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Topical Film-Forming Spray Loaded with Virgin Coconut Oil: Formulation and In Vitro Evaluation

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ABSTRACT
The present study focuses on the formulation and evaluation of a topical film-forming spray incorporating virgin coconut oil (VCO) for potential antifungal therapy. VCO, rich in medium-chain fatty acids such as lauric acid, exhibits significant antifungal activity and was utilized as a natural bioactive agent. The formulations were prepared using a solvent evaporation technique with ethyl cellulose and polyvinylpyrrolidone K30 as film-forming polymers, along with a eutectic mixture of menthol and camphor to enhance skin permeation. Preformulation studies, including FTIR analysis, confirmed the compatibility of VCO with selected excipients, while GC-MS analysis validated the presence of main fatty acids responsible for antifungal activity. A total of nine formulations (F1–F9) were developed and evaluated for physicochemical parameters such as viscosity, spray angle, pH, film formation time, drug content, and *in vitro* drug release. All formulations exhibited acceptable characteristics suitable for topical application. Drug release studies indicated controlled release behavior following zero-order kinetics with non-Fickian diffusion. Among all formulations, F5 was identified as the optimized and best formulation, demonstrating balanced performance in terms of viscosity, sprayability, film integrity, and controlled drug release. Accelerated stability studies confirmed that the optimized formulation remained stable over a period of six months under specified conditions. Thus, the developed VCO-loaded film-forming spray represents a promising, patient-friendly, and effective alternative for the topical management of fungal infections.

KEYWORDS: Ethyl cellulose, Film-forming spray, Polyvinylpyrrolidone K30, Topical delivery, Virgin coconut oil.

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INTRODUCTION
Transdermal drug delivery is a noninvasive method of drug delivery through the skin. This method involves the use of patches, gels, microneedles, creams, or other formulations containing active pharmaceutical ingredients. This is a barrier in the skin (epidermis, stratum corneum), but some formulation constituents enable drugs to diffuse through the skin's layers and reach the bloodstream. The benefits of transdermal drug delivery are that there are fewer side effects, no needles, and therefore less invasive, quicker, controlled delivery, better adherence, better therapeutic bioavailability, and easy application [1]. Dermatophyte infections, also known as dermatophytosis, are caused by fungi that target the outermost layers of skin, hair, and nails, particularly tissues rich in keratin. Dermatophytes, which are a group of fungi that includes the genera Trichophyton, Microsporum, and Epidermophyton, cause these infections. Tinea infections are named after the part of the body they affect, like Tinea pedis (feet), T. capitis (scalp), T. cruris (groin), T. corporis (general skin), and T. unguium (nails) [2]. Skin fungal infections require prompt treatment with suitable medications such as creams, powders, patches, ointments, or gels. However, patches can trap moisture, block sweat ducts, cause irritation, be difficult to apply on curved areas, and are often uncomfortable or less aesthetic [3]. Patches have size and shape restrictions, and semisolid preparations do not provide long-term skin contact; they need to be applied frequently and leave a greasy residue, which is not compliant. A superior solution is the use of film-forming sprays, which leave the drug and excipients behind by forming a thin film upon solvent evaporation, facilitating controlled and prolonged drug release [4]. Most commercial formulations include polymeric film formers and synthetic antifungal agents, which can irritate, allergize, or desiccate skin, especially sensitive skin. Rapid solvent loss and uneven film deposition can result in uneven drug delivery and poor retention, requiring repeated deposition-delivery procedures and lowering patient compliance [5,6]. The structural integrity and long-term drug release of conventional synthetic polymer layers are often compromised by their brittleness, leading to peel-offs or cracks. Additionally, the stratum corneum has extremely low permeability, which restricts drug diffusion, reduces bioavailability, slows healing, and increases the risk of recurrence. Since FFS containing natural antifungal agents is currently under development, it is crucial to develop more patient-friendly, biocompatible formulations with improved permeation, high skin adhesion, and broad therapeutic activity [5,7]. Virgin coconut oil (VCO) is of particular interest due to its antifungal effects. Its high levels of medium-chain fatty acids, such as lauric acid, enable this. Lauric acid and the derivative monolaurin can interfere with fungal cell membranes, resulting in cell lysis. According to the study by Bello et al., virgin coconut oil has a potent antifungal effect against A. flavus, A. niger, C. albicans, and P. chrysogenum. Among the extraction methods, the naturally fermented VCO showed a more potent antifungal effect against low structures than the hot-extracted VCO. These results indicate that natural fermentation improves the antifungal activity of VCO compared to heat-extraction procedures [8]. In another study, Mbim et al. reported that cold-pressed coconut oil showed vigorous anti-fungal activity against C. albicans and was superior to fluconazole in several in vitro assays. Oil was

more potent, with larger zones of inhibition (47-76 mm) than fluconazole (12-42 mm), and lower MICs (1.576.25) and MFCs (3.13-12.5) [9]. Nitbani et al. demonstrate that monolaurin and lauric acid can prevent the development of several fungal species, including Trichophyton, Microsporum, and Epidermophyton. Amphiphilicity of the two compounds is one of the reasons they are effective against fungi [10].

This research work aimed to develop a topical spray that forms a film, incorporating virgin coconut oil along with ethyl cellulose and polyvinylpyrrolidone K30 as the polymeric agents for film formation. The formula is characterized by a eutectic (menthol and camphor) mixture, which helps significantly to increase skin absorption by penetrating the stratum corneum [11,12]. This eutectic mixture is another solvent for film-forming polymers, a skin-cooling agent, and exhibits vigorous antifungal activity [2,13].

MATERIALS AND METHODS

Materials

Virgin coconut oil was purchased from Veda Oils Pvt. Ltd., Haryana, India. Ethylcellulose, Polyvinylpyrrolidone K30, and Camphor were obtained from CDH Pvt. Ltd., New Delhi, India. Propylene glycol 400 was obtained from S.D. Fine Chemical Pvt. Ltd., Ahmedabad, India. Analytical-grade solvents, such as menthol, acetone, chloroform, and ethanol, were used.

Methods

Drug Polymers / Excipients Compatibility Study by using FTIR Spectroscopy

Drug–polymer interactions were analyzed using FTIR (PerkinElmer Spectrum IR, version 10.7.2). Samples were prepared by mixing virgin coconut oil with KBr at a 1:100 ratio and scanned over 4000–450 cm^{-1}. The spectra were examined for any shifts or changes indicating physical interactions between the bioactive oil and excipients [14,15].

Determination of fatty acid profile by using GCMS

Formation of fatty-acid-methyl-esters

The process of methyl esterification was carried out via alkaline hydrolysis. 20 mg of virgin coconut oil was treated with 0.5 M methanolic sodium hydroxide, heated at 50 °C for 20 seconds, and then extracted with hexane. After phase separating, the upper layer was combined with methanolic HCl, subjected to vortex mixing, and the resultant upper layer was employed for chromatographic analysis [16].

Quantification via GC-MS

The FAME analysis was carried out using a PerkinElmer GC-MS (Auto System XL, Turbo Mass) fitted with an Elite-5 MS column measuring 30 meters in length, 0.25 mm in diameter. The device was maintained at 260°C. Helium was used as the carrier gas at a flow rate of 1 mL/min with a split ratio of 1:10. The oven temperature was raised from 75°C to 280°C at a rate of 10°C per minute. Then it was kept at a high level for 10 minutes. Mass spectra were obtained over the m/z range of 40 to 500 using an ion source temperature of 220°C and an interface temperature of 260°C. All tests were carried out in triplicate, and the FAME peaks were determined by comparing their chain lengths and retention times with established standards [16].

Preparation of bioactive oil-loaded formulations by using a solvent dissolving technique

The formulation of the virgin coconut oil film-forming spray was prepared using a solvent dissolving technique. Each sample of virgin coconut oil was separately dissolved in a solvent blend made up of ethanol, acetone, and chloroform (5:4:1). A solution was created in the eutectic mixture using precisely measured amounts of ethyl cellulose and polyvinylpyrrolidone K-30, to which the virgin coconut oil in the solvent mixture was gradually incorporated. The solution was agitated for 15 minutes at 80–100 rpm, followed by 10 minutes of sonication. PEG-400 was then added to the mixture, and stirring continued for an additional 15 minutes (**Table 1**). Subsequently, the solution was transferred into a refillable container equipped with a plastic dip tube having a 2 mm internal diameter [2,17].

Table 1: Composition of a Topical Film-Forming Spray Loaded with Virgin Coconut Oil

Components	Formulation Code								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
Virgin Coconut Oil (% w/v)	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Ethyl Cellulose (%w/v)	7.5	5	5	5	7.5	2.5	2.5	7.5	2.5
Polyvinylpyrrolidone K30 (%w/v)	3	3	1	2	2	3	2	1	1
Propylene glycol 400 (%v/v)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
*Eutectic Blend (%v/v)	10	10	10	10	10	10	10	10	10
**Solvent Mixture (Q.S.)	100	100	100	100	100	100	100	100	100

*Eutectic blend: equal portion of camphor & menthol (1:1)
**Solvent Mixture: Ethanol: Acetone: Chloroform (5:4:1)

EVALUATION OF PREPARED TOPICAL FILM-FORMING SPRAY

Volume of solution delivered each actuation

The volume of solution dispensed per actuation was calculated using the specified formula.

$$A_L = (W_t - W_o) / D_n$$

Here, W_t is the weight after actuation, W_0 is the weight before actuation, D_n is the formulation density, and A_L denotes the volume delivered per actuation [2].

Film Formation Time

The duration for the film to dry was assessed to ascertain the rate of solidification after the application of the solution. Under certain circumstances, the solution is sprayed onto the PVA membrane and allowed to dry at ambient temperatures [17].

pH determination

The formulation's pH was assessed using a calibrated digital pH meter. The meter was calibrated with pH four and pH seven buffer solutions, and the measurements were recorded after immersion of the probe in the test sample [17].

Spray angle

The spray angle assessment was conducted by dispersing a solution containing 10 mg of Sudan Red, for visibility, onto a white filter paper positioned 15 cm from the nozzle. The resulting circular spray pattern was assessed at three locations along the radius, and the spray angle (θ) was determined utilizing the corresponding formula.

$$\text{Spray angle } (\theta) = \tan^{-1} (l / r)$$

Here, r denotes the mean radius of the circle, while *l* indicates the distance from the nozzle to the sheet of paper [2].

Viscosity

A Brookfield viscometer (Model LVT/RVT) was used to measure the viscosity of the film-forming discharge at 25 ± 1°C. The spindle S61 turned at 12 rpm for 10 minutes. To ensure accuracy, each measurement was repeated three times. This test helped determine the optimal viscosity range for good sprayability [17].

Film flexibility, Stickiness and Water washability

The plasticity of the film was also tested by placing the spray on a PVA membrane and stretching it; films that did not tear were then considered flexible. Stickiness was determined by applying cotton to the dried film; the degree of fiber adhesion indicated stickiness. Moderate fiber deposition suggested medium stickiness and non-adherence to strands. Washability was assessed after drying and rated as Good (+++), Moderate (++), or Poor (+) [17].

Drug Content

The bioactive oil concentration in the film-forming solution was determined to ensure uniform dosage per spray. After dissolving the cellulose membrane coated with the spray in 5 ml of methanol (a total of 10 ml), the membrane was filtered through Whatman paper and suitably diluted. A control without the bioactive oil was prepared similarly, and the bioactive oil concentration was assessed at 653 nm using a UV-visible spectrophotometer relative to the control [15,18].

In-vitro diffusion studies by using a dialysis membrane

A diffusion study of the topical FFS was conducted *in vitro* using a franz diffusion cell equipped with a cellulose membrane (M.W. 12,000–14,000 Da) pre-soaked in pH 7.4 PBS. The membrane divided the donor and receptor compartments, with the receptor compartment containing phosphate buffer. Samples were obtained from the receptor compartment at designated intervals (0–420 min), with equal buffer replacement following each withdrawal. The quantification of the diffused bioactive oil was performed at 653 nm utilizing a UV-visible spectrophotometer following dilution with methanol [2,17]. The extractive spectroscopy method was utilized to analyze an appropriate aliquot, which was also reported in our previous work [19].

Drug release kinetics (in-vitro) studies

The results of the *in vitro* drug release study were assessed using four different models: zero-order, first-order, Higuchi, and Korsmeyer- Peppas models, to explore the drug release mechanism from the formulation [2,17].

Accelerated Stability Analysis

Under accelerated stability conditions, the optimized formulation was maintained at 40°C ± 2°C and 75% ± 5% relative humidity for 6 months, protected from light. After six months, formulations were evaluated in several ways, including viscosity assessment, pH measurement, volume of solution dispensed per actuation, and % CDR [15,20,21].

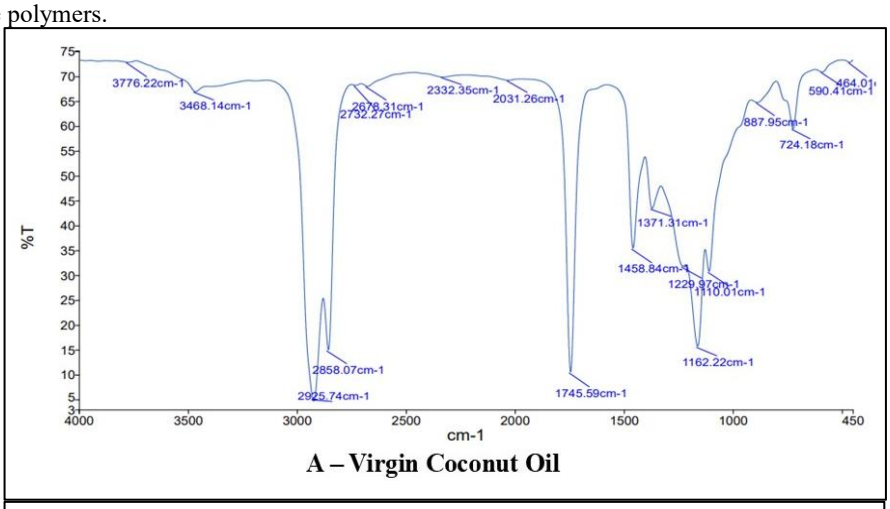
RESULTS AND DISCUSSION

Drug Polymer/Excipients Compatibility study by using FTIR Spectroscopy

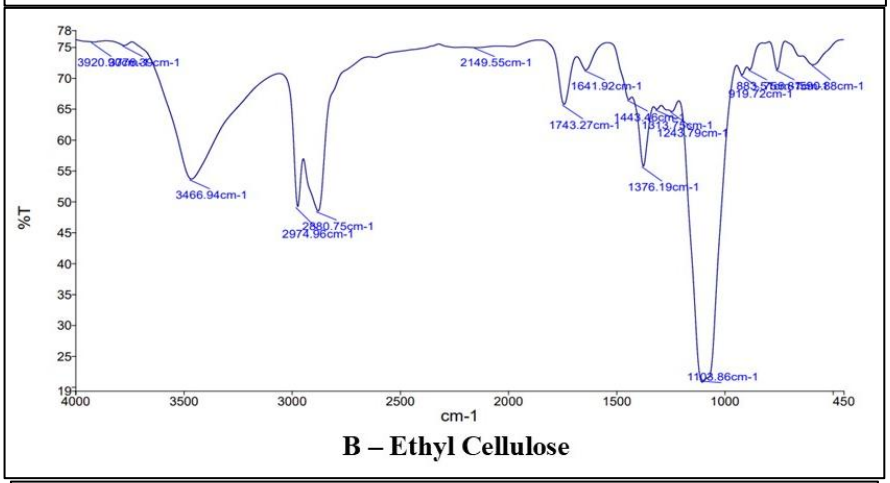
FTIR spectroscopy was used to characterize the organic complex and identify the functional groups present in the formulation. **Figure 1** shows the infrared spectra of the bioactive oil, each polymer, and the prepared blend. There were clear absorption bands in fresh virgin coconut oil at 3468.14 cm^{-1} (O–H stretching), 2925.74 cm^{-1} (C–H stretching), 1745.59 cm^{-1} (C=O stretching), 1458.84 cm^{-1} (C–H bending), and 1371.31 cm^{-1} (C–O stretching). Ethyl cellulose has distinct peaks at 3468.44 cm^{-1} (O–H stretching), 2974.96 cm^{-1} (C–H stretching), 1743.27 cm^{-1} (C=O stretching), and 1443.46 cm^{-1} (C–H bending). For

PVP K30, there were clear peaks at 3468.44 cm^{-1} (O–H stretching), 2959.28 cm^{-1} (C–H stretching), 1657.28 cm^{-1} (C=O stretching), and 1287.80 cm^{-1} (C–N stretching).

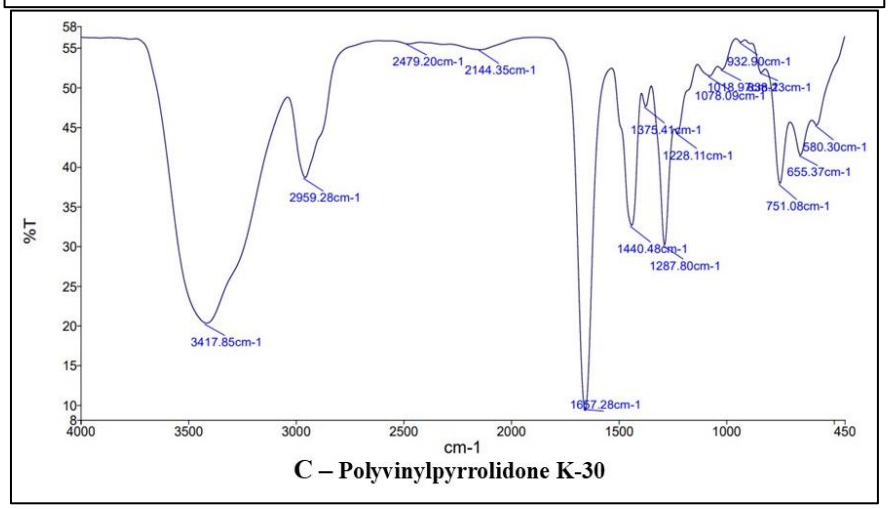
The leading absorption bands for PEG 400 were at 3401.02 cm^{-1}, 1461.20 cm^{-1}, 1353.54 cm^{-1}, 1250.44 cm^{-1}, and 1104.38 cm^{-1}. These bands corresponded to O–H stretching, C–H bending, and asymmetric/symmetric C–O–C ether vibrations. The FTIR spectrum of the physical mixture containing virgin coconut oil, ethyl cellulose, PVP K30, PEG 400, and other excipients preserved the principal peaks of virgin coconut oil at 3421.82 cm^{-1} (O–H stretching), 2920.31 cm^{-1} (C–H stretching), 1743.22 cm^{-1} (C=O stretching), 1459.83 cm^{-1} (C–H bending), and 1355.46 cm^{-1} (C–O stretching). The principal peaks of the bioactive oil were preserved in the bioactive oil–polymer blend, indicating that no significant chemical interactions occurred between the bioactive oil and the polymers.



A – Virgin Coconut Oil



B – Ethyl Cellulose



C – Polyvinylpyrrolidone K-30

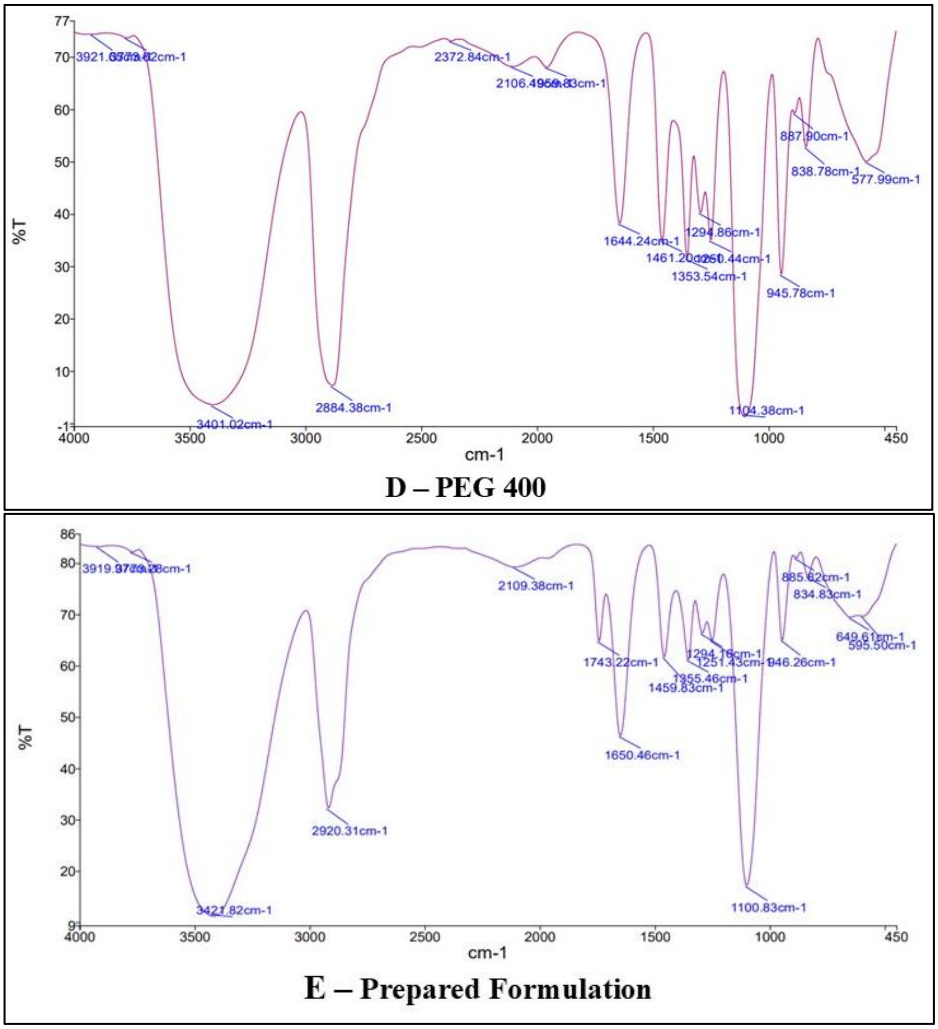


Figure 1: FTIR spectra. A- Virgin Coconut Oil, B- Ethyl Cellulose, C- PVPK 30, D- PEG 400, E- Prepared Formulation

Determination of fatty acid profile by using GCMS

Several essential components were identified by GC-MS profiling of the fatty acids in virgin coconut oil. Caprylic acid (C8:0), capric acid (C10:0), lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), and stearic acid (C18:0) were the main saturated fatty acids found. Furthermore, the main monounsaturated fatty acid in the oil was oleic acid (C18:1). Additionally, the research verified the existence of polyunsaturated fatty acids that are favorable to nutrition, including linoleic acid (C18:2). Gas chromatography showed that saturated fatty acids make up the majority of VCO's makeup, making up 88.58% of the total fatty acid content, the most significant percentage of any detected fatty acid class **(Figure 2**). Polyunsaturated fatty acids account for the lowest percentage of 2.47% of VCO, while monounsaturated fatty acids make up 8.33%. Saturated fatty acids make up the majority of the VCO, according to chromatography. It's interesting to note that it contains 20.68% myristic acid and 45.18% lauric acid, both of which have a potent antifungal effect **(Table 2)**.

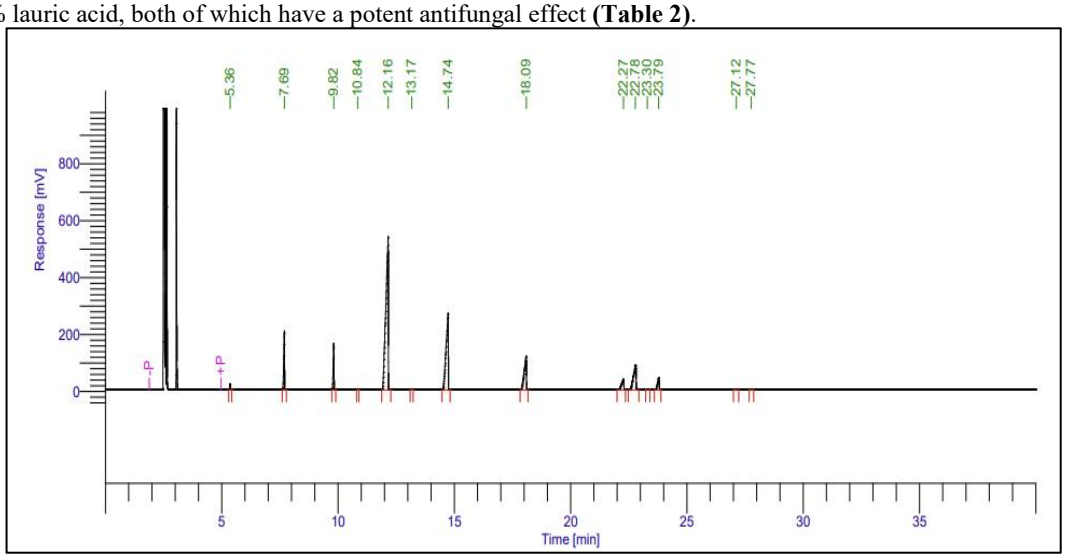


Figure 2: Chromatogram of Fatty Acid Methyl Ester from Virgin Coconut Oil

Table 2: Fatty acid Composition

Fatty Acid	Retention Time (min)	Observed Area (%)	Reported Area (%)	Reference
Saturated				[16]
Caprylic Acid (C8:0)	7.69	5.77	5.1	
Capric Acid (C10:0)	9.82	4.70	4.5	
Lauric Acid (C12:0)	12.16	45.18	44.6	
Myristic Acid (C14:0)	14.74	20.68	20.4	
Palmitic Acid (C16:0)	18.09	9.31	11.2	
Stearic Acid (C18:0)	22.27	2.94	2.6	
Monosaturated				
Oleic Acid (C18:1)	22.78	8.33	5.5	
Polyunsaturated				
Linoleic Acid (C18:2)	23.78	2.47	1.8	

EVALUATION OF PREPARED FORMULATIONS

Volume of solution delivered each spray

The prepared film-forming spray should deliver 0.17 ± 0.015 mL to 0.32 ± 0.026 ml per actuation. Polymer concentration affects spray volume; the higher the polymer content, the greater the viscosity, resulting in a delay in film formation and a longer time to set **(Table 3)**.

Viscosity

The viscosity of the formulated film-forming spray ranged from 9 ± 1.56 cp to 15 ± 1.73 cp (at 12 rpm), which is within the optimal range for FFS formulations. This is in specification with FFS formulations. Viscosity is an important factor that affects the film's uniformity, drying time, stability, and overall performance on the skin **(Table 3)**.

Table 3: Results for Volume of solution delivered each actuation, viscosity, and % cumulative drug release

Formulation Code	Volume of solution delivered each actuation (ml)	Viscosity (cps)	Percent cumulative drug release (%)
F1	0.17 ± 0.015	9 ± 1.155	81.47 ± 0.025
F2	0.24 ± 0.012	13 ± 0.577	83.29 ± 0.025
F3	0.26 ± 0.025	11 ± 3.055	83.10 ± 0.035
F4	0.22 ± 0.047	10 ± 1.527	82.76 ± 0.030
F5	0.25 ± 0.081	11 ± 1.154	80.09 ± 0.025
F6	0.23 ± 0.010	15 ± 1.732	85.13 ± 0.035
F7	0.22 ± 0.025	13 ± 1.00	83.79 ± 0.055
F8	0.32 ± 0.026	12 ± 1.154	81.46 ± 0.015
F9	0.18 ± 0.011	10 ± 0.573	81.66 ± 0.030

***Note:** mean ± SD (n=3)

In-vitro diffusion studies by using a dialysis membrane

All film-forming spray formulations underwent 420 minutes of *in vitro* diffusion testing **(Table 3)**. Formulation F5 had the lowest drug release of all of them (80.09 ± 0.025%), while formulation F6 had the highest (85.13 ± 0.035%). The levels of EC and PVP K30 had a significant impact on drug release. While higher PVP K30 marginally increased %CDR due to its leaching and release-promoting properties, higher EC levels decreased %CDR, confirming its function as a release-retarding agent. However, simultaneous increases in both polymers led to a reduction in %CDR, indicating an interactive inhibitory effect on drug diffusion **(Figure 3)**.

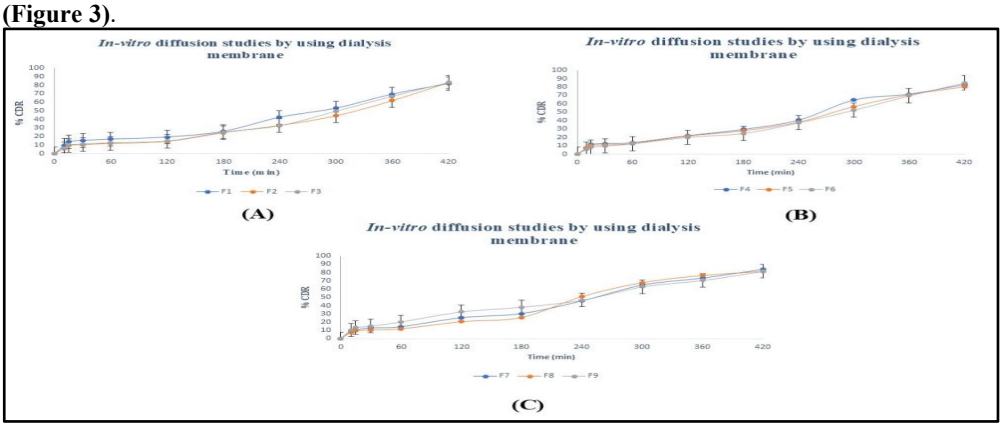


Figure 3: In-vitro percent cumulative drug release for formulations F1 to F9

Film Formation Time

The analysis showed that the film-forming time of the developed formulation was within the optimal range for a film-forming spray, ranging from 3 ± 0.58 minutes to 6 ± 0.73 minutes in winter and from 2 ± 0.57 minutes to 3 ± 0.68 minutes in summer **(Table 4)**.

pH determination

The pH of the solution ranged from 4.37 ± 0.020 to 5.08 ± 0.005, within the normal pH range of the skin and not expected to be irritating **(Table 4)**.

Spray angle

According to the analysis, the prepared formulations' spray angles showed a consistent distribution on the skin's surface, ranging from 28.19º ± 0.0251 to 35.41º ± 0.0264 **(Table 4)**.

Drug Content

One of the most critical aspects of the consistency and dependability of medication delivery systems is the amount of virgin coconut oil released with each spray. Each formulation's drug percentage remained constant at 1.19 ± 0.20 to 1.87 ± 0.20 mg/spray. The amount of drug per spray was used to calculate the % CDR **(Table 4).**

Table 4: Results for film formation time, pH, spray angle, and drug content per actuation

Formulation Code	Winter Film Formation Time (min)	Summer Film Formation Time (min)	pH	Spray angle (º)	Drug Content per actuation (mg)
F1	4 ± 0.76	2 ± 0.57	4.63 ± 0.025	33.95 ± 0.025	1.19 ± 0.020
F2	6 ± 0.73	2 ± 0.57	4.86 ± 0.020	32.36 ± 0.026	1.83 ± 0.010
F3	3 ± 0.59	3 ± 0.53	4.38 ± 0.028	35.41 ± 0.026	1.61 ± 0.020
F4	4 ± 0.73	2 ± 0.57	4.93 ± 0.015	30.48 ± 0.026	1.50 ± 0.020
F5	5 ± 0.42	3 ± 0.57	4.64 ± 0.011	29.15 ± 0.010	1.62 ± 0.025
F6	4 ± 0.72	3 ± 0.68	5.04 ± 0.010	28.89 ± 0.020	1.79 ± 0.025
F7	3 ± 0.58	2 ± 0.58	5.08 ± 0.005	28.19 ± 0.025	1.48 ± 0.025
F8	4 ± 0.57	3 ± 0.57	4.37 ± 0.020	30.08 ± 0.023	1.87 ± 0.020
F9	5 ± 0.56	3 ± 0.67	4.45 ± 0.020	29.38 ± 0.020	1.43 ± 0.020

***Note:** mean ± SD (n=3)

Film flexibility, Stickiness of the film and Water washability

The formulations (F1–F9) were evaluated for film flexibility, stickiness, and water washability using a qualitative grading system, showing noticeable variations in performance. F1 and F5 exhibited excellent flexibility and high stickiness, indicating good film-forming ability and adhesion; however, F1 showed lower washability compared to F5. Formulations F2, F3, F4, F7, and F8 demonstrated moderate properties, while F6 and F9 showed moderate flexibility with high stickiness and excellent washability. Among all, F5 was identified as the best formulation, as it provided an optimal balance of high flexibility, high stickiness, and acceptable washability, making it most suitable for the intended application **(Table 5)**.

Table 5: Results for Film flexibility, Stickiness of the film and Water washability

Formulation Code	Film flexibility	Stickiness	Water Washability
F1	+ + +	+ + +	+ +
F2	+ +	+ +	+ +
F3	+ +	+ +	+ +
F4	+ +	+ +	+ +
F5	+ + +	+ + +	+
F6	+ +	+ + +	+ + +
F7	+ +	+ + +	+ + +
F8	+ +	+ +	+ + +
F9	+ +	+ +	+ + +

***Note: Good (+++), Moderate (++), and Poor (+)**

In vitro drug release kinetics studies

Model fitting using an Excel-based program showed that the drug release from the film-forming spray followed zero-order kinetics, indicating a constant release rate independent of drug concentration. This suggests that the film acts as a physical barrier controlling release. The diffusion exponent (n) values ranged from 0.6327 to 0.7559, supporting a controlled, diffusion-mediated release mechanism (**Table 6)**. The formulations F1 through F9 exhibited non-Fickian anomalous diffusion, indicating a mixture of diffusion and erosion-controlled release of VCO.

Table 6: Drug release kinetics of prepared formulations (F1 to F9)

Formulation Code	Zero Order Kinetics (R^2)	First Order Kinetics (R^2)	Higuchi Model (R^2)	Korsmeyer Peppas Model (n values)
F1	0.9584	0.8830	0.8740	0.7296
F2	0.9392	0.8027	0.8260	0.6392
F3	0.9451	0.8357	0.8334	0.6529
F4	0.9741	0.9153	0.8963	0.6784
F5	0.9758	0.9111	0.8911	0.6501
F6	0.9671	0.8532	0.8663	0.6327
F7	0.9834	0.9287	0.9169	0.6862
F8	0.9693	0.9396	0.8931	0.6373
F9	0.9848	0.9516	0.9601	0.7559

Accelerated Stability study of optimized formulation

Accelerated stability testing for the optimized formulation (F5) was performed for 6 months at 40°C ± 2°C and 75% ± 5% RH. There were no substantial variations in the solution volume per actuation, pH, viscosity, and % CDR in the optimized formulation **(Table 7)**.

Table 7: Accelerated stability study of optimized formulation (F5)

Characteristics Parameters	Temperature: 40°C ± 2°C/75% ± 5% RH			
	Initial	After one month	After three months	After six months
Volume of solution delivered each spray	0.25 ± 0.081	0.24 ± 0.045	0.22 ± 0.032	0.18 ± 0.020
pH	4.64 ± 0.011	4.63 ± 0.014	4.65 ± 0.010	4.58 ± 0.009
Viscosity	12 ± 1.154	11.5 ± 1.247	10 ± 1.321	9 ± 1.527
% Cumulative Drug Release	80.25 ± 0.015	80.20 ± 0.020	80.18 ± 0.025	80.02 ± 0.032

CONCLUSION

The present study successfully developed and evaluated a virgin coconut oil-loaded topical film-forming spray using suitable polymeric systems. All formulations demonstrated acceptable physicochemical properties, effective film formation, and controlled drug release behavior following zero-order kinetics with non-Fickian diffusion. Among the developed formulations, F5 was identified as the optimized and best formulation, exhibiting balanced characteristics in terms of sprayability, film integrity, stability, and sustained drug release. Stability studies further confirmed the robustness of the optimized formulation under accelerated conditions. Future directions should focus on *in vivo* studies and clinical evaluation to confirm antifungal efficacy and safety. Additionally, further optimization for large-scale production, long-term stability studies, and incorporation of combination therapies may enhance the therapeutic potential of the developed system.

DATA AVAILABILITY STATEMENT

The data that support the findings of this research are available from the corresponding author upon reasonable request.

COMPETING INTERESTS

The authors declare no competing interests.

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