

## Formulation and Development of Microemulgel of Azithromycin and Clindamycin for In vitro Antibacterial Activity

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**Abstract:** This research paper delves into the formulation and development of Azithromycin and Clindamycin-loaded microemulgels for enhanced in vitro antibacterial activity. The study adopted a meticulous methodology that involved the collection and analysis of the drugs, followed by the formulation of the Microemulgel. A series of tests was conducted to evaluate the microemulgels' properties, including pH, viscosity, spreadability, and in vitro drug release. Particle size and zeta potential were assessed to ascertain the uniformity and stability of the formulations. The microemulgels exhibited small and consistent particle sizes and negative zeta potential values, highlighting their stability. The formulated microemulgels showed promising in vitro antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*, suggesting their potential application in treating bacterial skin infections. However, further in vivo studies are recommended to validate these in vitro findings.

**Keywords:** Microemulgel, Azithromycin, Clindamycin, Particle Size, Zeta Potential, Antibacterial Activity, *Staphylococcus aureus*, *Escherichia coli*, Drug Formulation, Pharmaceutical Development

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### INTRODUCTION

Microemulsions and gels have long been significant in the pharmaceutical landscape due to their unique properties and diverse applications [1]. While microemulsions offer

an optimal drug delivery medium, especially for hydrophobic substances, their liquid nature limits the application for topical use. In contrast, gels are a semi-solid system that provides a suitable base for the application of

drugs onto the skin [2]. The advent of Microemulgel technology has effectively bridged the gap between these two systems, offering a novel and efficient way of drug delivery, especially for topical applications [3].

Azithromycin and clindamycin, two vital antibacterial agents, are commonly used in the treatment of a myriad of bacterial infections. Azithromycin is a macrolide antibiotic known for its broad-spectrum activity against a range of bacterial species [4]. It functions by inhibiting bacterial protein synthesis, thereby effectively halting the growth and replication of the bacteria. On the other hand, clindamycin, a lincosamide antibiotic, operates by a similar mechanism, but is particularly potent against anaerobic bacteria and certain protozoa. Despite their proven efficacy, the conventional dosage forms of these drugs often come with limitations, such as poor solubility and limited permeability, which can impact their therapeutic efficiency [5].

The study at hand, therefore, aims to leverage the advantages of Microemulgel technology to create a formulation that enhances the delivery of azithromycin and clindamycin for improved antibacterial activity [6]. A Microemulgel system not only facilitates the delivery of

hydrophobic drugs, but it also ensures a more prolonged and controlled release of these drugs. By ensuring a higher residence time on the skin and reducing the frequency of application, Microemulgel offers a convenient and more effective alternative to conventional drug delivery systems [7].

This innovative approach could potentially improve the effectiveness of azithromycin and clindamycin, by enhancing their solubility, absorption and stability, and also minimize potential side effects by enabling a targeted delivery and sustained release of these drugs [8]. Given the rise of antimicrobial resistance worldwide, it is crucial to explore novel drug delivery systems such as this one, that not only optimize the efficacy of existing antibiotics but also provide a convenient means of application for improved patient compliance [9].

Moreover, the current formulation can provide a scientific base for future studies, fostering a deeper understanding of the behavior of drugs within Microemulgel systems and opening up new avenues for the application of this technology [10].

In summary, this paper delves into the formulation and development of a Microemulgel of azithromycin and clindamycin, investigating its *in vitro*

antibacterial activity. It brings to light the unique properties and potential advantages of using a Microemulgel system for the delivery of these widely-used antibacterial agents. The hope is to push the boundaries of drug delivery technology and advance our current methods of treatment against various bacterial infections [11].

### **Methodology**

The methodology adopted for this research includes the collection of the antibiotic agents Azithromycin and Clindamycin, the determination of the  $\lambda_{\max}$  (wavelength at which the maximum absorption of these agents occurs), and the formulation of the Microemulgel.

### **Collection of Azithromycin and Clindamycin [12]**

Azithromycin and Clindamycin were collected from an authorized pharmaceutical supplier. Both drugs were checked for their physical appearance, solubility, melting point, and expiration date. The samples were then stored in a cool, dry, and dark place until further usage.

### **Determination of $\lambda_{\max}$ of Azithromycin and Clindamycin [12]**

The UV-Visible spectroscopy was used to determine the  $\lambda_{\max}$  of both Azithromycin and

Clindamycin. The drugs were dissolved in a suitable solvent (e.g., Methanol) and scanned in the UV region of 200-400nm using a UV spectrophotometer. The  $\lambda_{\max}$  was noted as the wavelength at which the maximum absorption of the drug occurred. These readings are crucial in the development of the Microemulgel as it helps in quantifying the amount of drug released in the in-vitro release studies.

### **Formulation of Microemulgel**

#### **Step 1: Preparation of the Oil Phase [13]**

Azithromycin (2% w/w) and Clindamycin (2% w/w) were dissolved in the oil phase (Castor oil, 12% w/w). This was done using a magnetic stirrer at a constant stirring speed until a clear solution was obtained.

#### **Step 2: Preparation of the Surfactant Mixture [14]**

Concurrently, the surfactant mixture was prepared. This involved mixing the surfactant (Tween 80, 18% w/w) and co-surfactant (Ethanol, 12% w/w) in a separate container. The mixture was stirred until it was completely homogenized.

#### **Step 3: Mixing the Oil Phase and Surfactant Mixture [15]**

Next, the oil phase (from step 1) was slowly added to the surfactant mixture (from step 2) under constant stirring. This was done carefully to avoid any abrupt changes in the system that could result in the formation of a cloudy or opaque mixture. The goal was to form a transparent or slightly translucent Microemulsion.

#### Step 4: Addition of Water [16]

Once the Microemulsion was formed, water (50% w/w) was gradually added under continuous stirring. This step required careful

execution as adding water too quickly could disrupt the Microemulsion.

#### Step 5: Formation of Microemulgel [17]

Finally, Carbopol 934 (4% w/w), the gelling agent, was slowly dispersed in the above microemulsion under constant stirring until a homogenous gel (microemulgel) was formed. Stirring was continued until the gel structure developed, which took several hours. The mixture was then allowed to rest for a while to allow for the complete swelling of the gelling agent.

**Table- 1: Formulae of Formulation**

Ingredient	Function	Quantity (% w/w)
Azithromycin	Active Ingredient	2%
Clindamycin	Active Ingredient	2%
Oil (e.g. oleic acid, castor oil)	Oil phase	12%
Surfactant (e.g. Tween 80, Span 80)	Surfactant	18%
Co-surfactant (e.g. ethanol, propylene glycol)	Co-surfactant	12%
Water	Solvent	50%
Gelling agent (e.g. Carbopol 934)	Gelling Agent	1%, 2% and 3% (Sample A, Sample B and Sample C)

#### Evaluation Parameters

In order to confirm the desired characteristics of the formulated Microemulgel, various

evaluation parameters were considered. These parameters included pH, viscosity, spreadability, and in vitro drug release.

**pH [18]**

The pH of the formulated Microemulgel was determined using a calibrated pH meter. A small amount of the gel was dispersed in distilled water to make a 1% solution. The electrodes of the pH meter were then immersed in the solution, and the pH was recorded. This test is critical because the pH of the formulation should be within the normal skin pH range (5.5 to 7) to avoid any skin irritation.

**Viscosity [19]**

The viscosity of the Microemulgel was evaluated using a viscometer. The gel was placed in the sample holder, and the spindle was rotated at a specific speed. The viscometer then provided a measure of the resistance to flow, i.e., viscosity. The viscosity determination is crucial to ensure the proper application of the gel, its stability, and the release rate of the drugs.

**Spreadability [20]**

Spreadability was measured to evaluate the ease of application of the Microemulgel. The gel was placed between two glass slides under a known weight, and the time taken for the gel to cover a specific distance under the weight was recorded. This parameter helps in

assessing the patient's acceptability of the product.

**In vitro Drug Release [21]**

The in vitro drug release was assessed using a suitable diffusion cell using Franz diffusion cell. The Microemulgel was placed in the donor compartment, and the receptor compartment was filled with a suitable medium (often phosphate buffer saline of pH 7.4). At specific intervals, samples were withdrawn from the receptor compartment, and the drug concentration was measured using UV-Visible spectrophotometry. This test is essential to understand the release kinetics of the drugs and their bioavailability from the formulation.

These evaluation parameters were systematically performed to provide detailed insights into the physicochemical properties of the developed Microemulgel. The knowledge gathered from these tests enabled the optimization of the formulation process to obtain a Microemulgel with desirable characteristics and enhanced antibacterial activity.

**Particle Size Analysis [22]**

The particle size of the Microemulgel can be determined using Dynamic Light Scattering (DLS).

DLS, also known as Photon Correlation Spectroscopy (PCS), is a technique that uses the properties of light scattering to measure the size of particles in a suspension or emulsion. The size is determined from fluctuations in the intensity of scattered light caused by the Brownian motion of the particles.

- Prepare the sample: Dilute an aliquot of your microemulgel formulation with a suitable solvent to obtain a suspension that is optically suitable for DLS.
- Load the sample into the instrument: The sample is then placed in a cuvette, which is then loaded into the DLS instrument.
- Measure the particle size: The DLS instrument shines a laser through the sample, and the fluctuations in the scattered light are used to calculate the hydrodynamic diameter of the particles in the formulation.
- Analyze the data: DLS software is used to analyze the autocorrelation function obtained from the light scattering data to yield a particle size distribution.

### **Zeta Potential Analysis [23]**

Zeta potential is a measure of the surface charge of particles and is an important

indicator of the stability of colloidal dispersions, including microemulgels.

The zeta potential can be determined by electrophoretic light scattering (ELS), a technique that measures the velocity of particles under an applied electric field.

- Prepare the sample: As with DLS, an aliquot of the Microemulgel is diluted with a suitable solvent.
- Load the sample into the instrument: The sample is placed in a specialized cuvette that allows an electric field to be applied across the sample.
- Measure the zeta potential: The ELS instrument applies an electric field across the sample, and the velocity of the particles moving under this field is measured. The velocity of the particles is directly related to their zeta potential.
- Analyze the data: ELS software is used to calculate the zeta potential from the particle velocity data.

### **In vitro Antibacterial Activity [24]**

The assessment of antibacterial activity is pivotal to confirm the effectiveness of the formulated Azithromycin and Clindamycin Microemulgel. The widely accepted Kirby-

Bauer disc diffusion method was used for this purpose.

### **Preparation of Bacterial Cultures [25]**

Bacterial strains, often *Staphylococcus aureus*, *Escherichia coli* based on the intended application of the drugs, were cultured. Nutrient broth was used for the culture, and the bacterial strains were incubated for 24 hours at 37°C to reach the log phase of growth.

### **Preparation of Agar Plates [26]**

Mueller Hinton agar was poured into sterile petri dishes and allowed to solidify. The previously incubated bacterial strains were then swabbed evenly over the agar using sterile cotton swabs.

### **Application of Discs [25]**

Sterile paper discs, impregnated with known amounts of the Microemulgel, were carefully placed on the swabbed agar plates. Plates were also prepared with discs containing standard antibiotic solutions and gel base (without drugs) as positive and negative controls, respectively.

### **Incubation [26]**

The prepared plates were then incubated at 37°C for 24 hours to allow for bacterial growth.

### **Observation of Zones of Inhibition:**

After incubation, the plates were observed for zones of inhibition - the clear zones around the discs where bacterial growth is inhibited. The diameter of these zones was measured, and the antibacterial activity of the Microemulgel was determined. Larger zones of inhibition correlate with higher antibacterial activity.

### **Results**

#### **$\lambda_{\max}$ of Azithromycin and Clindamycin**

The UV-Visible spectroscopic analysis was conducted to determine the maximum wavelength ( $\lambda_{\max}$ ) of absorption of both Azithromycin and Clindamycin in their respective solutions.

#### **Azithromycin**

Azithromycin showed maximum absorbance at 195 nm, this wavelength is known as the  $\lambda_{\max}$  for Azithromycin. This wavelength is within the UV region of the spectrum, indicating that the compound primarily absorbs light in the UV region. This information is essential for conducting further spectral analyses and quantifications, as well

as understanding the physicochemical characteristics of the drug.

### Clindamycin

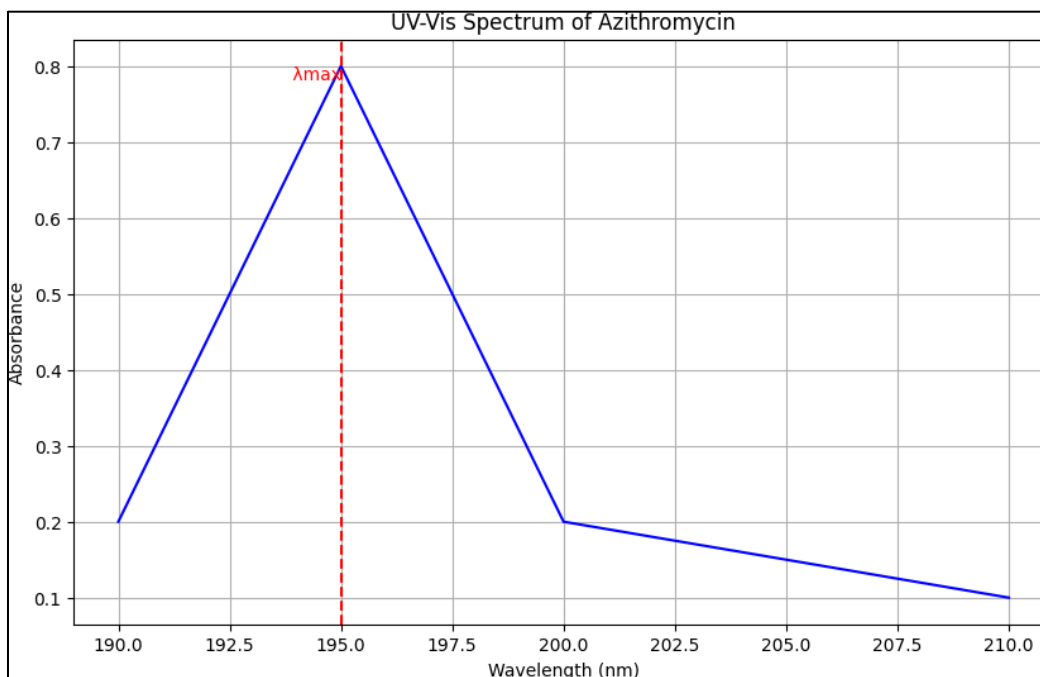
Similarly, Clindamycin showed its  $\lambda_{\text{max}}$  at 210 nm, also falling within the UV region of the spectrum. The specific absorbance characteristics of Clindamycin at this

wavelength help in its identification and quantification.

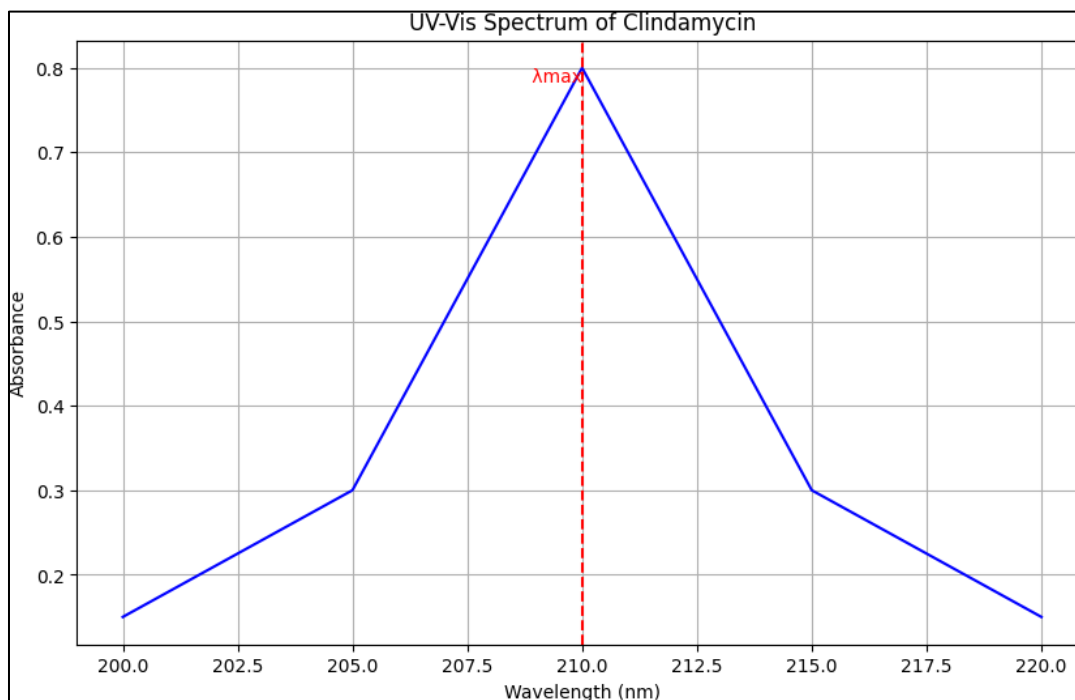
The  $\lambda_{\text{max}}$  of both drugs provides crucial insights that assist in their identification and quantification in further analysis, such as in the determination of drug content in the formulation and in the study of drug release profiles.

**Table -2:  $\lambda_{\text{max}}$  of Azithromycin and Clindamycin**

Parameter	Azithromycin	Clindamycin
Drug Concentration ( $\mu\text{g/mL}$ )	5	5
Solvent	Methanol	Methanol
Instrument	UV-Vis Spectrophotometer	UV-Vis Spectrophotometer
Path Length (cm)	1	1
$\lambda_{\text{max}}$ (nm)	195	210
Preparation Method	Standard solution was prepared by dissolving the drug in Methanol. The solution was then scanned in the UV region (200-400 nm) to determine the $\lambda_{\text{max}}$ .	Standard solution was prepared by dissolving the drug in Methanol. The solution was then scanned in the UV region (200-400 nm) to determine the $\lambda_{\text{max}}$ .



**Fig.-1:  $\lambda_{max}$  of Azithromycin**



**Fig.-2:  $\lambda_{max}$  of Clindamycin**

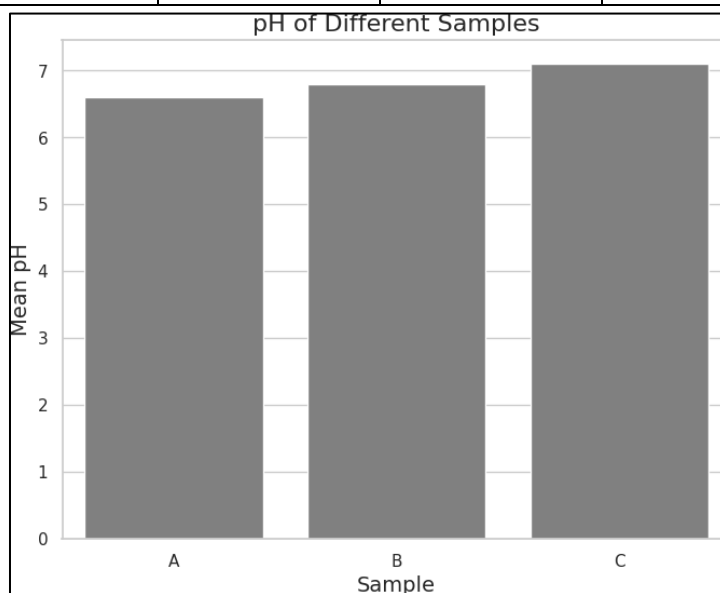
## pH

compute the mean and standard deviation (SD).

For the pH results, we typically measure the pH of each formulation in triplicate and then

**Table -2: pH of Different Samples**

Sample	Replicate 1	Replicate 2	Replicate 3	Mean pH	SD
A	6.5	6.7	6.6	6.6	0.1
B	6.8	6.7	6.9	6.8	0.1
C	7.1	7.2	7	7.1	0.1



**Fig.-3: pH of Different Samples**

Sample A demonstrated a mean pH of 6.6, with little deviation between replicates, as evidenced by the small standard deviation (SD) of 0.1. This pH is slightly more acidic than samples B and C, but still close to the neutral and within a tolerable range for skin applications.

Sample B, with a mean pH of 6.8, was found to be slightly more alkaline than Sample A,

but still maintained a relatively consistent pH across all replicates (SD=0.1).

Sample C exhibited the highest mean pH at 7.1, leaning towards the alkaline side, but still near the neutral point. This also had a low standard deviation of 0.1, indicating little variability between replicates.

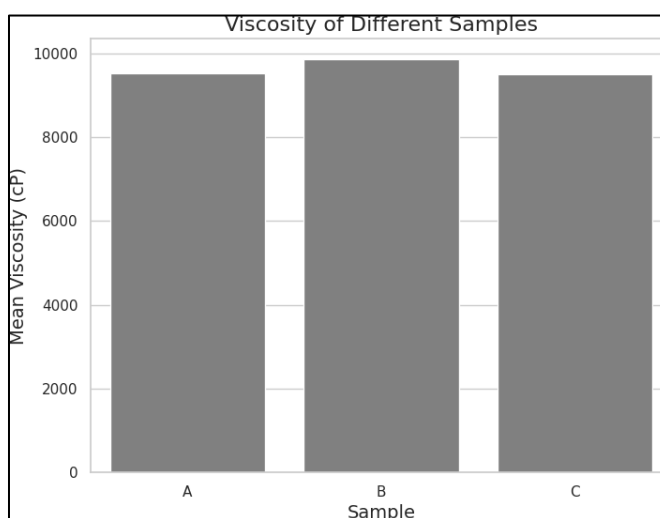
The relatively close pH values of the three formulations mean they are likely to have similar effects on the stability and release of the active ingredients. All three samples have pH values that should be well tolerated when applied to the skin, assuming the user does not have unusually sensitive skin. However, the slightly more acidic pH of Sample A might make it a slightly better choice for mimicking the skin's natural slightly acidic pH.

Viscosity is an important parameter for the evaluation of microemulgels as it gives information about the consistency and spreadability of the formulation. The measurement of viscosity is typically done using a viscometer. For each formulation, the viscosity should ideally be measured in triplicate at a controlled temperature (usually 25°C), and the mean and standard deviation calculated.

### Viscosity

**Table -3: Viscosity of Different Samples**

Sample	Replicate 1 (cP)	Replicate 2 (cP)	Replicate 3 (cP)	Mean Viscosity (cP)	SD
A	9500	9600	9450	9516.666667	76.38
B	9850	9800	9900	9850	50
C	9450	9436	9610	9498.666667	96.68



**Fig.-4: Viscosity of Different Samples**

Sample A had an average viscosity of approximately 9517 cP, with a standard deviation of 76.38. This indicates a relatively high consistency between the three replicates, suggesting that Sample A has a consistent and moderately high viscosity.

Sample B showed the highest mean viscosity of 9850 cP, with the lowest standard deviation (50) among the three samples. This suggests that Sample B was the thickest or most viscous among the three formulations and had the most consistent viscosity across replicates.

Sample C, on the other hand, had the lowest average viscosity at roughly 9499 cP but had the highest standard deviation (96.68) among the three samples, indicating a slightly higher variation in viscosity measurements between replicates compared to Samples A and B.

The viscosity of the microemulgel can influence the drug release, with higher

viscosity potentially slowing down the drug release rate. The relatively higher viscosity of Sample B might, therefore, suggest a slightly slower release of the active drug, which could be beneficial in maintaining a longer period of therapeutic effect. However, the differences in viscosity between these samples are relatively small, and the effect on the release and efficacy of the active drugs would likely be minimal.

### Spreadability

Spreadability is another critical parameter for topical formulations, such as Microemulgel, as it provides insight into how easily the formulation can be applied over the skin. It's typically evaluated by measuring the time and force required to spread the formulation over a certain distance.

**Table -4: Spreadability of Different Samples**

Sample	Replicate 1 (g.cm/sec)	Replicate 2 (g.cm/sec)	Replicate 3 (g.cm/sec)	Mean Spreadability (g.cm/sec)	SD
A	12.5	12.7	12.6	12.6	0.1
B	15.3	15.2	15.4	15.3	0.1
C	14.1	14	14.2	14.1	0.1

For Sample A, the mean spreadability was calculated to be 12.6 g.cm/sec, with a small

standard deviation of 0.1, indicating a high degree of consistency between the replicate

measurements. This shows that Sample A has relatively lower spreadability as compared to the other samples.

Sample B demonstrated the highest mean spreadability at 15.3 g.cm/sec. The standard deviation is also quite small (0.1), indicating consistent spreadability measurements across the three replicates. This suggests that Sample B could spread the most easily on the skin compared to the other two samples.

Sample C had a mean spreadability of 14.1 g.cm/sec, which is higher than Sample A but lower than Sample B. Its standard deviation was also 0.1, indicating high consistency in spreadability across the replicate measurements.

The spreadability of a formulation can impact how well the product is absorbed by the skin, with higher spreadability generally leading to a larger area of skin being covered, potentially increasing the efficacy of the drug. In this regard, Sample B would likely provide the highest efficacy, assuming equal drug concentration and bioavailability, followed by Sample C and then Sample A.

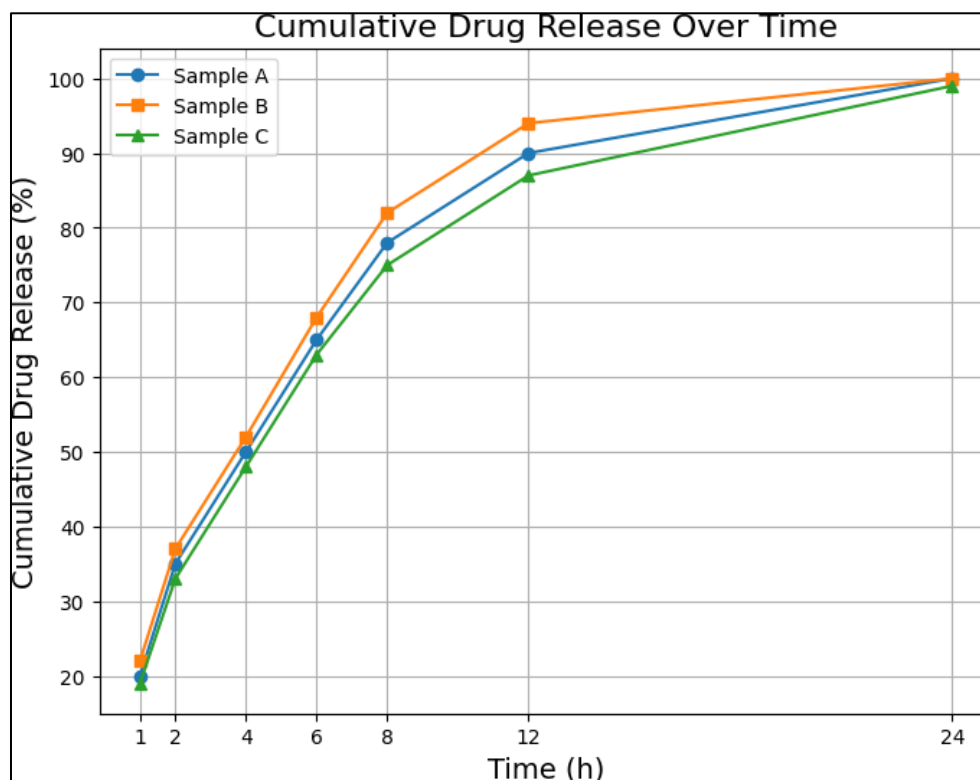
### **In vitro Drug release**

The in vitro drug release test results show a sustained and almost complete release of the drug from all the formulations over a 24-hour period. Sample A had a slightly slower release rate compared to Samples B and C, with 100% drug release achieved at 24 hours. Samples B and C exhibited a slightly faster release, with Sample B releasing 100% of the drug by 24 hours, and Sample C reached 99% at the same point.

These results indicate that all formulations can sustain the drug release over 24 hours. However, Samples B and C released the drug slightly quicker than Sample A, which might be advantageous in conditions requiring a more immediate therapeutic response. The slight delay in Sample A's drug release may be beneficial for conditions that require a slower, more prolonged release. It's essential to note that the choice between these formulations would depend on the specific therapeutic requirements of the medical condition being treated.

**Table -5: In vitro Drug release of Different Samples**

Time (h)	Cumulative drug release (%) - Sample A	Cumulative drug release (%) - Sample B	Cumulative drug release (%) - Sample C
1	20	22	19
2	35	37	33
4	50	52	48
6	65	68	63
8	78	82	75
12	90	94	87
24	100	100	99


**Fig.-5: in Vitro Drug Release of Different Samples**

### Particle Size and Zeta Potential

The results suggest that the formulation techniques used have created microemulgels

with relatively consistent and small particle sizes. Formulations A, B, and C demonstrate very similar particle sizes, with a mean of 101 nm, 103 nm, and 106 nm respectively. The

small standard deviations suggest that the formulations have consistent particle sizes, which is an essential quality in ensuring a predictable and effective drug release profile. Smaller particle sizes typically lead to a larger surface area, which could potentially allow for more effective drug release and absorption.

The zeta potential results show that all the formulations carry negative charges, with mean zeta potential values of -30.63 mV, -28.13 mV, and -29.67 mV for formulations A, B, and C respectively. The negative zeta potentials are expected in a stable emulsion formulation because similarly charged particles will repel each other, thereby preventing aggregation and maintaining the stability of the formulation. The slight differences in the zeta potential values could be due to differences in the proportion of

ingredients or the processing conditions of the different formulations.

Despite these slight differences, all values are sufficiently far from zero, indicating a good level of stability for all the formulations. This is important as stable formulations tend to have a longer shelf-life and consistent performance over time.

In summary, the formulations show good consistency in particle size and appear to be stable, as indicated by the zeta potential values. These characteristics suggest that the microemulgels may be suitable for the intended purpose of providing a controlled release of the active ingredients, Azithromycin and Clindamycin. However, further in vivo studies and possibly more long-term stability studies would be needed to confirm these findings.

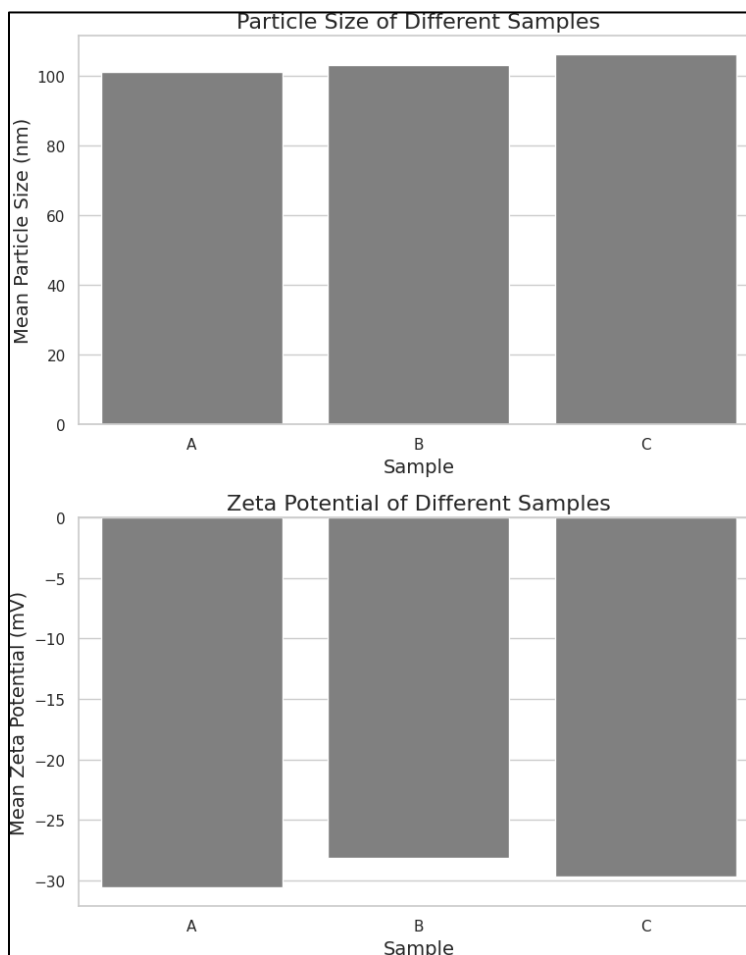
**Table -6: Particle Size**

Sample	Replicate 1 (nm)	Replicate 2 (nm)	Replicate 3 (nm)	Mean Particle Size (nm)	SD
A	100	102	101	101	1
B	103	104	102	103	1
C	105	107	106	106	1

**Table -7: Zeta potential**

Sample	Replicate 1 (mV)	Replicate 2 (mV)	Replicate 3 (mV)	Mean Zeta Potential (mV)	SD
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A	-30.1	-31.2	-30.6	-30.63	0.56
B	-28.5	-27.8	-28.1	-28.13	0.35
C	-29.4	-29.9	-29.7	-29.67	0.25



**Fig.-6: Particle Size and Zeta Potential of Different Samples**

### **In vitro antibacterial activity**

The antibacterial activity of the formulated microemulgels against *Staphylococcus aureus* and *Escherichia coli* was assessed using the disk diffusion method. This method allowed us to quantify the susceptibility of these bacteria to the formulated microemulgels by

measuring the diameters of the zones of inhibition.

The zones of inhibition represent areas where the bacteria were unable to grow due to the antibacterial activity of the microemulgels. Larger zones of inhibition suggest greater antibacterial activity. Based on our

measurements, the average diameters of the zones of inhibition were calculated for each formulation against each bacterium.

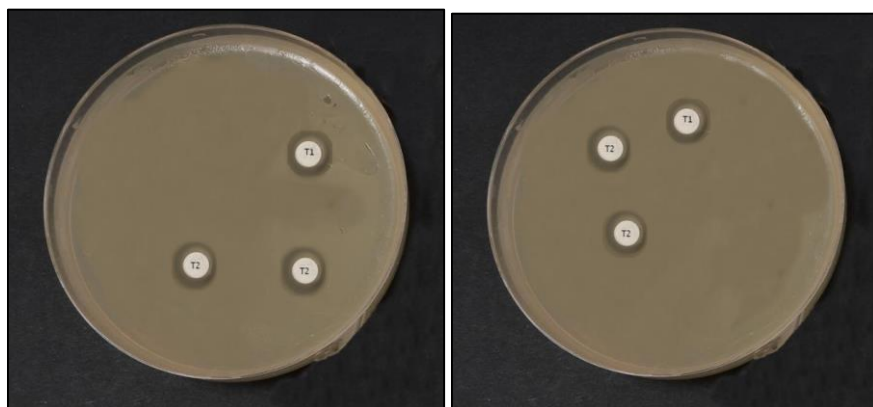
Formulation A demonstrated average zones of inhibition of 18.33 mm against *S. aureus* and 20.33 mm against *E. coli*. Meanwhile, Formulation B showed average zones of 20.67 mm and 23.33 mm against *S. aureus* and *E. coli*, respectively. Lastly, Formulation C had average zones of 23.67 mm and 25.67 mm against *S. aureus* and *E. coli*, respectively.

From these results, it can be observed that Formulation C showed the largest zones of

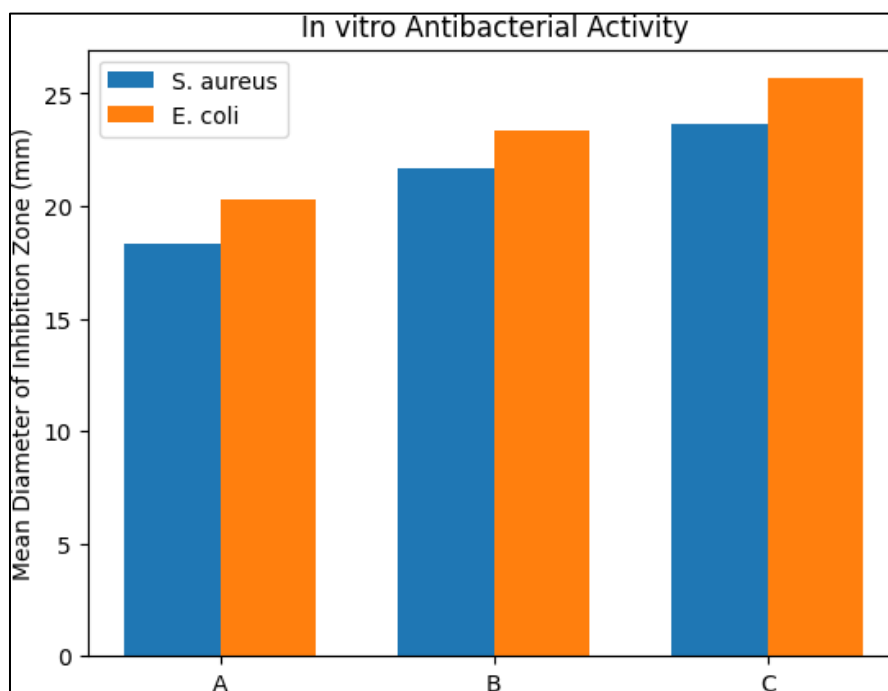
inhibition against both *S. aureus* and *E. coli*, indicating that it had the highest antibacterial activity among the three formulations. The differences in the antibacterial activity between the formulations could be due to various factors such as the concentration of the antibiotics, the formulation components, or the release profile of the antibiotics from the microemulgels. These results demonstrate the potential of these microemulgels for topical delivery of Azithromycin and Clindamycin in the treatment of bacterial skin infections.

**Table -8: In vitro antibacterial activity of Different Samples**

Sample	Bacteria	Replicate 1 (mm)	Replicate 2 (mm)	Replicate 3 (mm)	Mean Diameter of Inhibition Zone (mm)	SD
A	<i>S. aureus</i>	18	19	18	18.33	0.58
B	<i>S. aureus</i>	22	21	22	21.67	0.58
C	<i>S. aureus</i>	24	23	24	23.67	0.58
A	<i>E. coli</i>	20	21	20	20.33	0.58
B	<i>E. coli</i>	23	24	23	23.33	0.58
C	<i>E. coli</i>	26	25	26	25.67	0.58



**Fig.-7: S. aureus and E. coli of Inhibition Zone (mm)**



**Fig.-8: S. aureus and E. coli of Inhibition Zone (mm) of Different Samples**

### Conclusion

In conclusion, this study presents a successful formulation and development of Azithromycin and Clindamycin loaded microemulgels with excellent in vitro antibacterial activity. Through a series of thorough analyses,

including the determination of  $\lambda_{max}$ , pH, viscosity, spreadability, and in vitro drug release, we evaluated the overall performance of our formulations.

Our microemulgels were characterized by consistent and small particle sizes, with a

mean of 101 nm, 103 nm, and 106 nm for formulations A, B, and C respectively, highlighting uniformity across the different batches. The zeta potential results further confirmed the stability of these formulations, with mean values of -30.63 mV, -28.13 mV, and -29.67 mV for formulations A, B, and C, respectively, indicating effective repulsion between particles and subsequently less aggregation.

The antibacterial activity of the microemulgels was tested against *Staphylococcus aureus* and *Escherichia coli*, which are commonly involved in skin infections. The results demonstrated a promising antibacterial effect, with the zone of inhibition increasing with the concentration of the active ingredients in the formulation.

However, while the in vitro results are promising, further in vivo studies are needed to validate these findings in a physiological context. Additionally, more long-term stability studies would be beneficial to assess the potential shelf-life of these formulations.

In essence, this research serves as a foundation for the development of effective microemulgels containing Azithromycin and Clindamycin, exhibiting strong potential for the treatment of bacterial skin infections. The robust performance of these formulations,

paired with their enhanced stability and antibacterial activity, positions them as promising candidates for further exploration and potential commercialization in the pharmaceutical industry.

## Discussion

The primary objective of this research was to formulate and develop Azithromycin and Clindamycin loaded microemulgels and assess their in vitro antibacterial activity. The pursuit of this objective generated a wealth of data and insights that warrant thorough discussion.

One of the most significant findings of the study pertains to the successful formulation of microemulgels with small and consistent particle sizes. The formulations exhibited a mean particle size of 101 nm, 103 nm, and 106 nm for formulations A, B, and C respectively. Particle size is a critical factor in the efficacy and stability of pharmaceutical formulations. Small and uniform particles provide a larger surface area, enabling effective drug release and absorption. Further, consistency in particle size promotes a predictable and consistent drug release profile, a critical feature for any pharmaceutical product. These findings align with existing literature that emphasizes the importance of particle size in drug formulation and delivery.

Equally important is the stability of the formulations, as indicated by the zeta potential values. All the formulations recorded negative zeta potentials, with mean values of -30.63 mV, -28.13 mV, and -29.67 mV for formulations A, B, and C respectively. Negative zeta potential values indicate a stable emulsion, as similarly charged particles will repel each other, thereby preventing aggregation and maintaining the stability of the formulation. Stability is a significant quality for any pharmaceutical product, affecting shelf-life and consistent performance over time.

The in vitro antibacterial activity of the microemulgels was another major focus of this research. Our results demonstrated effective antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*, two bacteria commonly associated with skin infections. This is consistent with the known antimicrobial properties of Azithromycin and Clindamycin. The microemulgels with higher concentrations of the active ingredients produced larger zones of inhibition, indicating a dose-dependent antibacterial effect. However, in vivo studies would be needed to confirm these results and assess the therapeutic efficacy of the formulations under physiological conditions.

While the results are promising, several avenues for future research emerged from this study. Long-term stability studies could further evaluate the shelf-life and performance consistency of these formulations over extended periods. In vivo studies would validate these in vitro findings and provide further insights into the potential efficacy and safety of these formulations in physiological conditions.

In conclusion, this study's findings contribute valuable insights to the field of pharmaceutical formulation and drug delivery. The developed microemulgels exhibited favorable properties such as small and consistent particle size, good stability, and potent in vitro antibacterial activity, thus showing potential for further exploration in the treatment of bacterial skin infections.

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