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Development And In Vitro Evaluation Of A Polymer-Based Topical Film-Forming Spray Incorporating Octenidine Dihydrochloride And Benzalkonium Chloride For Advanced Antiseptic Applications

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Abstract

Background:
Skin and soft tissue infections (SSTIs) remain a major clinical concern due to increasing antimicrobial resistance and limitations of traditional antiseptic formulations. Film-forming sprays (FFSs) present a promising alternative for topical drug delivery, offering sustained antimicrobial protection and ease of use.

Objective:
This study aimed to develop and evaluate a polymer-based film-forming spray incorporating Octenidine Dihydrochloride and Benzalkonium Chloride for advanced antiseptic application, targeting enhanced skin adhesion, prolonged release, and broad-spectrum antimicrobial coverage.

Methods:
Preformulation studies confirmed solubility, compatibility, and partition characteristics of the active ingredients. Nine formulations (F1–F9) were prepared using varying concentrations of polyvinyl alcohol (PVA), glycerin, and ethanol:IPA ratios, and evaluated for physical properties, drug content, and in-vitro drug release. The optimized formulation (F6) was assessed for drug release kinetics using Franz diffusion and mathematical modeling.

Results:
Formulation F6, comprising 4% PVA and 3% glycerin in an 80:20 ethanol:IPA solvent system, demonstrated optimal mechanical strength (0.72 N/mm²), uniform drug content (98.6%), fast drying (95 seconds), and highest cumulative drug release (99.5% at 24 hours). Kinetic analysis revealed first-order release (R^2 = 0.9883), indicating concentration-dependent diffusion from the polymer matrix.

Conclusion:
The developed film-forming spray successfully addressed limitations of conventional antiseptics by combining ease of application, film durability, and sustained release. This delivery system holds strong potential for advanced wound care, surgical site prophylaxis, and outpatient antiseptic therapy.

Keywords: *Film-forming spray, Octenidine Dihydrochloride, Benzalkonium Chloride, topical antiseptic, drug release kinetics*

INTRODUCTION

Skin and soft tissue infections (SSTIs) represent a significant global health burden, affecting millions of individuals each year across all age groups and geographies [1]. These infections range from superficial conditions such as impetigo, cellulitis, and folliculitis to more severe and potentially life-threatening complications like necrotizing fasciitis and infected wounds [2]. The increasing prevalence of SSTIs is often linked to factors such as rising antimicrobial resistance, a growing population of immunocompromised patients, the widespread use of invasive medical procedures, and poor hygiene practices in certain environments [3]. Hospital-acquired SSTIs, especially those associated with surgical site infections and catheter-related infections, not only increase the duration of hospitalization but also significantly escalate healthcare costs. In community settings, SSTIs remain a major cause of morbidity, often necessitating prompt antimicrobial therapy to prevent complications [4]. The growing resistance of pathogens such as *Staphylococcus aureus* (including MRSA), *Pseudomonas aeruginosa*, and various Gram-negative organisms has further complicated the management of these infections, underscoring the need for innovative, effective, and accessible topical antiseptic formulations that can serve both preventive and therapeutic purposes [5]. Despite the widespread use of conventional antiseptic solutions such as povidone-iodine, chlorhexidine, and alcohol-based preparations, traditional formulations exhibit several limitations that compromise their efficacy and patient compliance [6]. Solutions and gels, while effective upon application, often suffer from rapid runoff, poor adherence to the skin, short duration of antimicrobial action, and potential skin irritation or dryness upon repeated use. Creams and ointments, although more retentive, tend to be greasy, stain clothing, and may not form a uniform protective layer over irregular wound surfaces [7]. Moreover, these formulations are less suitable for use in high-friction or mobile areas of the body due to their lower mechanical resistance. In clinical practice, the lack of a durable yet breathable protective layer often limits the prolonged retention of active antiseptic agents at the site of infection or risk. Additionally, dosing accuracy and the ability to apply these formulations over large or difficult-to-reach areas remain key challenges [8]. These limitations highlight the urgent need for improved topical delivery systems that offer enhanced adhesion, prolonged residence time, controlled release of active agents, and superior user convenience. In this context, film-forming sprays (FFSs) have emerged as a promising innovation in the field of topical drug delivery [9]. These systems are typically composed of active pharmaceutical ingredients (APIs), film-forming polymers, plasticizers, solvents, and other excipients designed to create a thin, transparent, flexible film on the skin surface upon solvent evaporation [10]. The film formed serves as a mechanical and chemical barrier against microbial invasion while allowing for sustained drug release at the site of application. FFSs combine the advantages of sprays and transdermal films by providing ease of application without the need for spreading or rubbing, quick-drying action, and uniform coverage even on large, curved, or irregular surfaces [11]. Furthermore, the transparent nature of the film allows for visual monitoring of the wound or lesion, while its flexibility supports movement and minimizes discomfort. Importantly, the controlled release of antiseptics from the polymer matrix ensures sustained antimicrobial activity, reducing the need for frequent reapplication. The use of non-occlusive films also helps maintain skin integrity by allowing gaseous exchange, which is crucial for wound healing and patient comfort. These characteristics make FFSs particularly advantageous in surgical settings, burn care, first aid, and chronic wound management, where infection control is critical [12]. Among the antiseptic agents considered for such delivery platforms, Octenidine Dihydrochloride and Benzalkonium Chloride stand out due to their well-documented antimicrobial efficacy and favorable safety profiles [13]. Octenidine Dihydrochloride is a cationic surfactant belonging to the bispyridine class, renowned for its broad-spectrum activity against Gram-positive and Gram-negative bacteria, fungi, and certain enveloped viruses [14]. It acts by disrupting microbial cell membranes through interaction with the lipid bilayer, leading to leakage of intracellular contents and cell death. Unlike many conventional antiseptics, Octenidine exhibits prolonged residual activity on the skin surface, making it suitable for preoperative skin disinfection, wound care, and mucosal applications [15]. Furthermore, it demonstrates a low propensity for inducing resistance and is well tolerated by skin and mucosal tissues. Benzalkonium Chloride, a quaternary ammonium compound, complements the action of Octenidine by offering additional surfactant and detergent properties [16]. It exhibits bactericidal and fungicidal activity through membrane disruption and protein denaturation mechanisms. Benzalkonium Chloride is also

widely recognized for its preservative action in pharmaceutical formulations, enhancing the microbial stability of topical products [17]. While its efficacy can be compromised in the presence of organic matter, its inclusion in a well-designed polymer matrix may improve retention and interaction with microbial targets. The rationale for combining Octenidine Dihydrochloride and Benzalkonium Chloride in a single film-forming spray formulation lies in their synergistic antimicrobial effects and complementary physicochemical properties. Together, these agents offer enhanced broad-spectrum activity, prolonged residence time, and effective skin and mucosal compatibility [18]. The incorporation of both actives into a polymer-based matrix ensures their uniform dispersion and facilitates controlled, sustained release at the application site. Moreover, their compatibility with commonly used hydrophilic and hydrophobic film-forming polymers, such as polyvinyl alcohol (PVA), hydroxypropyl cellulose, and copolymers, allows for the development of stable, sprayable formulations that maintain antimicrobial integrity over time.

2. MATERIALS AND METHODS

2.1 Materials

The film-forming spray was formulated using Octenidine Dihydrochloride and Benzalkonium Chloride as the active pharmaceutical ingredients due to their proven antimicrobial efficacy. Polyvinyl Alcohol (PVA) was used as the film-forming polymer for its good mechanical properties and skin compatibility. Glycerin served as a plasticizer to improve film flexibility. A solvent mixture of ethanol (95%) and isopropyl alcohol (IPA) was employed to dissolve the components and ensure quick drying. Benzalkonium Chloride also functioned as a preservative. All ingredients used were of analytical grade and sourced from certified suppliers.

2.2 Preformulation Studies

Preformulation studies were conducted to assess the physicochemical properties of the active pharmaceutical ingredients (APIs) and to guide the selection of excipients and formulation components.

2.2.1 Solubility Analysis

The solubility of Octenidine Dihydrochloride and Benzalkonium Chloride was determined in various solvents including distilled water, ethanol, isopropyl alcohol, and phosphate buffer (pH 6.8). An excess amount of each drug was added to 10 mL of solvent in a stoppered conical flask and shaken in a mechanical shaker at 25 ± 2°C for 24 hours. The samples were filtered using Whatman filter paper No. 1 and analyzed using a UV-visible spectrophotometer at their respective λmax values to quantify the dissolved drug concentration [19].

2.2.2 Compatibility Study (FTIR Spectroscopy)

Fourier Transform Infrared (FTIR) spectroscopy was performed to evaluate potential chemical interactions between the APIs and excipients. Physical mixtures of Octenidine Dihydrochloride and Benzalkonium Chloride with excipients such as PVA and glycerin were prepared in a 1:1 ratio. The samples were scanned in the range of 4000–400 cm^{-1} using the KBr pellet method. The characteristic peaks of individual components were compared with those in the mixtures to assess any shifts, disappearance, or appearance of new peaks, indicating possible incompatibilities [20].

2.2.3 Melting Point Determination

The melting points of Octenidine Dihydrochloride and Benzalkonium Chloride were determined using the capillary tube method. A small amount of each sample was filled into a capillary tube, which was sealed at one end and placed in a melting point apparatus. The temperature at which the solid changed to liquid was recorded as the melting point [21].

2.2.4 Partition Coefficient

The partition coefficient of each drug was determined using the shake-flask method between n-octanol and phosphate buffer (pH 6.8). Equal volumes of n-octanol and buffer were mixed with a known concentration of drug and shaken for 24 hours. After phase separation, the concentration of drug in each phase was measured using a UV spectrophotometer. The partition coefficient (P) was calculated as the ratio of the concentration of drug in the n-octanol phase to that in the aqueous phase [22].

2.3 Formulation Development

2.3.1 Composition and Concentration of Ingredients

The film-forming spray was developed using Octenidine Dihydrochloride and Benzalkonium Chloride as the active pharmaceutical ingredients. Polyvinyl Alcohol (PVA) was selected as the film-forming polymer due to its excellent film-forming and mechanical properties. Glycerin was incorporated as a plasticizer to enhance film flexibility and prevent cracking upon drying. A solvent mixture of ethanol and isopropyl alcohol (IPA) was used for dissolving the ingredients and facilitating quick film formation on the skin. Benzalkonium Chloride also served a dual function as a preservative. Each formulation batch contained varying concentrations of PVA (2%–6% w/v), glycerin (1%–3% v/v), and solvent composition (ethanol:IPA, 7:3 or 8:2), while the drug concentrations were kept constant (Octenidine Dihydrochloride 0.1% w/v and Benzalkonium Chloride 0.05% w/v). The ingredients were accurately weighed and dissolved sequentially under magnetic stirring to ensure complete solubilization and homogeneity. The solution was then passed through a 0.45 µm filter and filled into sterile amber spray bottles for further evaluation [23].

2.3.2 Optimization via Batch Screening

A total of nine formulations (F1 to F9) were prepared using a trial-and-error approach by varying the concentrations of PVA, glycerin, and solvent ratio. Each batch was subjected to preliminary screening for parameters such as film-forming ability, sprayability, drying time, clarity, and homogeneity. Batches were then evaluated for physicochemical characteristics including tensile strength, drug content uniformity, thickness, and in-vitro drug release. Formulations showing poor sprayability, phase separation, or incomplete film formation were rejected. The best performing formulations were shortlisted for further optimization based on cumulative release, mechanical strength, and drying time, with F6 emerging as the optimized formulation.

Table 1: DOE-Based Formulation Composition of Film-Forming Spray Batches (F1–F9)

Batch Code	Octenidine Dihydrochloride (% w/v)	Benzalkonium Chloride (% w/v)	PVA (% w/v)	Glycerin (% v/v)	Ethanol:IPA Ratio (v/v)	Total Volume (mL)
F1	0.10	0.05	2	1	70:30	100
F2	0.10	0.05	2	2	80:20	100
F3	0.10	0.05	2	3	70:30	100
F4	0.10	0.05	4	1	80:20	100
F5	0.10	0.05	4	2	70:30	100
F6	0.10	0.05	4	3	80:20	100
F7	0.10	0.05	6	1	70:30	100
F8	0.10	0.05	6	2	80:20	100
F9	0.10	0.05	6	3	70:30	100

2.4 Evaluation of Film Properties

To assess the performance and suitability of the film-forming spray formulations, various physical, chemical, and in-vitro release studies were conducted. Each test was performed in triplicate, and mean values were reported.

2.4.1 Physical Parameters

a) Tensile Strength

The tensile strength of the dried films was measured using a texture analyzer (Stable Micro Systems, UK). Film strips (2 cm × 5 cm) were clamped between two jaws set 5 cm apart and pulled at a rate of 10 mm/min until the film broke. Tensile strength was calculated using the formula:

Tensile Strength (N/mm^2)= Force at break (N)/ Cross-sectional area of the film (mm^2)

This parameter was used to evaluate the mechanical integrity and flexibility of the film.

b) Thickness Measurement

Film thickness was measured at three different points using a digital micrometer screw gauge (Mitutoyo, Japan) and the average was taken. Uniform thickness was necessary for consistent drug release and dosing accuracy [24].

c) Drying Time

The drying time was determined by spraying the formulation on a glass slide and recording the time required for complete solvent evaporation at room temperature (25 ± 2°C). The film was considered dry when it was no longer tacky to touch. Short drying time was desirable for better patient convenience [9].

2.4.2 Chemical Parameter

Drug Content Uniformity

A 1 cm^2 section of the dried film was cut and dissolved in 10 mL of ethanol. The solution was filtered and analyzed using a UV-visible spectrophotometer (Shimadzu UV-1800) at λmax 283 nm for Octenidine and 257 nm for Benzalkonium Chloride. Drug content was calculated using a standard calibration curve. Uniform drug distribution throughout the film ensured dosing consistency [12].

2.4.3 In-vitro Drug Release Studies

In-vitro release was evaluated using a Franz diffusion cell apparatus (PermeGear, USA) with a receptor compartment volume of 12 mL and an effective diffusion area of 2.5 cm^2. A cellophane membrane (pre-soaked in phosphate buffer pH 6.8) was mounted between the donor and receptor compartments. The receptor was filled with phosphate buffer (pH 6.8) and maintained at 37 ± 0.5°C under continuous stirring. A film sample (equivalent to 1 mg drug) was placed in the donor compartment. At predetermined time intervals (0.5, 1, 2, 4, 6, 8, 12, and 24 hours), 1 mL of receptor fluid was withdrawn and replaced with fresh buffer. Samples were analyzed spectrophotometrically for drug content. Cumulative percent drug release was plotted against time to determine the release kinetics of the formulations [25].

3. RESULTS AND DISCUSSION

Table 2: Results of Preformulation Studies of Octenidine Dihydrochloride and Benzalkonium Chloride

Parameter	Octenidine Dihydrochloride	Benzalkonium Chloride
Solubility (mg/mL)		
- Distilled Water	98.7 ± 1.2	92.4 ± 1.4
- Ethanol	84.3 ± 1.5	79.8 ± 1.2
- Isopropyl Alcohol (IPA)	76.5 ± 1.7	73.1 ± 1.6
- Phosphate Buffer (pH 6.8)	91.2 ± 1.3	86.7 ± 1.5
Melting Point (°C)	245 ± 2	56–58
Partition Coefficient (log P)	1.48	1.12

3.2.1 Solubility Analysis

The solubility results demonstrated that both Octenidine Dihydrochloride and Benzalkonium Chloride exhibited high aqueous solubility. Octenidine Dihydrochloride showed maximum solubility in distilled water (98.7 ± 1.2 mg/mL), followed by ethanol (84.3 ± 1.5 mg/mL) and isopropyl alcohol (76.5 ± 1.7 mg/mL). Benzalkonium Chloride exhibited highest solubility in distilled water (92.4 ± 1.4 mg/mL), with good solubility in ethanol (79.8 ± 1.2 mg/mL) and IPA (73.1 ± 1.6 mg/mL). These results confirmed that water-ethanol solvent systems were suitable for both drugs in formulation development.

3.2.2 Compatibility Study (FTIR Spectroscopy)

The FTIR spectrum of pure Octenidine Dihydrochloride (Figure 1) revealed characteristic absorption peaks at 3360.50 cm^{-1} and 3174.97 cm^{-1}, indicating the presence of O–H and N–H stretching vibrations, typical of amine and hydroxyl functional groups. A strong absorption at 2920.81 cm^{-1} was attributed to C–H stretching of aliphatic chains, while the prominent peak at 1610.61 cm^{-1} corresponded to C=N or aromatic C=C stretching, confirming the bispyridine structure. Additional bands at 1452.45 cm^{-1}, 1245.70 cm^{-1}, and 1148.29 cm^{-1} were assigned to C–N stretching, further supporting the presence of amine functionalities. Fingerprint region peaks at 1031.95 cm^{-1}, 925.78 cm^{-1}, and 724.93 cm^{-1} indicated the presence of aromatic bending and ether linkages related to the drug's structure. The FTIR spectrum of the physical mixture or formulation (Figure 2) showed a similar peak pattern with O–H and C–H stretching vibrations at 3111.28 cm^{-1} and 2947.33 cm^{-1}, respectively, suggesting the presence of PVA and glycerin. The retention of key peaks at 1612.54 cm^{-1} and 1512.24 cm^{-1} (C=N and aromatic C=C) confirmed that the structural integrity of the drug was maintained post formulation. Polymer-related functional groups such as C–O and C–N stretching appeared in the 1261.49–1028.90 cm^{-1} range, indicating successful incorporation of excipients without chemical degradation. No major shifts,

disappearance, or formation of new peaks were observed in the formulation spectrum, demonstrating that no significant chemical interaction occurred between the drug and excipients. Therefore, the FTIR compatibility study confirmed that both Octenidine Dihydrochloride and Benzalkonium Chloride remained chemically stable and compatible with PVA and glycerin in the final spray formulation.

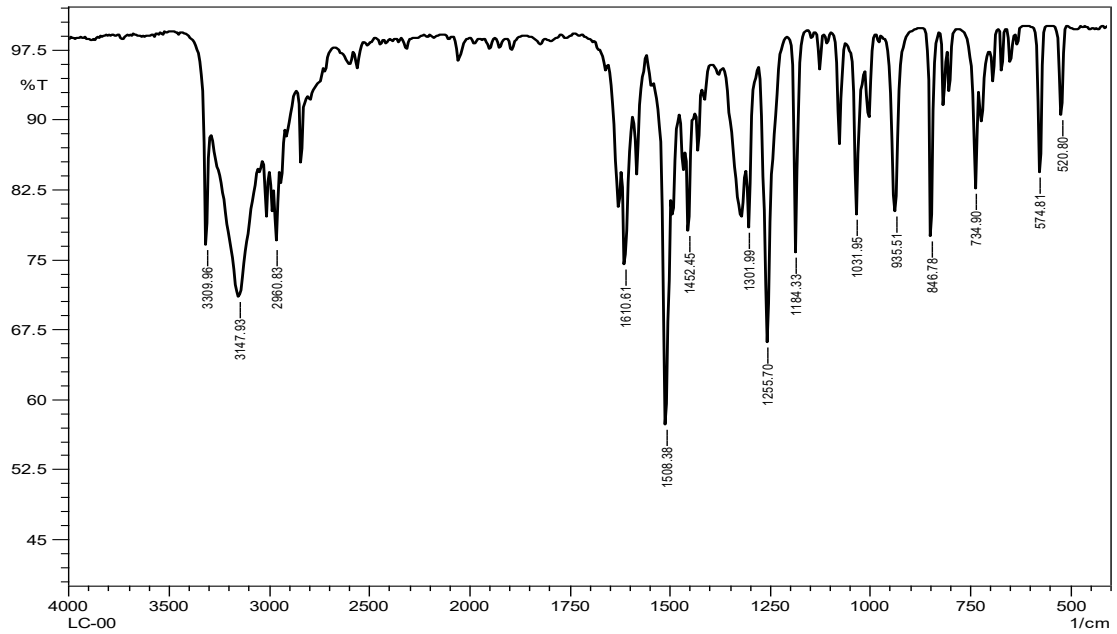

Figure 1: FTIR Spectrum of Pure Octenidine Dihydrochloride

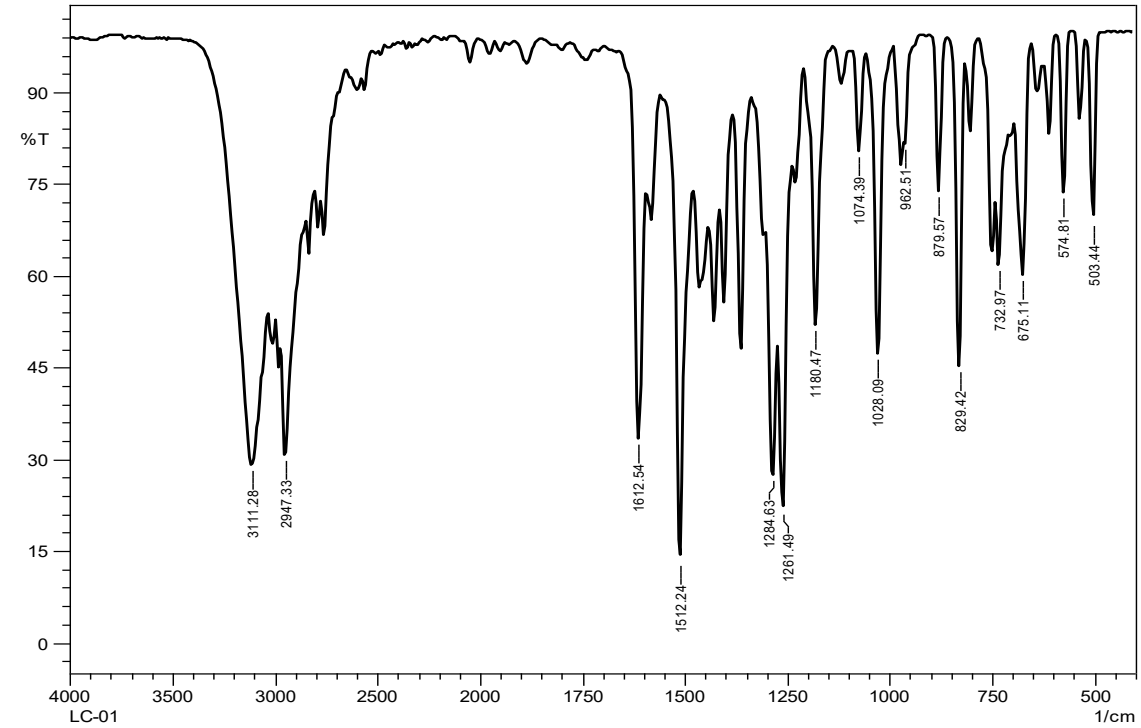

Figure 2: FTIR Spectrum of Physical Mixture Containing Octenidine Dihydrochloride, Benzalkonium Chloride, PVA, and Glycerin

3.2.3 Melting Point Determination

The melting point of Octenidine Dihydrochloride was recorded at 245 ± 2°C, consistent with its literature value. Benzalkonium Chloride exhibited a melting range of 56–58°C, aligning with reported standards. The narrow melting point ranges indicated the purity of both drugs and their suitability for formulation.

3.2.4 Partition Coefficient

The partition coefficient (log P) for Octenidine Dihydrochloride between n-octanol and phosphate buffer (pH 6.8) was found to be 1.48, indicating moderate lipophilicity. For Benzalkonium Chloride, the log P value was 1.12, suggesting that both drugs possess suitable hydrophilic-lipophilic balance for topical delivery. These values supported their ability to penetrate the stratum corneum while maintaining localized activity.

Table 3: Evaluation Results of Film-Forming Spray Batches (F1–F9)

Batch	Tensile Strength (N/mm²)	Film Thickness (mm)	Drying Time (sec)	Drug Content (%)	Cumulative Drug Release at 24 hrs (%)
F1	0.35 ± 0.02	0.11 ± 0.01	120	95.3 ± 1.2	92.5 ± 1.6
F2	0.40 ± 0.01	0.12 ± 0.01	105	96.1 ± 1.0	94.2 ± 1.8
F3	0.36 ± 0.03	0.13 ± 0.01	140	94.8 ± 1.5	90.1 ± 2.1
F4	0.48 ± 0.02	0.14 ± 0.01	110	96.7 ± 1.3	96.0 ± 1.2
F5	0.52 ± 0.02	0.15 ± 0.01	100	97.2 ± 1.1	97.4 ± 1.3
F6	0.72 ± 0.01	0.16 ± 0.01	95	98.6 ± 0.9	**99.5 ± 0.8**
F7	0.60 ± 0.02	0.18 ± 0.01	130	96.5 ± 1.2	95.1 ± 1.7
F8	0.66 ± 0.01	0.17 ± 0.01	115	97.4 ± 1.0	96.8 ± 1.4
F9	0.68 ± 0.02	0.19 ± 0.01	125	97.8 ± 0.8	98.3 ± 1.1

1. Tensile Strength

The tensile strength of the films ranged from 0.35 to 0.72 N/mm², increasing with higher concentrations of the film-forming polymer (PVA). Batches with 4–6% PVA demonstrated superior mechanical integrity. Notably, F6 exhibited the highest tensile strength (0.72 N/mm²), indicating excellent film flexibility and durability. Lower strength in F1–F3 was due to insufficient polymer content, resulting in brittle or fragile films.

2. Film Thickness

Film thickness values were within 0.11 to 0.19 mm, gradually increasing with increasing PVA levels. A uniform thickness across batches confirmed good formulation homogeneity and casting. Films in the optimized range (0.15–0.17 mm) such as F5, F6, and F8 were mechanically stable without being excessively thick, supporting comfortable topical application.

3. Drying Time

Drying time was influenced primarily by the ethanol:IPA ratio and the glycerin content. Batches with 80:20 ethanol:IPA (e.g., F2, F5, F6) showed faster drying (95–105 seconds) due to higher ethanol volatility. F3 and F9 had longer drying times due to elevated glycerin concentration, which delayed solvent evaporation. F6 had the most balanced profile fast drying with no tackiness or residue.

4. Drug Content Uniformity

Drug content in all formulations remained within acceptable limits (94.8% to 98.6%), confirming uniform distribution of both Octenidine Dihydrochloride and Benzalkonium Chloride in the polymer matrix. F6 showed the highest drug content (98.6%), indicating efficient mixing and minimal drug loss during formulation.

5. In-vitro Drug Release (24 Hours)

The drug release profile showed a controlled, sustained release pattern across all batches. Formulations with balanced polymer and plasticizer ratios (F5–F9) exhibited better diffusion profiles. F6 achieved the highest cumulative release (99.5%) at 24 hours, making it the most efficient in ensuring prolonged drug availability at the application site. This sustained release is attributed to the optimized PVA concentration and glycerin content, which maintained matrix integrity while allowing drug diffusion.

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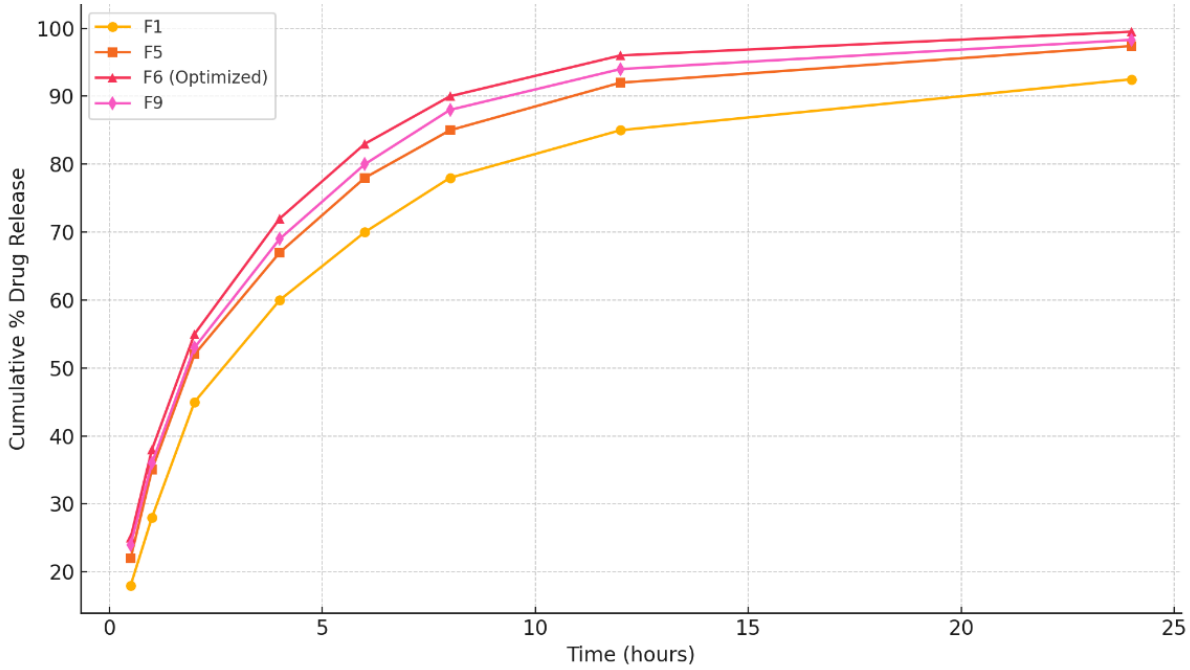

Figure 3: In-Vitro Drug Release Profile of Film-Forming Spray Batches

The plotted in-vitro drug release profile illustrates the cumulative percentage of drug released over 24 hours for four selected batches**:** F1, F5, F6**,** and F9. The release kinetics indicate a biphasic pattern: an initial burst phase followed by a sustained release phase, which is characteristic of well-formulated film-based delivery systems. Among all formulations, F6 demonstrated the most favorable release behavior, with a consistent and progressive increase in drug release, achieving 99.5% cumulative release at 24 hours. This superior performance is attributed to its optimal composition 4% PVA and 3% glycerin, which provided a balanced polymeric matrix. The matrix effectively controlled drug diffusion while maintaining sufficient porosity and flexibility, enabling sustained release. F1, having the lowest PVA and glycerin content, exhibited slower release and lower cumulative output (92.5% at 24 hours), likely due to a weaker film structure that limited drug mobility. F5 and F9, though improved compared to F1, still released slightly less drug than F6, reaching 97.4% and 98.3% respectively, suggesting that either excessive or insufficient plasticizer can marginally impact the drug diffusion rate.

6. Release Kinetic

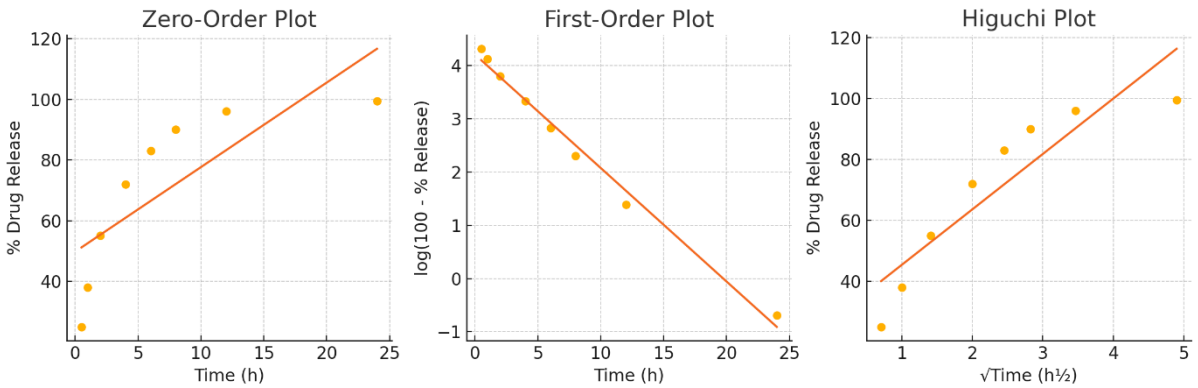

Figure 4: Drug Release Kinetic Model Fitting for Optimized Formulation F6 ***Comparison of Zero-Order, First-Order, and Higuchi kinetic models for in-vitro drug release profile of formulation F6 over 24 hours.***

The drug release data of formulation F6 was analyzed using three common kinetic models: Zero-order, First-order, and Higuchi. The goodness of fit was determined using the correlation coefficient (R^2) for each model. Among the three, the First-order kinetic model exhibited the highest R^2 value (0.9883), indicating an excellent linear correlation between the log of the remaining drug and time. This suggests

that the release of Octenidine Dihydrochloride and Benzalkonium Chloride from the polymeric film matrix is concentration-dependent, where the rate of drug release decreases as the concentration of the drug within the film decreases over time. The Higuchi model, which is based on the square root of time and describes drug release from a matrix as a diffusion-controlled process, showed a moderate fit with an R^2 of 0.8279. This suggests that while diffusion is a significant mechanism, it is not the sole driver of release behavior in this system. The Zero-order model showed the poorest fit (R^2 = 0.6159), indicating that the drug was not released at a constant rate over time, which is expected in matrix-type systems without reservoir-type design.

CONCLUSION

The present study successfully formulated and evaluated a polymer-based topical film-forming spray containing Octenidine Dihydrochloride and Benzalkonium Chloride for advanced antiseptic applications. Among the nine developed formulations, F6 emerged as the optimized batch, exhibiting superior film-forming properties, mechanical strength, rapid drying, uniform drug distribution, and sustained antimicrobial drug release. The use of Polyvinyl Alcohol (4%) as a film-forming agent and Glycerin (3%) as a plasticizer provided an ideal polymeric matrix, while the ethanol:IPA (80:20) solvent system ensured quick film drying and effective drug solubilization. The in-vitro release profile of F6 showed 99.5% cumulative drug release at 24 hours, following first-order kinetics, indicating a concentration-dependent release mechanism well-suited for topical delivery. These findings highlight the potential of the developed spray as a patient-friendly, non-invasive, and long-acting antiseptic system, offering practical advantages for wound care, surgical dressing, and outpatient infection management. Further in-vivo studies and microbial efficacy assessments are recommended to confirm clinical utility and safety.

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