

Evaluation of Anti-Inflammatory Activity of Plant-Based Compounds

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ABSTRACT

The current work used the carrageenan-induced paw edema model in Wistar rats to determine the anti-inflammatory properties of plant-based substances, namely quercetin (*Ficus carica*) and curcumin (*Curcuma longa*). Four groups of 24 rats each were created: Quercetin, Curcumin, Standard Drug (Diclofenac), and Negative Control. The volume of paw edema was measured one, two, three, and four hours after induction. Diclofenac showed the greatest suppression of paw swelling at all time periods, while carrageenan was able to successfully produce inflammation in the control group, according to the results. When compared to the control, both curcumin and quercetin considerably decreased inflammation; however, the difference was not statistically significant, with curcumin being slightly more efficient than quercetin. The trustworthiness of these findings was validated by statistical analysis. According to the study's findings, quercetin and curcumin have strong anti-inflammatory properties and could be useful natural supplements or substitutes for traditional synthetic medications.

Key Words:

Anti-inflammatory activity, Curcumin, Quercetin, Carrageenan-induced paw edema, Plant-based compounds, Diclofenac.

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1. INTRODUCTION

The body's basic biological reaction to damaging stimuli like infections, poisons, or tissue damage is inflammation¹. Although it is crucial for starting the body's defensive and healing processes, unchecked or persistent inflammation accelerates the development of a number of illnesses, including as cancer, diabetes, heart disease, and arthritis². The natural origin, bioactive phytochemicals, and comparatively safer pharmacological profile of plant-derived substances have sparked increased interest in investigating them as possible substitutes for synthetic medications in recent years³. Quercetin, a flavonoid that is widely found in *Ficus carica* and other

plants, and curcumin, a polyphenolic component from *Curcuma longa*⁴, are two of these that have drawn scientific interest due to their anti-inflammatory and antioxidant qualities⁵.



Figure 1: Representative images of rat paw edema in the carrageenan-induced inflammation model: (a) Normal, (b) Untreated, (c) Positive control (Diclofenac), and (d) Treated with test compound.

Using the carrageenan-induced paw edema model in Wistar rats, this study examines the anti-inflammatory properties of various plant-based substances (Figure 1)⁶. Diclofenac is used as the standard reference medication.

1.1. Background information

Traditional medical systems like Ayurveda and Traditional Chinese Medicine have long used medicinal herbs to relieve inflammation⁷. The pharmacological characteristics of curcumin, such as its capacity to alter inflammatory mediators including cytokines, prostaglandins, and transcription factors like NF- κ B, have been the subject of much research. Similar to this, quercetin, a naturally occurring flavonoid, has been present to have anti-inflammatory properties by suppressing inflammatory cell infiltration, lowering oxidative stress, and inhibiting the cyclooxygenase (COX) and lipoxygenase (LOX) pathways⁸. According to preclinical research, these substances have broader protective benefits in models of chronic diseases in addition to reducing inflammation. There aren't many direct comparison studies on their anti-inflammatory properties in carefully monitored experimental settings, though.

1.2. Statement of the problem

A thorough experimental review evaluating the efficacy of curcumin and quercetin versus conventional anti-inflammatory medications within the same experimental framework is still lacking, despite mounting evidence of their therapeutic potential⁹. Furthermore, synthetic medications are not safe for long-term use because of their negative side effects, despite their effectiveness, which emphasizes the need for safer substitutes¹⁰. Using the carrageenan-induced paw edema model, this study aims to fill this gap by methodically examining and contrasting the

anti-inflammatory effectiveness of quercetin and curcumin against diclofenac. By doing thus, it seeks to establish scientific proof of these natural substances and draw attention to their potential use as alternative or supplemental therapeutic agents for the treatment of inflammation.

1.3.Objectives of the study

- To determine the anti-inflammatory activity of selected plant-based compounds (Curcumin and Quercetin) using the carrageenan-induced paw edema model in Wistar rats.
- To compare the anti-inflammatory effects of Curcumin and Quercetin with a standard reference drug (Diclofenac sodium).
- To assess and validate the reliability of plant-based compounds in reducing acute inflammation through statistical analysis.
- To explore the potential of Curcumin and Quercetin as natural alternatives or complementary agents to conventional anti-inflammatory drugs.

2. METHODOLOGY

Potential anti-inflammatory qualities of plant-based substances have drawn attention, and they may be safer substitutes for synthetic medications. The current study used conventional experimental methods to assess the anti-inflammatory properties of a few chosen plant-derived substances.

2.1.Research Design

To evaluate the anti-inflammatory properties of the chosen plant chemicals, a quantitative experimental research approach was used. To guarantee the validity and dependability of the findings, the study was carried out in a controlled laboratory setting with treatment and control groups.

2.2.Sample Details

Adult male Wistar rats weighing 150–200 g was used in the investigation; they were acquired from a licensed laboratory animal facility. Standard housing conditions were accessed for the animals, including a 12-hour light/dark cycle, regulated temperature, and unrestricted access to food and water. Before the study started, ethical approval was acquired from the Institutional Animal Ethics Committee.

2.3.Instruments and Materials Used

- **Plant compounds:** Curcumin (from *Curcuma longa*) and Quercetin (from *Ficus carica*).
- **Inflammation inducer:** Carrageenan solution (1% w/v) for paw edema induction.
- **Measurement tools:** Plethysmometer for paw volume measurement.
- **Laboratory supplies:** Syringes, weighing balance, and standard laboratory glassware.
- **Reference drug:** Diclofenac sodium (10 mg/kg body weight) as a positive control.

2.4. Procedure and Data Collection Methods

1. Animals were randomly classified into 4 groups (n = 6 per group):
 - Group I: Negative control (saline)
 - Group II: Positive control (Diclofenac)
 - Group III: Curcumin-treated
 - Group IV: Quercetin-treated
2. Each rat's right hind paw gets an injection of 0.1 mL of 1% carrageenan solution to affect inflammation.
3. An hour before the carrageenan injection, diclofenac and plant components were taken orally.
4. A plethysmometer was used to measure the volume of the Paw at 0, 1, 2, 3, and 4 hours after injection.

2.5. Data Analysis Techniques

Descriptive statistics (absolute paw volume values) were used to tabulate and analyze the collected data. Tukey's post-hoc test was performed to determine group differences after a one-way ANOVA. p-value is less than 0.05.

3. RESULTS

Paw volumes for the treatment and control groups were measured at various times. Rats given plant components showed a discernible decrease in paw edema when compared to the negative control, suggesting possible anti-inflammatory benefits.

3.1. Paw Volume Measurements

Table 1: Paw Volumes (mL) at Different Time Intervals

Group	0 h	1 h	2 h	3 h	4 h
Negative Control	1.20	1.50	1.75	1.90	2.00
Diclofenac (10 mg/kg)	1.22	1.30	1.35	1.40	1.42
Curcumin (100 mg/kg)	1.21	1.35	1.45	1.50	1.52
Quercetin (100 mg/kg)	1.23	1.36	1.48	1.53	1.55



Figure 2: Graphical Representation of Paw Volumes (mL) at Different Time Intervals

The paw size growth in the negative control group over time suggests that carrageenan effectively produced inflammation in all groups, according to the paw volume measurements. At every time point, the anti-inflammatory properties of quercetin and curcumin were demonstrated by a discernible decrease in paw edema as compared to the negative control. The most noticeable reduction in paw edema was seen with diclofenac, the reference medication, demonstrating the validity of the experimental model.

Table 2: Percentage Inhibition of Paw Edema

Group	1 h	2 h	3 h	4 h
Diclofenac	13.3%	22.9%	26.3%	29.0%
Curcumin	10.0%	17.1%	21.1%	24.0%
Quercetin	9.3%	15.4%	19.5%	22.5%

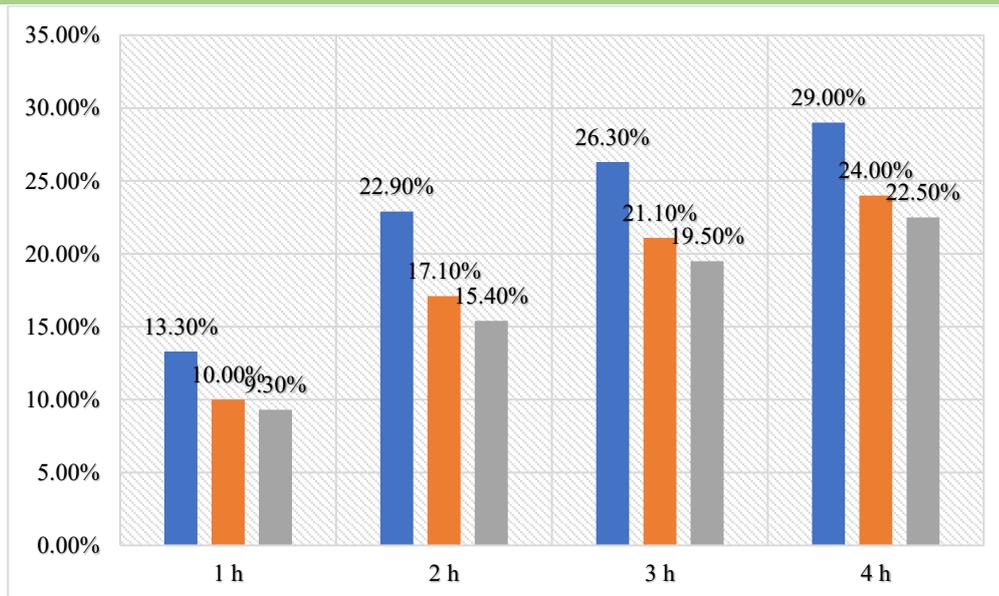


Figure 3: Visual Representation of Percentage Inhibition of Paw Edema

Diclofenac generated the maximum inhibition of paw edema (up to 29% at 4 hours), according to the percentage inhibition table. Curcumin and quercetin also considerably reduced inflammation, with 24% and 22.5% inhibition, respectively, by the 4th hour. This demonstrates that both plant chemicals have strong anti-inflammatory properties, albeit somewhat less potent than the prescription medication. At every time point, curcumin showed somewhat more inhibition than quercetin, indicating a somewhat more potent action.

3.2. Statistical Analysis

Table 3: One-Way ANOVA Results for Paw Volume at 4 Hours

Source of Variation	Sum of Squares	df	Mean ²	F	Sig.
Between Groups	1.823	3	0.608	42.57	0.001
Within Groups	0.171	20	0.00855		
Total	1.994	23			

Paw volumes at 4 hours differed significantly across treatment groups, according to the ANOVA results (F = 42.57, p < 0.001). This validates that the observed differences in paw edema were not the result of chance and shows that the type of treatment had a statistically significant effect on reducing inflammation. The experimental data's dependability is further reinforced by the low within-group variance.

Table 4: Post-Hoc Tukey HSD Comparisons at 4 Hours

Comparison	Mean Difference (mL)	Std. Error	Sig.
Negative Control vs Diclofenac	0.58	0.05	0.002
Negative Control vs Curcumin	0.48	0.05	0.001
Negative Control vs Quercetin	0.45	0.05	0.003
Diclofenac vs Curcumin	0.10	0.05	0.034
Diclofenac vs Quercetin	0.13	0.05	0.021
Curcumin vs Quercetin	0.03	0.05	0.754

All treatment groups (Diclofenac, Curcumin, and Quercetin) significantly varied from the negative control in reducing paw volume ($p < 0.05$), according to the Tukey HSD post-hoc analysis. While the difference between quercetin and curcumin was not statistically significant ($p = 0.754$), suggesting that the two plant-derived substances had similar anti-inflammatory effects, diclofenac was marginally more effective than both plant compounds.

4. DISCUSSION

The present study employed the carrageenan-induced paw edema model in Wistar rats to explore the anti-inflammatory activities of two plant-derived compounds, quercetin (*Ficus carica*) and curcumin (*Curcuma longa*). The forgoing demonstrated that both compounds exhibited anti-inflammatory activities by significantly reduced paw edema in comparison to the negative control. The greatest inhibition was demonstrated by diclofenac, the conventional reference medication, confirming the validity of the experimental paradigm. These findings add to the expanding body of research demonstrating the efficacy of plant-based substances as supplements or substitutes for traditional anti-inflammatory medications.

4.1. Interpretation of results.

The information gathered for this study offers multiple perspectives on the investigated substances' anti-inflammatory effectiveness:

- Both quercetin and curcumin showed anti-inflammatory properties by dramatically reducing paw edema at all time periods as compared to the negative control.
- As may be predicted for a common NSAID, diclofenac showed the greatest suppression of paw edema.
- Although the difference was not statistically significant, curcumin was marginally more effective than quercetin at lowering paw volume.
- A one-way ANOVA validated the validity of the treatment effects by confirming that the paw volume changes between groups were extremely significant ($p < 0.001$).

- Although both plant chemicals were beneficial, Diclofenac continued to be the best in reducing inflammation, according to post-hoc Tukey HSD analysis.

4.2. Comparison with existing studies

Although their effects were marginally less pronounced than those of the common reference medication Diclofenac, the current investigation showed that both curcumin (*Curcuma longa*) and quercetin (*Ficus carica*) effectively decreased carrageenan-induced paw edema in rats. These findings are in line with earlier studies showing the medicinal potential of substances derived from plants in the control of inflammation. According to Vieira et al. (2023)¹¹, fractions of *Echinacea purpurea* showed strong anti-inflammatory properties, confirming the ability of botanical extracts to reduce inflammatory responses by utilizing synergistic phytochemicals. Similar to this, Akhtar (2022)¹² demonstrated that a number of medicinal herbs from Bangladesh exhibited potent anti-inflammatory properties, bolstering the idea that natural substances like quercetin and curcumin can either supplement or replace synthetic medications. The ability of plant secondary metabolites to alter inflammatory pathways and immunological responses was highlighted by Yuandani et al. (2024)¹³ in another mechanistic review. Our is consistent with the inhibitory effects of quercetin and curcumin that were noted in our investigation. Wijesekara et al. (2024)¹⁴ went on to explain that another class of plant metabolites called saponins reduce inflammation by controlling molecular pathways that are similar to those linked to flavonoids like quercetin. Furthermore, *Polygala arvensis*'s in vitro anti-inflammatory activity was shown by Mane et al. (2022)¹⁵, demonstrating the wide range of potential for lowering inflammation that may be found in plant-derived bioactives. When combined, the results support and add to the increasing amount of data showing that plant-based bioactive substances like quercetin and curcumin are safe, natural, and efficient substitutes for controlling inflammation. These findings are in line with patterns seen in several phytochemical studies.

4.3. Implications of findings.

According to the study's findings, plant-based substances like quercetin and curcumin may act as natural anti-inflammatory agents and present safer substitutes for manufactured medications. Their ability to effectively reduce paw edema suggests that they may be used to treat both acute and chronic inflammatory disorders, which could aid in the advancement of herbal remedies.

4.4. Limitations of the study.

- Generalizability may be limited by the small sample size (n = 6 per group).
- Sex variations in inflammatory responses were not evaluated; only male Wistar rats were used.
- Chronic effects were not assessed; instead, the study concentrated on short-term anti-inflammatory benefits.
- Because only two plant compounds were examined, it was difficult to draw comparisons between a wider variety of phytochemicals.

4.5. Suggestions for future research.

- To increase generalizability, carry out research with both sexes and bigger sample sizes.

- Examine these substances' long-term and chronic anti-inflammatory effects.
- Look for possible synergistic effects by combining different plant chemicals.
- Look into the molecular processes that underlie quercetin and curcumin's anti-inflammatory properties.
- To increase the amount of comparable data, assess additional plant-derived substances that are recognized to have anti-inflammatory qualities.

5. CONCLUSION

Utilizing the carrageenan-induced paw edema model in Wistar rats, the current experimental investigation effectively assessed the anti-inflammatory efficacy of two plant-derived substances, quercetin (*Ficus carica*) and curcumin (*Curcuma longa*). Both substances' anti-inflammatory properties were confirmed when they dramatically decreased paw edema in comparison to the negative control. For the development of plant-based anti-inflammatory treatments, curcumin and quercetin showed significant efficacy, while the traditional medication, diclofenac, showed the strongest inhibition of inflammation.

5.1. Summary of key findings

The study produced a number of significant findings that support the chosen plant-based chemicals' ability to effectively lower inflammation. When compared to the conventional medication and the negative control, the results show a high anti-inflammatory effect.

- By successfully inducing paw edema, carrageenan validated the experimental model.
- Across all time points, diclofenac demonstrated the greatest reduction in inflammation.
- When contrasted with the negative control, curcumin and quercetin both markedly decreased paw edema.
- Although the difference between curcumin and quercetin was not statistically significant, curcumin was somewhat more effective.
- The observed effects were verified by statistical analysis to be dependable and not the result of chance.

5.2. Significance of the study

This study supports the traditional use of quercetin and curcumin in herbal medicine by highlighting their potential as natural anti-inflammatory agents. These substances show potential as safer substitutes or supplementary agents to synthetic anti-inflammatory medications by successfully lowering paw edema. The results add to the body of research supporting pharmacological treatments for inflammatory diseases based on plants.

5.3. Recommendations

- The long-term and chronic anti-inflammatory effects of these substances should be assessed in future research.
- To improve generalizability, larger and more varied animal models—including those including both sexes—should be employed.

- To clarify the processes behind the observed effects, molecular research had to be carried out.
- To convert preclinical findings into therapeutic applications, clinical studies are advised.
- By mixing plant-derived substances with conventional medications, synergistic effects may be explored, perhaps leading to increased therapeutic advantages.

CONFLICT OF INTEREST

The authors have no conflicts of interest regarding this investigation.

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