower layer confirmed steroids, whereas yellow coloration indicated triterpenoids.

Tests for Mucilage and Gums

The sample was added to absolute alcohol with continuous stirring. The precipitate obtained was dried and examined for swelling behavior, confirming mucilage and gums.

Tests for Waxes

The extract was treated with alcoholic alkali reagent. Formation of soap-like material due to saponification indicated the presence of waxes.

3. Formulation of A Suitable Topical Therapeutic System

3.1 Preparation of Hydrogel Containing Plant Extracts

Hydrogels were prepared using varying ratios of **Carbopol 934** and **Sodium Carboxymethyl Cellulose (CMC)** (3:0, 3:1, 2:1, 1:1, 0:3, 1:2, and 1:3). The polymers were dispersed in 50 ml of distilled water with continuous stirring. Methyl and propyl parabens were dissolved separately in 5 ml of distilled water by heating, followed by cooling. Propylene glycol (5% w/v) was added and mixed with the polymer dispersion. Extracts of *Solanum xanthocarpum* (1 g) and *Sarcostemma acidum* (1 g) and Thuja Occidentalis (1 g) were dissolved in a minimal quantity of ethyl alcohol and incorporated into the gel base. The final volume was adjusted to 100 ml with distilled water. Triethanolamine was added dropwise to adjust the pH to **6.8–7.0** and achieve suitable gel consistency. Formulations F1, F2, F6, and F7 exhibited turbidity and clumping and were discarded. Clear and stable formulations (F3, F4, and F5) were selected for further evaluation. A control gel was prepared using the same procedure without plant extracts.

Preparation of Hydroalcoholic Gel Containing Plant Extracts

The optimized polymer blend was dispersed in distilled water under continuous stirring. Preservatives were dissolved separately, cooled, and mixed with propylene glycol before incorporation into the polymer base. Plant extracts were dissolved in ethanol and added to the formulation. The final volume was adjusted to 100 ml with distilled water, and triethanolamine was added to adjust the pH between **6.8 and 7.0**. A control hydroalcoholic gel was prepared similarly without plant extracts.

Characterization and Evaluation of The Formulation

4.1 Preliminary Phytochemical Screening

Preliminary phytochemical investigations were carried out on various solvent extracts of *Solanum xanthocarpum* and *Sarcostemma acidum*, Thuja Occidentalis to identify the presence of major bioactive constituents. Standard qualitative chemical tests were performed, and the observations are summarized in Tables 6.1(a) and 6.2(b). The results indicate variation in phytoconstituent distribution depending on the solvent used.

4.2 Extractive Values

The extractive values of different solvent extracts of both plants were determined to evaluate the solubility of phytoconstituents in various solvents. The percentage yield of extracts is presented in Tables 6.3(a) and 6.3(b)

4.3 (a): Extractive values of Solanum xanthocarpum

Sr. No.	Solvents	Extractive values (%w/w)
1.	Pet-ether	2.62
2.	Water	17.2
3.	Chloroform	6. 9
4.	Ethanol	15.5
5.	Methanol	14.5

Table 4.3(b): Extractive values of Sarcostemma acidum

Sr. No.	Solvents	Extractive values (%w/w)
1.	Pet-ether	0.60
2.	Water	1.6
3.	Chloroform	1.2
4.	Ethanol	1.8
5.	Methanol	2.7

The findings revealed that *Solanum xanthocarpum* exhibited higher extractive value in ethanol, whereas *Sarcostemma acidum* showed maximum extractive yield in methanol. Since the major active constituents were predominantly present in these extracts, the **ethanolic extract of** *S. xanthocarpum* and **methanolic extract of** *S. acidum* were selected for further formulation and evaluation studies.

4.3 Evaluation of Gel Formulation

4.3.1 Physical Examination

All prepared gel formulations were visually inspected for organoleptic characteristics such as color, texture, homogeneity, and overall appearance. The formulations exhibited a uniform greenish color and smooth consistency without any visible particulate matter.

4.3.2 pH Measurement

The pH of the formulated gels was determined using a calibrated digital pH meter. One gram of gel was dispersed in 100 mL of distilled water and allowed to equilibrate for two hours. Measurements were performed in triplicate, and the average pH values were recorded to ensure accuracy and reproducibility.

4.4 Composition of Gel Formulations

Different gel formulations (F1–F7 and FH)

Table 4.4: Composition of gel formulations containing plant extracts=

Ingredient	F1	F2	F3	F4	F5	F6	F7	FH
Carbopol 934 (gm)	3	3	2	1	-	1	1	1
Sodium CMC (gm)	-	1	1	1	3	2	3	2
S. *xanthocarpum* (% w/w)	1	1	1	1	1	1	1	1

Sarcostemma acidum (% w/w)	1	1	1	1	1	1	1	1
Thuja occidentalis(%w/w)	1	1	1	1	1	1	1	1
Propylene glycol 400 (5%)	5	5	5	5	5	5	5	5
Methyl Paraben (0.5%) (ml)	0.2ml	0.2 ml	0.2 ml	0.2 ml	0.2 ml	0.2 ml	0.2 ml	0.2 ml
Propyl Paraben (0.2%) (ml)	5 ml	5 ml	5 ml	5 ml	5 ml	5 ml	5 ml	5 ml
Triethanolamine (ml)	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Distilled water (ml)	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml	q.s. to 100ml

Where:

- **FE** = Ethosome gel containing *S. xanthocarpum* and *S. acidum* extracts
- **F1–F7** = Hydrogel formulations with thuja occidentalis
- **FH** = Hydroalcoholic gel Each formulation was adjusted to a final volume of 100 mL using distilled water.

4.5 Formulation Characterization and Optimization

During formulation development, different concentrations of Carbopol and Sodium CMC were evaluated. Some batches (F1, F2, F5, and F7) showed deficiencies in viscosity, spreadability, and uniformity, leading to their exclusion from further studies. Formulations F3, F4, and F6 demonstrated acceptable physicochemical properties and were therefore selected for detailed evaluation.

4.7 Compatibility Studies

FTIR Spectral Analysis

Fourier Transform Infrared (FTIR) spectroscopy was performed to evaluate possible interactions between the plant extracts and formulation excipients. The IR spectra of the formulations and individual extracts (Figures 6.7–6.10) showed no significant peak shifts, disappearance, or formation of new peaks. This confirmed the absence of chemical or physical incompatibility and demonstrated good compatibility between the active constituents and excipients used.

4.8 Standard Calibration Curve

Table 4.8: Standard calibration curve of *S. xanthocarpum* at 206 nm

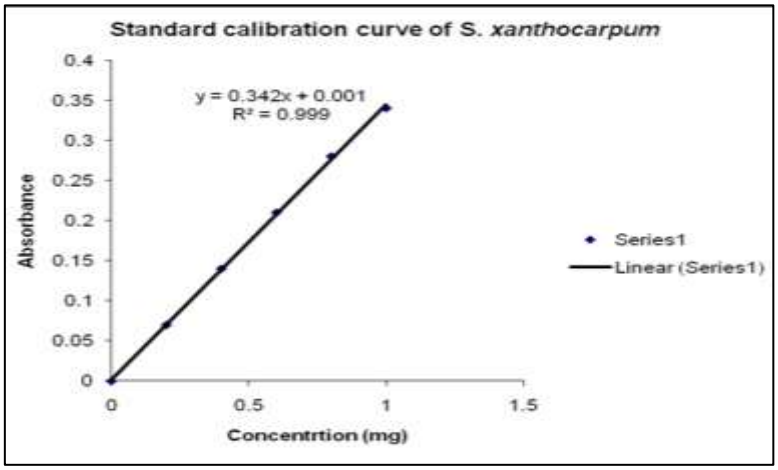
S. No	Concentration (µg/ml)	Absorbance
1.	Blank 0.2	0.000
2.	0.4	0.059
3.	0.6	0.141
4.	0.8	0.212
5.	1.0	0.283
6.		0.341

4.8. Calibration Curve of Solanum xanthocarpum

Time Interval (Min)	% Drug release of Formulation	
	F6	FH
15	8.31	11.23
30	14.56	17.31
45	20.91	27.56

60	28.38	35.91
90	38.23	46.38
120	46.15	54.23
180	50.21	62.15

A standard calibration curve for *Solanum xanthocarpum* extract was constructed by measuring absorbance at 206 nm across various concentrations, following Beer–Lambert's law. The data obtained are presented in Table 6.8, and the calibration curve is shown in Figure 4.9.



4.8.2 Calibration Curve of *Sarcostemma acidum*

The standard calibration curve of *S. acidum* extract was prepared by plotting absorbance versus concentration at 359 nm. The linear relationship confirmed adherence to Beer's law.

4.9 In Vitro Drug Release Study

The in vitro drug release profile of optimized hydrogel (F6) and hydroalcoholic gel (FH) was evaluated using a fabricated diffusion cell. The cumulative percentage drug release at different time intervals is shown in Table 4.11.

Table 4.11: Percentage drug release of formulated gels

S. No.	Concentration (µg/ml)	Absorbance
1.	Blank	0.000
2.	0.2	0.059
3.	0.4	0.141
4.	0.6	0.212
5.	0.8	0.283
6.	1.0	0.341

The hydroalcoholic gel (FH) exhibited a higher drug release compared to hydrogel F6. Release kinetics were analyzed using first-order and Higuchi models, as depicted in Figures 4.12–4.14.

4.15 Stability Studies

Stability studies were conducted on the optimized gel formulations under accelerated conditions. No changes in color, appearance, or homogeneity were observed. The pH values remained within the acceptable range of 6.2–7.2. Viscosity, spreadability, and drug content remained stable throughout the study period, with drug content ranging between 90% and 103%.

Table 4.16: Accelerated stability study of optimized gel formulations

Batch	Color	Appearance	Spreadibility (gm.cm/sec)	Consistency (60 Sec)	Viscosity (cps)	Ph	Drug content (%)
F6	Greenish	Homogeneous	19.53	5	22230	6.98	99.77
FH	Greenish	Homogeneous	22.13	8	16951	7.01	99.86

CONCLUSION OF RESULTS

The results confirmed that the optimized gel formulations containing ethanolic extract of *Solanum xanthocarpum, Thuja occidentalis* and methanolic extract of *Sarcostemma acidum* possessed desirable physicochemical properties, compatibility, stability, and controlled drug release behavior, supporting their potential use as a topical therapeutic system.

CONCLUSION AND DISCUSSION

The present research was undertaken to develop, characterize, and evaluate a topical herbal gel incorporating extracts of *Solanum xanthocarpum* and *Sarcostemma acidum* and Thuja Occidentalis hydrogel and hydroalcoholic gel systems were formulated with the objective of improving topical delivery and therapeutic performance. During the extraction phase, dried plant materials of *S. xanthocarpum* and *S. acidum* and Thuja Occidentalis were subjected to Soxhlet extraction using solvents of varying polarity, namely ethanol, methanol, chloroform, and petroleum ether. Phytochemical screening revealed that the ethanolic extract of *S. xanthocarpum* and the methanolic extract of *S. acidum* and Thuja Occidentalis possessed a higher concentration of bioactive constituents when compared with other solvent extracts. Based on these findings, the selected extracts were considered most suitable for formulation development. Hydrogel and hydroalcoholic gel formulations were prepared using different concentrations of Carbopol 934 and Sodium carboxymethyl cellulose (CMC) as gelling agents. During the preliminary evaluation, certain formulations (F1, F2, and F5) showed unsatisfactory characteristics such as poor viscosity, lack of uniformity, and inadequate spreadability, leading to their rejection. The remaining formulations (F3, F4, and F6) demonstrated acceptable physicochemical properties and were therefore selected for detailed evaluation. Among all the evaluated batches, the hydroalcoholic gel formulation FH, containing both selected plant extracts, exhibited the most favorable drug release profile. The formulation showed a cumulative drug release of 26.43% within 30 minutes and 76.09% at 180 minutes. The presence of ethanol in the formulation significantly enhanced drug diffusion and permeability, thereby improving the release characteristics of the gel. Overall, the study indicates that the hydroalcoholic gel formulation FH possesses promising attributes as a topical anti-inflammatory preparation. In light of the increasing demand for herbal formulations due to their perceived safety, biocompatibility, and reduced side effects compared to synthetic drugs, the developed formulation highlights the therapeutic potential of *Solanum xanthocarpum* and *Sarcostemma acidum and thuja occidentalis*. Further pharmacological and clinical investigations may help to establish its efficacy and safety for topical application.

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