RESEARCH PAPER

A Novel Nanoemulgel Platform for the Topical Administration of Flecainide Acetate: A Strategy to Enhance Therapeutic Compliance in Arrhythmia Management.

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ABSTRACT
Flecainide acetate is a potent antiarrhythmic agent with limited topical bioavailability due to physicochemical constraints. This study aimed to develop and evaluate a nanoemulsion-based topical gel of flecainide acetate to enhance drug solubility, stability, and sustained drug release. Preformulation studies, including organoleptic properties, melting point, solubility analysis, partition coefficient, and FT-IR spectroscopy, were conducted. Nanoemulsions were formulated using Captex 200 as the oil, Tween 80 as the surfactant, and PEG 400 as the co-surfactant based on pseudo-ternary phase diagrams. Optimized nanoemulsions were characterized by droplet size, zeta potential, viscosity, refractive index, pH, and in vitro diffusion studies. The optimized formulation was incorporated into a Carbopol 940 gel base and evaluated for its physicochemical properties, drug content, spreadability, in vitro release, and stability. The results demonstrated excellent stability, high drug release (91.23% at 12 h), and satisfactory physicochemical characteristics, indicating the potential of the nanoemulgel as an effective topical delivery system for flecainide acetate.

Keywords: Keywords: Flecainide acetate (FCA), Nanoemulsion, Nanoemulgel, Topical drug delivery, Carbopol 940.
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INTRODUCTION

Flecainide acetate is a BCS Class IC antiarrhythmic drug used to manage cardiac arrhythmias. It is a potential sodium channel blocker that slows the conduction velocity of the heart. It also has a positive effect on potassium channels, which exhibit antiarrhythmic properties. Conventional FCA administration is associated with systemic adverse effects, necessitating the urgent need for an alternative drug delivery method. Novel drug delivery systems provide opportunities to enhance the therapeutic efficiency of FCA by enabling controlled and sustained release formulations to improve bioavailability and facilitate targeted drug delivery to cardiac tissues. These technologies, such as nanoparticles, liposomes, hydrogels, and nano-emulsions, have the potential to reduce systemic toxicity by improving drug solubility and bioavailability. [4-6].

Topical drug delivery systems are widely used because of their ability to deliver drugs directly to the site of action, reduce systemic side effects, and improve patient compliance. However, conventional topical formulations often suffer from poor drug penetration and uncontrolled drug release. To address these limitations, nanoemulsion-based delivery systems have gained significant attention in recent years [1-2].

Nanoemulsions are oil and water dispersions stabilized by interfacial surfactants and co-surfactants, with droplet sizes in the range of 50n–1000 nm. They are kinetically stable in nature, and their small droplet size and large surface area enhance drug solubilization, stability, and skin permeability compared to those of conventional emulsions [1,3-4]. The incorporation of nanoemulsions into a gel base results in the formation of nanoemulgels, which combine the advantages of both systems, offering ease of application, prolonged residence time, and controlled drug release [7,8].

Nanoemulsions, characterized by their small droplet size and high surface area, facilitate improved skin penetration and controlled drug release (insert reference). The selection of suitable oils, surfactants, and co-surfactants is crucial for developing a stable nanoemulsion. Pseudo-ternary phase diagrams are commonly used to optimize formulation composition and identify nanoemulsion regions [2,5]. Therefore, this study focused on the development and characterization of a flecainide acetate-loaded nanoemulsion and its incorporation into a Carbopol-based topical gel to achieve improved stability and sustained drug release. This will provide a targeted, efficient, and patient-friendly approach to arrhythmia management.

Extensive research has focused on developing flecainide acetate formulations using innovative drug delivery systems. Crijns et. evaluated inhaled flecainide acetate for the acute cardioversion of recent-onset atrial fibrillation [9]. Fernanda T Silva and team studied pulmonary delivery of flecainide to enhance efficiency in atrial fibrillation [10], while Omar, M. et. studied the potential of lipid emulsion therapy for acute flecainide overdose [11]. In contrast, Casiraghi et al. studied the critical aspects of preparing a Flecainide Acetate Oral Solution for pediatrics [12], whereas Paola M performed a stability study of an oral liquid dosage of flecainide acetate for pediatric use [13]. Allen et al. derived the of stability of Flecainide Acetate in Extemporaneously Compounded

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Oral Liquids with other active drugs [14]. Despite its potential, none of studies have yet explored the development of a Flecainide Acetate nanoemulsion-based topical gel specifically designed to improve systemic drug delivery

MATERIALS AND METHODOLOGY

Materials and Instrumentation

Flecainide acetate was received from Metrochem API Private Limited, Mumbai, as a gift sample for research purposes. CAPTEX® 200, Tween 80, Carbopol 940, and PEG 400 were of analytical grade or met the formulation standards. All reagents and solvents were of analytical grade, and Milli-Q ultrapure water was used throughout the experiments. Formulation development and evaluation were performed using an analytical balance (US-300, Cyber Lab, USA) for precise weighing, while a magnetic stirrer (Remi Eq. Pvt. Ltd. (India) ensured a uniform mixing. Characterization was conducted using a UV–visible spectrophotometer (UV-1800, Shimadzu Corporation) for drug content analysis. Moreover, the pH and viscosity of the formulation were determined using a digital pH meter (PM100, Welltronix) and a DV-E viscometer (Brookfield, USA), respectively.

Preformulation Studies

Preformulation studies were conducted to establish the physicochemical properties of Flecainide Acetate. The organoleptic characteristics, such as color, odor, and physical state, were assessed through visual inspection, while the melting point was determined using the capillary method to verify drug purity. The maximum absorption wavelength (λmax) was confirmed by scanning the drug between 200 and 400 nm by dissolving it in an equal mixture of Methanol: Water (50:50 %v/v). A calibration curve was constructed in methanol over a concentration range of 2–20 µg/mL, with absorbance measured at 295 nm in triplicate. The equilibrium solubility of FCA was studied in various oils, surfactants, and co-surfactants by equilibrating excess drug at 37 ± 1°C for 24hours, followed by centrifugation at 5000 rpm for 10 min, and the supernatant was analyzed spectrophotometrically at 296 nm. Lipophilicity was determined using an n-octanol:water (1:1) partition coefficient system with the shake flask method. The potential drug–excipient interactions were investigated using FT-IR spectroscopy with the KBr press pellet technique.

Excipient screening and Phase study:

Based on the solubility results, Captex 200 was selected as the oil phase, Tween 80 as the surfactant, and PEG 400 as the co-surfactant. The solubilizing capacity of the selected excipients was quantified using UV spectrophotometry to ensure maximum drug incorporation into the nanocarriers. Pseudo-ternary phase diagrams were constructed using the aqueous titration method to identify the nanoemulsion region. Captex 200, Tween 80, PEG 400, and distilled water were used as the oil, surfactant, co-surfactant, and aqueous phases, respectively. Various Smix ratios were evaluated, and the nanoemulsion regions were plotted using CHEMIX software.

Preparation and Characterization of Nanoemulsion

FCA-loaded nanoemulsions (2.5% w/w) were prepared by identifying optimal formulations within the nanoemulsion region of pseudo-ternary phase diagrams, specifically targeting maximum oil loading and minimal surfactant/co-surfactant (Smix) concentrations. The drug was first dissolved in the oil phase, followed by the incorporation of Smix and the dropwise addition of water under constant agitation. To achieve the desired droplet size, the formulations were ultrasonicated and stored at ambient temperature for further evaluation. The physical integrity of the prepared nanoemulsions was evaluated for thermodynamic stability testing, including heating–cooling, centrifugation, and freeze–thaw cycles. The stable formulations were further characterized for pH, viscosity, refractive index, zeta potential, polydispersity index, and morphological characteristics using scanning electron microscopy (SEM). The droplet size distribution and surface charge were measured using a zeta sizer, and kinetic drug release was measured using in vitro drug diffusion studies.

Preparation and Evaluation of Nanoemulsion-Based Gel

The optimized flecainide acetate nanoemulsion was transformed into a nanoemulgel by incorporating it into a Carbopol 940 polymeric base. Initially, Carbopol 940 was dispersed in purified water and hydrated overnight to ensure complete polymer swelling. The pre-formed nanoemulsion was then integrated into the hydrated gel base under continuous mechanical stirring, followed by the addition of triethanolamine to adjust the pH to 6.0–9.0, thereby facilitating gelation and ensuring uniform consistency. The resulting nanoemulgel was systematically evaluated for its organoleptic properties, including physical appearance, homogeneity, and grittiness, as well as physicochemical parameters such as pH, viscosity, and spreadability. To confirm dosage uniformity, the drug content was quantified using UV spectrophotometry at a maximum wavelength of 296 nm. Furthermore, *in vitro* drug release kinetics were investigated using a modified Keshary–Chien diffusion cell, employing a phosphate buffer (pH 7.4) as the receptor medium to simulate physiological conditions.

Stability Study

Accelerated stability studies of the optimized nanoemulgel were conducted at room temperature for one month. Samples were withdrawn on days 0, 15, and 30 and evaluated for physical appearance and drug content to assess the formulation stability.

RESULT

Preformulation and Characterization of FCA

Initial Preformulation studies were conducted to evaluate the identity of the drug sample. Organoleptic evaluation characterized the drug as a white, odorless powder, consistent with the powder form of Flecainide Acetate. The melting point, determined via the capillary method, was found to be in the range of 146-1520 C. Furthermore, the maximum absorption wavelength (λmax) was identified as 296 nm to establish a basis for subsequent analytical quantification, as shown in Figure 1

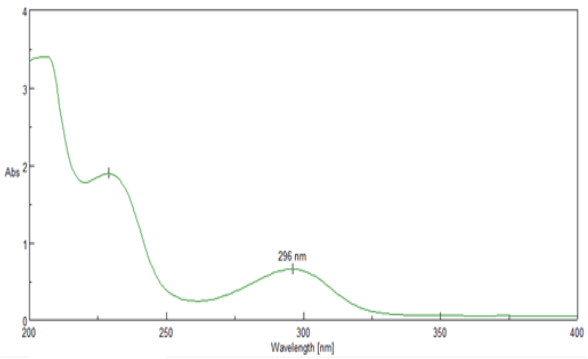

Figure: 1 Wavelength max (λmax) of Flecainide Acetate (FCA)

Preparation of Calibration Curve for Flecainide Acetate

A calibration curve for FCA (Figure 2) was constructed to establish a linear relationship between the drug concentration and absorbance. Standard solutions of FCA were prepared in the concentration range of 0–50 µg/mL and measured using a UV–visible spectrophotometer, and all measurements were performed in triplicate. The absorbance values increased proportionally with concentration, showing a linear response with a regression coefficient (R^2) of 0.9929 and a slope of 0.0198 over the studied range, confirming the suitability of the method for the quantitative estimation of FCA in subsequent studies

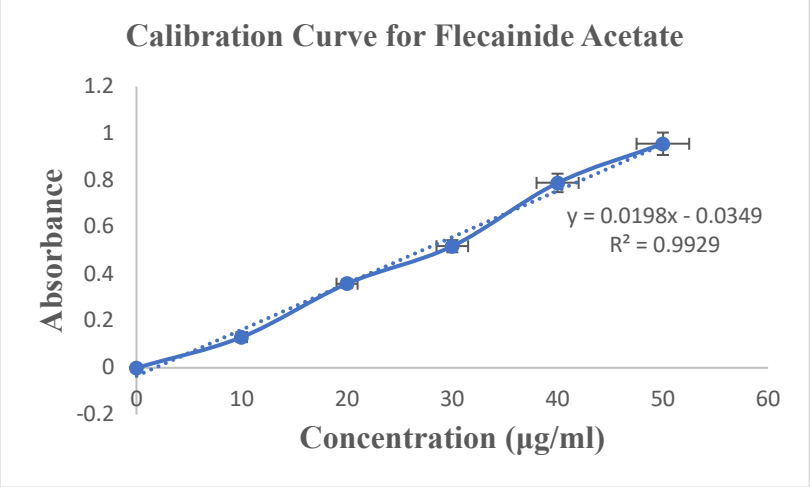

Figure 2 Calibration Curve for Flecainide Acetate

Identification of Drug- Flecainide Acetate by FT-IR Spectroscopy

The FT-IR spectrum of FCA exhibited characteristic absorption peaks corresponding to its functional groups, confirming the drug identity and purity. A prominent absorption band observed at 3305.52 cm^{-1} corresponds to N–H stretching vibrations, which falls within the standard range of 3300–3400 cm^{-1}, indicating the presence of an amine group. The C–H stretching vibration was observed at 2712.67 cm^{-1}, which is associated with aliphatic C–H bonds and is close to the expected range of 2920–2850 cm^{-1}. A strong absorption peak at 1735.67 cm^{-1} was assigned to the C=O stretching vibration, consistent with the characteristic range of 1750–1730 cm^{-1}, confirming the presence of a carbonyl functional group in the drug. Additionally, the peak observed at 1217.34 cm^{-1} corresponds to C–N stretching vibrations, which falls within the standard range of 1250–1050 cm^{-1}, further supporting the structural integrity of the flecainide acetate. The presence of all characteristic peaks without significant shifts indicates the drug's purity and the absence of chemical interactions, confirming its suitability for formulation development.

Solubility Studies and Excipient Selection

To identify the most suitable components for the Flecainide Acetate (FCA) drug delivery system, equilibrium solubility was evaluated across a range of aqueous and organic solvents, oils, surfactants, and co-surfactants, and the results are tabulated in Table-1. The solubility profile of FCA showed distinct preferences across different chemical classes, providing a quantitative roadmap for the development of formulations. According to the USP classification, FCA is freely soluble in water (48.4 ± 0.02 mg/mL), a characteristic that favors rapid dissolution but necessitates a robust lipidic carrier for sustained or targeted delivery

Table 1: Equilibrium Solubility of FCA in Various Vehicles

Category	Excipient	Solubility (mg/mL)
Solvents	Water	48.4 ± 0.02
	DMSO	15.38 ± 0.019
	Ethanol	10.12 ± 0.45
Oils	Captex 200	43.41 ± 0.18
	Triacetin	37.8 ± 0.22
	Oleic Acid	26.94 ± 0.37
	Isopropyl Myristate (IPM)	10.55 ± 0.21
Surfactants	Tween 80	50.7 ± 0.35
	Tween 20	35.5 ± 0.89
	Span 20	12.4 ± 0.54
Co-surfactants	PEG 400	45.78 ± 0.17
	PEG 200	42.04 ± 0.15
	Propylene Glycol (PG)	37.61 ± 0.14

Among the lipophilic phases, Captex 200 exhibited the highest solubilizing capacity (43.41 ± 0.18 mg/mL), followed by triacetin. These results indicate that Captex 200 is the most effective oil for maximizing drug loading and preventing precipitation within the internal phase of a nanoemulsion. Tween 80 was identified as the superior surfactant for stabilization (50.7 ± 0.35 mg/mL), significantly outperforming Span 20. The high solubility of Tween 80 indicates better drug-surfactant compatibility, which is essential for maintaining fine dispersion and improving systemic bioavailability.

Furthermore, screening of co-surfactants revealed that PEG 400 provided the most favorable environment for FCA (45.78 ± 0.17 mg/mL). The synergistic use of PEG 400 with Tween 80 is expected to lower the interfacial tension and enhance the flexibility of the surfactant film. Consequently, based on these solubility findings, a ternary system consisting of Captex 200 (oil), Tween 80 (surfactant), and PEG 400 (co-surfactant) was selected as the optimal vehicle for the further development of the FCA nanoemulsion

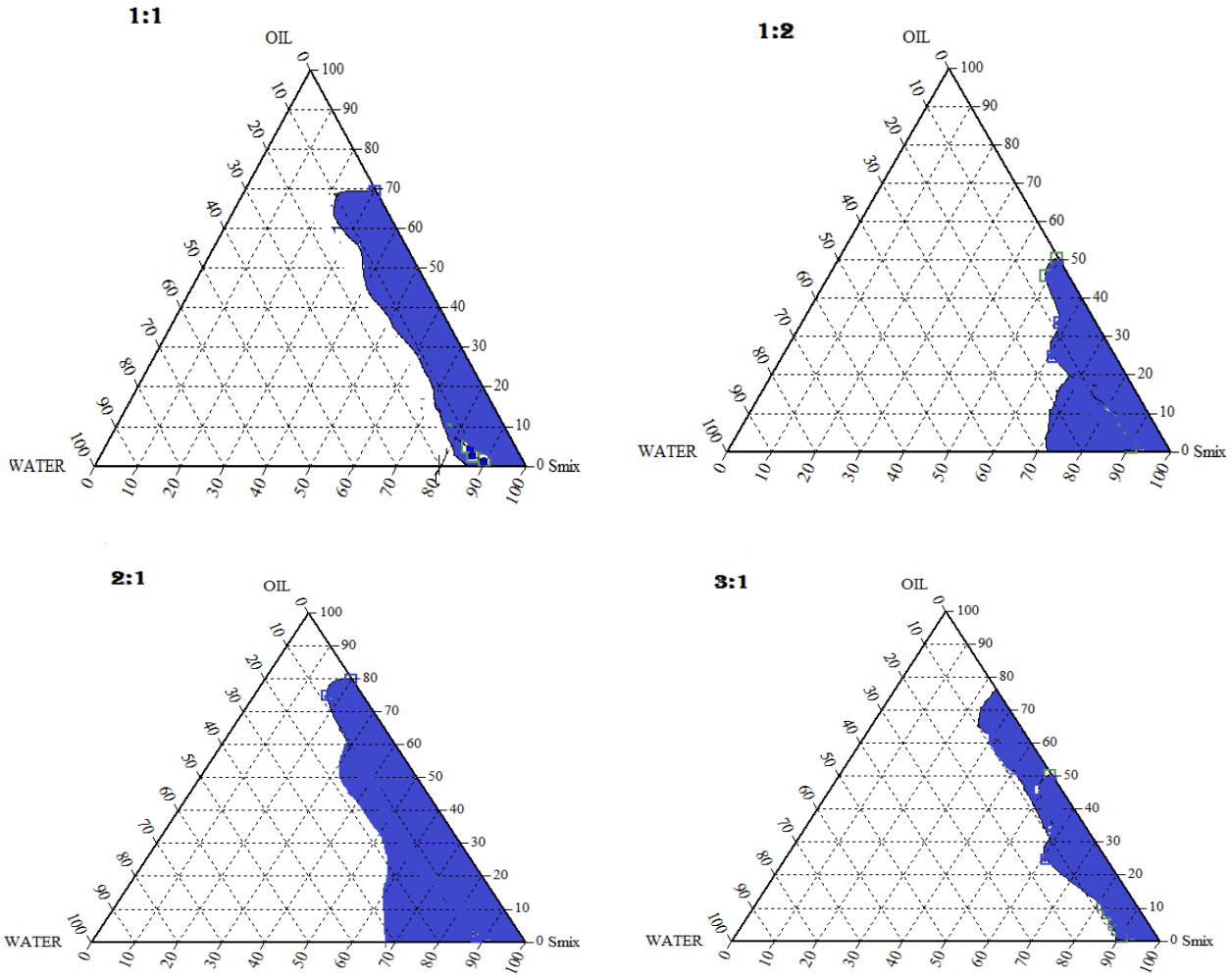

Figure: 2 Pseudo-ternary phase diagrams showing the o/w Nanoemulsion (shaded area) regions of CAPTEX 200 (oil), tween80 (surfactant), PEG 400 (cosurfactant) at Smax ratio 1:1, 1:2, 2:1 &3:1

Table 2 presents a systematic formulation design for self-emulsifying or nanoemulsion systems, where the effects of the Smix ratio (Surfactant: Co-Surfactant), oil/Smix ratio, and water content on the properties of the formulation are investigated. The Smix ratio varied between 1:1, 1:2, and 2:1 to assess how different proportions of surfactants and co-surfactants influenced the emulsification efficiency, droplet size, and stability of the emulsions. The oil/Smix ratio ranged from 1:1 to 1:5, reflecting changes in the relative amount of oil to surfactant mixture, which can impact drug solubilization, droplet formation, and the overall system stability. Different combinations of oil, Smix, and water volumes were used to prepare 16 distinct formulations, allowing for the evaluation of their self-emulsifying behavior, droplet size distribution, and drug-loading capacity. This factorial design provides a structured approach to identify the optimal composition that produces a stable, efficient, and reproducible nanoemulsion system with maximum drug solubilization and desired physicochemical properties

CODE	Smix Ratio	Oil/Smix Ratio	Oil	Smix	Water
1	1:1	1:4	10	40	50
2	1:1	1:5	10	50	40
3	1:1	1:2	15	35	50
4	1:1	1:1	15	30	40
5	1:2	1:4	10	40	50
6	1:2	1:5	10	50	40
7	1:2	1:2	15	35	50
8	1:2	1:1	15	30	40
7	2:1	1:4	10	40	50
10	2:1	1:5	10	50	40
11	2:1	1:2	15	35	50
12	2:1	1:1	15	30	40
13	3:1	1:4	10	40	50
14	3:1	1:5	10	50	40
15	3:1	1:2	15	35	50
16	3:1	1:1	15	30	40

Table: 2 Pseudo ternary phase diagram for selection of Optimized Formulation

Characterization of trial batch

Dilution test

The prepared nanoemulsion formulation was diluted in 1:10, 1:50, and 1:100 ratios with distilled water, and the system did not show any sign of separation and was found to be clear. Therefore, the prepared nanoemulsion was of the O/W type.

Thermodynamic stability studies of nanoemulsion

Nanoemulsions are thermodynamically and physically stable systems formed at a particular concentration of oil, surfactant, and water, making them stable against phase separation, creaming, or cracking. Thermostability differentiates nanoemulsions from emulsions with kinetic stability and eventually phase separation. Thus, the formulations were tested for their physical (dispersion) stability using centrifugation, heating-cooling, and freeze-thaw cycles. Only those formulations that survived the dispersion stability tests were selected for further study.

The results of the stress stability testing for different formulations, assessing their physical stability under heating and cooling, centrifugation, and freeze-thaw cycles, were consistent. Most formulations (Codes 1, 2, 4, 5, 7–12) passed all stability tests, indicating that they were physically stable, resistant to phase separation, and capable of maintaining integrity under thermal and mechanical stress. Code 3 passed heating and cooling as well as centrifugation but failed the freeze-thaw cycle, suggesting that it may be susceptible to instability when exposed to repeated freezing and thawing, likely due to droplet coalescence or phase separation. Code 6 failed all tests, indicating poor stability under stress conditions, possibly due to an inadequate surfactant/co-surfactant balance or an improper oil/Smix ratio. Overall, these results allowed the identification of formulations with robust physical stability suitable for further development, while unstable formulations required reformulation or optimization of their composition

CODE	Viscosity(cP)	pH	refractive index	Drug release
1	47±0.15	6.27 ± 0.11	1.226 ± 0.001	84.68±1.24
2	37±0.30	5.82 ± 0.05	1.214 ± 0.001	85.67±2.26
3	Fail	Fail	Fail	Fail
4	49±0.23	6.97 ± 0.05	1.129 ± 0.01	85.78±1.26
5	62±0.08	5.6 ± 0.10	1.235 ± 0.001	92.67±1.34
6	Fail	Fail	Fail	Fail
7	37±0.33	6.95 ± 0.11	1.272 ± 0.002	91.34±2.13
8	**30±0.41**	**6.0 ± 0.10**	**1.272 ± 0.04**	**96.68±2.65**
9	56±0.11	5.72 ± 0.05	1.275 ± 0.001	78.54±4.24
10	40±0.31	5.62 ± 0.05	1.281 ± 0.002	74.67±2.26
11	70±0.09	6.0 ± 0.1	1.325 ± 0.02	80.67±1.67
12	82±0.35	5.71 ± 0.11	1.303 ± 0.01	85.67±1.26

Table:3 Characterization of trial batch

Table 3 summarizes the physicochemical properties and drug release evaluation of various formulations (Codes 1–12). Most formulations showed acceptable viscosity, pH, refractive index, and drug release, indicating suitable stability and performance of the formulations. The viscosity values ranged from 30 to 82 cP, with higher viscosity (Codes 11 and 12) potentially providing slower drug release due to a thicker matrix, whereas lower viscosity (Codes 2, 7, and 8) may favor faster release. The pH values were generally within the physiological range (5.6–6.97), ensuring compatibility with topical or oral administration. The refractive index, ranging from 1.129 to 1.325, reflects the clarity and uniformity of the formulations, with minor variations likely due to differences in the oil, Smix, and water ratios of the formulations.

Drug release varied significantly across formulations, ranging from 74.67% (Code 10) to 96.68% (Code 8), indicating that the composition strongly affects the release kinetics. Formulations 3 and 6 failed all evaluations, suggesting instability or phase separation, likely owing to improper Smix or oil ratios. Overall, formulations 5, 7, and 8 exhibited optimal drug release with acceptable viscosity and pH, making them promising candidates for further development. These data highlight the critical influence of formulation parameters on stability, flow properties, and drug release profiles.

Characterization of the Optimized nanoemulsion batch

The optimized formulation exhibited a particle size range of 50–100 nm. Zeta potential analysis, performed via electrophoretic light scattering (ELS), yielded a value of −16.3 mV, with a corresponding electrophoretic mobility of −0.000126 cm²/V·s. This moderately negative surface charge promotes electrostatic repulsion between nanoparticles, thereby mitigating aggregation and enhancing colloidal stability. The zeta potential distribution

exhibited a sharp, narrow peak, suggesting a homogeneous population with a uniform surface charge. Although values exceeding ±30 mV are typically indicative of high stability, the recorded potential of ±16 mV is sufficient to maintain adequate dispersion for the intended application.

Dose Calculation for Loading Drug containing Nanoemulsion into topical Gel

The drug loading for the topical formulation was standardized at 1% (w/w). For the experimental 20 g batch, the amount of Flecainide Acetate required was determined through a weight-to-weight proportionality calculation (1000 mg API/100 g gel). Consequently, 200 mg of the API was loaded into the nanoemulsion (NE) system, which was subsequently thickened with carbopol to produce a homogenous 20 g medicated gel. This ensured that the final product maintained a consistent drug density equivalent to a standard 1% (w/w) commercial preparation.

Evaluation of Preliminary Trial Batches of Topical Gel:

To evaluate the influence of polymer density on the rheological and textural properties of the final product, three distinct nanoemulsion gel formulations (**FANEG1, FANEG2, and FANEG3**) were developed. The compositions are listed in **Table 4**

Ingredient	FANEG1	FANEG2	FANEG3
Carbopol 940 (%w/v)	0.5	1.0	2
Propylene glycol(mL)	5	5	5
Methyl paraben	0.1	0.1	0.1
Propyl paraben	0.05	0.05	0.05
Triethanolamine(mL)	0.25	0.25	0.25
Water(mL)	100	100	100

Table 4: Quantitative Composition of Flecainide Acetate Nanoemulsion Gels (FANEG)

The primary variable in these formulations was the concentration of Carbopol 940, which was adjusted from 0.5% to 2.0% (w/v). This range was selected to systematically investigate the impact of polymer concentration on the critical gel parameters, specifically viscosity, spreadability, and extrudability.

Propylene glycol was maintained at a constant concentration (5% v/v) to serve as both a humectant and a skin penetration enhancer, ensuring consistent hydration of the gel matrix. For microbial stability, a synergistic combination of methyl paraben (0.1%) and propyl paraben (0.05%) was used.

The gelation process was triggered by the addition of triethanolamine, which acted as a neutralizing agent to adjust the pH to a physiological range, thereby facilitating the cross-linking of Carbopol 940 chains into a three-dimensional network. All formulations were prepared to a final volume of 100 mL using distilled water. This experimental design allowed for a direct correlation between the structural density of the polymer and the resulting physicochemical performance of the Flecainide Acetate nanoemulsion gel

CODE	Viscosity(cP)	pH	refractive index	Drug release
1	47±0.15	6.27 ± 0.11	1.226 ± 0.001	84.68±1.24
2	37±0.30	5.82 ± 0.05	1.214 ± 0.001	85.67±2.26
3	Fail	Fail	Fail	Fail
4	49±0.23	6.97 ± 0.05	1.129 ± 0.01	85.78±1.26
5	62±0.08	5.6 ± 0.10	1.235 ± 0.001	92.67±1.34
6	Fail	Fail	Fail	Fail
7	37±0.33	6.95 ± 0.11	1.272 ± 0.002	91.34±2.13
8	**30±0.41**	**6.0 ± 0.10**	**1.272 ± 0.04**	**96.68±2.65**
9	56±0.11	5.72 ± 0.05	1.275 ± 0.001	78.54±4.24
10	40±0.31	5.62 ± 0.05	1.281 ± 0.002	74.67±2.26
11	70±0.09	6.0 ± 0.1	1.325 ± 0.02	80.67±1.67
12	82±0.35	5.71 ± 0.11	1.303 ± 0.01	85.67±1.26

Table 5 Evaluation of Carbopol gel

The physicochemical properties of the FANEG series are listed in **Table 5**. All formulations were colorless, odorless, and uniform. An increase in Carbopol 940 concentration led to a marginal reduction in pH from 6.5 ± 0.03 to 6.1 ± 0.02 and a significant, concentration-dependent surge in viscosity, ranging from 9267 ± 43 cP to 16571 ± 15 cP. Consequently, an inverse relationship was observed between viscosity and spreadability; FANEG1 exhibited

the highest spreadability (16.78 ± 0.61 gm · cm/sec), while FANEG3 showed the lowest (4.67 ± 1.96 gm · cm/sec). These results confirm that while a higher polymer density enhances structural integrity, it proportionately restricts the ease of topical application.

Characterization of Optimized batch

The evaluation of the gel formulation showed that it was transparent and odorless, indicating a visually clear and acceptable product. The pH of the gel was 6.5 ± 0.03, which is close to the natural skin pH, making it suitable for topical application. The spreadability was 16.78 ± 0.61 gm·cm/sec, indicating ease of application on the skin, while the viscosity was 9267 ± 43 cP, indicating moderate thickness that ensures the gel maintains its form without being too stiff. The drug content was 95.85 ± 0.12%, demonstrating uniform drug distribution within the formulation and confirming the efficiency of the preparation process. Overall, the gel exhibited desirable physicochemical properties suitable for topical application.

In-vitro release study

In vitro studies revealed a gradual and sustained release of Flecainide Acetate from the gel formulation. The drug release followed a time-dependent trajectory, starting with a modest 4.31% at 1 h and reaching 45.68% at the 6 h midpoint. This steady increase reflects a controlled diffusion mechanism through the Carbopol-stabilized nanoemulsion network. At 10 and 12 h, the cumulative release reached 72.56% and 91.23%, respectively. This release pattern is advantageous for maintaining concentrations within the therapeutic window for extended durations, potentially reducing the required dosing frequency and enhancing patient adherence

Ingredient	FANEG	FANEG	FANEG
Carbopol 940	0.5	1.0	2
Propylene	5	5	5
Methyl paraben	0.1	0.1	0.1
Propyl paraben	0.05	0.05	0.05
Triethanolamine(mL	0.25	0.25	0.25
Water(mL)	100	100	100

Table: 6 In-vitro release study

Stability Study

The stability study of the gel formulation at room temperature over 30 days showed that all measured parameters remained constant, indicating good physicochemical stability. The pH remained steady at 6.5, suggesting that the formulation maintained skin compatibility over time. The spreadability and viscosity remained unchanged, indicating that the gel maintained its consistency and ease of application throughout the study period. Additionally, the drug content remained unchanged at above 95%, indicating no significant degradation or loss. Overall, these results confirm that the formulation is stable at room temperature for at least one month, maintaining both its functional properties and drug integrity.

CONCLUSION

In this study, we successfully developed a novel Flecainide Acetate (FCA) nanoemulsion-based gel (nanoemulgel) for topical administration. Through rigorous preformulation and solubility screening, a ternary system comprising Captex 200, Tween 80, and PEG 400 was identified as the optimal vehicle, yielding a stable oil-in-water nanoemulsion with a uniform droplet distribution. The integration of this system into a Carbopol 940 matrix produced a formulation with ideal rheological properties, including pH compatibility and high spreadability. Notably, the optimized nanoemulgel exhibited sustained in vitro drug release over 12 h and maintained excellent stability under ambient conditions. These findings suggest that the developed nanoemulgel represents a viable and promising delivery platform for FCA, potentially enhancing therapeutic efficacy and patient compliance through localized or controlled systemic absorption.

Conflict of Interest

All authors affirm that there are no conflicts of interest.

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