RESEARCH PAPER

Formulation, Optimization, and Evaluation of Emulgel Containing Eucalyptus Oil

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ABSTRACT

Utilizing carbopol 934P as a gelling agent, this study aims to create, optimize, and assess an emulgel with eucalyptus oil for topical use. To achieve the desired consistency, the gel base was made with carbopol 934P in a range of concentrations (0.5-1% w/w) and neutralized with triethanolamine. A stable emulgel was produced by mixing the optimized gel basis with the emulsion phase, which contained eucalyptus oil, in a ratio of 1:1. The stability, antibacterial activity, in-vitro diffusion profile, drug content, viscosity, extrudability, spreadability, and pH of the manufactured formulations were assessed. With homogeneous medication content, great spreadability and extrudability, and appropriate pH values compatible with skin (5.5-6.8), the optimized formulation exhibited good physical features. Antibacterial testing against Staphylococcus aureus & Escherichia coli showed substantial zones of inhibition, indicating its antimicrobial activity, while in-vitro diffusion investigations suggested persistent drug release. No discernible changes in color, pH, or consistency were noted following one month of stability testing conducted in accordance with ICH standards. The findings suggest that the developed eucalyptus oil emulgel provides an effective, stable, and patient-friendly topical formulation with potential therapeutic benefits for bacterial skin infections and inflammation.

Keywords: Emulgel, Eucalyptus oil, Carbopol 934P, Topical drug delivery, Antibacterial activity, In-vitro diffusion, Stability study

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Introduction

Topical drug delivery systems are widely used for local treatment of various skin disorders due to their ability to deliver drugs directly to it of action while minimizing systemic side effects [1-2]. However, conventional topical formulations often suffer from limitations like poor penetration, greasy texture, and phase instability [3]. To overcome these drawbacks, emulgels a novel combination of emulsions and gels have gained significant attention in recent years [4-5]. Emulgels integrate the advantages of both emulsions (enhanced solubility of lipophilic drugs) and gels (improved patient compliance and controlled release), providing an effective vehicle for topical drug administration [6-7].

Carbopol 934P is a widely used gelling agent that imparts desirable viscosity, stability, and smooth texture to formulations [8-9]. Its ability to form a clear, stable, and thixotropic gel makes it suitable for emulgel preparation. Eucalyptus oil, a natural essential oil known for its potent antibacterial, antifungal, and anti-inflammatory properties, serves as an effective therapeutic agent for treating microbial skin infections and inflammatory conditions [10]. Incorporating eucalyptus oil into an emulgel base enhances its therapeutic potential by ensuring sustained drug release and improved skin penetration [11-12].

Present study concentrations on formulation, optimization, and evaluation of an emulgel containing eucalyptus oil, using Carbopol 934P as a gelling agent. Various concentrations of Carbopol were

investigated to optimize the gel base [13-14]. Following ICH criteria, the emulgels were tested for physical properties, viscosity, extrudability, spreadability, stability, drug content, antibacterial activity, and in-vitro drug diffusion [15]. Study aims to develop a stable and current eucalyptus oil emulgel formulation suitable for topical application with enhanced therapeutic efficacy and patient acceptability.

Experimental Work

Optimization of gel formulation

Carbopol 934P as a gelling agent in production of gel. Carbopol 934P concentrations were employed in a variety of concentration ranges (0.5 to 1 percent) [16].

Table 1: Formula of gel

Batch no. ingredient	**F1**	**F2**	**F3**
Carbopol 934 (g)	0.25	0.375	0.5
Water (ml)	q.s.		
Triethanolamine (ml)	q.s.		
Where (a) is volume taken in ml and (b) is the weight taken in g.			

Preparation of gel, emulsion & emulgel

To generate a uniform mixture, the specified amount of Carbopol 934 was weighed and mixed thoroughly with water in a temperature range of 65-70°C for 10 minutes using a magnetic stirrer set at 1000±200 rpm. This process was carried out in accordance with the ingredients listed in Table 1. The trapped air can escape if you let the preparation stand for a few minutes. Next, add the triethanolamine gelling agent in the recommended amount while swirling continuously with a spatula to prevent air from becoming trapped. Then the rest of the water was mixed in [17].

To make the oil phase, Span 20 was combined with peppermint oil, eucalyptus oil, and light liquid paraffin. To make aqueous phase, Tween 20 was dissolved in water that had been filtered. Before being added to oil phase, Methylparaben and Propylparaben were dissolved in propylene glycol. The oil and water were heated to 70–80°C independently, and then, while stirring constantly, oil was gradually added to water until combination cooled to room temperature. A tightly sealed airtight container was used to keep the emulsion that was produced (Table 2).

Table 2: Composition of Emulsion (Optimized Batch)

Ingredient	**Quantity taken**
Eucalyptus oil (a)	2.1
Light liquid paraffin (a)	4.37
Peppermint oil (a)	1.05
Span 20 (a)	2.8
Tween 20 (a)	1.4
Methylparaben (b)	0.003
Propylparaben (b)	0.01
Propylene glycol (a)	5
Water (a)	q.s.
Where (a) is volume taken in ml and (b) is the weight taken in g.	

To prepare the emulgel, obtained emulsion was blended by gel base in a 1:1 ratio using a mechanical stirrer (RQT-127/Remi) at a speed of 5000–6000 rpm for approximately 10–20 minutes [18].

Evaluation of Emulgel

Physical Examination

The color, uniformity, texture, and phase separation of the developed emulgel formulations were visually inspected.

pH

A 1% emulgel dispersion was prepared and maintained at 27±1°C. pH was determined by digital pH meter (Systronics pH system 362).

Viscosity

Rheological properties of emulgel were assessed using a Brookfield viscometer (Brookfield, Fungilab).

Spreadability

A glass slide setup was used, where approximately 2 g of gel was placed on a ground glass slide. Another slide of the same size, equipped with a hook, was placed over it. A 100 g weight was applied for 5 minutes to eliminate air bubbles and ensure a uniform gel film. Excess gel was removed from the edges. The upper slide was then pulled using a 20 g weight attached to the hook by a thread, and the time (in seconds) required for the upper slide to move a distance of 7.5 cm was recorded. A shorter time indicated better spreadability.

Extrudability

The gel formulations were filled into collapsible aluminum tubes, sealed, and weighed. The tubes were placed between two glass slides and a 500 g weight was applied. After removing the cap, the extruded gel was collected and weighed, and the percentage of extruded gel was calculated.

Drug Content

The drug content in the emulgel was analyzed by sonicating 1 g of the formulation in methanol. The mixture was diluted, filtered to obtain a clear solution, and analyzed spectrophotometrically. The drug concentration was determined using calibration data.

In-vitro Drug Diffusion Study

In-vitro drug release was carried out using a Franz diffusion cell with an egg membrane. The membrane was uniformly spread with 200 mg of emulgel and clamped between the donor and receptor compartments. The receptor chamber was filled with 40 ml phosphate buffer (pH 5.5) and stirred at 37°C using a magnetic stirrer. Samples (2 ml) were withdrawn at 1-hour intervals and replaced with an equal volume of fresh buffer. The drug content was measured at 209 nm using a UV spectrophotometer (Pharmaspec 1700, Shimadzu, Japan) against phosphate buffer (pH 5.5) as a blank. A plot of drug diffusion per unit area versus time was prepared for further analysis [19].

Antibacterial Activity

The antibacterial potential of the formulated emulgel was tested using the agar well diffusion method against standard bacterial strains—Escherichia coli (Gram-negative) and Staphylococcus aureus (Gram-positive). The bacterial cultures were obtained from Yashwantrao Chavan Institute of Science College, Satara. All materials used, such as Petri plates, cotton plugs, micropipettes, sterile syringes, test tubes, volumetric flasks, spatulas, cork borers, and glass spreaders, were sterilized and handled aseptically. The nutrient agar medium was prepared by dissolving accurately weighed quantities of peptone, beef extract, sodium chloride, and agar in distilled water. The pH was adjusted to 7.0 and the medium was sterilized at 121°C for 20 minutes under 15 psi pressure. Approximately 20 ml of the sterilized medium was poured into each Petri plate and allowed to solidify at room temperature under aseptic conditions before use.

Table 3: Components used for the preparation of agar medium

Ingredient	Quantity
Peptone (b)	2.5
Beef extract (b)	0.8
Sodium chloride (b)	1.5
Agar agar I (b)	7.5
Distilled water (a)	250
Where (a) is volume taken in ml and (b) is the weight taken in g.	

For the preparation of agar plates (Table 3), about 20 ml of sterilized nutrient agar medium was poured into each sterile Petri plate under aseptic conditions. The plates were allowed to solidify at room temperature for approximately 20 minutes in a sterile environment. The test microorganisms used in this study were Staphylococcus aureus (Gram-positive) and Escherichia coli (Gram-negative). A bacterial suspension of each strain was prepared, and 0.1 ml of the suspension was uniformly spread over the solidified agar surface using a sterilized glass spreader under aseptic conditions to ensure even distribution of the inoculum.

Wells were made in the inoculated agar plates using a sterile cork borer with an 8 mm diameter. Each plate contained four wells—one designated as the positive control, another as the negative control, and the remaining two for testing eucalyptus oil and the formulated emulgel, respectively. The respective samples were carefully dispensed into the wells using a sterile micropipette. The plates were then kept in a refrigerator for approximately 2 hours to facilitate proper diffusion of the samples into the medium. After

diffusion, the plates were incubated at 37°C for 24 hours. Post incubation, the plates were observed, and the zones of inhibition around each well were measured to determine the antibacterial efficacy of the test samples [20–22].

Stability Study

Stability testing of the emulgel was conducted following ICH guidelines at a temperature of 40 ± 2°C and 75% relative humidity (RH). The emulgel formulations were filled into clean, lacquered collapsible aluminum tubes, and multiple samples were stored in a humidity chamber maintained at 40°C and 75% RH. The formulations were evaluated for changes in appearance and pH at intervals of 7, 15, and 30 days [23].

Results & Discussion

Optimization of gel formulation

Concentrations of gelling agents were optimized based on their integrity (Table 4). Carbopol 934P optimized as gelling agents with the desired consistency.

Table 4: Optimization of gel formulation

Trial batches	Carbopol 934 (%)	Gelling integrity
F1	0.25	Liquid
F2	0.37	Semisolid
F3	0.50	semisolid

Evaluation of emulgel

To obtain an emulgel, prepared emulsion was mixed into gel basis in a 1:1 ratio using a mechanical stirrer (RQT-127/ Remi) at 5000-6000 rpm for around 10-20 minutes.

Physical examination

The color, consistency, homogeneity, and phase separation of prepared emulgel formulation were all visually checked (Table 5).

Table 5: Physical properties of emulgel

Physical properties	Observation
Color	White
Homogeneity	Homogenous
Consistency	Semisolid
Phase separation	Not observed

The pH of the formulation should be such that it should be non-irritating to the skin. The formulation's pH was observed to be 5.523±0.0047, this range of pH lies in normal pH of the skin (Table 6).

Spreadability

The emulgel was found to have a spreadability of 30.33±0.471 g.cm/sec. Table 6 shows that the addition of propylene glycol, a humectant, improved the spreadability of emulgel.

Table 6: pH and Spreadability of emulgel

Sr. No.	pH	Spreadability
1	5.52	30
2	5.52	31
3	5.53	30
Mean	5.52	30.33
Standard deviation	0.0047	0.471

Viscosity

Brookfield viscometer (Fungilab) at 100 rpm with L4 spindle was used to determine viscosity of emulgel. The viscosity was discovered to be 2781 cPs. The viscosity of formulation was compared to that of a commercial cream. It had a lower viscosity than commercial cream. As the emulsifier content was increased, the viscosity increased as well.

Extrudability

It was determined that 81% of the emulgel could be extruded. The developed formulation exhibited good extrudability, meaning that less force was needed to remove material from the tube.

Drug content

One gram of emulgel formulation was used for drug content determination, dilutions were made with n-hexane until 500µg/ml concentration was obtained and subjected to UV spectrophotometer at 280 nm.

500 µg of emulgel contains 33.65 µg of drug theoretically and 30.26 µg practically.

Drug content = Actual conc. /Theoretical conc. x 100

The drug content of emulgel was shown to be 92.67%.

In-vitro drug diffusion study

Table 7: *In-vitro* drug diffusion Study

Time (h)	% CADD			Mean ± Std. Deviation
1	24.65	25.59	25.51	25.25 ± 0.425
2	31.83	32.55	32.55	32.31 ± 0.339
3	43.45	44.21	44.16	43.94 ± 0.347
4	52.39	53.09	53.37	53.37 ± 0.412
5	59.72	60.42	60.14	60.09 ± 0.287
6	68.35	71.54	69.26	69.71 ± 1.341
7	79.19	81.84	80.88	80.63 ± 1.095
8	81.16	82.16	81.11	81.47 ± 0.483
9	82.51	83.67	83.30	83.30 ± 0.564

A drug diffusion investigation of emulgel was performed in vitro using a Franz diffusion cell in a phosphate buffer pH 5.5 medium. The results show that emulgel formulations with a larger percentage of CADD resulted in increased release. According to Table 7 and Figure 1, the drug release from the formulation was determined to be 83.30% ± 0.564% after 9 hours, indicating a better % of CADD compared to emulgel formulation.

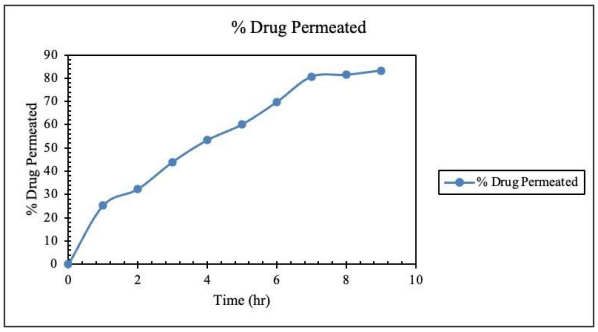

Figure 1: *In-vitro* drug diffusion study

Antibacterial activity

Outcome of antibacterial action of emulgel was examined *Escherichia coli* and *Staphylococcus aureus* by an agar well diffusion assay. The diameter of zone of inhibition of samples and the control group was shown in Table 8.

Table 8: Antibacterial activity of emulgel

Microorganism	Test sample	Zone of inhibition (mm)
Escherichia coli	Eucalyptus oil	25.3
	Emulgel formulation	29
	Positive control (+) std.	31
	Negative control (-)	-
Staphylococcus aureus	Eucalyptus oil	23
	Emulgel formulation	27
	Positive control (+) std.	30
	Negative control (-)	-

The positive and negative controls were used for the comparative analysis. Marketed Clobet Gm cream (clobetasol propionate, clotrimazole, and neomycin sulfate) was used as a positive control (+), and SWI was used as a negative control (-). Antibacterial activity of formulation and control groups were studied against *E. coli*, *S. aureus* that was shown in Figure 2.

Formulated emulgel showed highest zone of inhibition against *Escherichia coli* (29 mm), followed by *Staphylococcus aureus* (27 mm). Formulated emulgel showed its effectiveness against gram-positive & negative bacteria; hence it can be used as an antibacterial agent in skin disorders.

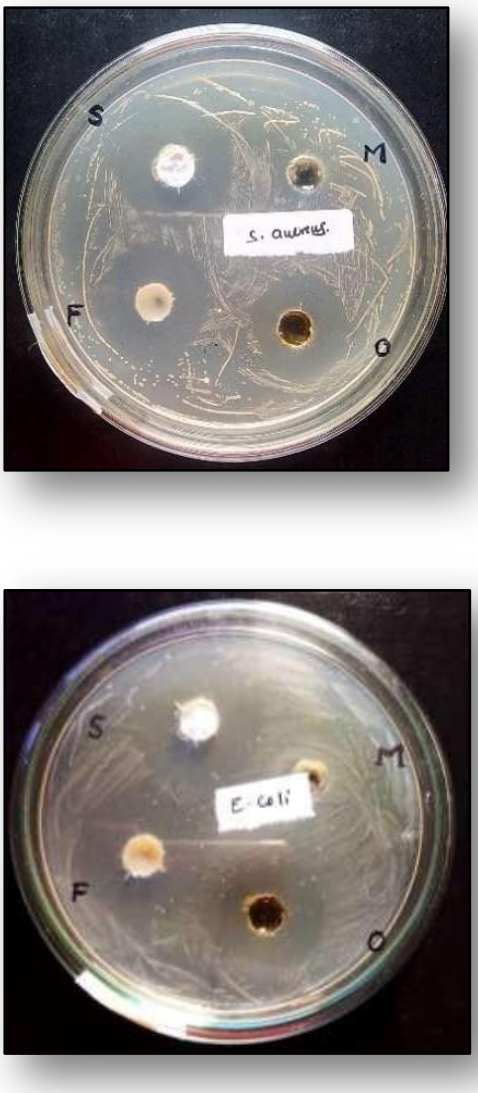

Figure 2: Antibacterial activity of formulation and control groups (O=Eucalyptus oil, M=sterile water for injection, F=prepared formulation, S=standard)

Stability studies

Observations of thermodynamic studies are quoted in Table 9 which denoted the stability of emulgel.

Table 9: Thermodynamic stability of the emulsion

Parameter	Centrifugation	Room Temperature
Phase separation	No	No
Creaming	No	No
Coalescence	No	No

During stability studies (Table 10), the appearance of the formulation was white to slightly yellowish. From the results, it was noted that there were no major changes observed in pH, and drug content, and drug diffusion. Comparative study of emulgel showed no significant difference before and after testing. This revealed more stability of emulsion when it was incorporated in a gel base and that formulation was stable over the period of 3 months.

Table 10: Stability studies

Property	Formulation	0 Month	1 Month	2 Month	3 Month
Physical appearance	Emulsion	No change			
	Emulgel	No change			
Gelling integrity	Emulgel	No change			
pH	Emulsion	5.28	5.28	5.27	5.27
	Emulgel	5.523 ±0.4	5.523 ±0.4	5.522 ±0.3	5.521 ±0.4
Drug content	Emulgel	92.67 %	92.31 %	91.78 %	90.63 %
% drug diffused	Emulgel	83.30 ± 0.564	83.24 ± 0.564	82.97 ± 0.564	82.71 ± 0.564
Where the value of pH, drug content, and % drug diffuse in 9 h are mean ±SD for triplicate determination					

Conclusion

The study successfully formulated and optimized an emulgel containing eucalyptus oil using Carbopol 934P as a gelling agent. Among various formulations, optimized batch exhibited excellent physical stability, appropriate pH, desirable viscosity, and superior spreadability and extrudability characteristics. The produced emulgel showed strong antibacterial activities against *Escherichia coli* and *Staphylococcus aureus* and offered sustained drug release, according

to the in-vitro diffusion and antibacterial activity investigations. The stability studies also showed that the formulation didn't change even when stored at high temperatures for long periods of time. In comparison to more traditional formulations, the eucalyptus oil emulgel that was created in this study shows promise as a method for topical therapy due to its higher efficacy, simpler application, and higher rate of patient compliance.

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