Comparative Antibacterial Activity of Curcuma longa and Zingiber officinale Against Escherichia coli

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***Abstract*—The increasing prevalence of antibiotic resistance has necessitated the exploration of alternative antimicrobial agents, particularly those derived from natural sources. Plant-based compounds have gained significant attention due to their bioactive properties and reduced side effects. The present study aimed to evaluate and compare the antibacterial efficacy of ethanolic extracts of Curcuma longa (turmeric) and Zingiber officinale (ginger) against environmental isolates of Escherichia coli.**

Ethanolic extracts of turmeric and ginger were prepared using standard solvent extraction techniques. Environmental samples were collected and subjected to microbiological isolation and biochemical identification to obtain E. coli strains. The antibacterial activity was assessed using the agar well diffusion method on sterile nutrient agar plates. Zones of inhibition were measured in centimeters, and experiments were performed in triplicates to ensure reproducibility.

The results demonstrated that both extracts exhibited notable antibacterial activity against E. coli. However, turmeric extract showed a comparatively larger zone of inhibition than ginger extract, indicating higher efficacy. The observed activity is attributed to the presence of bioactive compounds such as curcumin and gingerol.

In conclusion, turmeric exhibited superior antibacterial potential compared to ginger against environmental E. coli. These findings highlight the potential of plant-derived extracts as alternative antimicrobial agents and support further research for their application in pharmaceutical and therapeutic fields.

***Index Terms*—Antibacterial activity; Escherichia coli; Curcuma longa; Zingiber officinale; Ethanolic extract; Agar well diffusion; Natural antimicrobials; Antibiotic resistance**

I. INTRODUCTION

The rapid emergence and global spread of antibiotic-resistant microorganisms have become a critical public health concern, significantly undermining the effectiveness of conventional antimicrobial therapies. The widespread overuse and misuse of antibiotics in clinical, agricultural, and veterinary practices have accelerated the development of resistance mechanisms among pathogenic bacteria, leading to increased morbidity, mortality, and healthcare costs. This alarming trend has necessitated the urgent exploration of novel and sustainable antimicrobial alternatives (World Health Organization, 2020; Ventola, 2015). In this context, plant-derived antimicrobial agents have gained considerable scientific attention due to their natural origin, reduced side effects, and the presence of diverse bioactive compounds capable of targeting multiple microbial pathways (Praditya et al., 2019; Newman & Cragg, 2020).

Medicinal plants have long been utilized in traditional medicine systems for the treatment of infectious diseases. Among these, Curcuma longa (turmeric) and Zingiber officinale (ginger) are extensively studied for their pharmacological and therapeutic properties. Turmeric contains curcumin, a polyphenolic compound known for its potent antimicrobial, anti-inflammatory, and antioxidant activities. Curcumin has been reported to disrupt bacterial cell membranes, inhibit nucleic acid synthesis, and interfere with essential enzymatic processes, thereby exerting strong antibacterial effects (Adamczak et al., 2020; Dai et al., 2022). Similarly, ginger contains bioactive constituents such as gingerol, shogaol, and zingerone,

which exhibit significant antibacterial and antifungal activities. These compounds are known to impair microbial cell integrity and metabolic pathways, contributing to their antimicrobial efficacy (Rahim et al., 2024).

Escherichia coli is a Gram-negative, facultatively anaerobic bacterium commonly present in the gastrointestinal tract of humans and animals. While many strains are harmless, certain pathogenic variants are responsible for severe intestinal and extraintestinal infections. Environmental E. coli is widely recognized as an indicator organism for fecal contamination in water and food systems, making it highly relevant in environmental and public health studies. Its adaptability, rapid growth, and well-characterized physiology make it an ideal model organism for evaluating antimicrobial activity (Jang et al., 2017).

Despite the growing body of literature on plant-derived antimicrobials, comparative studies specifically evaluating the antibacterial efficacy of turmeric and ginger against environmental isolates of E. coli remain limited. Most existing studies focus on clinical strains or individual plant extracts, thereby highlighting a gap in comparative analysis under standardized experimental conditions. Addressing this gap is essential for identifying potent natural antimicrobial agents and optimizing their application in therapeutic and pharmaceutical contexts.

Therefore, the objective of this study was to evaluate and compare the antibacterial activity of ethanolic extracts of turmeric and ginger against environmental E. coli using the agar well diffusion method. This study aims to contribute to the expanding field of phytochemical-based antimicrobials and to provide insights into their potential role as effective alternatives in combating bacterial infections in the era of increasing antibiotic resistance.

II. MATERIALS AND METHODS

2.1 Sample Collection and Isolation of Escherichia coli

Environmental samples were collected from sewage water, using sterile, autoclavable containers to prevent external contamination. Sampling was conducted under aseptic conditions, and all samples were transported to the laboratory in insulated containers and processed within 4–6 hours of collection to maintain microbial viability.

Serial dilution of the samples was performed using sterile distilled water to obtain countable microbial loads. Aliquots from appropriate dilutions were initially inoculated onto sterile Eosin Methylene Blue (EMB) agar plates and incubated at 37°C for 18–24 hours. The use of EMB agar facilitated the selective isolation and differentiation of Gram-negative enteric bacteria, particularly Escherichia coli, which produces characteristic metallic green sheen colonies due to vigorous lactose fermentation.

Following incubation, well-isolated colonies exhibiting typical morphological characteristics were selected and subcultured onto sterile Nutrient Agar plates to obtain pure cultures. This step ensured the maintenance and propagation of the isolated strain under non-selective conditions for subsequent experimental analysis (Jang et al., 2017). Further confirmation was carried out using standard biochemical tests, including Indole, Methyl Red, Voges–Proskauer, and Citrate utilization (IMViC tests) (Cappuccino & Welsh, 2017).

2.2 Preparation of Plant Extracts

Fresh rhizomes of Curcuma longa (turmeric) and roots of Zingiber officinale (ginger) were procured from local markets and authenticated based on morphological characteristics. The plant materials were thoroughly washed with distilled water to remove adhering dirt and impurities, followed by air-drying using hot air over to prevent degradation of thermolabile compounds.

The dried samples were ground into fine powder using a sterile mortar and pestle. Approximately 50 g of each powdered sample was subjected to solvent extraction using 95% ethanol, a widely used solvent for efficient extraction of phytochemicals such as phenolics and flavonoids. The extraction process was carried out using a maceration technique, wherein the plant material was soaked in ethanol and agitated intermittently at room temperature to ensure maximum extraction of bioactive compounds (Dai et al., 2022).

Figure 1. Schematic representation of plant extract preparation from Curcuma longa and Zingiber officinale.

The resulting extracts were filtered using Whatman No. 1 filter paper to remove particulate matter. The concentrated extracts were transferred to sterile, airtight containers and stored at 4°C until further use. Proper storage conditions were maintained to preserve the stability and bioactivity of the extracted compounds (Hussain et al., 2022).

2.3 Antibacterial Assay Using Agar Well Diffusion Method

The antibacterial activity of the plant extracts was evaluated using the agar well diffusion method, which is a standard and widely accepted technique for assessing antimicrobial efficacy. Nutrient Agar plates were prepared and sterilized by autoclaving at 121°C for 15 minutes. The sterile medium was poured into Petri plates and allowed to solidify under aseptic conditions.

A standardized bacterial inoculum was prepared by suspending freshly grown E. coli colonies in sterile Nutrient Broth for 24 hours. The turbidity of the suspension was adjusted to match the 0.5 McFarland standard, corresponding to approximately 1.5×10^8 CFU/mL, ensuring uniform bacterial density across experiments (Balouiri et al., 2016).

The prepared inoculum was evenly spread across the surface of Nutrient agar plates using sterile cotton swabs to obtain a uniform bacterial lawn. Wells of approximately 6 mm diameter were aseptically punched into the agar. Each well was filled with a fixed volume (typically 50–100 µL) of the prepared plant extracts.

Positive controls (standard antibiotics such as Gentamycin) and negative controls (Sterile Distilled water) were included to validate the results. The plates were incubated at 37°C for 24 hours, after which antibacterial activity was assessed based on the formation of clear zones surrounding the wells.

2.4 Measurement of Zone of Inhibition

Following incubation, the antibacterial activity of the extracts was quantified by measuring the diameter of the zones of inhibition around each well. Measurements were taken in centimeters using a calibrated ruler to ensure precision.

Each experiment was conducted in triplicate to ensure reproducibility and reliability of the results. The average zone of inhibition for each extract was calculated, and the consistency of results was assessed by evaluating the variation among replicates. The agar well diffusion method provided a visual and quantitative measure of antibacterial activity, facilitating comparison between different plant extracts (Balouiri et al., 2016).

2.5 Statistical Analysis

All experimental data were expressed as mean ± standard deviation (SD) to represent variability and reproducibility. Statistical analysis was performed using appropriate software tools to determine the significance of differences between groups.

Comparisons between turmeric and ginger extracts were conducted. This statistical approach allowed for the evaluation of whether observed differences in antibacterial activity were meaningful and not due to random variation. The application of statistical analysis strengthened the validity and reliability of the experimental findings.

III. RESULTS

3.1 Isolation and Identification of Escherichia coli

Following serial dilution and inoculation on Eosin Methylene Blue (EMB) agar, well-defined colonies exhibiting a characteristic metallic green sheen were observed after incubation at 37°C for 18–24 hours. This distinct appearance indicated strong lactose fermentation, suggestive of Escherichia coli.

Selected colonies were subsequently subcultured onto sterile Nutrient Agar plates, resulting in the formation of discrete, well-isolated pure colonies. The colonies appeared circular, smooth, and creamy-white in morphology, confirming successful purification under non-selective conditions.

Further biochemical characterization using IMViC tests revealed a pattern of Indole positive (+), Methyl Red positive (+), Voges–Proskauer negative (−), and Citrate negative (−). This characteristic (++−−) profile confirmed the identity of the isolate as E. coli.

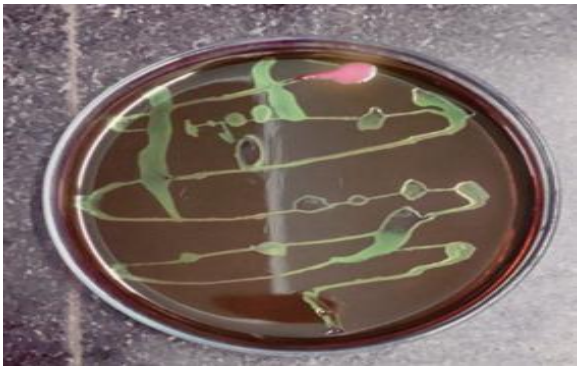

Figure 2: Isolation of Escherichia coli on Eosin Methylene Blue (EMB) agar

3.2 Preparation of Plant Extracts

Ethanolic extraction of Curcuma longa (turmeric) and Zingiber officinale (ginger) yielded concentrated crude extracts with distinct physical characteristics.

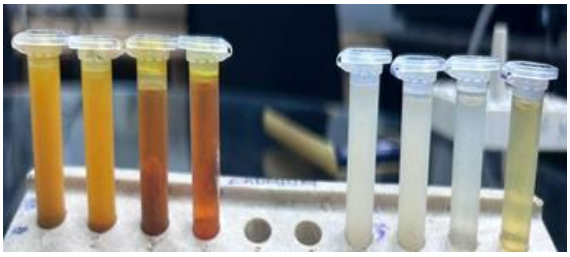

Figure 3. Extraction and storage of plant-derived ethanolic extracts

The turmeric extract appeared deep yellow with a viscous consistency, while the ginger extract exhibited a light yellow to pale brown coloration with comparatively lower viscosity. Filtration using Whatman filter paper effectively removed particulate impurities, resulting in clear filtrates.

Subsequent concentration and storage at 4°C preserved the extracts without any visible signs of contamination, precipitation, or degradation, indicating successful extraction and stability of phytoconstituents.

3.3 Antibacterial Activity by Agar Well Diffusion Method

Both turmeric and ginger extracts demonstrated observable antibacterial activity against E. coli, as evidenced by the formation of clear zones surrounding the wells in the agar plates.

The zones of inhibition were distinctly visible after 24 hours of incubation at 37°C, confirming the ability of the extracts to inhibit bacterial growth. The positive control (Gentamycin) exhibited a pronounced and well-defined inhibition zone, whereas the negative control (ethanol) showed no inhibitory effect, validating the experimental setup.

The results indicate that both plant extracts possess bioactive compounds with antibacterial properties, although their efficacy varied.

3.4 Measurement of Zone of Inhibition

Quantitative assessment of antibacterial activity revealed that turmeric extract exhibited greater inhibitory potential compared to ginger extract.

3.4.1 Turmeric extract showed a mean zone of inhibition ranging between 14–18 mm

3.4.2 Ginger extract exhibited a comparatively lower range of 10–14 mm

3.4.3 The positive control demonstrated the maximum inhibition, while the negative control showed 0 mm inhibition

All experiments were conducted in triplicate, and the measurements showed minimal variation, indicating high reproducibility. The calculated mean values and low standard deviations confirmed the consistency and reliability of the observations.

A comparative analysis (represented graphically) highlighted the superior antibacterial efficacy of

turmeric extract over ginger extract against E. coli.

Table 1: Antibacterial Activity of Turmeric (Curcuma longa) and Ginger (Zingiber officinale) Extracts Against E. coli

Treatment / Concentration	Diameter (cm)	Radius (cm)	Zone of Inhibition (cm²)
Positive Control (Gentamicin)	4.90	2.45	18.86
Negative Control (Distilled Water)	—	—	—
T100	2.90	1.45	6.60
T75	2.00	1.00	3.14
T50	1.70	0.85	2.27
T25	1.60	0.80	2.01
G100	2.10	1.05	3.46
G75	1.50	0.75	1.77
G50	—	—	—
G25	1.40	0.70	1.54

3.5 Statistical Analysis

The experimental data were expressed as mean ± standard deviation (SD), demonstrating a low degree of variability among replicates. Statistical comparison between turmeric and ginger extracts indicated a significant difference in antibacterial activity, with turmeric showing enhanced efficacy.

The application of statistical analysis confirmed that the observed differences were not due to random variation, thereby strengthening the validity of the results. These findings support the conclusion that turmeric possesses greater antibacterial potential against E. coli under the tested conditions.

IV. DISCUSSIONS

The antibacterial activity of turmeric and ginger extracts was evaluated based on the zone of inhibition against E. coli. Both extracts demonstrated measurable inhibitory effects, indicating their antibacterial potential.

Turmeric extract exhibited a larger average zone of inhibition compared to ginger extract. The mean inhibition zone for turmeric ranged between 14–18 mm, while ginger showed a comparatively lower range of 10–14 mm. The positive control showed the highest inhibition, whereas the negative control exhibited no inhibitory effect.

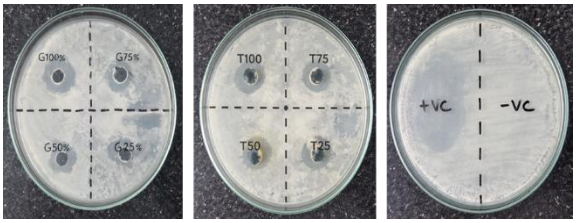

Figure 4. Antibacterial activity of plant extracts against Escherichia coli demonstrated by agar well diffusion assay.

(A) Zones of inhibition produced by ginger extract at varying concentrations: G25 (25%), G50 (50%), G75 (75%), and G100 (100%).

(B) Zones of inhibition produced by turmeric extract at varying concentrations: T25 (25%), T50 (50%), T75 (75%), and T100 (100%).

(C) Control plate showing the positive control (+VC; antibiotic disc) and negative control (−VC; sterile distilled water).

Triplicate analysis ensured consistency of results, with low standard deviation values indicating reproducibility. The comparative bar graph clearly illustrated the superior antibacterial activity of turmeric extract over ginger extract.

The present study demonstrated that both turmeric and ginger extracts possess antibacterial activity against E. coli, with turmeric showing significantly higher efficacy. This difference in activity can be attributed to variations in phytochemical composition and concentration of active compounds.

Curcumin, the primary active compound in turmeric, has been reported to disrupt bacterial cell membranes, inhibit protein synthesis, and interfere with nucleic acid function. These mechanisms collectively contribute to its strong antibacterial activity. On the other hand, gingerol present in ginger exhibits antimicrobial effects through membrane disruption and inhibition of microbial enzymes, though its activity appears comparatively less potent.

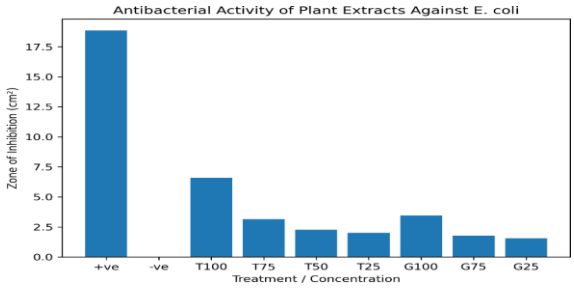

Figure 5. Antibacterial activity of turmeric

(T25–T100) and ginger (G25–G100) extracts against Escherichia coli, expressed as zone of inhibition (cm^2). Gentamicin was used as the positive control (+ve), while distilled water served as the negative control (−ve) and showed no inhibitory effect. A concentration-dependent increase in antibacterial activity was observed for both extracts, with turmeric exhibiting comparatively higher efficacy than ginger at corresponding concentrations.

The findings of this study are consistent with previous research indicating strong antibacterial activity of turmeric extracts against Gram-negative bacteria. Variations in inhibition zones may be influenced by factors such as extraction method, solvent concentration, and bacterial strain variability.

The use of ethanol as a solvent played a crucial role in extracting bioactive compounds effectively, as ethanol is known to solubilize a wide range of phytochemicals. The agar well diffusion method provided a reliable and reproducible means of evaluating antibacterial activity.

However, certain limitations must be considered. The study was conducted in vitro, and results may differ under in vivo conditions. Additionally, only one bacterial strain was tested, limiting the generalizability of findings.

Overall, the study highlights the significant potential of plant-based antimicrobials and supports their further exploration as alternatives to conventional antibiotics.

V. CONCLUSION

The present study systematically evaluated the antibacterial potential of ethanolic extracts of Curcuma longa (turmeric) and Zingiber officinale (ginger) against environmental isolates of Escherichia coli.

Both extracts demonstrated measurable antibacterial activity, confirming the presence of bioactive phytochemicals with inhibitory effects on bacterial growth.

Among the tested samples, turmeric exhibited significantly higher antibacterial efficacy, as evidenced by larger zones of inhibition across all tested concentrations. This enhanced activity can be attributed to curcumin, a well-documented antimicrobial compound capable of disrupting bacterial cell integrity and essential metabolic pathways. Ginger extract, although effective, showed comparatively lower inhibition, suggesting differences in phytochemical potency and concentration.

The inclusion of appropriate positive and negative controls validated the experimental design, while triplicate analysis and low standard deviation values ensured reproducibility and reliability of the results.

Overall, the findings reinforce the potential of plant-derived antimicrobials as sustainable and effective alternatives to conventional antibiotics. Turmeric, in particular, emerges as a promising candidate for further development in antimicrobial therapeutics, especially in the context of rising antibiotic resistance.

VI. FUTURE SCOPE

While the present study establishes the antibacterial potential of turmeric and ginger extracts, several avenues remain open for further investigation. Future research should focus on determining the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) to quantitatively define antimicrobial potency with higher precision.

Expanding the study to include a broader spectrum of microorganisms, including Gram-positive bacteria and multidrug-resistant strains, would enhance the applicability and clinical relevance of the findings. Additionally, exploring synergistic interactions between plant extracts and conventional antibiotics may provide innovative strategies to combat antimicrobial resistance.

Isolation, purification, and structural characterization of active phytoconstituents such as curcumin and gingerol should be undertaken to better understand their molecular mechanisms of action.

Advanced approaches, including molecular docking and omics-based studies, could further elucidate their target pathways.

Moreover, in vivo studies and toxicity assessments are essential to evaluate safety, pharmacokinetics, and therapeutic efficacy under physiological conditions. The incorporation of these extracts into drug delivery systems, food packaging, or antimicrobial coatings also presents promising translational applications.

Collectively, these future directions will bridge the gap between preliminary in vitro findings and real-world biomedical and industrial applications.

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