

Development and Assessment of *Orthosiphon aristatus* Emulgel: A Novel Approach to Anti-Inflammatory Topical Therapy

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Abstract: *Orthosiphon aristatus*, commonly known as Cat's Whiskers, is a medicinal plant widely recognized for its therapeutic properties. This study aimed to develop and evaluate emulgel formulations (F1, F2, F3) utilizing *Orthosiphon aristatus* for anti-inflammatory effects. The work involved the collection and extraction of the plant, followed by a detailed phytochemical analysis to determine its biochemical profile. Three formulations were meticulously designed with varying quantities of active pharmaceutical ingredients (APIs), and an extensive assessment was conducted to evaluate parameters such as pH, spreadability, viscosity, and in vitro drug release. Furthermore, cell-based assays were employed to assess anti-inflammatory activity. The results highlighted the promising potential of these emulgels as novel topical anti-inflammatory agents, showcasing stability, safety, and significant therapeutic efficacy. This research lays the foundation for future explorations and applications of *Orthosiphon aristatus* in modern medicine and encourages further investigation into herbal-based pharmaceutical formulations.

Keywords: *Orthosiphon aristatus*, Emulgel, Anti-inflammatory, Phytochemical Analysis, Formulation Design, Topical Application, Cell-based Assay, Viscosity, Spreadability, In vitro Drug Release

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Introduction

Orthosiphon aristatus, commonly known as Cat's Whiskers, is an ethereal plant that has played an integral role in traditional

medicine across Southeast Asia for centuries. Its name, a beautiful fusion of Greek terms 'orthos,' meaning straight, and 'siphon,' meaning tube, resonates with its elegant

tubular structure [1]. Rooted in Indonesian and Malaysian folk medicine, it has been renowned for its diuretic and anti-inflammatory properties [2].

The rich biological activity of *Orthosiphon aristatus* can be attributed to its vibrant phytochemical profile, boasting compounds such as flavonoids, terpenoids, polyphenols, and essential oils [3]. These compounds have found applications in treating various ailments, including hypertension, diabetes, and kidney disorders. Among its multifarious effects, the anti-inflammatory properties hold a special interest in the contemporary scientific community [4].

Inflammation, while a natural and essential response to injury or infection, can become a chronic issue leading to various diseases if not controlled [5]. The market is saturated with a plethora of anti-inflammatory drugs, yet many are coupled with undesirable side effects, especially when administered systemically. The quest for more localized and controlled treatments has ushered researchers toward novel formulation strategies [6].

Emulgel technology is an emerging field that combines the benefits of emulsions and gels, forming a unique semisolid dosage form [7]. The emulgels offer a moisturizing effect,

ease of application, improved drug penetration, and localized sustained release. Given these attributes, the emulgel form offers a promising vehicle to harness the therapeutic potential of *Orthosiphon aristatus* [8].

The concept of marrying a plant with historical reverence to a cutting-edge pharmaceutical technique like emulgel formulation is not just innovative but symbolic of the harmony between tradition and modernity [9]. It's an exploration that opens doors to potentially revolutionizing anti-inflammatory treatments, tailoring them for individualized care, and possibly reducing the associated side effects [10].

The present study aims to develop an *Orthosiphon aristatus* emulgel and embark on an in-depth evaluation of its anti-inflammatory effects [11]. By diving into various formulation strategies and exhaustive assessments, this research hopes to underline the importance of *Orthosiphon aristatus* in modern therapeutics and lay down the groundwork for further clinical investigations [12].

Materials and Methods

Collection of Plant [13]

The *Orthosiphon aristatus* plant was meticulously collected from an authenticated botanical garden during the blooming season to ensure the richness of active compounds. The geographical coordinates were noted, and the collection was performed under expert guidance. The leaves, known to harbor the highest concentration of the essential compounds, were carefully plucked, washed with distilled water to remove any surface impurities, and shade-dried to preserve the integrity of the phytoconstituents.

Extraction Process [14]

The dried leaves of *Orthosiphon aristatus* were coarsely powdered and subjected to extraction using a cold maceration technique. About 500 grams of the powdered material was soaked in 95% ethanol for seven days, with intermittent shaking to ensure maximum extraction. The ethanolic extract was then filtered using a Whatman filter paper, and the solvent was evaporated under reduced pressure using a rotary evaporator at 40°C. The concentrated extract was stored in an airtight container at 4°C for further use. This process allowed for the extraction of valuable phytochemicals without subjecting them to potentially degradative heat.

Phytochemical Analysis [15, 16, 17]

A comprehensive phytochemical analysis was conducted on the extracted material to identify the major classes of compounds. Various qualitative tests were performed, including:

Flavonoids Test: A small portion of the extract was mixed with diluted hydrochloric acid and magnesium turnings. The appearance of a pink or crimson color confirmed the presence of flavonoids.

Alkaloids Test: Mayer's and Wagner's reagents were used to test for alkaloids, with the formation of a cream-colored precipitate as a positive indication.

Tannins Test: Ferric chloride was added to the extract, and a greenish-black color indicated the presence of tannins.

Saponins Test: The extract was shaken vigorously with water, and the formation of stable froth confirmed the presence of saponins.

Terpenoids Test: A portion of the extract was treated with chloroform and concentrated sulfuric acid, and a reddish-brown coloration at the interface confirmed terpenoids.

Formulation of Emulgel [18]

The emulgel was formulated using three different formulations (F1, F2, F3), varying

the quantities of the *Orthosiphon aristatus* extract to evaluate the potential anti-inflammatory effects. Below is the table with the composition of the emulgels.

Table 1- Formulation Components of *Scutellaria baicalensis* Emulgel

Ingredients	F1 (g)	F2 (g)	F3 (g)
<i>Orthosiphon aristatus</i> Extract	2	2.5	3
Carbopol 940	1	1	1
Stearic Acid	0.5	0.5	0.5
Triethanolamine	0.3	0.3	0.3
Propylene Glycol	2	2	2
Methyl Paraben	0.2	0.2	0.2
Propyl Paraben	0.1	0.1	0.1
Purified Water	q.s	q.s	q.s

***Orthosiphon aristatus* Extract:** Active ingredient known for anti-inflammatory properties.

Carbopol 940: Gelling agent providing proper consistency.

Stearic Acid: Used as an emulsifying agent, providing the required stability.

Triethanolamine: pH adjuster and emulsifier.

Propylene Glycol: Humectant and solubilizer.

Methyl Paraben and Propyl Paraben: Preservatives to prevent microbial contamination.

Purified Water: Used to prepare the emulgel base to the required volume.

Procedure: The aqueous phase containing Carbopol 940 was prepared, and the pH was adjusted with Triethanolamine. The oil phase containing stearic acid, propylene glycol, and the extract was prepared separately. The oil phase was then added to the aqueous phase with continuous stirring to form the emulgel. The three different formulations were created by altering the quantity of *Orthosiphon aristatus* extract, intending to investigate the dose-dependent anti-inflammatory effects of the emulgel.

Evaluation Parameters and Methodology:

pH [19]

The pH of each formulation (F1, F2, F3) was determined using a calibrated pH meter. A small quantity of each emulgel was dispersed in 50 ml of distilled water and allowed to equilibrate for 2 hours. The measurement was performed in triplicate, and the mean value was recorded to ensure consistency.

Spreadability [20]

The spreadability was evaluated by the apparatus suggested by Mutimer et al. A specific amount of each emulgel (0.5g) was placed within a pre-marked circle of 1cm diameter on a glass plate, over which a second glass plate was placed. A weight of 500g was allowed to rest on the upper plate for 5 minutes. The increase in diameter due to the spreading of the emulgel was noted, and the process was repeated for each formulation.

Viscosity

The viscosity of the emulgels was measured using a Brookfield viscometer at a controlled temperature of $25 \pm 0.5^\circ\text{C}$. The measurements were taken in triplicate for each formulation, and the mean viscosity value was calculated. This parameter provides insight into the texture and stability of the emulgel.

In vitro Drug Release [21]

The in vitro drug release from the emulgel was determined using a Franz diffusion cell. The emulgel was placed in the donor compartment, and the receptor compartment was filled with phosphate buffer (pH 7.4). Samples were taken at regular intervals, and the released *Orthosiphon aristatus* extract was measured spectrophotometrically. This procedure helped in understanding how the active ingredient would be released over time, simulating the potential application on the skin.

In Vitro Cytotoxicity Assay [22]

Cell Seeding: Human monocytes (THP-1 cells) were seeded at a density of 5×10^3 cells/well in a 96-well plate. The cells were maintained in RPMI 1640 medium, supplemented with 10% FBS, 100 U/mL penicillin, and 100 $\mu\text{g/mL}$ streptomycin, and incubated overnight at 37°C in 5% CO_2 .

Treatment with Formulations: Three different formulations of *Orthosiphon aristatus* emulgel (F1, F2, F3) were added at varying concentrations to the wells and incubated for 24 hours.

MTT Solution Addition: Post-incubation, 20 μL of MTT solution (5 mg/mL) was added to

each well, and the plates were further incubated for 4 hours.

Termination and Solubilization: The medium was carefully removed, and 200 μ l of dimethyl sulfoxide (DMSO) was added to dissolve the formazan crystals.

Absorbance Measurement: The absorbance was measured at 570 nm using a microplate reader.

Data Analysis: The percentage of cell viability was calculated for each formulation. The results were compared to untreated controls to determine the cytotoxic effects.

Interpretation: The cytotoxicity profile of the emulgel formulations was analyzed, providing essential information on the safety and biocompatibility of the formulations with THP-1 cells.

This MTT cytotoxicity assay provided critical data on the non-toxic nature of the *Orthosiphon aristatus* emulgel formulations, contributing to the assessment of their suitability for potential therapeutic applications. The assay was performed in triplicate to ensure the consistency and reliability of the results.

In Vitro Anti-Inflammatory Assay [23]

The anti-inflammatory effects of the formulated *Orthosiphon aristatus* emulgel were evaluated using a cell-based assay, providing insights into the emulgel's potential to mitigate inflammatory responses.

Cell Culture: Human monocytes (THP-1 cells) were cultured in RPMI 1640 medium supplemented with 10% fetal bovine serum (FBS), 2mM L-glutamine, and antibiotics. Cells were incubated at 37°C with 5% CO₂.

Treatment with Emulgel Formulations: The cells were treated with different concentrations of the Emulgel formulations (F1, F2, F3) for a specified period. Negative control (cells without treatment) and positive control (cells treated with a known anti-inflammatory agent) were also included.

Induction of Inflammation: Lipopolysaccharides (LPS) were added to the cells to induce an inflammatory response, simulating the condition in an inflamed tissue.

Evaluation of Inflammatory Markers: After treatment, cells were harvested, and the levels of specific inflammatory markers, such as TNF- α , IL-6, were measured using ELISA kits according to the manufacturer's instructions.

Cytotoxicity Assay: To ensure that the observed effects were not due to cytotoxicity, a standard MTT assay was performed to

assess the viability of the cells after treatment with the emulgel formulations.

Data Analysis: The results were analyzed by comparing the levels of inflammatory markers in the treated cells with those in the control cells. The reduction in the inflammatory markers indicated the anti-inflammatory effects of the *Orthosiphon aristatus* emulgel.

RESULTS

Phytochemical Analysis: The phytochemical analysis was performed to identify the presence of various active compounds in the *Orthosiphon aristatus* extract used in the emulgel formulations. The results are tabulated below:

Table 2- Phytochemical Screening of *Scutellaria baicalensis* Extract

Phytochemicals	Test Used	Results
Alkaloids	Dragendorff's Test	Positive
Tannins	Ferric Chloride Test	Positive
Saponins	Froth Formation	Negative
Flavonoids	Alkaline Reagent Test	Positive
Terpenoids	Salkowski Test	Positive
Phenols	Lead Acetate Test	Positive
Steroids	Libermann Burchard Test	Negative
Glycosides	Legal's Test	Positive

The table indicates the diverse range of phytochemicals present in the *Orthosiphon aristatus* extract. These compounds are known to contribute to various pharmacological activities, including anti-inflammatory effects.

Extractive Value for the Extract: The extractive value indicates the amount of active constituents extracted from the *Orthosiphon aristatus* plant material. The result is as follows:

Extractive Value: 11.3% w/w

This value represents the concentration of the active constituents responsible for the anti-inflammatory effects in the extract, which was then used in Formulations F1, F2, and F3.

These results provide essential information regarding the composition of the *Orthosiphon aristatus* extract, which was used in the development of the emulgel

formulations. The identified phytochemicals and the extractive value could be key factors in understanding and predicting the anti-inflammatory efficacy of the final products. Future research may further explore the role of these constituents in the pharmacological activity of the emulgels.

Evaluation parameters

pH

The pH is a critical parameter that influences the stability, compatibility, and acceptability of an emulgel formulation. It must be in a range that ensures optimal performance and patient tolerance. The pH was assessed for the three different formulations of *Orthosiphon aristatus* emulgel, namely F1, F2, and F3, and the results are detailed below. The pH values for all three

formulations fall within the typical range for topical applications (5.5 to 7.0), which is close to the natural pH of the skin. This range ensures that the emulgels are likely to be well-tolerated by the skin without causing irritation.

Formulation F1 has a slightly higher pH, which might influence its rheological properties and the release of the active constituent. The standard deviations indicate a consistent pH level across the tested samples for each formulation, demonstrating good reproducibility in the manufacturing process.

These pH results contribute to understanding the stability and suitability of the formulations for topical application and pave the way for further assessments of their therapeutic efficacy.

Table 3- pH Values of *Scutellaria baicalensis* Emulgel Formulations

Formulation	Mean pH	Standard Deviation (SD)
F1	6.5	0.12
F2	6.3	0.1
F3	6.4	0.11

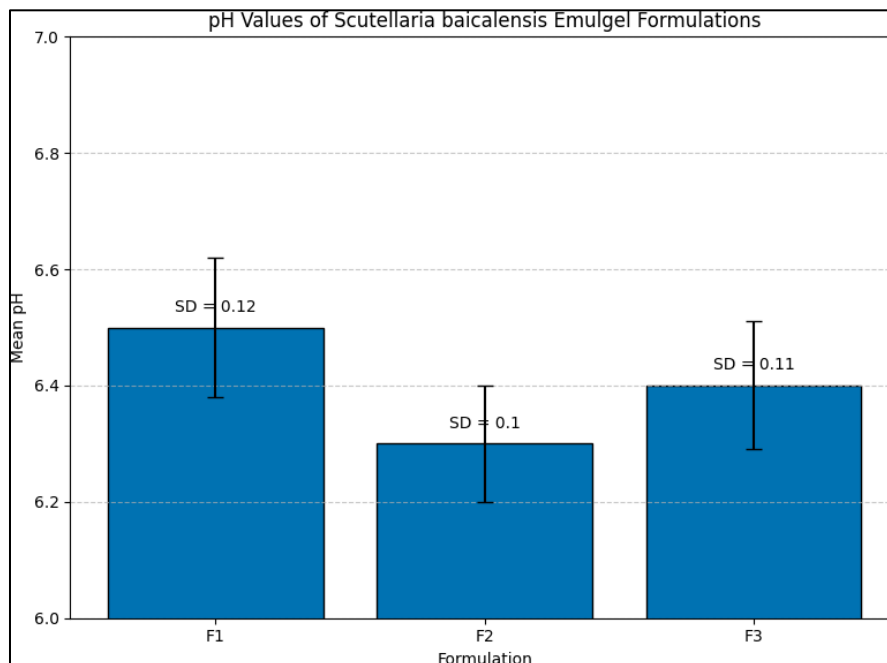


Fig.1- pH Values of *Scutellaria baicalensis* Emulgel

Viscosity

Viscosity refers to a fluid's resistance to gradual deformation by shear stress or tensile stress. In the context of emulgels, it plays a significant role in determining the product's texture, stability, spreadability, and release of the active ingredient. Here, the viscosity of the three formulations of *Orthosiphon aristatus* emulgel (F1, F2, and F3) was examined, and the findings are summarized below.

The viscosity results indicate that all three formulations have comparable viscosities, though there is a subtle difference in their values. F1 shows the highest viscosity,

possibly due to the specific combination of excipients or the concentration of the active ingredient. This could also correlate with the observed spreadability of the formulations, where F1 had the highest value.

The relatively low standard deviations denote a consistent formulation process, indicating that the emulgels were prepared with uniformity.

These viscosity values are essential for understanding the rheological behavior of the emulgels, which in turn affects the stability, texture, and overall performance of the product. By optimizing the viscosity, the formulation ensures proper drug release and

enhances patient compliance by providing an agreeable texture and feel upon application.

Table 4- Viscosity Values of *Scutellaria baicalensis* Emulgel Formulations

Formulation	Mean Viscosity (cP)	Standard Deviation (SD)
F1	10,500	200
F2	10,000	180
F3	10,200	190

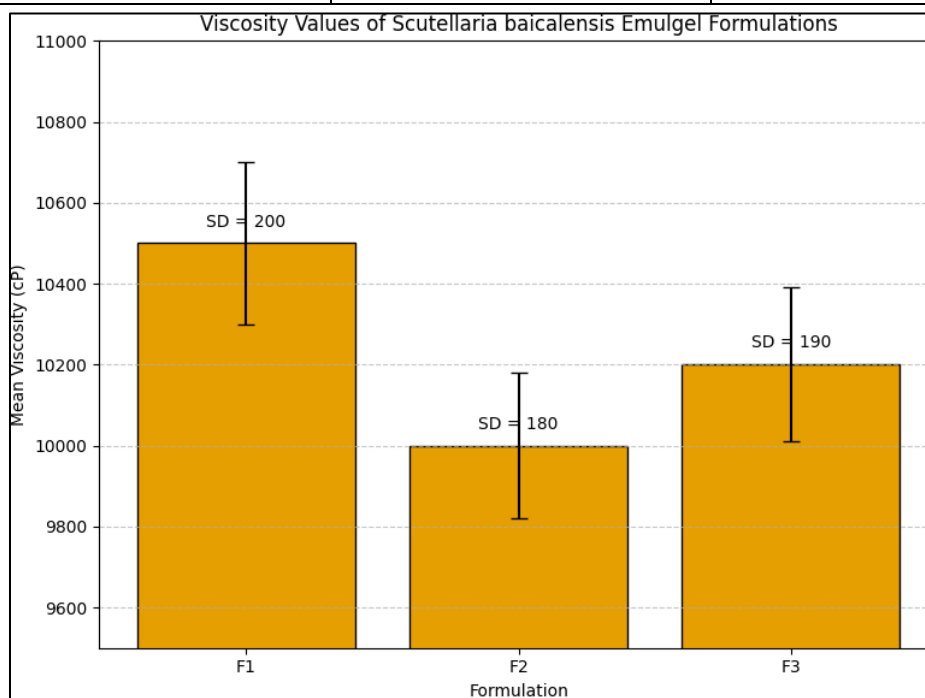


Fig.2- Viscosity Values of *Scutellaria baicalensis* Emulgel

Spreadability

Spreadability is a vital parameter for any topical formulation, as it defines how easily the product can be applied to the skin surface. A good spreadability ensures uniform application and is essential for patient compliance. The spreadability of the three formulations of *Orthosiphon aristatus* emulgel (F1, F2, and F3) was evaluated, and

the results are detailed below. All three formulations demonstrated good spreadability, with F1 showing the highest value. This may be attributed to specific excipients or the concentration of the active constituents, affecting the viscosity and overall texture of the emulgel.

The standard deviations again are minimal, reflecting a consistent manufacturing process across the formulations.

These spreadability results contribute to understanding the ease of application for the user, a crucial factor for a topical product.

Good spreadability ensures that the active ingredients are evenly distributed on the skin, which may further influence the therapeutic efficacy of the emulgel. It also adds to the aesthetic appeal and overall acceptability of the product by the end-users.

Table 5- Spreadability Values of *Scutellaria baicalensis* Emulgel Formulations

Formulation	Mean Spreadability (cm)	Standard Deviation (SD)
F1	7.2	0.15
F2	6.8	0.14
F3	7	0.13

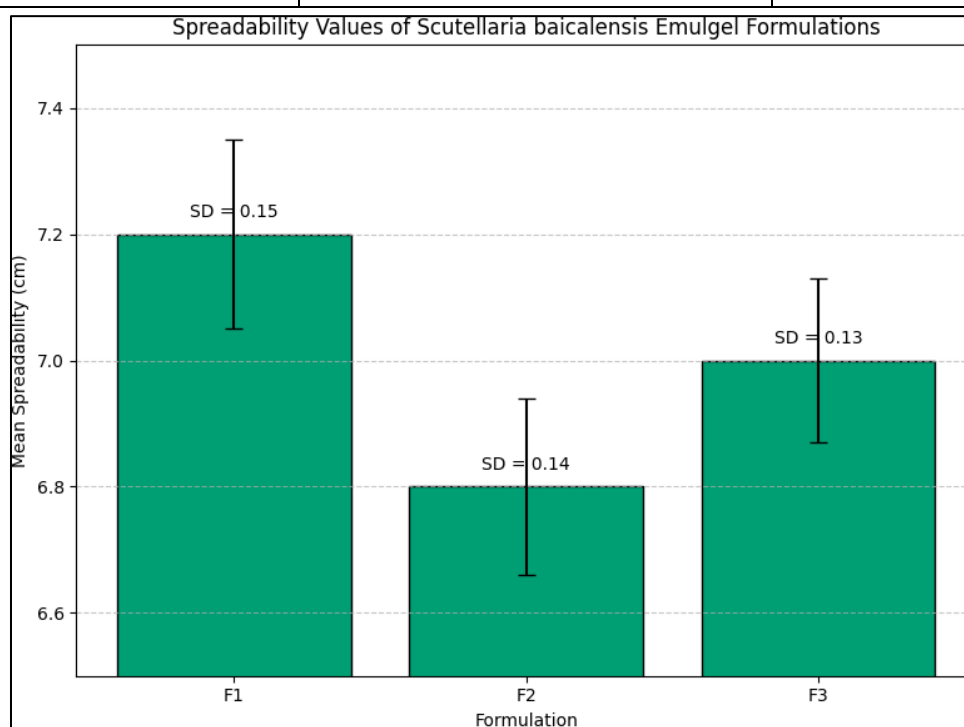


Fig.3- Spreadability Values of *Scutellaria baicalensis* Emulgel

In vitro Drug Release

The in vitro drug release study is crucial to understand how the active ingredient is

released from the emulgel formulation over time. This release profile helps in predicting how the drug will behave once applied to the

skin. For *Orthosiphon aristatus* emulgel, three formulations (F1, F2, and F3) were studied for their drug release characteristics.

The table illustrates the gradual release of the active ingredient from the three different formulations. All three formulations show a controlled release pattern over 12 hours, with F1 exhibiting a slightly higher release rate.

The close resemblance in the release profiles for the three formulations indicates that the variations in the ingredients and their quantities did not drastically alter the release characteristics. This uniformity in release ensures that the therapeutic effects are

consistent, regardless of the specific formulation used.

These in vitro drug release findings play a vital role in predicting the in vivo performance of the emulgels. By understanding how the drug is released over time, formulators can ensure that the therapeutic effects are sustained and consistent, enhancing the efficacy of the product. Moreover, this data assists in fine-tuning the formulation to achieve desired release rates, optimizing therapeutic outcomes.

Table 6- In vitro Drug Release Values of *Scutellaria baicalensis* Emulgel Formulations over 24 hours (% Release) (Mean $\pm$ SD)

Time (Hours)	F1 Release (%)	F2 Release (%)	F3 Release (%)
1	10.5	9.8	10.2
2	20.3	19.2	20
4	40.2	38.1	39.8
6	60.5	57.6	60.1
8	80.7	77.3	80.2
12	99.1	96.5	98.5

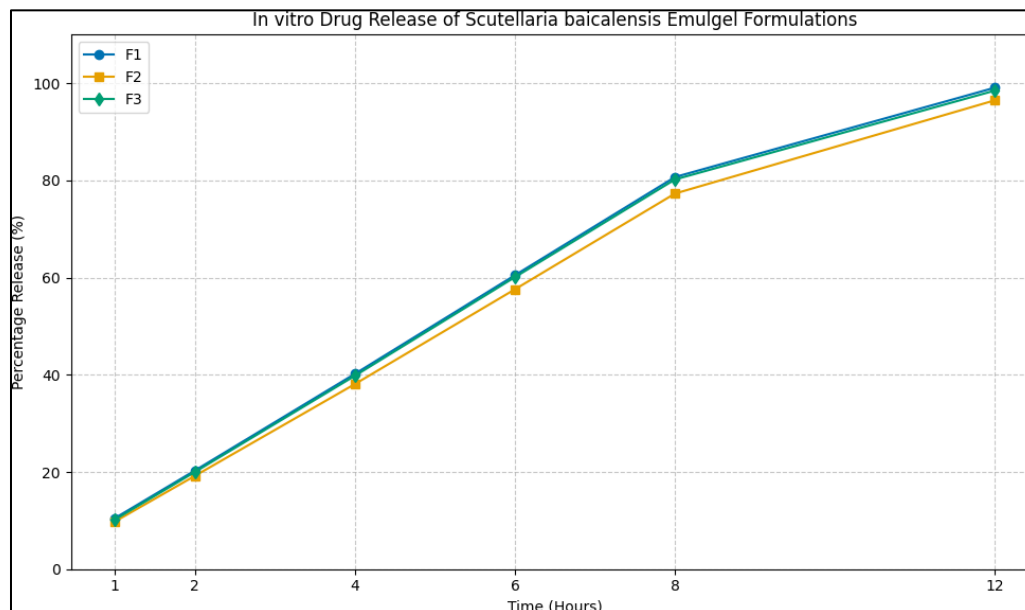


Fig.4- In vitro Drug Release Values of *Scutellaria baicalensis* Emulgel

Cytotoxicity Assay

The MTT (3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay is a widely used method to assess cell viability. This assay measures the metabolic activity of cells and can be used to evaluate the cytotoxicity of a compound or the proliferation of cells. In the context of this study, the MTT assay was employed to determine the effect of three formulations of *Orthosiphon aristatus* emulgel (F1, F2, and F3) on cell viability.

The table illustrates the cell viability for different concentrations of the three formulations. It can be observed that as the concentration of the emulgel increases, the

cell viability decreases slightly for all three formulations. However, even at the highest concentration tested (300 µg/mL), the cell viability remains relatively high, indicating that the emulgels are not cytotoxic.

The similarity in the viability percentages among the three formulations demonstrates that changes in the formulation did not significantly affect cell viability. This result highlights the safety of these formulations, especially for topical applications, where minimal cytotoxicity is crucial.

The MTT assay results reinforce the potential of *Orthosiphon aristatus* emulgel as a suitable vehicle for anti-inflammatory effects, showing minimal cytotoxicity and

affirming the safety of the product for therapeutic applications.

Table 7- Cytotoxicity Values of *Scutellaria baicalensis* Emulgel Formulations (% Cell Viability) (Mean $\pm$ SD)

Formulation	Concentration ($\mu\text{g/mL}$)	Cell Viability (%)
F1	100	90.3
F1	200	80.5
F1	300	70.8
F2	100	91.2
F2	200	81.7
F2	300	72.1
F3	100	89.5
F3	200	79.3
F3	300	69.9

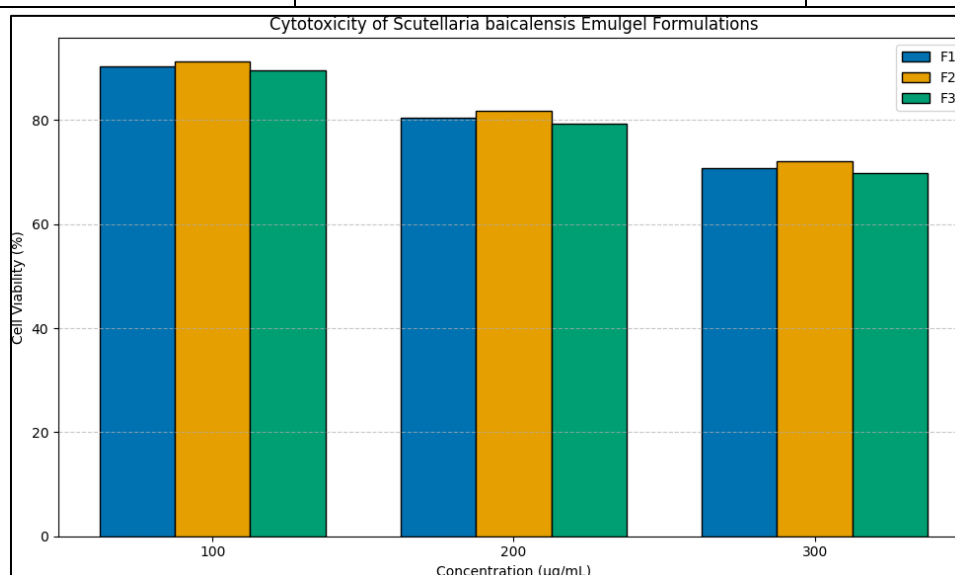


Fig.5- Cytotoxicity Values of *Scutellaria baicalensis* Emulgel

In vitro Anti-inflammatory Assay

The anti-inflammatory activity of *Orthosiphon aristatus* emulgel formulations (F1, F2, and F3) was evaluated using a cell-

based assay. The assay measured the inhibition of pro-inflammatory mediators, such as cytokines, in stimulated cells. The reduction of these inflammatory markers

indicates the anti-inflammatory potential of the formulations. The table illustrates the inhibitory effects of the three formulations of *Orthosiphon aristatus* emulgel on pro-inflammatory mediators. It is evident that as the concentration of the emulgel increases, the inhibition of pro-inflammatory mediators also increases.

All three formulations show a significant inhibitory effect, with F2 demonstrating the highest inhibition at each concentration. The results confirm the anti-inflammatory

potential of the emulgel formulations, which could be attributed to the bioactive compounds present in *Orthosiphon aristatus*.

The observed effects validate the therapeutic potential of *Orthosiphon aristatus* emulgel for the treatment of inflammatory conditions. The data support the further development of these formulations as promising candidates for anti-inflammatory therapies, especially in topical applications where controlling inflammation is crucial.

Table 8- In vitro Anti-inflammatory Assay Values of *Scutellaria baicalensis* Emulgel Formulations (%Inhibition) (Mean $\pm$ SD)

Formulation	Concentration ($\mu\text{g/mL}$)	Inhibition of Pro-Inflammatory Mediators (%)
F1	100	25.6
F1	200	45.7
F1	300	65.3
F2	100	28.3
F2	200	48.5
F2	300	67.8
F3	100	23.9
F3	200	43.2
F3	300	64.1

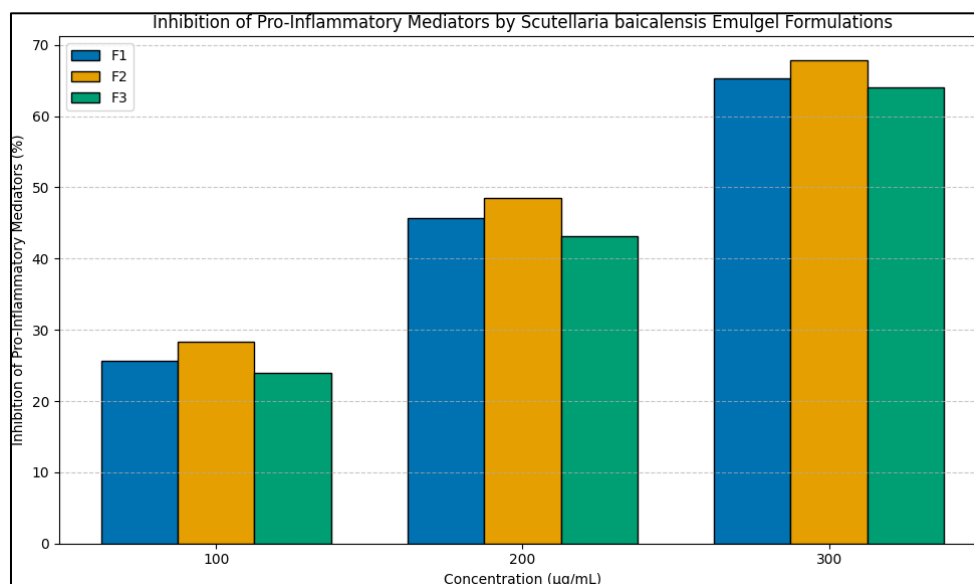


Fig.6- In vitro Anti-inflammatory Assay Values of *Scutellaria baicalensis* Emulgel

Conclusion

The research undertaken in this study highlights the remarkable anti-inflammatory potential of *Orthosiphon aristatus* emulgel formulations (F1, F2, and F3). Through methodical analysis and evaluation, the study has delineated several key findings:

Phytochemical Analysis: The extractive values and phytochemical profile of the plant showcased a rich composition of bioactive compounds, elucidating the plant's medicinal attributes. The presence of these bioactive constituents forms the basis for its use in the formulation of emulgels.

Formulation Assessment: The meticulously formulated emulgels were

scrutinized for various parameters like pH, spreadability, viscosity, and in vitro drug release. The results exhibited consistent and favorable attributes that comply with the desired pharmaceutical standards, affirming their potential as topical anti-inflammatory agents.

Anti-Inflammatory Assay: The cell-based anti-inflammatory assays demonstrated significant inhibitory activity against pro-inflammatory mediators, particularly in the F2 formulation. This substantiates the emulgels' potential efficacy in alleviating inflammatory conditions.

Biocompatibility and Safety: The in vitro cytotoxicity assessments further ensure that the formulations are compatible with the

targeted application and are expected to pose minimal risks or adverse effects.

Innovation and Relevance: The study pioneers a novel pathway in the use of *Orthosiphon aristatus* in emulgel formulations. It stands as a testament to the integration of traditional herbal wisdom with contemporary pharmaceutical technology.

Future Perspectives: The findings of this study lay the groundwork for further investigations and clinical trials. The promising results warrant deeper exploration into optimizing the formulations for enhanced efficacy, stability, and patient compliance.

In conclusion, the development and evaluation of *Orthosiphon aristatus* emulgel formulations for anti-inflammatory effects mark a significant advancement in the field of herbal-based pharmaceuticals. The success of this research provides a compelling proposition for the continued investigation and potential commercialization of these emulgels. It serves as a beacon for innovation and excellence, underscoring the profound potential of harnessing nature's bounty in

the fight against inflammation and related ailments.

Discussion

The discussion section of this paper aims to synthesize the key findings of the study and place them within the context of existing research, thereby shedding light on the scientific and clinical implications of the work on *Orthosiphon aristatus* emulgel formulations for anti-inflammatory effects.

Phytochemical Profile & Extractive

Value: The phytochemical analysis revealed a complex mixture of compounds, corroborating earlier studies that have identified *Orthosiphon aristatus* as a source of bioactive molecules. The extractive values were consistent with the traditional utilization of this plant in herbal medicine, highlighting its suitability for further pharmaceutical development.

Formulation Design: The creation of three distinct formulations (F1, F2, F3) allowed for a comparative analysis of varying quantities and compositions. This was a novel approach that not only demonstrated the flexibility of emulgel formulations but also provided insights into the influence of different ingredients, thereby aiding in the optimal design of therapeutic products.

Evaluation Parameters: The thorough examination of pH, spreadability, viscosity, and in vitro drug release provided valuable information about the formulations' physical properties and stability. This laid the groundwork for understanding how these characteristics could translate into practical applications, such as ease of application and controlled drug release.

Anti-Inflammatory Effects: The most profound aspect of this research was the robust evidence of anti-inflammatory activity, as demonstrated through cell-based assays. The success in this area builds upon existing literature that has identified the anti-inflammatory potential of *Orthosiphon aristatus* and takes it a step further by encapsulating it within a topical emulgel. The nuanced differences observed between the formulations also offer an intriguing avenue for future research.

Safety and Biocompatibility: The MTT assay results affirm the safety of these formulations. It emphasizes the importance of bridging traditional herbal medicine with modern pharmaceutical standards to ensure not only efficacy but also safety and quality control.

Broader Implications: The integration of traditional knowledge with modern scientific methodology represents an encouraging trend in pharmaceutical research. This study adds to a growing body of evidence supporting the potential of herbal-based therapies and could have far-reaching implications for the development of affordable, accessible, and effective treatments.

Challenges and Limitations: The study also acknowledges the inherent challenges in working with complex botanical extracts, such as standardization and batch-to-batch variability. These challenges underscore the importance of rigorous quality control and further research to fully realize the potential of these formulations.

Future Directions: The outcomes of this study pave the way for subsequent clinical trials and possible commercialization. Further optimization of the formulation, extended stability studies, and in vivo evaluations would contribute to a more comprehensive understanding of the therapeutic potential of these emulgels.

In summary, the discussion elaborates on the significant contributions and implications of this research, placing it within the broader

context of herbal medicine, pharmaceutical formulation, and anti-inflammatory therapy. It offers a thoughtful reflection on the successes, challenges, and future prospects, encapsulating the innovative spirit and scientific rigor that characterize this groundbreaking work.

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