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PREPARATION AND EVALUATION OF ANTIBACTERIAL MUPIROCIN CREAM EMULSION USING COCAMIDOPROPYL BETAINE EMULSIFIER

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ABSTRACT
Background: This study aimed to develop and evaluate an antibacterial cream emulsion containing mupirocin using Cocamidopropyl betaine (CAPB) as an emulsifier. Mupirocin, a topical antibiotic effective against *Staphylococcus aureus* (including methicillin-resistant strains), was formulated into a cream to enhance its topical delivery. **Materials and Methods:** Mupirocin cream emulsion formulations were developed with varying concentrations of CAPB, PEG-400, and glycerol monostearate. The cream formulations were mainly evaluated for *in vitro* diffusion tests, antibacterial activity tests, and stability studies. **Result and Discussion:** CAPB produced a stable cream emulsion formulation (F7) at 30% concentration and 2% PEG-400. The formulation (F7) exhibited sustained drug release over 3.5 hours in the diffusion test. The formulation F7 showed a higher zone of inhibition, 32.16±2.2 mm, than the marketed mupirocin cream, 29.56±1.35 mm, for the *Staphylococcus aureus* strain. The prepared cream formulation F7 was found stable over 90 days at different temperature conditions (8±2°C, 25±2°C and 40±2°C). **Conclusion:** The study concludes that CAPB effectively enhances mupirocin cream solubility and antibacterial properties, making it a promising option for treating bacterial skin infections.

INTRODUCTION

Bacterial infections have a significant impact on human health, causing both morbidity and mortality. MRSA and other antibiotic-resistant bacteria represent a serious risk since they can result in longer hospital admissions, more expensive medical care, and greater death rates. In developing countries, limited access to healthcare and antibiotics exacerbates the problem. Improved sanitation, vaccination, responsible antibiotic use, and continuous medical treatment innovation control bacterial infections [1]. According to the 2017 Global Burden of Disease (GBD) database, bacterial skin infections caused 76,000 deaths between 2007 & 2017 [2]. Poor hygiene, compromised immune systems, obesity, and long-term skin disorders like psoriasis and eczema are the common causes of bacterial skin infections. Athletes and healthcare professionals are more vulnerable due to frequent contact with microorganisms [3].

Mupirocin is highly effective against methicillin-resistant bacteria, such as *Staphylococcus aureus* [4]. *Staphylococcus aureus* is an infection-causing agent for skin infections such as impetigo, folliculitis, and infected wounds. Mupirocin cream can help prevent secondary bacterial infections in wounds, burns, and minor cuts, aiding in faster healing and reducing

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complications [5]. Cellulitis and erysipelas are common infections caused by *Streptococcus species*, causing painful, erythematous, oedematous, and brawny lesions with hazy borders. Secondary infections include intertrigo, acute infectious eczematoid dermatitis, beard pseudo-folliculitis, and toe web infection [6]. Bacterial surface proteins and polysaccharide capsules make them more pathogenic capabilities, facilitating adhesion to host tissues, evading immune responses, and protecting against phagocytosis [7]. Even though some gram-positive bacteria are susceptible to antibiotics like beta-lactams, which work by targeting peptidoglycan synthesis, they have developed ways to fight back. For example, they make beta-lactamase and change the structure of their cell walls to stop antibiotics from attaching. When mupirocin, a crotonic acid derivative, binds to the bacterial enzyme isoleucyl-tRNA, it stops the production of proteins. This prevents bacterial growth and cell death [8]. Mupirocin exhibits bacteriostatic effects at low concentrations, inhibiting bacterial proliferation, and becomes bactericidal at higher concentrations, effectively killing the bacteria. Due to its rapid systemic metabolism, mupirocin is used mainly in topical formulations for skin infections and nasal decolonization of MRSA [9]. Cocamidopropyl betaine is the zwitterionic surfactant, prepared by reacting coconut oil fatty acids with dimethylaminopropylamine to produce intermediate cocamidopropyl dimethylamine, which further reacted with sodium monochlorate. It is widely used to manufacture cosmetic formulations and is nonallergic in the purest form (free from contaminants). It is a biodegradable emulsifier (known as green surfactant), a non-toxic, non-irritant surfactant, stable overall pH conditions in various cosmetic formulations, and advantageous over synthetic surfactants [10, 11].

CAPB is a novel natural amphoteric surfactant widely used in cosmetic formulations but not as an emulsifier in pharmaceutical topical formulations. So, an approach has been proposed to study its use as an emulsifier in mupirocin cream emulsion, which will enhance the solubility of mupirocin and provide a better or comparable antibacterial effect against the marketed cream formulation [12].

MATERIALS AND METHODS

Drugs and excipients obtained from various manufacturers and chemical suppliers are mentioned in parentheses. Mupirocin (Quality Pharma Products, Mumbai), Cocamidopropyl betaine (Prakash Chemicals, Mumbai), Beeswax (Modern Industries, Nashik), Liquid paraffin (Pallav Chemicals, Mumbai). PEG-400, Glycerol monostearate, Methyl paraben and Propyl paraben and White petroleum jelly (Vishal Chemicals, Nashik).

Drug Characterization

Organoleptic properties

Drug mupirocin was tested physically for appearance, color, and odor characteristics.

Melting Point

The capillary technique was used to determine the melting point of mupirocin. A small quantity of mupirocin was placed in a capillary tube attached to a thermometer and dipped in a Thiele tube with paraffin, and a melting point was noted.

pH determination

It was conducted by preparing a 1% solution of mupirocin in water, and its pH was measured using a digital pH meter.

UV visible spectrophotometric characterization

10 mg mupirocin was dissolved in 2 ml ethanol and diluted up to 100 ml in phosphate buffer, pH 6.8, to obtain a 100 ppm stock solution. From the stock solution, dilutions of 5, 10, 15, 20, 25, and 30 ppm were prepared, and their absorbance at ʎmax was measured against 20% ethanolic phosphate buffer, pH 6.8, as a blank using UV-visible spectrometer (JASCO V730). The calibration curve of mupirocin was plotted as absorbance versus concentration in ppm [13, 14].

Solubility

Mupirocin was dissolved in a 2% ethanol-containing phosphate buffer solution, pH 6.8. The drug was gradually added to the solution, and solubility was observed from initial dissolution to reach saturation. The resulting solution was filtered, and the filtrate was suitably diluted to measure concentration using the UV visible spectroscopic method and standard calibration curve [15].

FTIR -spectroscopy

The mupirocin, CAPB, and cream formulation mixture containing the drug, beeswax, White petroleum jelly, liquid paraffin, PEG400, methylparaben, propylparaben, and CAPB sample were screened using an ATR-FTIR spectrometer (JASCO FT/IR 4600). The FTIR spectrum was obtained, and functional groups were identified to study the drug excipient compatibility [16].

Formulation development

The development of antibacterial formulations involved combining various ingredients in varying quantities to achieve a stable, spreadable, antibacterial semisolid cream. Each formulation contained 2% mupirocin as the antibacterial agent, with beeswax as a thickening agent and emulsifier [17]. White petroleum jelly is an emollient and occlusive agent [18]. White liquid paraffin is added as an emollient and solvent. Polyethylene glycol (PEG400) and glycerol monostearate were used at varying concentrations as a humectant and co-emulsifier. [19]. Methylparaben and propylparaben were used as preservatives in small amounts [20]. Cocamidopropyl betaine (30%) was added in varying amounts (10, 20, and 30 gm) to reduce surface tension and improve emulsification. The CAPB concentrations were randomly selected to use up to 30%. CAPB is safe and nontoxic at 30% concentration in the rinse of cosmetic products [21]. The developed formulations are shown in Table 1.

Table 1: Formulation of mupirocin cream emulsion

Ingredients (gm)	Formulation codes								
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
Mupirocin	2	2	2	2	2	2	2	2	2
Beeswax	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
White petroleum jelly	10	10	10	10	10	10	10	10	10
Liquid paraffin	5	5	5	5	5	5	5	5	5
PEG400	2.5	2.5	2.5	-	-	-	2	3	4
Glycerol monostearate	-	-	-	2	2	2	-	-	-
Methyl paraben	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Propyl paraben	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cocamidopropyl Betaine	10	20	30	10	20	30	30	30	30
Water q.s.	100	100	100	100	100	100	100	100	100

Method of preparation of mupirocin cream

The cream formulation contained aqueous and oil phases. Liquid paraffin, white bee wax, and petroleum jelly were combined and melted in a china dish over a water bath at 70°C. At the same time, mupirocin was added continuously by stirring for 5 minutes to prepare the oil phase. CAPB, PEG 400 glycerol monostearate, methylparaben, propylparaben, and water were mixed to prepare the clear aqueous phase.

The aqueous phase is heated to 70°C as the oil phase. The aqueous phase was gradually added drop by drop to the oil phase while stirring continuously for 5 minutes. The mixture was homogenized using a heavy-duty mechanical stirrer (REMI) at 1000 rpm for 10 minutes to obtain consistent cream emulsion, and then the mixture was cooled slowly at room temperature.

Evaluation of mupirocin cream

Physical appearance

Cream formulations were evaluated physically for color, odor, and semisolid nature.

pH determination

It was conducted using a pH meter, which involved immersing the electrode into the cream to measure its acidic or alkaline nature [17].

Cream phase separation test

The prepared cream was maintained in a firmly covered container at room temperature away from sunlight for one month, and the phase separation was observed using a centrifuge at 3000 rpm [22].

Viscosity

It was performed using a Brookfield viscometer (DV-II Pro model), with readings taken three times after dipping spindle no. 07 into a beaker containing 100 gm of cream samples. All viscosity measurements were performed at 25°C [17].

Spreadability

Spreadability was performed using the parallel-plate method. This method placed 1 gram of cream between two glass plates

of dimensions 20 x 20 cm. A weight of 25, 50, and 75 grams was placed on the top plate for 1 minute. Then, the diameter of the spread cream between the plates was measured as D1, D2, D3, D4, and D5, and the average of these diameters was calculated. and the area of spread was compared. In these cases, spreadability was determined and compared by the following formula [23].

$$S = \pi \times \frac{d^2}{4}$$

Where, S-spreading area (cm^2), depending on mass,
d^2- spreading area diameter

Washability test

Mupirocin cream was applied to the skin and washed under tap water until oiliness or greasiness disappeared [24].

Skin Irritancy test

Mupirocin cream was applied to a marked area on the forehand. The signs of redness, swelling, or irritation over the skin were observed for twelve hours [25].

***In–vitro* Franz diffusion study**

Generally, fish are readily available in the market and are used as seafood. Fish skin was used as a membrane for drug permeation studies. Vaam sea fish skin was obtained from a local abattoir, cleansed using fresh water, and kept in pH 6.8 phosphate buffer till use. Fish skin was used as a membrane. Franz diffusion cells with a receptor compartment capacity of 25 ml were used for in vitro diffusion experiments. The dermal membrane of fish skin was separated from the epidermis layer and positioned between the diffusion cell's donor and receptor compartments. A pH 6.8 phosphate buffer was added to the diffusion cell's receptor compartment. All of the diffusion cell components were positioned on a magnetic stirrer. A still pin was used to continuously swirl the solution in the receptor compartment at the speed of 50 revolutions per minute and a temperature of 32 °C. Mupirocin cream (0.5 gm) was applied to the fish skin dermal membrane. The 0.5 ml sample was taken out at 30-minute intervals, and an equal quantity of fresh phosphate buffer was added to the receptor compartment. The drug content was determined using a UV-visible spectrophotometer [26, 27].

Drug Content test

The cream emulsion formulation of 0.5g was weighed in a 50 ml volumetric flask. Phosphate buffer, pH 6.8, was added up to the 100 ml mark. The mixture was agitated using an orbital shaker at 100 rpm for 3 hours. After agitation, the mixture was filtered using filter paper. The filtrate's 1 ml was diluted to 10 ml using Phosphate buffer, pH 6.8. The sample was analyzed using a UV-visible spectrophotometer to determine the % content of mupirocin present in the cream [28].

***In-vitro* antibacterial activity**

Antibacterial activity was performed against *the Staphylococcus aureus MSRA ATCC 33591 strain.* The agar-well diffusion method was used to measure zones of inhibition. The test micro-organism was inoculated by spreading microbial inoculum over the Muller-Hinton agar plate. Holes of 8 mm diameter were punched aseptically with a sterile cork borer, and 100µl test formulation F7, commercial standard (marketed cream), and Standard Amikacin samples were placed into the well. The plate was incubated at 37°C for 72 hours. The antibacterial agents diffuse in the agar medium and inhibit the growth of microbial strain under test. The plate was observed for the zone of inhibition. Results were recorded [28, 29].

Stability study

ICH Q1A(R2) guidelines were followed for the accelerated stability studies on formulation F7, which were to be conducted over 180 days. The test monitored changes in color, appearance, smell, phase separation, pH change, content uniformity, and consistency of the cream under storage conditions of 8 ±2°C, 25±2°C, and 40±2°C [30].

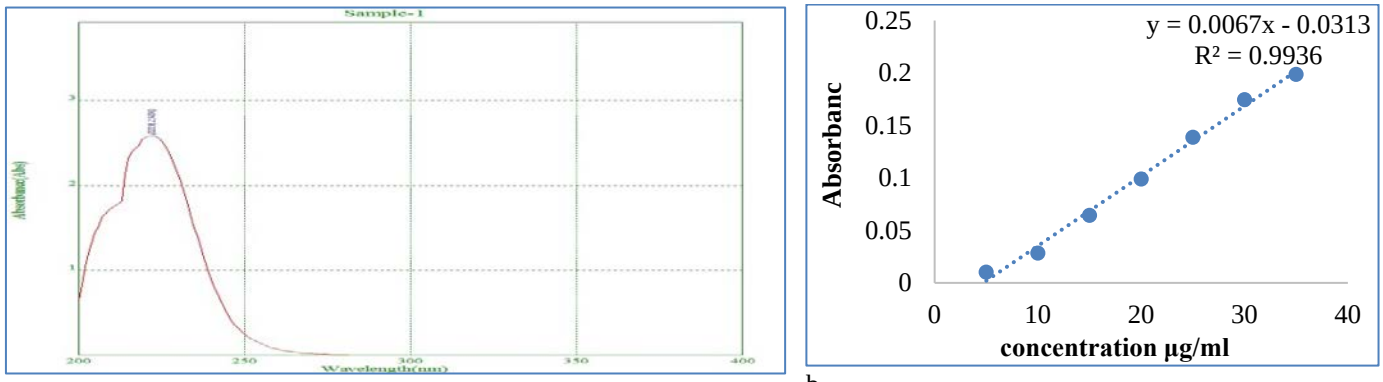
RESULTS AND DISCUSSION

Physical examination revealed mupirocin to be a white crystalline powder with no odor. The melting point of mupirocin ranged between 78 and 79 °C compared to standard values ranging from 77 to 78 °C. The 1% mupirocin solution pH in distilled water ranged from 5.5 to 6.1. indicating a weak acidic nature. The drug was found to be 99.64% soluble in 2% alcoholic phosphate buffer, pH 6.8, indicating free solubility in the solvent to prepare a standard calibration curve and diffusion study.

UV-visible spectroscopic study

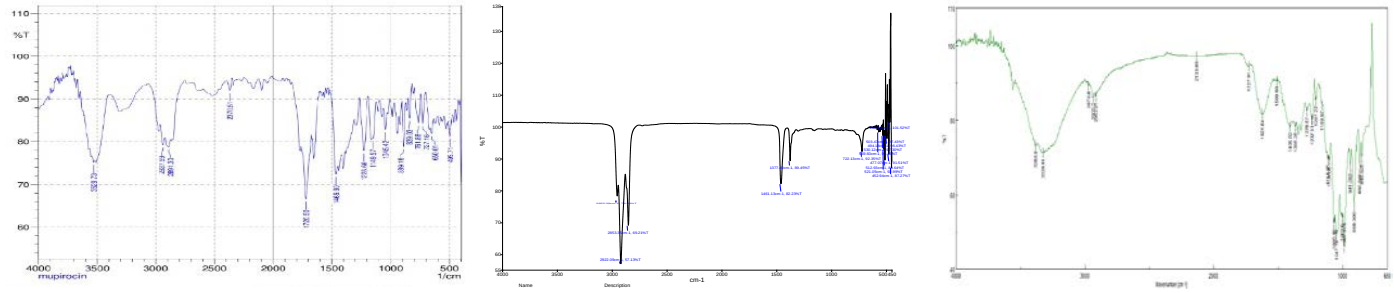
UV-visible spectroscopic studies obtained the UV-visible spectrum shown in Figure 1a. By the UV-visible spectrophotometric method, mupirocin was produced λmax at 222nm in alcoholic Phosphate buffer pH 6.8. The calibration

curve was constructed for 5 to 35 ppm solutions, which showed linearity in absorption, obeyed Beer-Lambert law with R2 value 0.9936, and had an equation of line y = 0.0067x—0.0313. The spectrum and calibration curve are shown in Figure 1b.



a b

Figure 1: a. UV-visible spectrum of mupirocin and b. Calibration curve of mupirocin



a **b** **c**

Figure 2: a. FTIR spectrum a. mupirocin, b. CAPB and c. cream formulation mixture (F1)

FTIR Spectroscopy studies

The FTIR spectrum for mupirocin, CAPB, and cream formulation mixture (F1) is shown in Figure 2. Notable peaks observed in drug and cream formulation were a strong O-H stretch around 3529.73 cm^{-1}, indicated alcohol or carboxylic acid groups, and a strong C=O stretch around 1726.50 cm^{-1}, typical of carbonyl compounds like esters. Peaks around 2973.19 cm^{-1} and 2881.90 cm^{-1} suggest C-H stretching in alkanes, while peaks in the 1200-1000 cm^{-1} region indicate C-O stretching in esters or carboxylic acids. These characteristic absorptions confirmed the presence of alcohol, ester, and carboxylic acid groups in mupirocin and cream formulation, indicating compatibility between the drug and excipients.

The prepared topical mupirocin cream emulsions (F1 to F9) were examined visually for color, consistency, state, and odor. All cream samples were observed to be white and have a pleasant odor with a semisolid consistency. The pH of all mupirocin formulations F1 to F9 was found in the range of 6.9 to 7.15. The observed cream pH corresponds to the skin pH, which recommends less chance of skin irritation on use.

Phase separation studies

In phase separation studies, each formulation was stored at room temperature for a month and observed physically. Formulation F1 and F2 separate on storage at room temp in one week. Formulation F3 was stable after 1 month at room temperature. Formulations F4, F5, and F6 containing glyceryl monostearate produced gritty formulations found stable but not smooth to the touch. As the concentration of CAPB increased in formulations F1, F2, and F3, the cream's stability increased. Formulation F3 contains 30% CAPB and produces a stable cream emulsion compared to its lower concentration in F1 and F2. So, a 30 % concentration of CAPB was used in the formulations F7, F8, and F9. Samples F1 to F9 were in a semi-solid state, with F1 and F2 being described as unstable in consistency, while F3 to F9 were stable. Samples F4 to F6 containing glyceryl monostearate exhibited consistent grittiness, whereas F7 to F9 were stable without grittiness. The effect of co-emulsifier PEG-400 was studied on the cream formulations. As the concentration of PEG-400 was decreased, the stability of formulation F7 was not affected. It also observed that increased concentrations of PEG-400 in F8 and F9 produced stable cream formulations, as no

phase separation was observed. Centrifugation separates phases or the ingredients of different densities. The poor emulsification of creams results in creaming, caking, and phase separation instabilities.

Viscosity studies

Using the Brookfield viscometer, spindle number 07, the viscosity of the antibacterial cream was reported in centipoise at various rpm 10, 20, 30, 50, 60, and 100. The viscosity of stable and non-gritty formulations F3, F7, F8 and F9 was measured. The rheogram of viscosity vs. rpm was plotted as shown in Figure 3. It was observed that as the concentration of PEG400 was increased in the formulations, the viscosity increased in formulations in ascending order F7 (2% PEG), F3 (2.5% PEG), F8 (3% PEG), and F9 (4% PEG). It is reported that PEG is a non-ionic polymer. It can interact with anionic surfactant to increase the viscosity at critical micelle concentration. This interaction is produced by charging the polymer in the presence of polyelectrolytes [31].CAPB is a zwitterionic surfactant, and its cationic part interacts with PEG 400, improving the emulsion system's viscosity.

Viscosity of cream formulations was observed at 25 °C and different rpm. Viscosity versus rpm rheogram was plotted and shown in Figure 3. The cream formulations F3, F7, F8, and F9 decreased viscosity by applying force (rpm), indicating a shear thinning system formed. Formulation F3 ranges viscosity 11954-6021 centipoise, F7 ranges 9500 – 5000 centipoise, F8 ranges 15600-7532 centipoise and F9 ranges 19200-16599 centipoise. It was observed that PEG400 produced soft and non-gritty formulations with CAPB. GMS produced gritty and inconsistent formulations with CAPB.

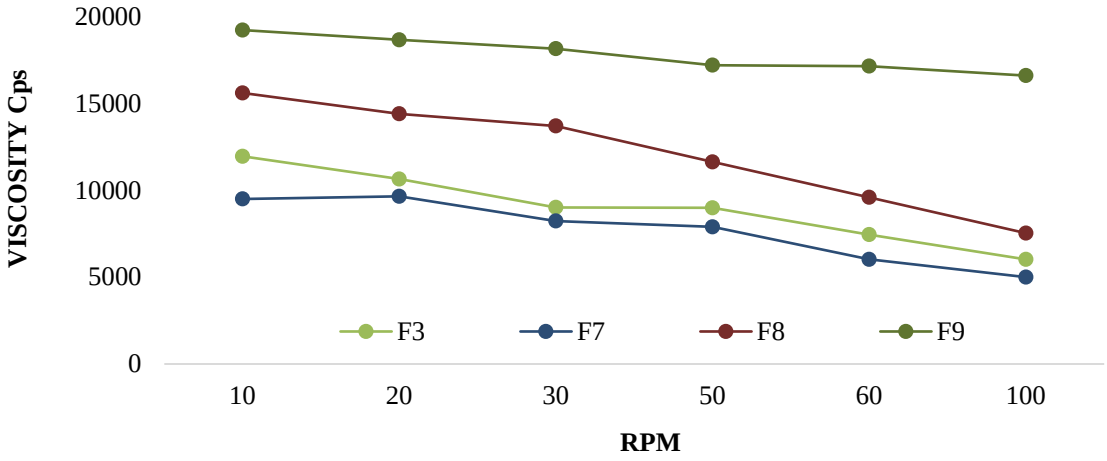


Figure 3: Rheogram of mupirocin cream emulsion formations

Table 2: Evaluation of mupirocin cream emulsion formulations

Formulation	Spreadability (cm^2) for applied weight			Content Uniformity (%)
	25g	50g	75g	
F3	30.32±1.26	32.23±1.33	36.02±1.31	99.64±1.85
F7	33.20±1.22	37.15±1.41	40.91±1.70	99.25±2.14
F8	25.24±1.18	27.40±1.36	29.42±1.25	98.92±2.35
F9	22.23±1.17	25.91±1.32	28.54±1.27	99.01±2.10
Marketed	36.20±2.25	38.94±1.65	41.52±1.14	99.27±1.14

(n=3, Average ± standard deviation)

Spreadability study

Formulations F3, F7, F8, and F9 showed comparable spreadability when different weights were applied to the slides. Formulation F9 had shown the lowest spreadability, 28.54±1.27 cm^2, which contained a high amount of PEG-400. Formulation F4 contains the lowest amount of PEG-400 and was shown the highest spreadability, 40.91±1.70 cm2. The results of the spreadability study depicted that the spreadability of cream formulation depends upon the concentration of PEG-400. It was also observed that spreadability values increased with the application of stress. In the test, as the weight in grams increased from 25 to 75 grams, spreadability gradually increased. This

indicated that cream should be applied over the skin surface with stress. The spreadability values of all formulations concerning applied weight are noted in Table 2. The creams with good spreadability spread over a large skin surface area with small force. This property improves patient compliance, acceptance, and uniform application of cream. The spreadability varies due to particle size, shape, and distribution changes of the dispersed phase, continuous phase, and emulsifier.

Washability study

It was observed that all cream formulations F3, F7&, F8, and F9 were washable within one minute under forced tap water, and no greasiness or oiliness remained over the skin surface.

Irritancy test

The irritancy test was performed on the skin surface of the forearm to observe irritation, redness, and swelling. All formulations F3, F7, F8, and F9 showed no irritation and redness over the skin surface. The irritancy test indicated the safety of the mupirocin cream. The mupirocin content was observed at 98.92% to 99.64%. The drug was uniformly distributed in the cream formulations. The topical formulations may produce irritation, redness, and swelling, which are unacceptable.

***In–vitro* Franz diffusion study**

Mupirocin-marketed cream and formulation F7 were studied for diffusion through fish skin membranes. Formulation F7 showed better diffusion than the marketed preparation. It was depicted that the improvement of the solubility of mupirocin in CAPB affected the emulsified cream formulation, resulting in improved diffusion through the fish membrane compared to the marketed preparation. Mupirocin cream formulation F7 was diffused 98.11% in 210 minutes, while the marketed preparation diffused 88.05%. The drug was diffused through the skin surface in a sustained manner. Formulation F7 and marketed formulation was shown comparable diffusion. Formulation F7 is better diffused or penetrated through the fish skin membrane. % cumulative drug diffusion (CDD) Vs. time in minutes was presented graphically in Figure 4.

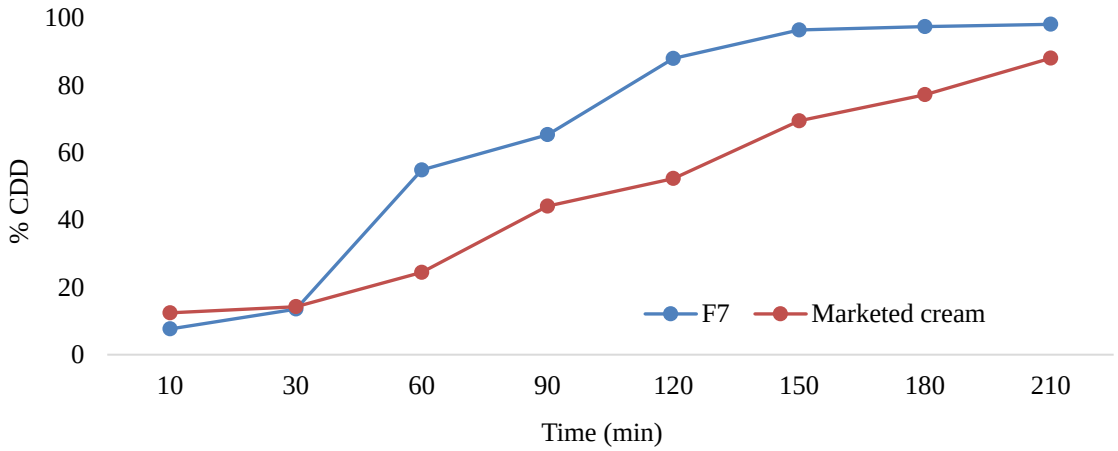


Figure 4: *In–vitro* drug diffusion for cream formations

CAPB forms the micelles in the cream base at which mupirocin solubility was enhanced. The solubilized drug with a lipophilic property penetrated through the fish skin membrane. The improved penetration leads to better drug diffusion from formulation F7 than the marketed formulation in 3.5 hours. The skin surface is an emulsified phospholipid bilayer, and drugs formulated as creams may effectively interact with the skin and penetrate the biological membranes.

***In Vitro* antibacterial activity of cream**

Test sample F7 and Commercial standard (marketed mupirocin cream) and standard as amikacin cream were compared for an antibacterial effect on *staphylococcus aureus* bacterial stain. Formulation F7 showed a higher value of zone of inhibition 32.16±2.2 mm than the marketed mupirocin cream 29.56±1.35 mm and standard amikacin cream 28.08±1.14 mm, as shown in Figure 5. Formulation F7 was shown to have a better antibacterial effect than commercial standards against *staphylococcus aureus*. The better antibacterial effect of formulation F7 indicated emulsification of mupirocin in cream emulsion, improved solubility, and potential penetration inside the bacterial cell wall. Also, the amphoteric nature of CAPB may interact with the anionic groups present on bacterial cell walls, which alters the cell wall permeability to penetrate mupirocin.

After penetration, mupirocin binds to the bacterial enzyme isoleucyl-tRNA, stops the production of proteins, and thus acts as a bactericidal.

Figure 5: Zone of inhibition of mupirocin cream (F7) and marketed cream

Stability study

Formulation F7 remained stable for appearance (semisolid), color (white), odor (pleasant), no phase separation, and smooth consistency at storage conditions (8±2°C, 25±2°C, and 40±2°C) for 30, 60, and 90 days. It was observed that pH of the formulation remains neutral in the range of 7.05 to 7.18. The content uniformity test depicts the mupirocin content in the acceptable range of 99.24 ±0.36. It was shown that Formulation F7 produced stable emulsion at low, medium, and higher temperature conditions. The potential emulsification of mupirocin cream using CAPB may be credited to the similarity in densities of water and oil phases or the interfacial interaction of involved ingredients.

Table 3: Stability study of mupirocin cream (F7) at low, room, and high temperature

Parameter	Stability test temperature conditions and period (days)											
	8±2°C				25±2°C				40±2°C			
	0	30	60	90	0	30	60	90	0	30	60	90
Appearance	G	G	G	G	G	G	G	G	G	G	G	G
Color	W	W	W	W	W	W	W	W	W	W	W	W
Odor	G	G	G	G	G	G	G	G	G	G	G	G
Phase separation	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS
Consistency	G	G	G	G	G	G	G	G	G	G	G	G
pH	6.94	6.95	6.98	6.97	6.9	6.95	7.02	6.99	7.15	7.04	7.15	7.11
% Content	99.64	99.05	99.15	99.32	99.25	99.54	99.24	99.50	99.95	98.85	98.75	98.65

G- good, W-white, NPS- no phase separation

CONCLUSION

CAPB and PEG-400 were more effective in formulating mupirocin cream emulsions than glycerol monostearate (GMS) emulsifiers. A 30% concentration of CAPB was found to be more helpful in producing a stable emulsion in the cream formulation. CAPB produced a stable, viscous, spreadable, washable emulsion (F7) at 30% concentration in combination with 2% PEG-400. CAPB interacts with PEG 400 to increase the formulation viscosity. The study demonstrated a sustained drug release for 3.5 hours with improved diffusion compared to the marketed cream preparation. It was also shown to have better antibacterial effects on *Staphylococcus aureus* than marketed cream formulations. CAPB formulates a mupirocin cream emulsion to improve patient compliance and antibacterial activity.

FINANCIAL ASSISTANCE

NIL

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Avinash B. Gangurde was involved in study design, data collection and analysis, manuscript drafting, & correspondence. Suraj R. Pagar was engaged in experimental work. All authors read and approved the final manuscript, confirming agreement with the content and conclusions presented.

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