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Original Article

Formulation and Evaluation of Antiacne Emulgel Using *Aloe vera*

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ABSTRACT

Introduction: Emulgels are emerging as efficient topical drug delivery systems due to their dual-release mechanism, combining the benefits of both emulsions and gels. This system facilitates the enhanced delivery of hydrophobic drugs directly to the target site. *Aloe vera*, known for its antimicrobial and anti-inflammatory properties, offers a promising herbal approach in emulgel formulations for acne treatment. **Materials and Methods:** In this study, *Aloe vera*-based emulgels were formulated using sodium Carboxymethyl Cellulose (CMC) as the gelling agent. A series of formulations (F1-F5) were developed and evaluated for key physicochemical parameters including physical appearance, pH, viscosity, spreadability, extrudability, drug content, *in vitro* drug release, antiacne activity, and stability. The influence of formulation variables on viscosity and drug release was assessed to optimize the formulation. **Results:** Among the tested formulations, F4 exhibited the most favorable characteristics. It showed a pH within the skin-compatible range, excellent spreadability and extrudability, high drug content (91.64%), and the highest drug release (83.51%) within 4 hr. Furthermore, F4 demonstrated significant antiacne activity, showing a 21 mm zone of inhibition at a 50 µL concentration against *Propionibacterium acnes*. The formulation remained stable under accelerated conditions. **Conclusion:** The optimized *Aloe vera*-based herbal emulgel, utilizing sodium CMC as a gelling agent, demonstrated excellent physicochemical properties and promising anti-acne efficacy. Thus, it can be considered a potential candidate for topical treatment of acne infections, offering a safe and effective herbal alternative.

Keywords: *Aloe vera*, Antiacne activity, Experimental factors, Extrudability, Herbal emulgel, *in vitro* release, Sodium CMC, Spreadability.

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INTRODUCTION

The skin is the most accessible organ, which has the potential to expedite the delivery of many drugs with improved efficacy. New methods and techniques are currently under investigation in the topical delivery of drugs. Topical drug delivery involves the direct application of a drug-containing formulation to the skin to treat cutaneous disorders. To overcome problems such as stickiness and a low spreading coefficient, the use of emulgel has increased in both cosmetic and pharmaceutical preparations (Sah *et al*., 2017). Emulgels are emulsions, either water-in-oil (w/o) or Oil-in-Water (o/w) systems that are transformed into a semi-solid form by incorporating a suitable gelling agent. These systems serve as controlled-release drug delivery vehicles, where the drug dispersed in the internal phase gradually diffuses through the external phase to reach the skin, allowing for sustained absorption (Kumar *et al*., 2016).

Herbal medicine still carries a lot of significance, as more than 70% of the entire population and a major part of traditional treatment involve the use of herbal extracts and their active constituents. *Aloe vera* is mainly used to treat first and second-degree burn wounds. It is also known for its anti-inflammatory, antifungal effects, and increased immune activity. Due to its decreased histamine activity, it tends to accelerate the healing process of burn wounds. It offers a natural way to treat stubborn and fungal

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infections (Ojha *et al.*, 2017; Panwar *et al.*, 2015; Ashara *et al.*, 2016).

MATERIALS AND METHODS

Materials

Aloe Vera (The Organic Factory, Bhopal), Sodium CMC, Liquid paraffin, span 20, Tween 20, Propylene glycol, Propyl paraben, Methyl paraben was obtained from S D Fine-Chem Limited, Mumbai.

Methods

Organoleptic properties and solubility

Aloe vera gel powder was examined for its colour, odour, and appearance. Solubility analysis was carried out by dissolving 5 mg of the drug in about 5 mL of solvent such as distilled water (Eckhart *et al.*, 2013).

UV estimation of *Aloe vera* gel powder

Preparation of phosphate buffer pH 7.4

About 8 g of NaCl was added to a beaker containing 800 mL of distilled water. 200 mg of KCl and 1.44 g of Na_2HPO_4 were added to the resultant solution. 245 mg of KH_2PO_4 was added, and the solution was adjusted to the desired pH.

Preparation of standard stock solution of *Aloe vera* and determination of λ_{max}

10 mg of the *Aloe vera* gel powder was weighed and dissolved in a small portion of phosphate buffer p^H 7.4, and the volume was made up to 100 mL using buffer solution to obtain a standard stock solution of 100 µg/mL, sonicated for 10 min to obtain a clear solution.

Calibration curve of *Aloe vera* gel powder in phosphate buffer pH 7.4

From the above solution, 2, 4, 6, 8, and 10 mL were withdrawn and diluted with buffer solution to get standard solutions of concentrations: 2,4,6,8, and 10 µg/mL within the beers range of 2-10 µg/mL. The volume was made up to 10 mL in different series of volumetric flasks with phosphate buffer p^H 7.4 and mixed well. The calibration curve for the solutions was measured at 206.4 nm against phosphate buffer solution of p^H 7.4 as blank (Sah *et al.*, 2017).

Compatibility study of drug and excipient

FT-IR Spectroscopy

Compatibility study of obtained sample of drug and another polymer were analyzed by FT-IR spectroscopy. The pellets were produced by utilizing KBr and the samples were examined in the ratio of 1:100 KBr. Prepared pellets were analyzed with functional group frequencies of *Aloe vera*, Sodium CMC and their combination respectively compared with that of original spectrum. FT-IR spectroscopy was examined to know the compatibility between the drug and excipients in order to produce a safe and efficacious formulation.

DSC analysis

The DSC was performed to check for any interchange between polymer and drug and to assess the thermal behavior. By using Indium, instrument was calibrated for its temperature. Samples were kept in aluminum pans and thematically sealed by utilizing nitrogen gas. Heating rate was 100°C/min (Budiman *et al.*, 2020).

Formulation development

Preparation of gel

A 50 g batch of sodium CMC gel was prepared by dispersing 2.5 g of sodium CMC powder in 50 mL of purified water using a moderate-speed stirrer (50 rpm). The pH of the gel was then adjusted to a range of 6.5-6.8 using 0.5 N sodium hydroxide.

Preparation of emulsion:

The emulsion was prepared using a conventional method. The oil phase was formulated by dissolving Span 20 in liquid paraffin in varying ratios as specified in the formulation table. Simultaneously, the aqueous phase was prepared by dissolving Tween 20 in purified water according to the same formulation ratios. Separately, 1 g of *Aloe vera* extract was mixed with 0.15 g of methylparaben and 0.05 g of propylparaben, which were dissolved in 5 g of propylene glycol. This solution was then incorporated into the aqueous phase. Both the oil and aqueous phases were heated individually to 70-80°C. Following heating, the oil phase was slowly added to the aqueous phase with continuous stirring at 500 rpm until the mixture cooled down to room temperature, resulting in the formation of a stable emulsion (Suganya *et al.*, 2017).

Formulation of *Aloe* vera emulgel

Six *Aloe vera* emulgel formulations were prepared by blending the previously obtained emulsions with the gel base in a 1:1 ratio. The mixing was carried out with gentle stirring until a uniform and homogeneous emulgel was formed. The detailed composition of each formulation is provided in Table 1.

Evaluation of *Aloe vera* Emulgel

Clarity/Appearance

The prepared formulations were examined against white background and black background. They were visually inspected for their color, homogeneity and consistency.

PH

pH of the formulations was determined with the help of a digital pH meter. For measuring pH, initially the pH electrode was calibrated using phosphate buffer pH 7.4 and 1% solution of

formulation was taken. Then, the electrode was immersed into the emulgel formulation and constant readings were taken in triplicate.

Viscosity

The viscosity of the prepared emulgel was measured with the help of a Brookfield digital viscometer. The viscosity was measured using spindle no. TL4 at different rpm. The viscosity measurement was repeated in triplicate, and average readings were taken for standard deviation.

Spreadability

Spreadability study was done by using two glass slides of length 8 cm. 500 mg of emulgel was weighed accurately and placed on one glass slide. Another glass slide was gradually placed on it from a height of about 5 cm. A weight of about 5 g was placed on the upper glass slide. After 1 min, the circumference of the circle that was spread was measured in cm. The observed diameter is a measure that designates the type of gel formed.

Drug content

Drug content was estimated by dissolving about 1g of emulgel into 100 mL of phosphate buffer of p^H 7.4. 1 mL was withdrawn from the above solution and diluted up to 10 mL with phosphate buffer. The phosphate buffer at pH 7.4 was preferred over water, as the drug exhibited the highest solubility. The resultant solution was sonicated for 30 min and then filtered. The absorbance was measured spectrophotometrically at 206.4 nm.

In vitro permeation study

The permeation study of emulgels was carried out with the help of a Franz diffusion cell. Dialysis membrane of pore size 150 µm was used as an artificial membrane. The membrane was soaked in phosphate buffer pH 7.4 prior to the study for 24 hr and carefully mounted between the donor and receptor chambers. 150 mg of emulgel was weighed accurately and spread on the membrane. 12.5 mL of 7.4 pH phosphate buffer was used as a dissolution medium which was placed in the receptor medium. Both the compartments were kept in contact with each other and the setup was maintained at a temperature of 37±0.5°C. The solution in the receptor compartment was stirred with the help of a magnetic bead. At specific time intervals, samples of 1 mL were pipetted out in a series of volumetric flasks and replaced with the same amount of fresh buffer solution. This investigation was continued for 5 hr. Samples at different time intervals were analyzed by a UV spectrophotometer at 206.4 nm. The amount of drug permeated was determined.

Determination of Minimum Inhibitory Concentrations (MIC)

The MIC was determined for extracts obtained from non-heat-treated plant material using the broth dilution method. Various concentrations of the extract (10, 5, 2.5, 1.25, and 0.625 mg/mL) were prepared through successive two-fold serial dilutions in Nutrient Broth (NB). A volume of 0.1 mL of each dilution was added to 6 test tubes containing NB. Subsequently, 10 mL of a standardized inoculum of the test pathogen was introduced into each tube.

The test tubes were then sealed with sterile cotton plugs or screw caps and incubated at 37°C for 24 hr. Following incubation, the tubes were observed for turbidity. The lowest concentration of the extract that showed no visible microbial growth was recorded as the Minimum Inhibitory Concentration (MIC).

In vitro antibacterial study

The antiacne efficacy of the formulated *Aloe vera* emulgels was assessed against *Propionibacterium acnes* using the agar well diffusion technique. *Aloe vera* extract served as the standard reference. A concentration of 50 µg/mL was used for the study. Sterile agar plates seeded with *Propionibacterium acnes* were prepared, and wells were carefully filled with the respective emulgel formulations.

The plates were then incubated at 37°C for 24 hr. Following incubation, the diameter of the inhibition zones around each well was measured, indicating the antibacterial potential of the formulations at the given concentration (Briones *et al.*, 2020; Shukla *et al.*, 2019; Khadabadi *et al.*, 2010; Dandagi *et al.*, 2020; Urmaliya *et al.*, 2016; Kaewbanjong *et al.*, 2014; Lee *et al.*, 2015; Jain *et al.*, 2017).

RESULTS

Standard calibration curve of *Aloe vera*

A standard calibration curve of *Aloe vera* was developed using UV-visible spectrophotometry at a wavelength of 206.4 nm. The absorbance was measured for various concentrations ranging from 1 to 10 µg/mL. The average absorbance values recorded for concentrations of 1, 2, 4, 6, 8, and 10 µg/mL were 0.043±0.00043, 0.068±0.001, 0.126±0.001, 0.187±0.001, 0.211±0.0043, and 0.241±0.001, respectively (n=3). The calibration curve showed excellent linearity with a correlation coefficient (R^2) of 0.998, confirming the method's accuracy and suitability for the quantitative estimation of *Aloe vera* in the prepared formulations. These results are illustrated graphically in Figure 1.

Compatibility study

Compatibility study using FTIR spectroscopy

FTIR analysis was conducted to identify the functional groups present in pure *Aloe vera* and its mixture with Sodium CMC. The following key functional groups were observed: Nitro compounds (O-N=O stretch) were identified in the range of 1320-1550 cm^{-1}. In pure *Aloe vera*, the corresponding peak appeared at 1363.28 cm^{-1}, while in the mixture with Sodium CMC, the peak shifted

to 1325.72 cm^{-1}. Carbonyl groups (C=O stretch) typically occur between 1600-1900 cm^{-1}. Pure *Aloe vera* showed a peak at 1602.53 cm^{-1}, whereas the mixture exhibited a slightly lower peak at 1587.15 cm^{-1}. Alkane groups (CH_3 stretch) are found in the region of 2850-3250 cm^{-1}. In pure *Aloe vera*, a peak was noted at 2957.62 cm^{-1}, while in the *Aloe vera*-Sodium CMC mixture, the peak was observed at 2920.01 cm^{-1}.

Differential Scanning Calorimetry (DSC)

The thermogram obtained from the DSC study is shown in Figure 2(a), which indicates that the melting point of *Aloe vera* was found to be 95.83°C. This value matches with the literature citation of 89-91°C and *Aloe vera* with Sodium CMC was found to be 95.74°C. This value matches with the literature citation of 89-91°C as shown in Figure 2(b).

Formulation Design

The study was carried out to design and develop an herbal emulgel comprising natural extract for therapeutic activity, along with natural adjuvants as a remedy for antiacne studies. In the present investigation, eight formulations of herbal emulgel were prepared using Sodium CMC and Carbopol 940 in varying concentrations as shown in Table 1.

Evaluation parameters

Clarity/Appearance

The prepared emulgels were evaluated for physical appearance, pH measurements, spreading capacity, drug content estimation, rheological evaluation, *in vitro* drug diffusion study, followed by *in vitro* antiacne assay for optimized formulation and MIC studies. All the formulations were found to be opaque in nature and white in color.

PH

The pH of the formulations ranged between 6.01 to 6.68.

Viscosity

The rheological evaluation of the prepared *Aloe vera* emulgel formulations revealed pseudoplastic behavior, characterized by a consistent decrease in viscosity with increasing shear rate. This shear-thinning property is advantageous for topical application, ensuring ease of spreadability and improved patient compliance.

Table 1: **Formulation design.**

Sl. No.	*Aloe vera* (g)	Sodium CMC (g)	Carbopol 940(g)	Liquid paraffin (mL)	Span 20 (mL)	Tween 20 (mL)	Propylene glycol (mL)	Water (up to mL)
1	1	2.	-	5	2	5	5	100
2	1	2.5	-	5	2	10	5	100
3	1	2.75	-	10	4	5	5	100
4	1	2.75	-	10	4	10	5	100
5	1	-	2.5	5	2	5	5	100
6	1	-	2.5	5	2	10	5	100
7	1	-	2.75	10	4	5	5	100
8	1	-	2.75	10	4	10	5	100

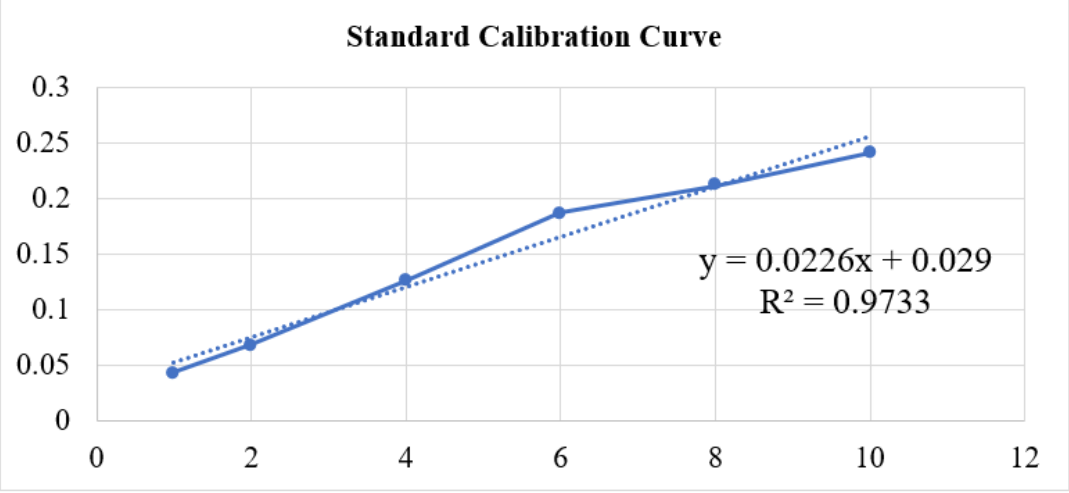

Figure 1: Standard calibration curve of *Aloe vera* at 206.4 nm.

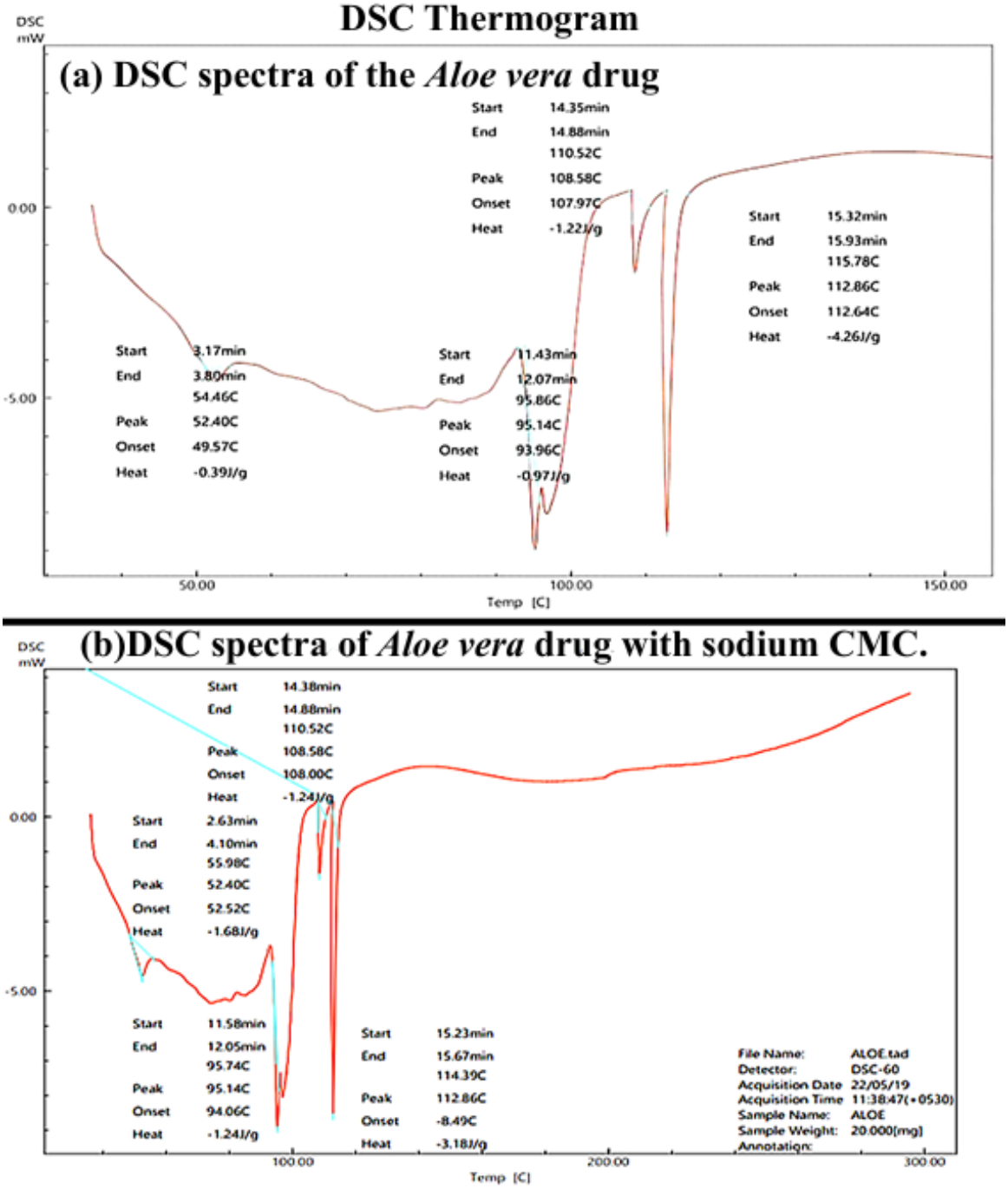

Figure 2: (a)DSC spectra of the *Aloe vera* drug (b) DSC spectra of *Aloe vera* drug with sodium CMC.

Among the formulations, F5 exhibited the highest viscosity at low shear (31,214 cps at 1 RPM). In comparison, the optimized formulation F4 demonstrated a viscosity of 22,113 cps at 1 RPM, which decreased markedly to 4,404.9 cps at 10 RPM. Such non-Newtonian flow behavior supports the suitability of these emulgels for dermal use, offering both therapeutic efficacy and desirable application properties.

Spreadability

Spreadability is an important attribute of topical formulations, affecting ease of application and therapeutic performance. In this study, the spreadability of the *Aloe vera* emulgel formulations ranged from 3.2 to 4.8 cm. Formulations containing a lower concentration of the gelling agent, such as F1, F2, and F3, exhibited higher spreadability values around 4.5 to 4.6 cm, while formulation F4 recorded the highest spreadability of 4.8 cm. In contrast, formulations with a higher gelling agent concentration F5 to F8 showed lower spreadability, ranging between 3.2 and 3.5 cm. This inverse relationship between the concentration of the gelling agent and spreadability highlights the impact of viscosity on formulation performance.

Drug content

The drug content of the *Aloe vera* emulgel formulations ranged from 75.16% to 91.64%, indicating uniform dispersion of the active ingredient within the base. Among all the tested formulations, F4 demonstrated the highest drug content at 91.64%, followed by F2 and F1 with values of 89.82% and 89.13%, respectively. Formulations F5 to F8 exhibited relatively lower drug content, ranging from 75.16% to 79.23%, which may be attributed to increased viscosity affecting the drug entrapment efficiency. These findings confirm that formulation F4 not only offered the best drug loading capacity but also maintained consistency in drug distribution.

In vitro permeation study

The % cumulative drug permeation values of all formulations after 5 hr ranged between 60.3 and 83.51%. F4 showed the highest drug permeation at the end of 5 hr. The comparative diffusion profile of all formulations is shown in Figure 3.

Minimum Inhibitory Concentration (MIC) studies

The MIC value is crucial in determining the appropriate dosage of the extract to be incorporated into the formulation. The MIC was determined through *in vitro* broth dilution testing to identify the lowest concentration required to inhibit microbial growth. In practical formulation design, this concentration may be adjusted (generally multiplied by a factor of 2-4) to account for differences between *in vitro* and *in vivo* conditions. Based on the results, the MIC value of *Aloe vera* extract against *Propionibacterium acnes* was found to be between 10-20%w/v, indicating significant antibacterial activity. This suggests that the *Aloe vera*-based emulgel possesses effective anti-acne potential through inhibition of *Propionibacterium acnes* growth.

In vitro antibacterial study (antiacne study)

In vitro antiacne study was performed as described in the methodology section against the *Propionibacterium acne* strain for optimized formulation F4. The highest zone of inhibition of 21 mm was observed at a concentration of 50 µL.

DISCUSSION

The development of *Aloe vera*-based emulgel was carried out using sodium Carboxymethyl Cellulose (CMC) and Carbopol 940 as gelling agents, along with Span 20 and Tween 20 as emulsifying agents. The successful formulation was confirmed through FTIR and DSC analysis, which revealed no chemical interaction between the herbal extract and excipients, ensuring the stability and compatibility of the formulation.

The pH of all formulations ranged from 6.01 to 6.68, closely aligning with the natural pH of human skin. This indicates that the formulations are unlikely to cause irritation, making them suitable for topical application.

Rheological studies demonstrated pseudoplastic behavior with shear-thinning properties, indicating that the viscosity of the emulgel decreases with increased shear rate. This is ideal for topical preparations, allowing the product to spread easily while maintaining sufficient consistency on the skin.

The spreadability of the formulations ranged between 3.2 to 4.8 cm, suggesting good application properties and confirming that the emulgels fall into the fluid gel category. This contributes to ease of application and better patient compliance.

The drug content ranged from 75.16% to 91.64%, with Formulation F4 containing the highest amount of active ingredient. Additionally, *in vitro* drug release studies showed

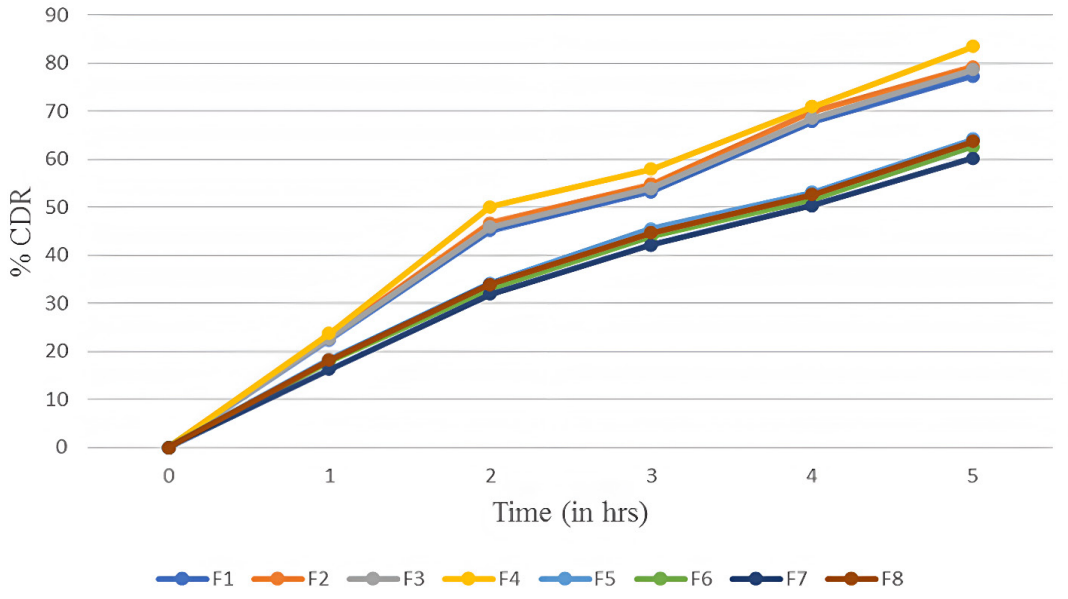

Figure 3: Comparative *In vitro* diffusion profile of all formulations.

cumulative permeation between 60.3% and 83.51% over 5 hr, with F4 again displaying the highest release. These results suggest effective drug incorporation and efficient delivery through the skin.

The antibacterial activity of the optimized formulation (F4) showed a zone of inhibition of 21 mm against *Propionibacterium acnes* at a 50 µL dose, confirming its potential as an anti-acne agent. The lower MIC value of *Aloe vera* extract against *Propionibacterium acnes* further supports its targeted efficacy.

Every experiment was conducted in triplicate, and the Mean±Standard Deviation (SD) is used to describe the results. Only descriptive statistics were utilized to analyze the results because the study concentrated on formulation optimization and preliminary characterisation.

CONCLUSION

The present study successfully formulated and evaluated an *Aloe vera*-based herbal emulgel using Sodium CMC and Carbopol 940 as gelling agents. The optimized formulation (F4) exhibited:

- Excellent physical and rheological properties,
- High drug content (91.64%),
- Superior drug release profile (83.51% in 5 hr),
- Significant antibacterial activity (21 mm zone of inhibition against *Propionibacterium acnes*).

These findings indicate that *Aloe vera* emulgel is a promising topical delivery system for the treatment of acne. Its natural origin, skin compatibility, and effective antimicrobial properties make it a potential safe and effective alternative to synthetic anti-acne formulations.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

pH: Potential of hydrogen. **SD:** Standard Deviation; **Sodium CMC:** Sodium carboxymethyl cellulose; **w/o:** Water-in-oil emulsion; **o/w:** Oil-in-water emulsion; **FTIR:** Fourier Transform Infrared Spectroscopy; **DSC:** Differential Scanning Calorimetry; **KBr:** Potassium bromide; **NaCl:** Sodium chloride; **KCl:** Potassium chloride; **Na_2HPO_4:** Disodium hydrogen phosphate; **KH_2PO_4:** Potassium dihydrogen phosphate; **^oC:** Degrees Celsius; **g:** Gram; **mL:** Millilitre; **mg:** Milligram. **µg/mL:** Micrograms per millilitre; **µL:** Microlitre; **rpm:** Revolutions per minute; **cps:** Centipoise (unit of viscosity); **nm:** Nanometre; **µm**: Micrometre; **cm:** Centimetre; **UV:** Ultraviolet; **R^2:** Coefficient of determination; **cm^{-1}:** Wavenumber used in infrared spectroscopy. **NB:** Nutrient broth; **MIC:** Minimum inhibitory concentration; **% w/v:** Percentage weight per volume; **% CDR:** Percent cumulative drug release; **F_4:** Optimized formulation number 4; **24 hr:** 24-hr period; **TL4:** Spindle used in the Brookfield viscometer for viscosity measurement; **S D Fine:** S D Fine-Chem Ltd., (chemical supplier).

AUTHORS CONTRIBUTIONS

Kamaladevi Kshatriya-Methodology, study design, data analysis, manuscript drafting.

Shivanand Swamy Panchayya Hiremath-Conceptualisation, data acquisition, validation, and critical review of the manuscript.

Jathin Subhash Kalal-Experimental work, data interpretation, and preparation of figures and tables.

Fatima Sanjeri Dasankoppa-Statistical analysis, manuscript editing, Literature review and data compilation.

Mahesh Yadav- Assistance in manuscript writing.

Pradeep Bhimagouda Mirje-Statistical analysis, technical assistance, and manuscript editing.

Jayatheertha Lokapur-Support in data collection and manuscript formatting.

Arpitha Jayatheertha Lokapur-Support in data collection and manuscript formatting.

Rohan Ravsaheb Latwade-Data analysis and referencing.

Pranav Babasaheb Patil- Assistance in visualisation, figure preparation and final manuscript review.

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