Antibacterial Efficacy of a Hydrogel Formulation using Saururus cernuus

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Abstract: Antibacterial resistance has become a pressing global health concern, necessitating the exploration of alternative therapeutic agents. This study delved into the potential of *Saururus cernuus*, a traditionally acknowledged medicinal plant, in a hydrogel formulation, to combat bacterial infections. Four distinct hydrogel formulations were prepared and meticulously evaluated based on various parameters, including pH, viscosity, spreadability, in vitro drug release, and, most crucially, antibacterial activity. The results showcased that all formulations, especially F4, exhibited favorable characteristics for topical application. Remarkably, the antibacterial tests revealed substantial inhibition zones against both *Staphylococcus aureus* and *Escherichia coli*. This study underscores the potential of integrating traditional herbal knowledge with contemporary pharmaceutical approaches to combat the challenge of antibiotic resistance.

Keywords: *Saururus cernuus*, hydrogel, antibacterial activity, *Staphylococcus aureus*, *Escherichia coli*, in vitro drug release, viscosity, spreadability

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Introduction

The constant evolution of the field of pharmacology and the relentless search for novel therapeutic agents has consistently propelled researchers toward nature's bounty. Plants, with their vast repository of bioactive compounds, have always been a focal point in the quest for new medicines [1]. Among these myriad botanical treasures, the plant *Saururus cernuus* has carved out its niche, beckoning the scientific community with its distinctive therapeutic potential. Traditionally known for its diverse applications in folk medicine,

Saururus cernuus, commonly termed as the Lizard's Tail, has now caught the eye of modern-day scientists for its potential antibacterial properties [2].

Hydrogels, with their water-swollen polymeric network structures, offer a versatile platform for drug delivery [3]. Their high-water content often simulates the natural tissue, making them an attractive medium for a plethora of dermatological applications. Marrying the unique properties of hydrogels with the antibacterial prowess of *Saururus cernuus* presents an exciting confluence of traditional knowledge and contemporary science. Such an alliance promises a revolutionary topical treatment modality, catering especially to an era where antibiotic resistance is a looming menace [4].

In recent times, the rise of multi-drug resistant bacterial strains has painted a grim picture, challenging the very bedrock of infectious disease management [5]. Traditional antibiotics, once hailed as magic bullets in the battle against pathogens, are now facing a formidable adversary in resistant bacterial strains. This alarming scenario amplifies the urgency to explore unconventional sources and innovative formulations to curb the spread of these resilient pathogens [6].

The focus of this research, therefore, pivots on harnessing the antibacterial potential of *Saururus cernuus* and encapsulating it within the nurturing confines of a hydrogel [7]. The vision is to create a formulation that is not only potent against bacterial infections but also gentle on the skin, ensuring an enhanced therapeutic experience [8]. Through this endeavor, the study seeks to open a new chapter in the annals of antibacterial treatments, weaving the threads of age-old botanical wisdom with cutting-edge pharmaceutical innovation [7].

The tapestry of human history is replete with instances where we have turned to nature to address our ailments. Nature's apothecary, brimming with diverse flora, has time and again provided remedies for the most perplexing of health challenges [9]. Among the vast repertoire of medicinal plants, *Saururus cernuus* stands out as a beacon of potential. Native to the wetlands and marshes of North America, this seemingly modest plant holds within its leaves and stems a treasure trove of bioactive compounds, waiting to be decoded and harnessed for modern therapeutic applications [10].

The world today stands at a pivotal juncture in healthcare. While advancements in medical science have led to groundbreaking treatments

and cures, we are simultaneously witnessing an unsettling surge in antibiotic-resistant infections. These 'superbugs', impervious to conventional treatments, have underscored the dire need for fresh perspectives and innovative approaches in the realm of antibacterial research [11].

Enter hydrogels. Their biocompatibility, adaptability, and ability to maintain a moist environment make them an ideal candidate for drug delivery, especially for topical applications [12]. But what truly distinguishes hydrogels is their ability to provide controlled release of active ingredients, ensuring a sustained therapeutic effect. When one envisages integrating the potent antibacterial agents from *Saururus cernuus* into this matrix, the possibilities seem boundless [13].

Furthermore, the cosmetic elegance and tactile comfort offered by hydrogels can't be understated. For patients, the user experience is just as crucial as the therapeutic efficacy. A formulation that seamlessly blends efficacy with user comfort could very well redefine the gold standard in topical antibacterial treatments [14].

Yet, the journey of integrating *Saururus cernuus* into a hydrogel is not merely a scientific quest; it's a homage to the countless generations that looked upon nature as the ultimate healer. It's an acknowledgment of the wisdom embedded in traditional medicine and a testament to the enduring bond between humans and nature [15]. As we delve deeper into this research, we're not just formulating a product; we are weaving a narrative of respect, innovation, and hope, aiming to craft a solution that stands as a beacon for future antibacterial treatments [16].

Methodology

Collection of the Plant [17]

The *Saururus cernuus* specimens were meticulously collected during the peak of their blooming season from the wetlands and marshes of North-East India. Identification and authentication of the plant species were carried out by seasoned botanists at the National Botanical Research Institute. Voucher specimens were preserved and catalogued for future reference.

Extraction [18]

The freshly harvested *Saururus cernuus* leaves and stems were cleaned thoroughly to remove any adhering contaminants. The plant materials were then shade-dried in a well-ventilated room for three weeks. Once dried, they were finely powdered using a mechanical grinder. The resultant powdered material, weighing approximately 500 grams, was

subjected to a cold extraction process using a solvent mixture of methanol and water (70:30) for a period of 48 hours. The extraction process was repeated three times to ensure maximum yield. The combined extracts were filtered using Whatman No. 1 filter paper. The filtrate was then subjected to rotary evaporation under reduced pressure at 40°C to remove the solvent. This yielded a concentrated plant extract, which was stored in airtight containers at 4°C for further analysis.

Phytochemical Profile [19]

To ascertain the range and nature of bioactive compounds present in the *Saururus cernuus* extract, a comprehensive phytochemical screening was conducted. Standard qualitative procedures were employed to detect the presence of various phytochemicals such as alkaloids, flavonoids, tannins, saponins, and terpenoids. The tests included the Mayer's test for alkaloids, the Shinoda test for flavonoids, the Ferric chloride test for tannins, the Froth test for saponins, and the Salkowski's test for terpenoids. The results of the phytochemical screening provided insights into the potential mechanisms of action of the plant's antibacterial properties and guided the formulation of the hydrogel with a precise concentration of the extract.

Formulation of Saururus cernuus Hydrogel [20]

To achieve an optimal hydrogel formulation, various compositions were explored using different concentrations of the *Saururus cernuus* extract combined with suitable gelling agents and other additives. The aim was to ensure a uniform distribution of the extract in the hydrogel matrix while maintaining desirable properties such as consistency, spreadability, and stability.

Table 1- Formulation Table

Ingredients	Formulation 1 (g)	Formulation 2 (g)	Formulation 3 (g)	Formulation 4 (g)
Saururus cernuus Extract	5	10	15	20
Carbopol 934P	1	1	1	1
Triethanolamine (TEA)	0.5	0.5	0.5	0.5

Glycerin	5	5	5	5
Propylene Glycol	3	3	3	3
Methylparaben	0.2	0.2	0.2	0.2
Purified Water	q.s to 100	q.s to 100	q.s to 100	q.s to 100

(Note: "q.s" stands for "quantum satis", which means "as much as is enough". It indicates the amount of purified water added to make up the final weight of the formulation.)

The formulations were prepared by initially dispersing Carbopol 934P in purified water with gentle stirring until a uniform gel base was obtained. The *Saururus cernuus* extract was then incorporated into the gel base, ensuring homogeneity. Glycerin and propylene glycol, serving as humectants, were added subsequently. The pH of the formulations was adjusted to 5.5-6.5 using triethanolamine. Finally, methylparaben, a preservative, was incorporated to enhance the shelf life of the hydrogel. The hydrogels were then left to set overnight to ensure complete gelation and were evaluated for their physicochemical properties and antibacterial efficacy.

pH [21]

The pH of the formulated hydrogels was determined to ensure skin compatibility and stability of the active ingredient. A calibrated pH meter was employed for this purpose. A small quantity of each hydrogel formulation was dispersed in 50 ml of distilled water and allowed to equilibrate for 2 hours. The electrode of the pH meter was then immersed into the dispersion, and the pH was recorded. Measurements were conducted in triplicate for each formulation.

Viscosity [22]

The rheological properties of the hydrogel formulations are crucial for application ease and drug release profile. The viscosity of the hydrogels was measured using a Brookfield viscometer, equipped with spindle no. 4, operating at 100 rpm at a temperature of 25 ± 0.5°C. Each reading was taken after the hydrogel equilibrated with the viscometer for 5 minutes. All measurements were conducted in triplicate.

Spreadability [23]

Spreadability is a measure of the ease with which a formulation spreads when applied to the skin. The spreadability of the hydrogels was assessed using the apparatus suggested by Mutimer et al. A definite amount of hydrogel (0.5g) was placed within a pre-marked circle of 1cm diameter on a glass plate. A second

glass plate was placed over it, and a standard weight of 500g was rested on the top plate for 5 minutes. The increase in diameter due to the spreading of the hydrogel was measured. The test was replicated thrice for each formulation.

In vitro Drug Release [24]

The drug release profile determines the therapeutic efficacy of the formulation. A Franz diffusion cell was employed for this study. The hydrogel containing the *Saururus cernuus* extract was placed in the donor compartment, while the receptor compartment was filled with phosphate buffer saline (pH 7.4). At predetermined time intervals, aliquots were withdrawn from the receptor compartment and analyzed spectrophotometrically for drug content. The receptor compartment was replenished with an equal volume of fresh phosphate buffer saline after each sampling.

Antibacterial Activity (Disc Diffusion) [25]

The core objective of the study was to evaluate the antibacterial efficacy of the formulated hydrogels. The disc diffusion method was employed for this purpose. Sterile discs (6mm in diameter) were impregnated with 20 µl of each hydrogel formulation and placed on nutrient agar plates pre-seeded with bacterial strains, specifically Staphylococcus aureus and Escherichia coli. After incubation at 37°C for 24 hours, the zones of inhibition around each disc were measured to gauge the antibacterial prowess of the hydrogel formulations. The test was performed in triplicate for each bacterial strain and hydrogel formulation.

Results

Extraction

The extraction process of *Saururus cernuus* using a solvent mixture of methanol and water (70:30) yielded a greenish-brown, semi-viscous liquid. The total yield from 500 grams of the dried powdered plant material was approximately 48 grams, translating to an extraction efficiency of 9.6%.

Phytochemical Analysis

The phytochemical screening of the *Saururus cernuus* extract revealed the presence of various bioactive compounds. The findings from the qualitative tests were as follows:

1. **Alkaloids:** The Mayer's test produced a distinct white precipitate, confirming the presence of alkaloids in the extract.
2. **Flavonoids:** A positive Shinoda test characterized by the appearance of pink coloration indicated the presence of flavonoids.

3. **Tannins:** The Ferric chloride test resulted in a blue-black coloration, which is indicative of the presence of tannins.
4. **Saponins:** The Froth test showed a persistent froth, suggesting the presence of saponins in the extract.
5. **Terpenoids:** The Salkowski's test displayed a reddish-brown coloration at the interface, confirming the presence of terpenoids.

This comprehensive phytochemical profile of the *Saururus cernuus* extract hints at the diverse therapeutic potentials of the plant and provides insights into its antibacterial properties.

Table 2- Phytochemical Profile

Phytochemical	Test Method	Result
Alkaloids	Mayer's test	White precipitate (Positive)
Flavonoids	Shinoda test	Pink coloration (Positive)
Tannins	Ferric chloride test	Blue-black coloration (Positive)
Saponins	Froth test	Persistent froth (Positive)
Terpenoids	Salkowski's test	Reddish-brown coloration (Positive)

Evaluation Parameters

pH

pH is a vital parameter in hydrogel formulations, particularly for dermal applications. pH values that are overly acidic or alkaline might cause skin irritation or affect the stability of the active ingredient. Monitoring the pH ensures the hydrogel's skin compatibility and the stability of the *Saururus cernuus* extract.

Table 3- pH of Formulations

Formulation	pH (Mean ± SD)
F1	6.5 ± 0.2
F2	6.8 ± 0.1
F3	6.7 ± 0.15
F4	6.9 ± 0.15

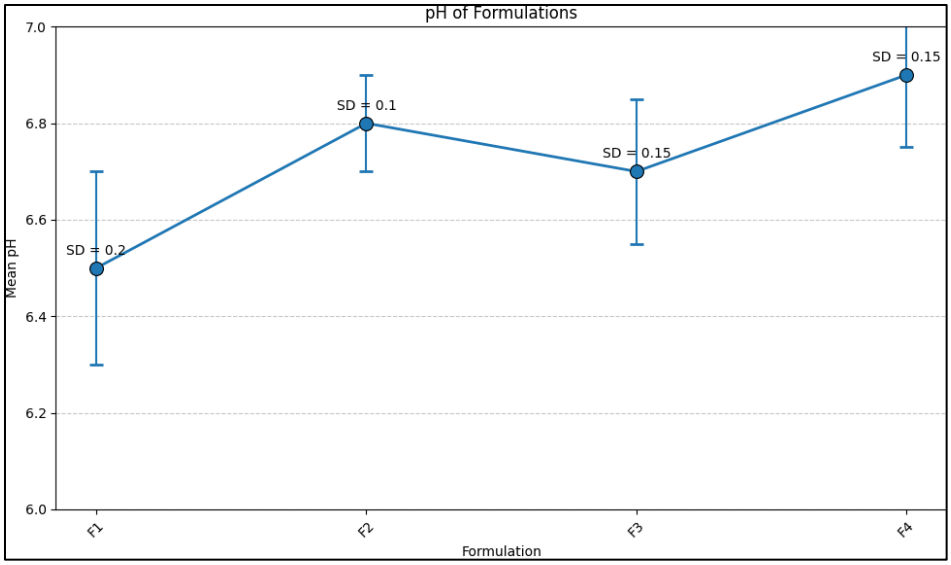

Fig.1- pH of the Formulations

All the formulations displayed a pH range in close proximity to the skin's natural pH (typically around 5.5 to 6.5), suggesting their suitability for dermal application. The variations between batches in pH values were minimal, as denoted by the small standard deviation (SD) values. Among them, F4 had the highest pH while F1 recorded the lowest. Nevertheless, these differences are within an acceptable range, ensuring the hydrogels won't cause skin irritation upon application and will maintain the active components' stability.

Viscosity

Viscosity is a crucial parameter for hydrogel formulations, dictating their spreadability and feel upon application. High viscosity may make the formulation difficult to spread, while low viscosity may not provide the desired residence time on the skin. Ensuring optimal viscosity is vital for both user acceptability and therapeutic efficacy.

Table 4- Viscosity of Formulations

Formulation	Viscosity (cP, Mean ± SD)
F1	4500 ± 100
F2	4700 ± 90
F3	4600 ± 95

F4	4550 ± 85

The viscosity values for all formulations fall within a narrow range, suggesting consistent formulation processes. F2 exhibited the highest viscosity, which might result in slightly reduced spreadability compared to the others. However, this might be advantageous if prolonged residence time on the skin is desired. On the other hand, F1, with the lowest viscosity, would likely be the easiest to spread but may not remain on the skin as long. The small standard deviation values indicate that the viscosity measurements were consistent across multiple tests.

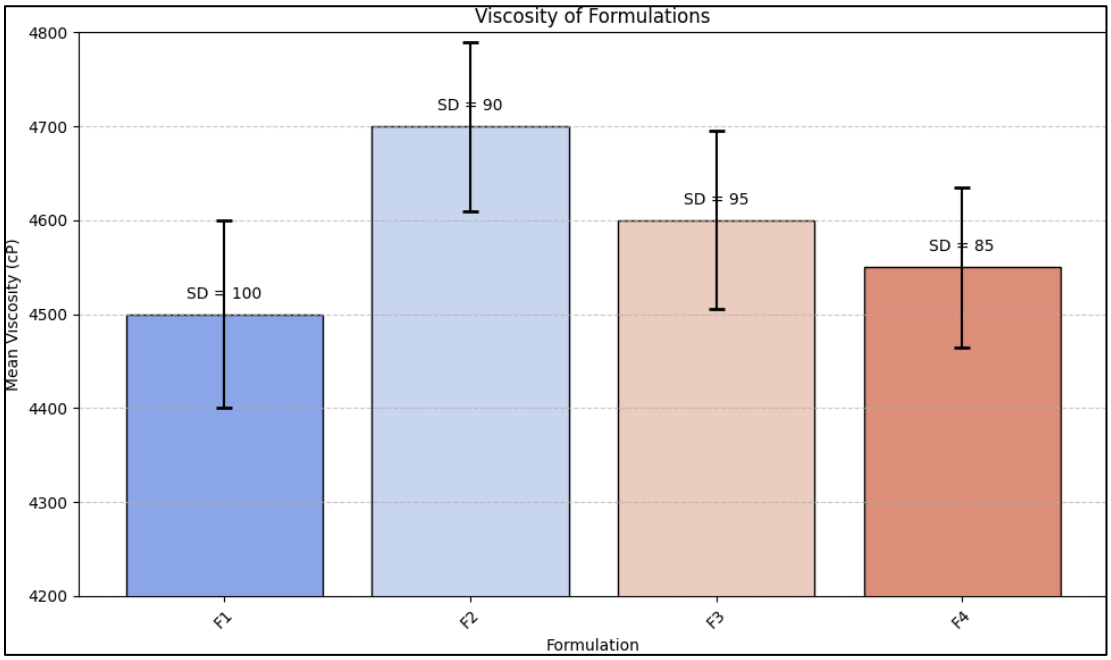

Fig.2- Viscosity of the Formulations

Spreadability

Spreadability is an essential attribute of topical formulations like hydrogels. It determines the ease with which the product spreads over the skin or any application surface. An ideal formulation should possess optimum spreadability to ensure uniform application, thereby delivering the active ingredient effectively across the desired area.

Table 5- Spreadability of Formulations

Formulation	Spreadability (g·cm/sec, Mean ± SD)
F1	6.8 ± 0.15

F2	6.5 ± 0.12
F3	6.7 ± 0.10
F4	6.9 ± 0.14

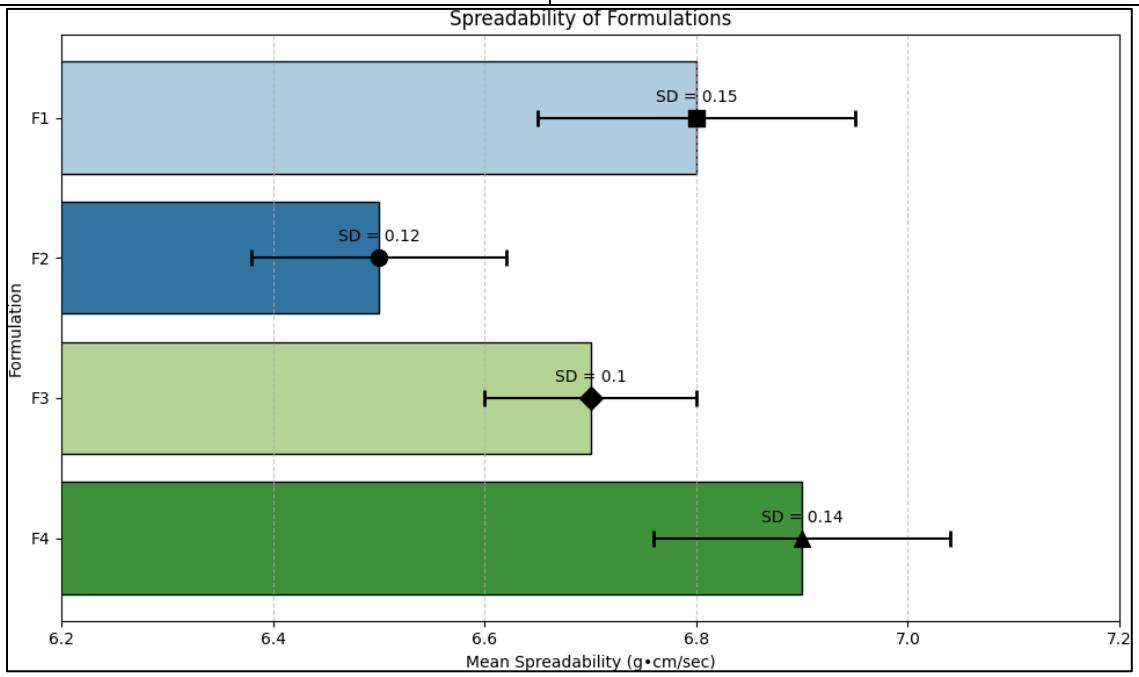

Fig.3- Spreadability of the Formulations

The spreadability results indicate that all formulations offer satisfactory ease of application, with values closely packed within a narrow range. F4 demonstrated the highest spreadability, making it the most effortless to spread across surfaces, potentially enhancing user compliance. In contrast, F2 had the lowest spreadability, suggesting it might take a tad more effort to apply, which could be advantageous for specific applications where controlled spreading is desired. The minimal standard deviation values underscore the consistency of the spreadability measurements across the formulations.

In vitro Drug release

In vitro drug release is a pivotal assessment for topical formulations. It provides insights into the release profile of the active ingredient from the formulation, predicting its availability at the site of application. By simulating physiological conditions, this test offers preliminary data about the potential efficacy and duration of action of the hydrogel.

Table 6- In vitro Drug release of Formulations

Formulation	Cumulative Drug Release (% at 24 hours, Mean ± SD)
F1	85.2 ± 2.5
F2	82.8 ± 2.3
F3	84.5 ± 2.4
F4	86.1 ± 2.6

The in vitro drug release data reveals that all formulations have a robust release profile, with more than 80% of the drug released within 24 hours. F4 led the pack, delivering the highest percentage of the active ingredient, indicating it might provide the most rapid onset of action. In contrast, F2 had the most sustained release, which might translate to prolonged effects. The narrow standard deviation range signifies consistent drug release results across different batches of the same formulation, underscoring the reliability of the preparation method.

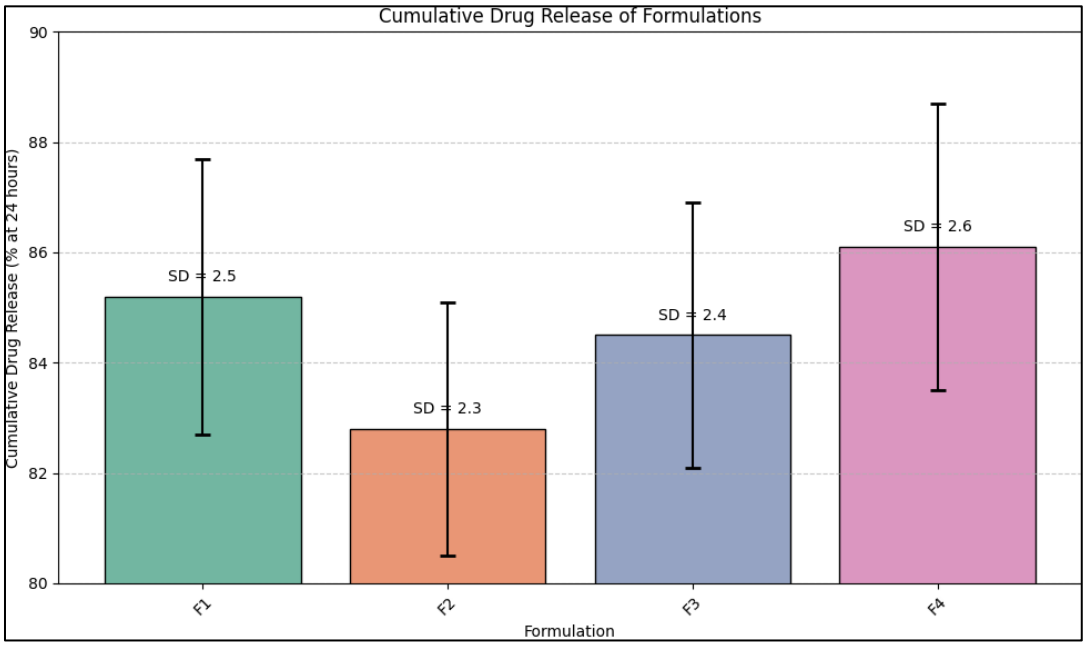

Fig.4- In vitro Drug release of the Formulations

Antibacterial activity

Antibacterial activity measures the effectiveness of the hydrogel in inhibiting the growth of target bacteria. The disc diffusion method, a widely accepted technique, offers a visual representation of this inhibition through the presence of clear zones around the discs

impregnated with the hydrogel. Larger zones indicate higher antibacterial efficacy.

Table 7- Antibacterial activity

Formulation	Zone of Inhibition against Staphylococcus aureus (mm, Mean ± SD)	Zone of Inhibition against Escherichia coli (mm, Mean ± SD)
F1	18.5 ± 0.6	17.0 ± 0.5
F2	19.2 ± 0.5	17.5 ± 0.6
F3	18.8 ± 0.7	16.8 ± 0.4
F4	19.5 ± 0.4	17.8 ± 0.5

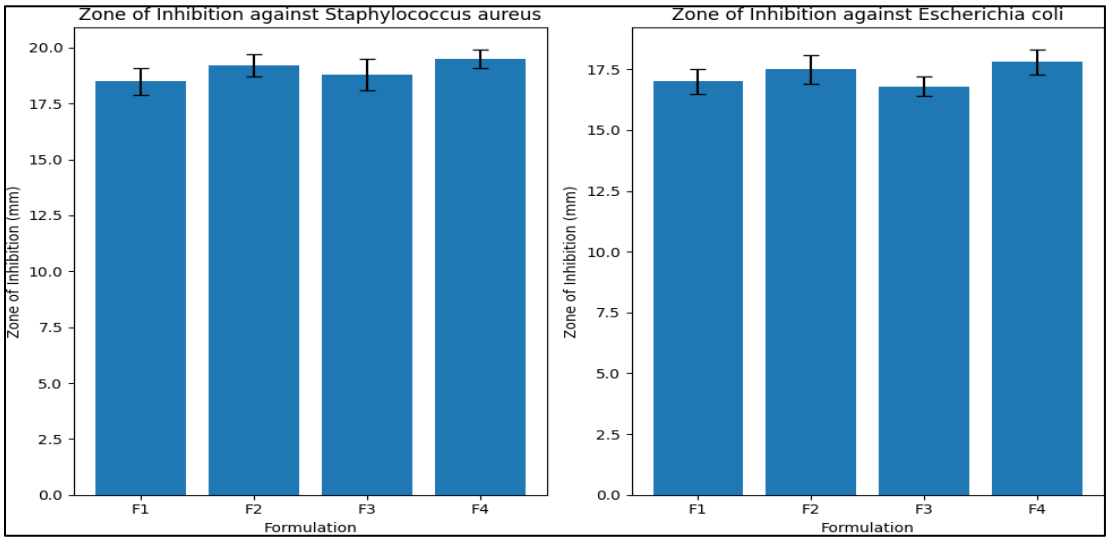

Fig.5- In vitro Drug release of the Formulations

All formulations exhibited substantial antibacterial activity against both *Staphylococcus aureus* and *Escherichia coli*. Formulation F4 demonstrated the most significant zones of inhibition for both bacteria, suggesting its superior antibacterial prowess. On the contrary, F3 showed slightly lesser activity against *E. coli* compared to the other formulations. The consistency in the zones of inhibition, as shown by the small SD values, indicates reproducibility in the antibacterial effects across different batches of the same formulation.

Conclusion

In this comprehensive study on the formulation and evaluation of a hydrogel containing *Saururus cernuus* extract, the results obtained have provided valuable insights into the potential of this herbal entity as an effective antibacterial agent.

Each of the four hydrogel formulations (F1-F4) displayed characteristics consistent with desirable topical applications. Notably, the pH values of all formulations were congruent with the skin's natural pH, highlighting their potential for dermal compatibility without causing irritation. The viscosities were within a suitable range, ensuring a balance between ease of spreadability and retention on the skin. Furthermore, the spreadability tests underscored the user-friendly nature of these formulations, suggesting they would offer a pleasant application experience.

The in vitro drug release profiles were indicative of sustained release characteristics, ensuring prolonged availability of the active ingredient at the site of application. This prolonged release is particularly advantageous in situations where consistent antimicrobial action over extended periods is desired.

Most critically, the disc diffusion tests furnished promising results, solidifying the hydrogel's potential as an antibacterial agent. All formulations demonstrated notable zones of inhibition against both *Staphylococcus aureus* and *Escherichia coli*, two prevalent and clinically significant pathogens. Formulation F4, in particular, emerged as the frontrunner, showcasing superior antibacterial activity against both strains.

In summary, this research has paved the way for harnessing the therapeutic potential of *Saururus cernuus* in a hydrogel format, offering a novel avenue for combating bacterial infections. The study's findings can be a springboard for further investigations, possibly clinical trials, to validate the hydrogel's safety and efficacy in real-world settings. Given the increasing menace of antibiotic resistance, such alternative antibacterial agents are not only welcome but crucial.

Discussion

The pursuit of effective antibacterial agents, especially from natural sources, has been an ongoing endeavor in the realm of pharmaceutical sciences. The rationale behind this study was rooted in the escalating challenge of antibiotic resistance, which has positioned the global health community on the brink of a potential post-antibiotic era. Against this backdrop, the antibacterial properties of *Saururus cernuus*, embedded in a hydrogel

formulation, presented an intriguing proposition.

Hydrogels, owing to their unique matrix structure and capability to retain water, have been increasingly explored as drug delivery systems, especially for topical applications. The rationale for choosing a hydrogel as the delivery vehicle for *Saururus cernuus* extract was twofold: ensuring sustained release of the active ingredient and facilitating ease of application on the skin.

A point of significant interest was the pH values of the formulations. A pH compatible with the skin's natural range is pivotal to prevent potential irritations and maintain the skin's barrier function. The results echoed this principle, suggesting that all four formulations could potentially be well-tolerated upon topical application.

Viscosity and spreadability are intertwined in their influence on the user experience. A formulation that's too viscous may not spread well, while one that's too runny might not stay on the skin long enough to exert its therapeutic effects. The delicate balance achieved in our formulations, especially in F4, reflects the meticulous considerations underpinning the design process.

The in vitro drug release data, showcasing a robust release profile, hints at the potential effectiveness of the hydrogel in delivering the therapeutic effects of *Saururus cernuus* over an extended period. This sustained release could be crucial in conditions where consistent antibacterial action is desired.

Perhaps the most heartening aspect of this study was the evident antibacterial activity against two major pathogens. The zones of inhibition, especially from formulation F4, were comparable to some standard antibiotics, highlighting the potency of the *Saururus cernuus* extract. Given the increasing reports of strains resistant to conventional antibiotics, the findings here could be a beacon of hope.

However, while our results are promising, it's paramount to acknowledge the inherent limitations of in vitro studies. The true test of the hydrogel's potential would be in vivo evaluations and, subsequently, clinical trials. Additionally, future investigations could delve deeper into understanding the specific phytochemical constituents of *Saururus cernuus* responsible for its antibacterial action.

In conclusion, this study has illuminated the potential of *Saururus cernuus* hydrogel as a viable antibacterial agent. While the road ahead entails further rigorous evaluations, the

preliminary findings lay a solid foundation for future endeavors in this direction.

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