

In-Vitro Antiinflammatory Activity of Ethanolic Extract of *Gymnostachyum* *warrieranum* Leaves

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Abstract: *Background:* *Gymnostachyum warrieranum* is a medicinal plant in the Acanthaceae family that has very little scientific information on its pharmacological potential, safety, and phytochemical makeup. The goal of the present investigation was to evaluate the invitro antiinflammatory effect of ethanolic extract.

Methods: Soxhlet extraction was used to extract the verified entire plant material using 95% ethanol. The extract was characterised for preliminary phytochemical screening. Assays for Protein denaturation and HRBC membrane stabilisation were used to evaluate in vitro antiinflammatory efficacy.

Results: Yield of ethanolic extract of GW is 8.72% w/w. Flavonoids, phenolic substances, tannins, glycosides, steroids, terpenoids, and other secondary metabolites were detected by phytochemical screening. EEGW generated $78.09 \pm 0.00\%$ HRBC membrane stabilisation and $82.12 \pm 0.00\%$ inhibition of protein denaturation at 300 $\mu\text{g/mL}$.

Conclusion: The results show that *Gymnostachyum warrieranum*'s ethanolic extract has a rich phytochemical profile and potential antiinflammatory properties. The promise of EEGW as a source of bioactive phytoconstituents is supported by the dose-dependent pharmacological effects. To determine its medicinal potential, further research incorporating the isolation of active chemicals, mechanistic analyses, and formulation development is necessary.

Keywords: *Gymnostachyum warrieranum*; Acanthaceae; ethanolic extract; phytochemical screening; antiinflammatory activity

I. INTRODUCTION

Medicinal plants have historically constituted an important source of therapeutic agents and continue to occupy a significant position in modern pharmaceutical and biomedical research. The therapeutic value of plants is primarily associated with the presence of a wide variety of primary and secondary metabolites, including alkaloids, flavonoids, phenolic compounds, tannins, glycosides, terpenoids, steroids, saponins and other structurally diverse constituents. These compounds may exhibit antioxidants, anti-inflammatory, antidiabetic, antimicrobial, hepatoprotective, cardioprotective and several other biological activities¹⁻⁴.

The present investigation was undertaken to provide a systematic scientific evaluation of *Gymnostachyum warrieranum*, with particular emphasis on its pharmacognostic standardization, and evaluation of antiinflammatory activities. The study was designed as an integrated investigation in which the crude plant material was first subjected



to appropriate processing and quality assessment, followed by extraction and finally evaluated through in vitro models⁵.

Inflammation is a natural body response to injury or infection, but chronic inflammation causes diseases like arthritis. Leaves from many medicinal plants contain active compounds like flavonoids, tannins, and alkaloids that fight swelling and pain. Test-tube and cell-based assays let scientists screen plant extracts quickly and safely before testing on animals or humans.

Tissue damage, microbial infection, chemical irritants, or immunological responses may all cause inflammation, which is a complicated biological process. Prolonged or uncontrolled inflammatory responses contribute to the development of several chronic disorders, such as rheumatoid arthritis, diabetes mellitus, cardiovascular diseases, inflammatory bowel disease, and cancer, even tho inflammation is an essential protective mechanism that aids in tissue repair and the removal of harmful stimuli. Histamine, serotonin, bradykinin, prostaglandins, leukotrienes are among the many mediators that are released during inflammation. These mediators cause vasodilation, increased vascular permeability, leukocyte infiltration, and tissue damage. Consequently, stabilising cellular membranes and preventing the release of inflammatory mediators are crucial therapeutic approaches for reducing inflammation⁶⁻⁸. The ability of medicinal plants that contain flavonoids, phenolic compounds, tannins, saponins, alkaloids, and terpenoids to inhibit inflammatory pathways through various mechanisms, such as suppression of COX, LOX, iNOS, and NF-κB, has garnered significant attention. Several bioactive phytoconstituents that may contribute to anti-inflammatory action were found in the EEGW, according to preliminary phytochemical screening. Therefore, protein denaturation inhibition and HRBC membrane stabilisation tests will be used to assess the ethanolic extract's anti-inflammatory efficacy, with diclofenac sodium acting as the standard anti-inflammatory medication⁹.

Here we use HRBC Membrane Stabilization: Measures how well an extract stops red blood cell membranes from breaking under stress, mimicking cellular protection and **Protein Denaturation Inhibition:** Tests if the extract prevents proteins from changing shape, a major cause of inflammatory tissue damage

II. METHODOLOGY

Plant material

The leaves of *Gymnostachyum warrieranum* were collected from Aralam, Kannur district, Kerala, India,

Preparation of the plant material

Plant part was cleaned thoroughly with distilled water and the desired plant parts were dried under shade. The shade dried leaves were pulverized in a mechanical grinder to obtain coarse powder.

Preparation of the crude extracts

A weight of 50 grams of the coarsely powdered shade – dried sample was successively extracted by Soxhlet method using methyl 95% ethanol as solvent.

Phytochemical screening

Phytochemical screening were performed using standard procedures¹⁰⁻¹¹

III. IN VITRO ANTIINFLAMMATORY ACTIVITY

Protein Denaturation Assay

One of the main reasons for inflammation is protein denaturation. Thermal or chemical stress causes proteins to change their natural shape under inflammatory circumstances, resulting in the production of autoantigens that set off inflammatory reactions. Denatured proteins worsen tissue injury by promoting the synthesis of inflammatory mediators. Therefore, substances that might stop the denaturation of proteins are regarded as possible anti-inflammatory medicines. EEGW capacity to prevent heat-induced protein denaturation will be assessed using a slightly modified version of Mizushima and Kobayashi's approach. To create concentrations of 75, 150, 225, and 300 µg/mL, the ethanolic extract will be dissolved in phosphate-buffered saline. The protein substrate will be a freshly made 1% BSA solution. Different extract concentrations will be carefully combined with equal quantities of BSA solution. The



reference standard will be diclofenac sodium at the same concentrations, and the control will be phosphate buffer devoid of extract. To cause protein denaturation, the reaction mixtures will be heated to 70°C for five minutes after being incubated at 37°C for twenty minutes. A UV-visible spectrophotometer will be used to measure absorbance at 660 nm once it has cooled to room temperature. The absorbance of the test and control samples will be compared to determine the percentage inhibition of protein denaturation. The concentration-response curve will also be used to calculate the concentration that causes IC₅₀. Stronger anti-inflammatory action is shown by higher suppression of protein denaturation¹².

Membrane Stabilization Assay for HRBCs

In terms of structural organization, the human red blood cell membrane and the lysosomal membrane are quite similar. Lysosomal membranes become unstable during inflammation, releasing hydrolytic enzymes that worsen tissue damage. Therefore, it is anticipated that agents that can stabilise erythrocyte membranes would also stabilise lysosomal membranes and stop the release of inflammatory enzymes. As a result, the HRBC membrane stabilisation test is regarded as a trustworthy in vitro technique for evaluating anti-inflammatory effectiveness. After receiving ethical clearance and informed permission, fresh human blood will be drawn from healthy donors. After combining blood with Alsever's solution, it will be centrifuged for ten minutes at 3000 rpm. After being regularly cleaned with isotonic phosphate-buffered saline, the packed erythrocytes will be reconstituted as a 10% HRBC solution. The ethanolic extract will be produced in phosphate buffer at various concentrations (75, 150, 225, and 300 µg/mL). The test extract, phosphate buffer, hypotonic saline, and HRBC suspension will make up the reaction combination. The usual anti-inflammatory medication will be diclofenac sodium. After 30 minutes of incubation at 37°C, the mixtures will be centrifuged for 10 minutes at 3000 rpm. The percentage of membrane stabilisation will be computed by measuring the supernatant's absorbance at 560 nm. By preventing erythrocyte membrane lysis, more membrane stabilisation will signify stronger anti-inflammatory action¹³.

IV. ANALYSIS OF STATISTICS

Every experiment will be conducted in triplicate (n = 3). The mean ± SEM will be used to represent the results. GraphPad Prism software (Version 10) will be used to conduct statistical comparisons between groups using one-way ANOVA. A significant result is defined as p < 0.05.

V. RESULTS

In Vitro Anti-Inflammatory Properties: A complicated biological reaction to tissue damage, infection, or exposure to damaging stimuli is inflammation. Denaturation of proteins, which leads to the production of autoantigens and advances inflammatory illnesses, is one of the hallmarks of inflammation. As a result, suppression of protein denaturation is regarded as a trustworthy in vitro model for assessing natural products' capacity to reduce inflammation. The protein denaturation test was used in this work to evaluate the anti-inflammatory activity of the ethanolic extract of *Gymnostachyum warrierianum* (EEGW), and the results were compared with those of the common anti-inflammatory medication diclofenac sodium.

Protein Denaturation Assay: At doses between 75 and 300 µg/mL, the inhibitory efficacy of EEGW against heat-induced protein denaturation was assessed. Figure 4.14 shows the concentration-dependent inhibitory pattern, whereas Table 4.15 summarises the % inhibition of protein denaturation achieved for both EEGW and diclofenac sodium. Both EEGW and diclofenac sodium demonstrated a distinct concentration-dependent reduction of protein denaturation, as seen in Table 4.16. The anti-inflammatory activity gradually increased as the extract's concentration increased, suggesting that the inhibitory impact was directly correlated with extract concentration.

Diclofenac sodium showed 43.00 ± 0.00% suppression of protein denaturation at the lowest dose tested (75 µg/mL), whereas EEGW generated 29.03 ± 0.02%. Even at the lowest dose tested, the extract showed detectable anti-inflammatory action, despite EEGW's inhibitory activity being less than that of the standard medication. When the concentration was raised to 150 µg/mL, EEGW's inhibitory activity significantly increased to 48.01 ± 0.00%, which is



about 65% more than what was seen at 75 µg/mL. Diclofenac sodium maintained more inhibitory action than the extract, producing $60.01 \pm 0.02\%$ inhibition under the same experimental circumstances. Protein denaturation inhibition was significantly enhanced by further concentration increases. Diclofenac sodium demonstrated $77.09 \pm 0.03\%$ inhibition at 225 µg/mL, whereas EEGW showed $65.00 \pm 0.01\%$ inhibition. EEGW showed a strong anti-inflammatory reaction at this dosage, suggesting that greater concentration significantly enhances its capacity to maintain protein structure and stop denaturation. For both treatments, the maximal inhibitory action was obtained at the highest quantity tested (300 µg/mL). Protein denaturation was inhibited $82.12 \pm 0.00\%$ by EEGW and $93.00 \pm 0.00\%$ by diclofenac sodium. The extract has significant anti-inflammatory action at greater doses, as shown by the inhibition that EEGW obtained at this concentration, which was equivalent to around 88% of the activity of the conventional medication. When EEGW and diclofenac sodium were compared, it was found that the difference in inhibitory activity steadily diminished as concentration increased. The extract and the conventional medication differed by about 14 percentage points at 75 µg/mL and by about 11 percentage points at 300 µg/mL. This finding implies that when the concentration rises, EEGW's anti-inflammatory properties become closer to those of diclofenac sodium. The concentration-dependent rise in protein denaturation inhibition for both EEGW and diclofenac sodium is graphically shown in Figure 4.16. Diclofenac sodium continuously caused more inhibition than EEGW at all doses, while both treatments showed almost linear increases in inhibitory action with increasing concentration. However, at greater doses, the extract showed strong inhibitory effect, suggesting major anti-inflammatory potential. The assay's high accuracy and repeatability are shown by the low standard deviation values found for all experimental concentrations. The observed concentration-dependent inhibitory response is reliable, as shown by the consistency of the experimental results. Preliminary phytochemical screening of EEGW indicated the presence of polyphenols which may be responsible for the antidiabetics effect shown in this research. By stabilising protein structure, suppressing the production of inflammatory mediators, inhibiting the cyclooxygenase and lipoxygenase pathways, stabilising membranes, and exhibiting antioxidant action, these phytoconstituents are known to prevent protein denaturation. Strong free radical scavenging abilities, particularly those of flavonoids and phenolic substances, decrease inflammatory tissue damage and oxidative stress. Overall, the findings unequivocally show that *Gymnostachyum warrieranum*'s ethanolic extract has strong in vitro anti-inflammatory action, as shown by its concentration-dependent reduction of protein denaturation. EEGW shown significant effectiveness, especially at higher dosages when its inhibitory impact approximated that of the reference medicine, even tho diclofenac sodium showed stronger inhibitory action throughout the research. These results imply that the extract may be a viable natural source of anti-inflammatory drugs as it includes bioactive components that may stop protein denaturation.

Table 1: In Vitro Anti-inflammatory Activity of the EEGW by Protein Denaturation Assay

Concentration (µg/mL)	EEGW (% Inhibition)	Diclofenac Sodium (%) Inhibition
75	29.03 ± 0.02	43.00 ± 0.00
150	48.01 ± 0.00	60.01 ± 0.02
225	65.00 ± 0.01	77.09 ± 0.03
300	82.12 ± 0.00	93.00 ± 0.00

Figure 1 shows the percentage reduction of heat-induced protein denaturation by the conventional medication diclofenac sodium and the ethanolic extract of *Gymnostachyum warrieranum* (EEGW) at doses between 75 and 300 µg/mL. Protein denaturation was inhibited in a concentration-dependent manner by both EEGW and diclofenac sodium. At all tested doses, diclofenac sodium exhibited higher inhibitory action; nevertheless, EEGW showed significant anti-inflammatory effect, reaching 82.12% inhibition at 300 µg/mL, which was comparable to the activity of the medication. These results suggest that EEGW has strong in vitro anti-inflammatory potential by stabilizing protein structure and preventing protein denaturation.



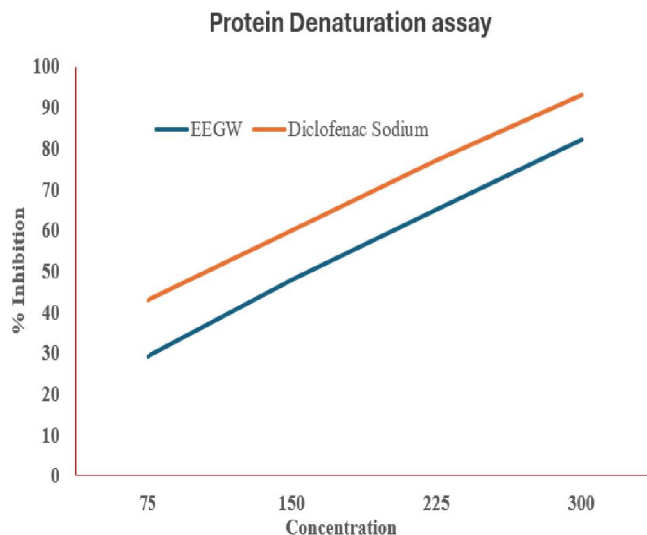


Figure 2.. In Vitro Anti-inflammatory Activity of the EEGW by Protein Denaturation Assay

Membrane Stabilizing Activity : The HRBC membrane stabilization test, a reliable in vitro technique for evaluating anti-inflammatory potential, was used to examine the membrane stabilising activity of the EEGW. Hydrolytic enzymes are released when lysosomal membranes become unstable during inflammation, which exacerbates tissue damage and inflammatory reactions. Protection of human red blood cells against hypotonicity-induced haemolysis is regarded as a crucial sign of membrane stabilization and anti-inflammatory action since the composition and structure of the erythrocyte membrane are similar to those of the lysosomal membrane. Table 4 shows the percentage membrane stabilisation shown by EEGW and the common anti-inflammatory medication diclofenac sodium at various doses. While Figure 4.16 shows the comparable concentration-dependent responses. as seen in Table 4. Throughout the experimental concentration range of 75–300 µg/mL, both EEGW and diclofenac sodium showed concentration-dependent membrane stabilising action. Protection against hypotonicity-induced haemolysis gradually increased as the extract's concentration increased, suggesting improved erythrocyte membrane stabilisation. EEGW showed $50.00 \pm 0.01\%$ membrane stabilisation at the lowest dose tested (75 µg/mL), whereas diclofenac sodium provided $58.00 \pm 0.01\%$ stabilisation. The extract exhibited significant membrane-protective effect by preventing haemolysis of around half of the erythrocytes subjected to hypotonic stress, despite the conventional medication exhibiting stronger activity at this dose. This result suggests that even at comparatively low doses, the extract has detectable anti-inflammatory effect. The membrane stabilising activity of EEGW rose to $56.00 \pm 0.02\%$ when the concentration was raised to 150 µg/mL, which is about a 12% increase over the activity seen at 75 µg/mL. At the same concentration, diclofenac sodium showed $60.02 \pm 0.03\%$ stabilization. The difference between the two treatments became less noticeable even tho the standard remained to exhibit somewhat higher activity, indicating that the membrane-protective components of EEGW become more potent as the concentration rises. At 225 µg/mL, there was a significant improvement in membrane stabilization. Diclofenac sodium showed $66.02 \pm 0.23\%$ membrane stabilization, whereas EEGW generated $69.01 \pm 0.02\%$. It's interesting to note that EEGW outperformed the usual medication at this dose by around 3 percentage points, suggesting that the extract had better membrane stabilizing function in these experimental settings. This finding indicates that EEGW has a particularly strong membrane-protective action at higher doses. For both treatments, the maximal membrane stabilization was achieved at the highest dose tested (300 µg/mL). Diclofenac sodium demonstrated $73.00 \pm 0.12\%$ stabilization, whilst EEGW showed $78.09 \pm 0.00\%$. The membrane stabilization generated by EEGW rose by around 56% as compared to the lowest concentration, which is equivalent to a roughly 1.6-fold increase in activity. Additionally, EEGW demonstrated greater protection against erythrocyte membrane



damage caused by hypotonicity, surpassing the membrane stabilizing action of diclofenac sodium by almost 5 percent. It is evident that there are two different response patterns when the two treatments are compared. Diclofenac sodium's well-known anti-inflammatory effectiveness was shown by its increased membrane stabilization at lower doses (75 and 150 $\mu\text{g/mL}$). EEGW, on the other hand, showed a steeper concentration-response relationship and increased activity more quickly as concentration rose. As a result, the extract outperformed diclofenac sodium at 225 $\mu\text{g/mL}$ and 300 $\mu\text{g/mL}$, suggesting that the active phytoconstituents in EEGW had more potent membrane-protective properties at greater doses. The extract successfully shielded erythrocyte membranes against osmotic stress-induced hemolysis, as shown by the concentration-dependent increase in membrane stabilization seen for EEGW. Like how lysosomal membranes stabilise during inflammation, erythrocyte membrane stabilization prevents cell membrane rupture and the consequent release of intracellular contents. The release of proteases, inflammatory enzymes, and other mediators that cause tissue injury is reduced when lysosomal membrane breach is prevented. Consequently, EEGW's superior membrane stabilizing activity provides compelling evidence for its ability to reduce inflammation. Both EEGW and Diclofenac Sodium show a concentration-dependent increase in membrane stabilization, as seen graphically in Figure 4.16. EEGW showed a more noticeable rise in membrane stabilization as the concentration climbed, eventually outperforming the conventional medication at higher doses, whilst diclofenac sodium showed greater action at lower values. The graph demonstrates EEGW's enhanced effectiveness at 225 $\mu\text{g/mL}$ and 300 $\mu\text{g/mL}$, highlighting the extract's exceptional capacity to preserve membranes. The assay's exceptional repeatability, accuracy, and dependability are shown by the very low standard deviation values attained throughout the experiment. Replicate determinations' consistency verifies that the biological activity of the extract, not experimental variance, is responsible for the observed variations between treatments. Preliminary phytochemical screening suggested the presence of polyphenols which may be responsible for the membrane stabilizing effect shown by EEGW. Through a variety of mechanisms, such as inhibiting lipid peroxidation, scavenging reactive oxygen species, stabilizing membrane phospholipids, suppressing the release of inflammatory mediators, and maintaining membrane permeability, these phytoconstituents are known to stabilize biological membranes. In particular, flavonoids and phenolic substances have strong antioxidant properties that shield membrane proteins and lipids from oxidative deterioration, maintaining membrane integrity in inflammatory situations. EEGW may include bioactive components that may successfully shield cellular membranes from inflammatory damage, as shown by the greater membrane stabilizing action seen at higher doses. This protective impact may help reduce tissue damage, attenuate the inflammatory cascade, and prevent the release of lysosomal enzymes. These pathways are those to be crucial for the treatment of long-term inflammatory conditions. Overall, the ethanolic extract of *Gymnostachyum warriaranum* has exceptional in-vitro anti-inflammatory efficacy by stabilisation of erythrocyte membranes, as shown by the HRBC membrane stabilisation test. At higher doses (225 and 300 $\mu\text{g/mL}$), the extract significantly outperformed diclofenac sodium in membrane stabilisation and showed a definite concentration-dependent membrane-protective action. These results indicate EEGW's potential as a promising natural anti-inflammatory therapeutic drug and imply that it contains strong anti-inflammatory phytoconstituents that may shield cellular membranes from inflammatory damage.



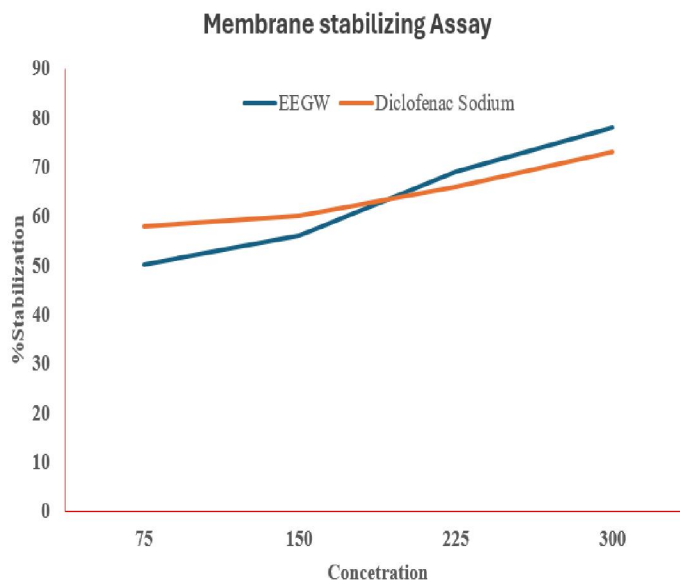


Figure 2. Membrane-stabilizing activity of EEGW compared with diclofenac sodium at different concentrations, expressed as percentage stabilization.

Table 2. In Vitro Membrane Stabilizing Activity (MSA) of the EEGW

Concentration (µg/mL)	EEGW (% Membrane Stabilization)	Diclofenac Sodium (% Membrane Stabilization)
75	50.00 ± 0.01	58.00 ± 0.01
150	56.00 ± 0.02	60.02 ± 0.03
225	69.01 ± 0.02	66.02 ± 0.23
300	78.09 ± 0.00	73.00 ± 0.12

Figure 2. shows the percentage of membrane stabilisation caused by diclofenac sodium and the ethanolic extract of *Gymnostachyum warrieranum* (EEGW) against hypotonicity-induced haemolysis of human red blood cells at doses between 75 and 300 µg/mL. Diclofenac sodium and EEGW both demonstrated concentration-dependent membrane stabilising action. EEGW showed superior membrane stabilisation at 225 µg/mL and 300 µg/mL, indicating a strong membrane-protective effect and significant in vitro anti-inflammatory potential thru stabilisation of erythrocyte membranes and prevention of hypotonicity-induced haemolysis, while diclofenac sodium showed greater activity at lower concentrations. In each of the examined experimental models, the ethanolic extract of *Gymnostachyum warrieranum* shown notable in vitro anti-inflammatory efficacy.

EEGW showed a concentration-dependent suppression of protein denaturation in the protein denaturation test, reaching a maximal inhibition of $82.12 \pm 0.00\%$ at 300 µg/mL, which was similar to the standard medication diclofenac sodium ($93.00 \pm 0.00\%$). EEGW also demonstrated concentration-dependent membrane protective action in the HRBC membrane stabilisation experiment, rising from $50.00 \pm 0.01\%$ to $78.09 \pm 0.00\%$ as concentration increased. Notably, at doses of 225 and 300 µg/mL, the extract showed more membrane stabilising action than diclofenac sodium, suggesting better membrane protection in the experimental setting.

VI. CONCLUSION

The ethanolic extract of *Gymnostachyum warrieranum* (EEGW) demonstrated significant concentration-dependent in vitro anti-inflammatory activity. Protein denaturation inhibition increased from 29.03% to 82.12%, while HRBC



membrane stabilization increased from 50.00% to 78.09%. EEGW showed strong activity at higher concentrations, particularly in membrane stabilization, indicating the presence of bioactive phytoconstituents with promising anti-inflammatory potential

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