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Therapeutic Potentials of *Curcuma longa* Rhizomes: Antioxidant, Anti-inflammatory, and Gastroprotective Activities

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ABSTRACT

Background: Inflammation is a natural defense mechanism, but its persistence contributes to chronic diseases such as arthritis, cardiovascular disorders, and cancer. Conventional nonsteroidal anti-inflammatory drugs (NSAIDs) are effective but are limited by gastrointestinal adverse effects. *Curcuma longa* L. (turmeric) is traditionally valued for its medicinal properties and has been reported to possess anti-inflammatory, antioxidant, and gastroprotective activities. This study investigated the phytochemical composition, antioxidant activity, anti-inflammatory potential, and gastroprotective effects of the ethanol extract of *Curcuma longa* (EECL) rhizomes.

Methods: Rhizomes of *Curcuma longa* were subjected to Soxhlet extraction using 80% ethanol. Phytochemical screening was conducted qualitatively and quantitatively. Functional groups were characterized using Fourier Transform Infrared (FTIR) spectroscopy. Antioxidant activity was evaluated by DPPH radical scavenging assay with ascorbic acid as the standard. The anti-inflammatory potential was determined in Wistar rats using carrageenan-induced paw edema, while histological evaluation of gastric tissues was performed to assess gastroprotective properties. Statistical analysis was carried out using one-way ANOVA followed by Newman–Keuls post hoc test, with significance set at $p < 0.05$.

Results: Phytochemical analysis revealed the presence of flavonoids (2.33%), terpenoids (2.30%), phenols (1.43%), alkaloids (1.35%), tannins (0.95%), and saponins (0.55%). FTIR analysis identified characteristic peaks corresponding to alkanes, alkenes, aromatic compounds, alcohols, carboxylic acids, and aromatic amines. EECL demonstrated dose-dependent DPPH radical scavenging activity with an IC_{50} of 212.87 µg/mL compared to 20.5 µg/mL for ascorbic acid. Oral administration of EECL (250, 500 and1000 mg/kg) significantly ($p < 0.05$) inhibited paw edema by 47.03–54.67%, whereas indomethacin (10 mg/kg) produced 60.55% inhibition. Histological analysis showed no lesions at 250 and 500 mg/kg EECL, but 1000 mg/kg induced mild gastric inflammation. In contrast, indomethacin caused marked mucosal damage.

Conclusion: The ethanol extract of *Curcuma longa* rhizomes exhibited significant antioxidant and anti-inflammatory properties, with notable gastroprotective effects at moderate doses. These findings provide scientific support for the traditional use of *Curcuma longa* in inflammatory conditions and suggest its potential as a safer natural alternative to NSAIDs. However, higher doses may compromise gastric safety, highlighting the importance of dose optimization for therapeutic applications.

Introduction

Inflammation is a fundamental physiological defense mechanism against infection, tissue injury, and toxins. It involves vascular alterations, immune cell recruitment, and the release of cytokines and mediators that act to restore homeostasis. While acute inflammation is protective, chronic and dysregulated inflammation contributes to the development of several diseases, including arthritis, diabetes, cardiovascular disorders, inflammatory bowel disease, and cancer[1,2]. This has stimulated increasing interest in natural products as safer sources of anti-inflammatory and antioxidant agents.

Among medicinal plants, *Curcuma longa* L. (turmeric; family Zingiberaceae) is well recognized for its broad pharmacological activities and long history of use in Ayurvedic, Chinese, and traditional medicine systems[3,4].

The rhizomes contain bioactive compounds such as curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin), essential oils, and phenolics, which are primarily responsible for its therapeutic potential[5].

Curcumin, the principal active constituent, exhibits potent antioxidant and anti-inflammatory properties through multiple mechanisms. It suppresses pro-inflammatory mediators including cyclooxygenase-2 (COX-2), lipoxygenase, phospholipase A_2, nitric oxide, tumor necrosis factor-α (TNF-α), and interleukins (IL-1, IL-6), while modulating transcription factors such as NF-κB and AP-1[6,7]. Concurrently, it functions as an antioxidant by scavenging free radicals, chelating transition metals, and enhancing the activity of endogenous antioxidant enzymes[8]. Analytical techniques such as Fourier Transform Infrared Spectroscopy (FTIR) facilitate the characterization of functional groups linked to antioxidant activity, whereas assays like 2,2-diphenyl-1-picrylhydrazyl (DPPH) are widely employed to quantify radical scavenging potential[9,10].

Beyond its systemic effects, *Curcuma longa* also demonstrates significant gastroprotective activity. Conventional anti-inflammatory agents such as NSAIDs often cause gastric mucosal injury through oxidative stress and suppression of protective prostaglandins. In contrast, curcumin has been shown to mitigate these adverse effects by strengthening gastric defenses, reducing lipid peroxidation, stimulating mucus secretion, and modulating pro-inflammatory cytokines[11,12]. Preclinical studies further confirm its protective effects against ethanol, indomethacin, and stress-induced gastric ulcers[13,14]. Additionally, curcumin inhibits Helicobacter pylori, a major risk factor for peptic ulcer disease and gastric cancer, thereby contributing to gastrointestinal protection[15].

Collectively, the antioxidant, anti-inflammatory, and gastroprotective properties of *Curcuma longa* highlight its therapeutic promise. This study investigates the antioxidant activity of *Curcuma longa* using FTIR and DPPH assays, along with its anti-inflammatory and gastroprotective potentials.

Materials and Methods

Plant Material Preparation

Fresh rhizomes of *Curcuma longa* L. were collected, washed thoroughly, and air-dried under shade to prevent photodegradation of curcuminoids. The dried rhizomes were ground into coarse powder using a mechanical grinder and stored in airtight containers until extraction.

Extraction

Approximately 200 g of the powdered rhizomes were extracted with 80% ethanol in a Soxhlet apparatus for 72 hours. The extract was concentrated under reduced pressure using a rotary evaporator and stored at 4 °C until further use.

Preliminary Phytochemical screening

Both qualitative and quantitative phytochemical screenings were performed following the established protocols of Trease and Evans[16] and De Silva et al.[17]. The ethanolic extract of Curcuma longa rhizome was tested for phytochemical constituents.

1,1-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity evaluation

A 0.1 mM solution of DPPH was prepared by dissolving the crystalline solid in methanol. Three milliliters of *Curcuma longa* rhizome extract, standard ascorbic acid (ASA), and control (methanol without extract) were tested at different concentrations (50, 100, 150, 200, and 250 µg/mL)[18]. One milliliter of the DPPH solution was added to each test tube, mixed, and incubated in the dark at room temperature for 30 minutes. Absorbance was measured at 517 nm using a spectrophotometer. A decrease in absorbance indicated free radical scavenging activity. The percentage inhibition of DPPH radicals was calculated, and antioxidant activity was expressed as IC_{50}, defined as the concentration of extract required to inhibit 50% of DPPH radicals.

$$\% \text{ Inhibition} = \frac{(\text{Absorbance of Control} - \text{Absorbance of Sample})}{\text{Absorbance of Control}} \times 100$$

Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

FTIR analysis of the extract was performed using validated methods (Liu and Kim[19]; Bolade et al[20].). An Agilent Cary 630 FTIR spectrometer equipped with Microlab PC software and an attenuated total reflectance (ATR) unit was used. The resolution was set at 8 cm^{-1} with a scan range of 4000–400 cm^{-1}.

Experimental animals

Wistar rats of either sex (150–200 g) were obtained from the Central Animal House, University of Ibadan. They were housed in cages under standard conditions of temperature, humidity, and light, fed with pelletized diet (Vital Feeds Ltd, PLC), and given water *ad libitum*. Animals were

acclimatized for five days in the Pharmacology Laboratory, Olabisi Onabanjo University, Sagamu Campus, prior to experimentation. All procedures complied with the "Principle of Laboratory Animal Care" (NIH Publication No. 85–23) and the guidelines for the investigation of experimental pain in conscious animals[21].

Anti-inflammatory evaluation

Carrageenan-induced rat paw oedema

Rats fasted overnight were divided into five groups (n = 5). Group 1 (control) received distilled water (10 mL/kg, p.o.). Groups 2–4 received the ethanol extract of *Curcuma longa* (EECL) orally at doses of 250, 500, and 1000 mg/kg, respectively. Group 5 (reference) received Indomethacin (10 mg/kg, p.o.). Acute inflammation was induced by injecting 0.1 mL of freshly prepared 1% (w/v) carrageenan suspension into the right hind paw of each rat. Paw volume was measured at 1, 2, 3, 4, and 5 hours using a plethysmometer (Ugo Basile, Italy). The difference between paw volume at time Vx and baseline (V0) was considered as the degree of edema (inflammatory response).

Assessment of Gastrointestinal Ulceration

This study evaluated whether the anti-inflammatory effects of *Curcuma longa* are accompanied by gastrointestinal ulceration, as observed with indomethacin, a non-steroidal anti-inflammatory drug (NSAID). Experimental groups received ethanol extract of *Curcuma longa* (EECL) orally at doses of 250, 500, and 1000 mg/kg, or indomethacin (10 mg/kg, p.o.), 1 hour prior to inflammation induction. Following treatment, the stomachs were excised, opened along the greater curvature, and examined macroscopically for mucosal lesions. The severity of gastrointestinal injury was determined histologically, and findings in EECL-treated groups were compared with those in the indomethacin-treated group.

Histological analysis

Stomach tissues were fixed in 10% formalin, embedded in paraffin, and sectioned at 5–6 μm. Sections were stained with Hematoxylin and Eosin (H&E) and examined under a light microscope (Olympus CH02). Gastric mucosal changes between control and treated groups were compared.

Statistical Analysis

Data were presented as mean ± standard error of mean (SEM). The IC_{50} values were determined by linear regression analysis. Comparison of data was done using One-way ANOVA alongside Dunnett's post-hoc tests for multiple comparisons. Graph Pad Prism 6 was used for statistical analysis. P-value of greater than 0.05 was considered significant (P<0.05).

Results

Phytochemical screening results

Qualitative and Quantitative phytochemical screening of the ethanol extract of the rhizomes of *Curcuma longa*

Preliminary qualitative screening of the ethanol extract of *Curcuma longa* confirmed the presence of tannins, phenols, alkaloids, saponins, flavonoids, and terpenoids. Quantitative analysis revealed

flavonoids (2.33%) as the most abundant, followed by terpenoids (2.30%), phenols (1.43%), alkaloids (1.35%), tannins (0.95%), and saponins (0.55%) (Table 1).

Table 1: Phytochemical screening of ethanol extract of the rhizomes of *Curcuma longa.*

Qualitative screening	*Curcuma longa*	Quantitative Screening
Tannin	+	0.95±0.003
Phenol	++	1.43±0.006
Alkaloid	++	1.35±0.004
Saponin	+	0.55±0.002
Flavonoid	++	2.33±0.083
Terpenoid	++	2.30±0.001

Interpretations

+ve = present

++ve = abundantly present

Statistical data were indicated as Mean± Standard Error Mean.

FT-IR Spectrum of the Ethanol extract of *Curcuma longa* rhizomes.

The FTIR spectrum of *Curcuma longa* rhizomes extract exhibited prominent peaks at 3420 cm^{-1}, 2924.9 cm^{-1}, 1690.1 cm^{-1}, 1512.54 cm^{-1}, and 1197.37 cm^{-1}. Figure 1 shows that the spectrum of the ethanol extract of *Curcuma longa* leaves revealed strong C–H stretching at 2924.9 cm^{-1}, conjugated with C=C stretching at 1512.54 cm^{-1}, confirming the presence of alkanes and alkenes. The C–C stretching at 1149.22 cm^{-1} suggested aromatic compounds, while the C–O bands at 1267.42 cm^{-1} confirmed the presence of carboxylic acids. The C–N bands at 1267.12 cm^{-1} indicated aromatic amines, while the C–O stretching at 1197.37 cm^{-1} confirmed the presence of alcohols and carboxylic acids (Figure 1).

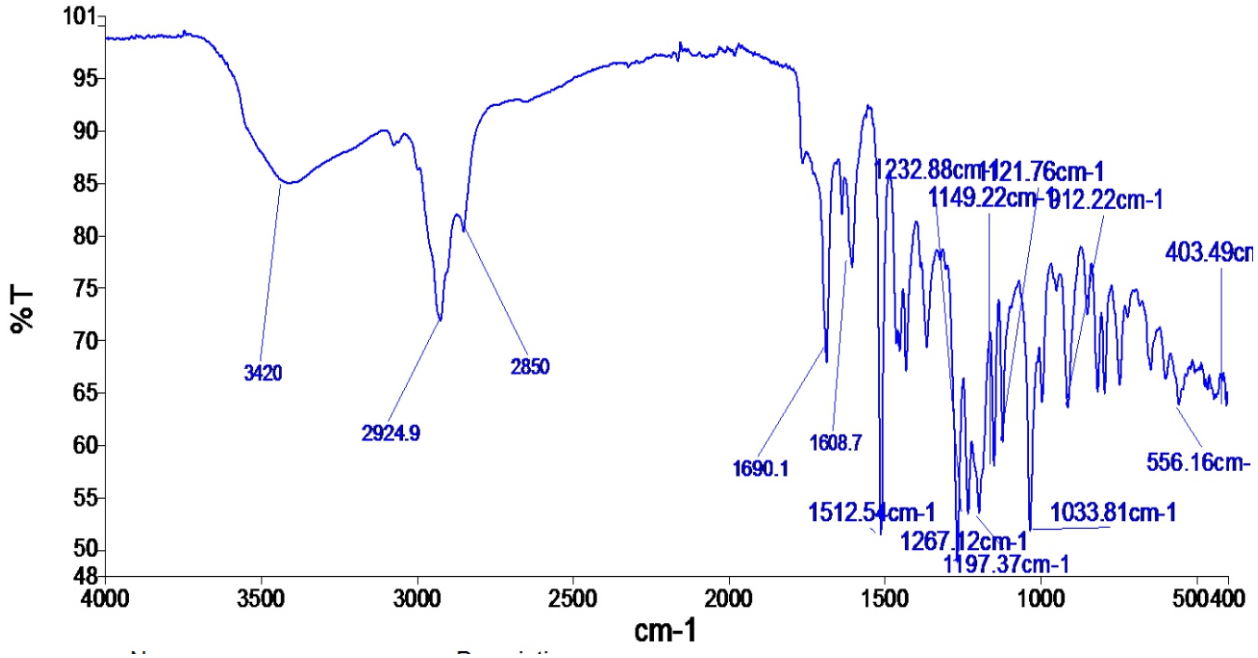

Figure 1: FT-IR Screening of Ethanol extract of *Curcuma longa* rhizomes

Determination of radical scavenging activity by DPPH (2,2-diphenyl-1-picrylhydrazyl) method.

The results of the DPPH radical scavenging assay of different concentrations of ethanol extract of *Curcuma longa* rhizomes and the standard, ascorbic acid, are presented in Table 2. All concentrations of the EECL rhizome extract tested demonstrated *in vitro* DPPH radical scavenging activity in a dose-dependent manner. Similarly, ascorbic acid exhibited increased radical scavenging activity as the concentration increased. The IC_{50} value of the EECL extract was 212.87 µg/mL, while that of ascorbic acid was 20.5 µg/mL (Table 2 and Figure 2).

Table 2: DPPH scavenging activity (% inhibition) by ascorbic acid and ethanol extract of *Curcuma longa* rhizome

EECL Concentration (µg/mL)	50	100	150	200	250	Mean ±SEM	IC_{50}
% Inhibition of DPPH by EECL	29.40	33.61	36.41	42.21	48.31	37.99±7.41	212.87 (µg/mL)
% Inhibition of DPPH by ASA	53.80	55.13	64.64	70.72	72.24	63.31±8.57	20.5(µg/mL)

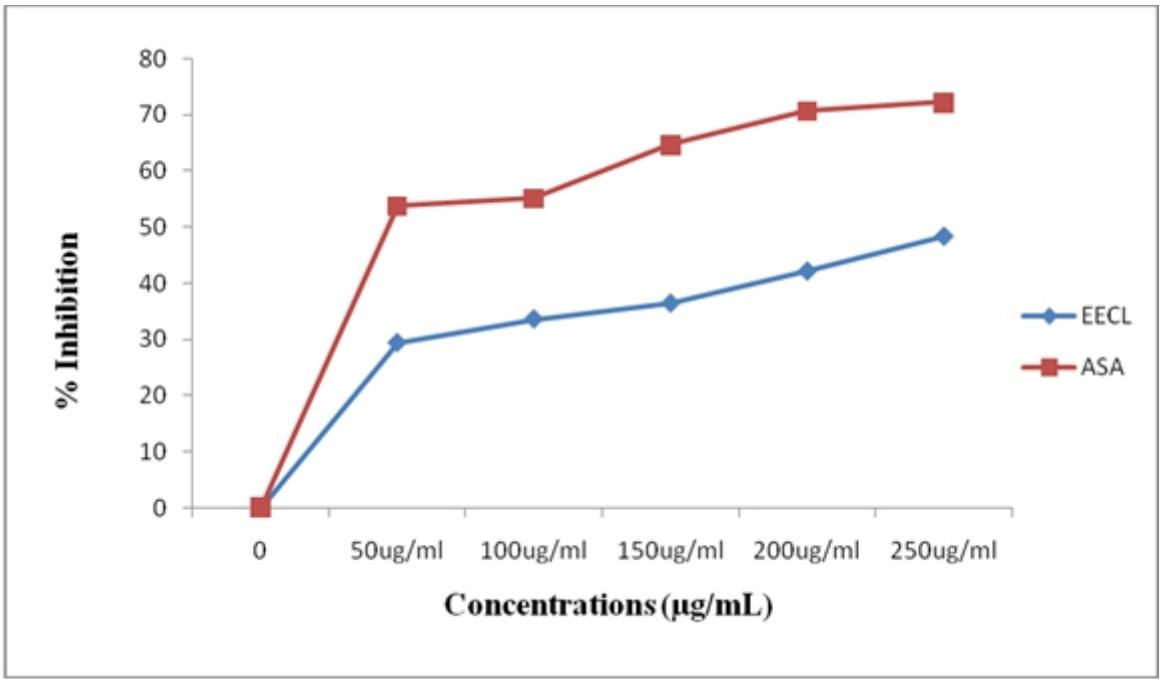

Figure 2: Plot of DPPH radical scavenging percentage between ascorbic acid and ethanol extract of the rhizome of *Curcuma longa*

Effects of Ethanol extract fractions of *Curcuma longa* rhizomes (EECL) in rat paw inflammation induced by carrageenan.

The results of the carrageenan-induced paw edema test in rats orally treated with EECL (250, 500, and 1000 mg/kg) showed that EECL exerted an anti-inflammatory effect by reducing paw volume in a dose-dependent manner (Figure 3).

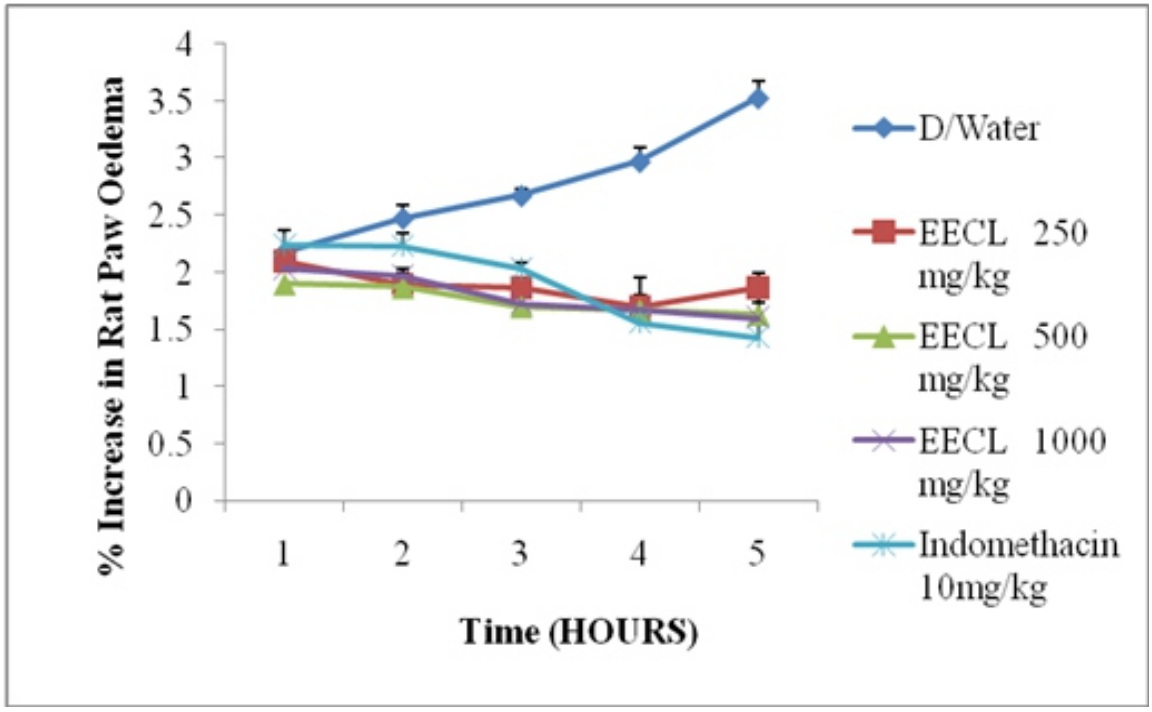

Figure 3: Effect of EECL (250, 500, 1000 mg/kg) on percentage increase in rat paw oedema volume in carrageenan –induced paw.

Effects of Ethanol extract of *Curcuma longa* rhizomes (EECL) on area under the curve (AUC) in rat paw (% Increase in Paw Volume at 5 hour).

The area under the curve (AUC) for the percentage increase in rat paw edema versus time showed that EECL significantly ($p < 0.05$) reduced total edema formation. The percentage inhibition of edema over 5 hours was 47.03%, 53.82%, and 54.67% for EECL at 250, 500, and 1000 mg/kg, respectively. Indomethacin (10 mg/kg), used as the positive control, significantly ($p < 0.05$) reduced edema formation by 60.55% (Figure 4).

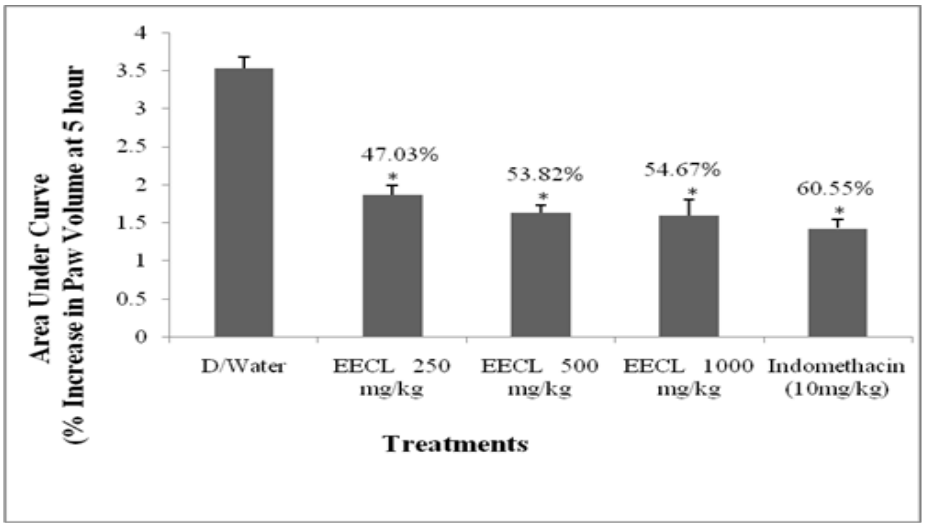

Figure 4: Values are presented as Mean ± SEM (n = 5). Statistical analysis was performed using ANOVA followed by Newman–Keuls post hoc test for multiple comparisons. *p < 0.05 was considered significant relative to distilled water.

Histological Analysis

Histological examination of gastric tissues revealed that control animals (distilled water, EECL 250 mg/kg, and EECL 500 mg/kg showed no observable gastric lesions. In contrast, EECL 1000 mg/kg produced moderate inflammation in the gastric pits, while indomethacin (10 mg/kg) induced hyperplasia of mucous neck cells.

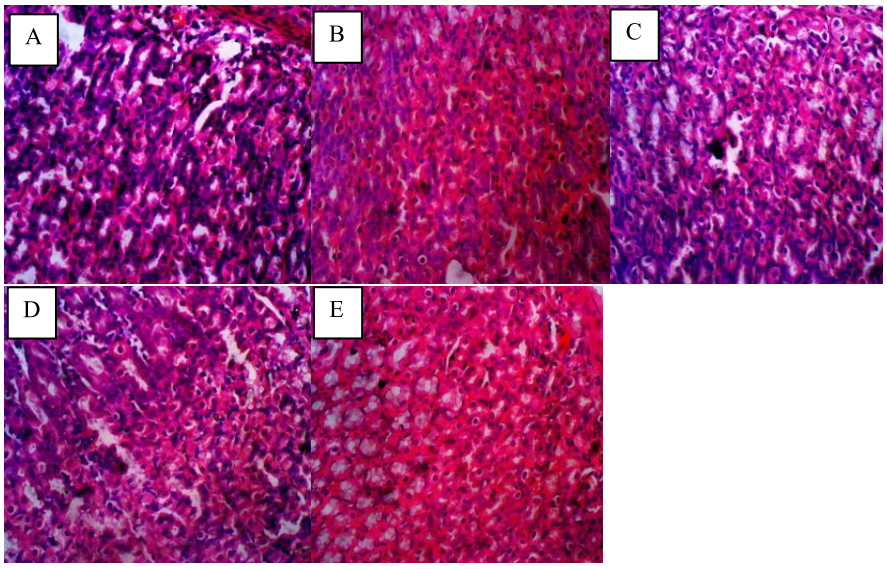

Figure 5: Effect of Ethanol extract of *Curcuma longa* and Indomethacin on the stomach of rats subjected to carrageenan induced-inflammation HE x400.

Histological examination of gastric tissues revealed that control animals (distilled water; A), EECL 250 mg/kg (B), and EECL 500 mg/kg (C) showed no observable gastric lesions. EECL 1000 mg/kg (D) produced moderate inflammation in the gastric pits, indomethacin (10 mg/kg; E) induced hyperplasia of mucous neck cells.

Discussion

Phytochemical screening of *Curcuma longa* rhizomes revealed the presence of saponins, anthraquinones, terpenoids, phenols, flavonoids, cardiac glycosides, steroids, and alkaloids. These findings are consistent with previous reports, including those of Morais-Braga et al[22], thereby supporting the established phytoconstituent profile of *Curcuma longa*. The pharmacological significance of these compounds has been widely documented. Phenolics and flavonoids, in particular, are known for their broad range of biological activities, including wound-healing, anti-inflammatory, anticancer, antibacterial, and antioxidant effects[23,24]. Similarly, saponins exhibit antidiabetic and cholesterol-lowering effects[25], while terpenoids are associated with therapeutic applications against cancer, malaria, and microbial infections[26].

Antioxidants play a critical role in neutralizing oxidative stress induced by free radicals. Phytochemicals such as flavonoids and phenolics function as free radical scavengers, inhibitors of lipid peroxidation, and modulators of redox homeostasis[27, 28]. In the present study, the antioxidant

capacity of *Curcuma longa* ethanol extract was evaluated using *in vitro* methods: the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay.

The DPPH radical scavenging assay further confirmed the antioxidant efficacy of *Curcuma longa*. The deep violet chromophore of DPPH is reduced to yellow upon interaction with hydrogen-donating antioxidants, enabling spectrophotometric quantification at 517 nm[29]. Our results demonstrated a concentration-dependent scavenging activity with reduced IC_{50} values, in agreement with earlier reports[30]. These activities are primarily attributed to the redox potential of phenolic compounds, which facilitate electron transfer, neutralize singlet oxygen, and decompose peroxides [31].

The anti-inflammatory activity of *Curcuma longa* extract was demonstrated using carrageenan-induced paw edema in Wistar rats, a well-established model for acute inflammation[32]. Carrageenan-induced edema typically exhibits a biphasic response: the initial phase (0–1 h) mediated by histamine, serotonin, bradykinin, and substance P, and the late phase (>1 h) associated with neutrophil infiltration, prostaglandin release, and pro-inflammatory cytokine production[32, 33]. In this study, *Curcuma longa* ethanol extract significantly reduced paw edema from the fourth to the fifth hour post-induction, suggesting its action is mediated through the suppression of prostaglandins and cytokine release during the late phase of inflammation. These findings align with those of Ismail et al.[34] and more recent work highlighting the anti-inflammatory potential of Curcuma derivatives[35].

Furthermore, histopathological analysis of rat gastric tissue indicated the absence of mucosal lesions in animals treated with *Curcuma longa* extract, contrasting with indomethacin-induced gastric damage. This demonstrates not only the anti-inflammatory efficacy but also the gastroprotective potential of *Curcuma longa*, corroborating prior observations of its protective role in gastrointestinal health[36].

Collectively, these results validate the traditional medicinal use of *Curcuma longa* and provide mechanistic insights into its antioxidant and anti-inflammatory effects. The synergistic contribution of flavonoids, phenolics, terpenoids, and other secondary metabolites underpins its pharmacological activities, suggesting that *Curcuma longa* extracts may serve as a promising adjunct in the development of safe, plant-derived therapeutics.

Conclusion

This study demonstrates that *Curcuma longa* rhizomes contain diverse phytochemicals that contribute to strong antioxidant and anti-inflammatory activities. The ethanol extract showed concentration-dependent radical scavenging effects and significantly reduced carrageenan-induced inflammation without gastric toxicity. These findings support its traditional use in managing oxidative stress and inflammatory conditions and highlight its potential as a safe, plant-derived therapeutic agent.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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