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Original Research Article

Formulation of topical polyherbal emulgel from essential oils and evaluation of its antimicrobial activities

Sivakumar Marappan[1]*, Nithya Murugan[1], Shanmugapriya Madheswaran[1], Perumal Perumal[2], Gokulnath Kumar[1], Vigneshwaran Senthilkumar[1], Yogeshwaran Nadesan[1]

[1]Dept. of Pharmacology, JKK Munirajahh Institute of Health Sciences College of Pharmacy, Tamil Nadu, India
[2]Dept. of Pharmaceutical Chemistry, JKK Munirajahh Institute of Health Sciences College of Pharmacy, Tamil Nadu, India

Abstract

Background: Topical drug delivery provides a localized, safe, and patient-friendly approach for treating skin infections, addressing drawbacks such as first-pass metabolism and systemic toxicity. Emulgels, which integrate the advantages of emulsions and gels, enhance stability, spreadability, and patient acceptability. The incorporation of essential oils further strengthens their potential as natural antimicrobial agents.
Aim and Objective: The study focused on formulating and evaluating polyherbal emulgels containing essential oils (lavender, cinnamon, and clove) to assess their antimicrobial efficacy against bacterial and fungal pathogens.
Materials and Methods: Six formulations (F1–F6) were developed using sodium alginate and sodium carboxymethyl cellulose in combination with Carbopol-940. All batches were evaluated for physicochemical properties, including colour, consistency, homogeneity, appearance, greasiness, washability, pH, spreadability, and viscosity. Antimicrobial activity was tested using the agar well diffusion method against *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Candida albicans*.
Results: All formulations were stable, with pH values between 6.03 and 6.81, aligning with the skin's physiological range. Carbopol-based batches showed superior spreadability and viscosity compared to alginate and CMC-based gels. Antimicrobial testing revealed that all formulations exhibited inhibitory activity, with formulation F5 demonstrating the greatest effectiveness, producing zones of inhibition of 35 ± 0.54 mm (S. aureus), 21 ± 0.34 mm (E. coli), 11 ± 0.26 mm (K. pneumoniae), and 16 ± 0.32 mm (C. albicans). Conclusion: The developed polyherbal emulgels containing essential oils displayed promising antimicrobial potential and acceptable physicochemical characteristics. Among them, formulation F5 showed the most favorable results, highlighting its potential.
Keywords: Polyherbal emulgel, Essential oils, Antimicrobial activity, Topical drug delivery, Skin infections

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1. Introduction

Topical drug delivery has gained considerable attention because it provides localized therapeutic action, bypasses first-pass metabolism, and minimizes systemic side effects while improving patient compliance.[1] Among different topical dosage forms, emulgels are particularly promising, as they integrate the advantages of both emulsions and gels, offering improved stability, spreadability, and patient acceptability.[2] These formulations are capable of delivering both hydrophilic and lipophilic drugs with sustained release and enhanced skin permeation.[3-4]

The concept of polyherbal formulations has been well recognized in both traditional and modern medicine due to their synergistic effects, lower toxicity, and broad spectrum of therapeutic potential. Combining multiple herbal agents often results in enhanced pharmacological activity compared to single drug preparations. Essential oils, in particular, are valued for their antimicrobial, anti-inflammatory, antioxidant, and wound-healing activities.[5,6] However, their clinical application is limited by issues such as volatility, poor solubility, and instability.[7]

Formulating essential oils into an emulgel system addresses these challenges by improving their stability, prolonging drug release, and increasing bioavailability.[8] Recent research highlights that polyherbal emulgels incorporating essential oils exhibit notable antimicrobial

*Corresponding author: Sivakumar Marappan
Email: nithi.m96@gmail.com

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activity and may serve as natural, safe, and effective alternatives to synthetic topical formulations. Therefore, the development and evaluation of polyherbal emulgels with essential oils represent a novel therapeutic approach for managing skin infections and related disorders[9]

2. Materials and Methods[10-17]

2.1. Procurement of plant essential oils

In order to develop the polyherbal emulgel formulation, plant-derived essential oils were procured from the local market.[10-17]

Table 1: Essential oils utilized in polyherbal emulgel formulation

S. No.	Essential oil
1.	Lavender Oil
2.	Cinnamon Oil
3.	Clove Oil

3. Additives Used in Polyherbal Emulgel Formulation

A variety of pharmaceutical excipients were employed in the formulation of polyherbal emulgel, each serving a specific functional role.

Table 2: Additives used in polyherbal emulgel formulation

S. No	Additive	Role in Formulation
1	Sodium alginate	Natural biopolymer, thickening and gelling agent, pH-stable, thermally resistant
2	Sodium Carboxy Methyl Cellulose	Emulsifier, stabilizer, thickener, gelling agent, binder
3	Propylene glycol	Humectant, solvent, skin penetration enhancer
4	Methyl Paraben	Preservative, prevents bacterial and fungal growth
5	Propyl Paraben	Preservative, antimicrobial agent, stability enhancer
6	Span 20 (Sorbitan Monooleate)	Lipophilic W/O emulsifier, emulsion stabilizer, dispersing agent
7	Tween 80 (Polysorbate 80)	Non-ionic surfactant, emulsifier
8	Sesame oil	Oil phase component, vehicle, penetration enhancer
9	Triethanolamine	Surfactant precursor, pH adjuster, stabilizer
10	Carbopol 940	Cross-linked polyacrylic acid polymer, primary gelling agent, viscosity enhancer

4. Preparation of Polyherbal Emulgel

The polyherbal emulgel formulations (F1–F6) were prepared using varying concentrations of gelling agents (sodium alginate and sodium Carboxy Methyl cellulose), while keeping other ingredients constant. Essential oils (lavender, cinnamon, and clove) were incorporated as active therapeutic agents. Carbopol 940 was used as the primary gelling agent, while propylene glycol, ethanol, and sesame oil were employed as solvents and penetration enhancers. Preservatives such as methyl paraben and propyl paraben were added to prevent microbial contamination. Span 20 and Tween 80 acted as emulsifiers to stabilize the oil and aqueous phases, and triethanolamine was used as a pH adjuster and stabilizer. Distilled water was used to make up the volume of the formulation. The detailed composition of the formulations is presented in **Table 3**.

Table 3: Composition of polyherbal emulgel formulations (F1–F6)

S. No	Ingredients (gm)	F1	F2	F3	F4	F5	F6
1.	Lavender Oil (ml)	0.3	0.3	0.3	0.3	0.3	0.3
2.	Cinnamon Oil (ml)	0.2	0.2	0.2	0.2	0.2	0.2
3.	Clove Oil (ml)	0.2	0.2	0.2	0.2	0.2	0.2
3.	Sodium Alginate	0.3	0.6	0.9	-	-	-
4.	Sodium Carboxy Methyl cellulose	-	-	-	0.3	0.6	0.9
5.	Carbopol 940	3	3	3	3	3	3
6.	Propylene glycol (ml)	5	5	5	5	5	5
7.	Ethanol (ml)	5	5	5	5	5	5
8.	Methyl Paraben	0.3	0.3	0.3	0.3	0.3	0.3
9.	Propyl Paraben	0.1	0.1	0.1	0.1	0.1	0.1
10.	Sesame oil (ml)	7	7	7	7	7	7
11.	Span -20 (ml)	1.0	1.0	1.0	1.0	1.0	1.0
12.	Tween 80 (ml)	0.5	0.5	0.5	0.5	0.5	0.5
13.	Triethanolamine (ml)	1.2	1.2	1.2	1.2	1.2	1.2
14.	Distilled water (ml)	Quantity Sufficient					

5. Preparation of Emulsion

The emulsion was formulated by accurately weighing the required quantities of Lavender oil, Cinnamon oil, Clove oil, and Ethanol, which were mixed thoroughly in Beaker.[1] In Beaker 2, Propylene glycol, Methyl paraben, and Propyl paraben were combined. The contents of Beaker 1 and Beaker 2 were then transferred into Beaker 3, to which Tween 80 and sufficient distilled water were added to constitute the aqueous phase. Simultaneously, Span-20 and Sesame oil were mixed in Beaker 4 to obtain the oily phase. Both phases were heated separately to 70–80°C, after which the oily phase was gradually incorporated into the aqueous phase with continuous stirring until a stable emulsion was achieved.

5.1. Preparation of gel

The gelling agents (sodium alginate or sodium CMC) were dispersed in distilled water and allowed to hydrate for 24 hours. Triethanolamine was then incorporated into the

hydrated polymer base, and the pH was carefully adjusted to 6.0–6.5 to obtain a smooth and uniform gel.

5.2. Preparation of emulgel

The previously prepared emulsion was gradually incorporated into the gel base with continuous stirring until a homogeneous and stable polyherbal emulgel was obtained.

5.3. Evaluation of emulgel

1. **Colour:** The emulgels were visually inspected for colour. Any change in colour was considered an indicator of instability, degradation of active constituents, or poor formulation quality.
2. **Consistency:** The consistency of the formulations was assessed visually and by touch, as this parameter is critical for both patient acceptability and formulation stability.
3. **Homogeneity:** The homogeneity of the formulations was examined to confirm uniform dispersion of oils and excipients. Inhomogeneity may lead to irregular drug release and reduced therapeutic performance.
4. **Appearance:** The overall appearance including clarity, texture, and smoothness was evaluated, as these factors greatly influence user compliance and product preference.
5. **Greasiness:** The formulations were examined for greasiness to ensure a non-oily feel. A non-greasy formulation is preferable for enhanced patient comfort and compliance.
6. **Washability:** Washability was determined by applying a small amount of emulgel to the skin and washing it with water. A desirable formulation should be easily washable without leaving a sticky or oily residue.
7. **pH**: The pH of the emulgels was measured using a digital pH meter. One gram of emulgel was dispersed in 50 mL of distilled water, and the pH was recorded. An ideal topical formulation should maintain a pH range of 5–7 to match skin physiology and prevent irritation.
8. **Spreadability:** Spreadability was evaluated by placing 1 g of emulgel between two glass slides, followed by applying a 50 g weight for 60 seconds. The diameter of spread was measured in triplicate, and the average was used to calculate spreadability using the formula:

   $$S = \frac{M \times L}{T}$$

   Where, : S= Spreadability; M= Mass; L=Diameter; T=Time.

9. **Viscosity:** Viscosity was determined using a Brookfield viscometer. One gram of emulgel was placed in the sample holder, and the spindle was rotated at 50 rpm. Readings were taken in triplicate, and the mean viscosity value was recorded.

6. Antimicrobial Evaluation

6.1. Microbial culture

Primary cultures of microorganisms were procured from a reliable microbiological source to ensure purity and reproducibility. The selected test organisms included Gram-positive bacteria (*Staphylococcus aureus*), Gram-negative bacteria (*Escherichia coli* and *Klebsiella pneumoniae*), and a pathogenic yeast (*Candida albicans*). These strains were selected due to their clinical relevance in skin and soft tissue infections

6.2. Antimicrobial activity

The antimicrobial activity of the polyherbal emulgel formulations was assessed using the agar well diffusion method. Nutrient Agar was used for bacterial cultures (*E. coli, S. aureus, K. pneumoniae*), while Sabouraud Dextrose Agar (SDA) was employed for *C. albicans*. A standardized inoculum (0.1 mL) of each microorganism was aseptically mixed with 20 mL of molten sterile agar and poured into pre-sterilized Petri plates. Plates were allowed to solidify at 40 °C for 30–40 minutes. Wells of uniform diameter were created using a sterile cork borer, and each was filled with 0.1 mL of the test formulations. Plates inoculated with bacterial strains were incubated at 37 °C for 24 h, while those inoculated with *C. albicans* were incubated at 28 °C for 48 h. After incubation, the zones of inhibition were measured in millimeters to determine the antimicrobial potential of each formulation.

7. Results and Discussion

7.1. Preparation of emulgel

Polyherbal emulgels were successfully formulated using essential oils such as lavender oil, cinnamon oil, and clove oil. Different gelling agents (Carbopol-940, sodium CMC, and sodium alginate) were employed at varying concentrations, guided by earlier literature reports on topical gel formulations. In total, six formulations (F1–F6) were developed, incorporating propylene glycol as a co-solvent, parabens as preservatives, and surfactants/emulsifiers (Span 20, Tween 80, and triethanolamine) to stabilize the emulsion base. The preparation method yielded smooth, semi-solid emulgels that were physically stable and suitable for topical application.

7.2. Evaluation of emulgel

All six formulations were subjected to evaluation parameters including colour, consistency, homogeneity, appearance, greasiness, washability, pH, spreadability, and viscosity (**Table 1**). The formulations appeared brown in colour, semi-solid in texture, and were non-greasy and washable. Consistency was found to be “very good” in F2 and F5, while the remaining batches showed “good” consistency. The pH of the formulations ranged between 6.03–6.81, which lies within the acceptable skin pH range (4.5–6.8), ensuring

compatibility for topical use. Spreadability varied between 3.5–5.6 g·cm/sec, with F3 and F6 demonstrating the highest spreadability, indicating better patient compliance during application. Viscosity measurements (1702–2712 cP) revealed that Carbopol-based formulations had higher viscosity compared to sodium CMC and sodium alginate-based gels, in agreement with previous findings that Carbopol provides enhanced viscosity and stability to topical formulations.

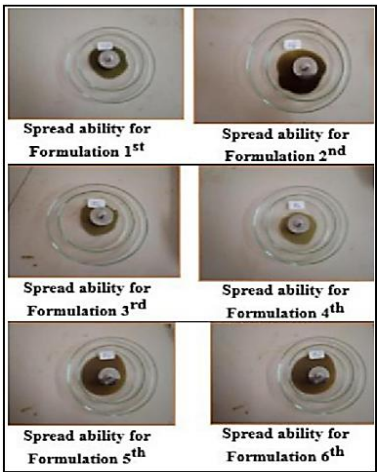

Figure 1: Spreadability for formulated batches

7.3. Antimicrobial activity

The antimicrobial efficacy of the emulgels was evaluated using the agar well diffusion method against *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Candida albicans*. The results (**Table 2**) demonstrated that all formulations exhibited antimicrobial activity, with formulation F5 showing the maximum inhibition zones across all tested organisms: *S. aureus* (35 ± 0.54 mm), *E. coli* (21 ± 0.34 mm), *K. pneumoniae* (11 ± 0.26 mm), and *C. albicans* (16 ± 0.32 mm). The superior activity of F5 may be attributed to the synergistic effects of the essential oils incorporated, particularly cinnamon and clove oils, which are known to possess strong antibacterial and antifungal properties. Lavender oil may also contribute through its broad-spectrum antimicrobial action and skin-soothing effects. These findings are consistent with previous reports where essential oils exhibited potent antimicrobial activities against Gram-positive and Gram-negative bacteria as well as fungi.

Overall, the study confirms that formulation F5 demonstrated optimum physicochemical properties and maximum antimicrobial activity, making it the most promising candidate for further pharmacological and clinical evaluations.

Table 4: Physicochemical evaluation parameters of formulated polyherbal emulgel batches (F1-F6)

Parameters	F1	F2	F3	F4	F5	F6
Colour	Brown	Brown	Brown	Brown	Brown	Brown
Consistency	Good	Very Good	Good	Good	Very Good	Good
Homogeneity	Good	Good	Good	Good	Good	Good
Appearance	Semi-solid	Semi-solid	Semi-solid	Semi-solid	Semi-solid	Semi-solid
Greasiness	Non-greasy	Non-greasy	Non-greasy	Non-greasy	Non-greasy	Non-greasy
Washability	Washable	Washable	Washable	Washable	Washable	Washable
pH	6.21	6.69	6.81	6.03	6.66	6.79
Spreadability	3.5	4.0	5.6	3.5	4.1	5.5
Viscosity	1702	2124	2702	1804	2120	2712

Table 5: Antimicrobial activity of optimized polyherbal emulgel (F5) Against Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, and Candida albicans

S. No	Target organisms	Zone of inhibition (mm)					
		F1	F2	F3	F4	F5	F6
1	Staphylococcus aureus	28±0.54	34±0.26	32±0.12	27±0.38	35±0.54	33±0.16
2	Escherichia coli	11±0.34	20±0.38	17±0.26	10±0.52	21±0.34	18±0.22
3	Klebsiella pneumoniae	9±0,26	11±0.12	10±0.44	8±0.48	11±0.26	10±0-26
4	Candida albicans	12±0.26	15±046	14±0.32	11±0.32	16±0.32	13±0.42

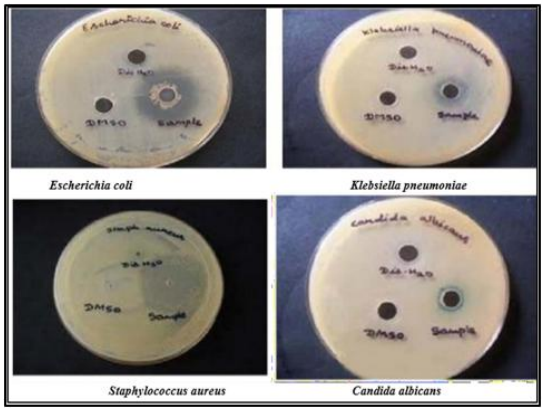

Figure 2: Antimicrobial activity of formulated polyherbal emulgel batches (F1–F6) against selected microorganisms (Zone of Inhibition in mm)

8. Conclusion

The study successfully formulated and evaluated polyherbal emulgels using essential oils of lavender, cinnamon, and clove. All six formulations (F1–F6) demonstrated acceptable physicochemical properties, non-greasy texture, and skin-compatible pH values. Among them, formulation F5 exhibited superior spreadability, viscosity, and the most significant antimicrobial activity against both Gram-positive and Gram-negative bacteria as well as Candida albicans. The results emphasize the potential of combining multiple essential oils within an emulgel system to achieve synergistic antimicrobial effects while ensuring formulation stability and patient acceptability. Therefore, polyherbal emulgels may serve as effective, natural, and safer alternatives to conventional topical antimicrobial preparations, warranting further pharmacological and clinical investigations to validate their therapeutic potential.

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None.

11. Conflict of Interest

None.

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