

Comparative In Vitro Study of Cinnamon (*Cinnamomum burmannii*) Extract and Ciprofloxacin on the Inhibition of *Escherichia coli* Growth Causing Urinary Tract Infection

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Abstrak

Kayu manis (*Cinnamomum burmannii*) mengandung berbagai senyawa bioaktif, terutama sinamaldehida dan eugenol, yang diketahui memiliki sifat antibakteri. Meningkatnya resistansi *Escherichia coli* terhadap antibiotik konvensional menyoroti perlunya pengembangan alternatif alami yang efektif dengan potensi antimikroba. Penelitian ini bertujuan untuk menentukan efektivitas antibakteri ekstrak kayu manis dibandingkan dengan siprofloksasin dalam menghambat pertumbuhan *Escherichia coli*. Penelitian ini merupakan penelitian eksperimental laboratorium menggunakan metode difusi cakram untuk mengukur aktivitas antibakteri. Hasil penelitian menunjukkan bahwa ekstrak kayu manis mampu menghambat pertumbuhan *Escherichia coli*, dengan rata-rata diameter zona hambat sebesar 11,84 mm pada konsentrasi 25%, 13,94 mm pada 50%, 17,52 mm pada 75%, dan 15,79 mm pada 100%. Sebagai pembanding, siprofloksasin menghasilkan zona hambat sebesar 18,37 mm, sedangkan akuades tidak menunjukkan efek penghambatan. Ekstrak kayu manis menunjukkan aktivitas antibakteri terhadap *Escherichia coli*, dengan efektivitas tertinggi pada konsentrasi 75%, meskipun daya hambatnya masih lebih rendah dibandingkan dengan siprofloksasin.

Kata kunci: antibakteri; *Cinnamomum burmannii*; *Escherichia coli*; siprofloksasin

Abstract

Cinnamon (*Cinnamomum burmannii*) contains various bioactive compounds, primarily cinnamaldehyde and eugenol, which are recognized for their antibacterial properties. The increasing resistance of *Escherichia coli* to conventional antibiotics underscores the necessity for developing effective natural alternatives with antimicrobial potential. This study aimed to assess the antibacterial efficacy of cinnamon extract in comparison to ciprofloxacin in inhibiting the growth of *Escherichia coli*. The research employed an experimental laboratory design utilizing the disc diffusion method to measure antibacterial activity. The results indicated that cinnamon extract effectively inhibited the growth of *Escherichia coli*, with mean inhibition zone diameters of 11.84 mm at 25%, 13.94 mm at 50%, 17.52 mm at 75%, and 15.79 mm at 100% concentrations. In comparison, ciprofloxacin produced an inhibition zone of 18.37 mm, while Aquadest exhibited no inhibitory effect. Cinnamon extract demonstrated antibacterial activity against *Escherichia coli*, with the highest efficacy observed at a concentration of 75%, although its inhibitory power was still lower than that of ciprofloxacin.

Keywords : antibacteria; *Cinnamomum burmannii*; ciprofloxacin; *Escherichia coli*

Introduction

Escherichia coli is one of the predominant bacteria naturally present in the normal human intestinal flora. While it plays a crucial role in maintaining gut microbiota balance, this bacterium can also act as a pathogen, causing various diseases both within the gastrointestinal

tract, such as diarrhea, and outside it, including pneumonia, bacteremia, and intra-abdominal infections like spontaneous bacterial peritonitis (1). The increasing potential for antibiotic resistance renders *E. coli* an important yet often overlooked pathogen, with rising mortality rates as the effectiveness of antimicrobial therapy declines (2). Infections caused by *Escherichia coli* can lead to a range of clinical manifestations, including diarrhea, abdominal pain, and fever; in severe cases, these infections may result in dehydration and systemic complications. Antibiotics are commonly employed as the primary treatment for these infections. Ciprofloxacin functions by inhibiting the activity of the bacterial enzymes DNA gyrase and topoisomerase II and IV, which are essential for bacterial DNA replication and transcription (3).

Infections caused by *Escherichia coli* are commonly treated with various classes of antibiotics. However, in recent years, the emergence of antibiotic-resistant *E. coli* strains has increased, particularly against β -lactam antibiotics such as penicillins and cephalosporins. This resistance is primarily due to the ability of *E. coli* to produce β -lactamase enzymes that degrade the β -lactam ring within the antibiotic structure, thereby diminishing the drug's effectiveness in eliminating bacteria. Consequently, treating infections caused by *E. coli* has become increasingly challenging, posing a significant dilemma in clinical practice (4).

Ciprofloxacin, a fluoroquinolone antibiotic, exhibits broad-spectrum activity against both Gram-negative and Gram-positive bacteria. Its mechanism of action involves the inhibition of the bacterial enzymes topoisomerase IV and DNA gyrase, which are essential for DNA replication and repair (5) Ciprofloxacin has demonstrated strong efficacy against *E. coli* and other pathogens responsible for soft tissue, urinary tract, and respiratory infections, making it one of the primary therapeutic options for treating both Gram-positive and Gram-negative bacterial infections (6).

Numerous studies have demonstrated that various plant extracts exhibit significant antimicrobial activity. One such extract is cinnamon (*Cinnamomum burmannii*), which has been shown to inhibit the growth of *Escherichia coli*. This antibacterial activity is attributed to its bioactive compounds—such as cinnamaldehyde, flavonoids, tannins, and phenols—which disrupt bacterial cell wall integrity and inhibit the proliferation of pathogenic microorganisms (7). Previous research by Retnaningsih et al. indicated that lemon peel (*Citrus limon L.*) extract effectively inhibited the growth of *Escherichia coli*, revealing strong to very strong antibacterial activity. This effect is attributed to its bioactive constituents, including saponins, tannins, alkaloids, and flavonoids, which damage bacterial cell walls and inhibit bacterial proliferation.

Furthermore, a positive correlation was observed between extract concentration and inhibition zone diameter, with higher concentrations resulting in stronger antibacterial effects against *E. coli* (8). Among plant-derived antibacterial agents, cinnamon bark exhibits remarkable antimicrobial potential. Research by Taufiqurrahman and Pijaryani (2023) reported that cinnamon bark extract effectively inhibited the formation of *E. coli* colonies, indicating its potential as a natural antibacterial agent. However, previous studies on *Cinnamomum burmannii* have generally focused on its broad-spectrum antibacterial effects, with limited investigation specifically targeting *E. coli* strains associated with urinary tract infections (UTIs). Moreover, many existing studies used varying extraction methods or lacked direct comparison with standard antibiotics, making it difficult to establish its relative potency. Therefore, further in vitro evaluation using standardized methods and comparative testing with conventional antibiotics such as ciprofloxacin is necessary to validate and strengthen its potential as a natural antibacterial alternative. Given the increasing prevalence of antibiotic-resistant *E. coli* strains, exploring cinnamon extract as a natural antibacterial agent has become increasingly important in efforts to reduce reliance on synthetic antibiotics. Therefore, the aim of this study was to evaluate the antibacterial effectiveness of cinnamon (*Cinnamomum burmannii*) extract in inhibiting the growth of *Escherichia coli* and to compare its activity with that of ciprofloxacin under in vitro conditions.

Materials and Methods

This study utilized an in vitro experimental design to assess the antibacterial activity of cinnamon (*Cinnamomum burmannii*) extract in comparison to ciprofloxacin against *Escherichia coli*. The research was conducted in the Microbiology Laboratory at Universitas Prima Indonesia, employing the disc diffusion method to measure bacterial growth inhibition zones. The extract concentrations tested were 25%, 50%, 75%, and 100%, with ciprofloxacin serving as the positive control and distilled water (Aquadest) as the negative control. Each treatment was repeated six times (n=6), and the inhibition zones were measured in millimeters using a digital caliper. Data obtained from the inhibition zone measurements were analyzed using one-way analysis of variance (ANOVA) to determine whether there were statistically significant differences in antibacterial activity among the treatment groups. When significant differences were detected, a Post Hoc Bonferroni test was applied to identify specific group differences between concentrations. A p-value of less than 0.05 was considered statistically

significant. This study received ethical approval from the Ethics Committee of Universitas Prima Indonesia with approval number 069/KEPK/UNPRI/IV/2025.

Materials

The materials used in this study included *Escherichia coli* isolates obtained from clinical urine samples, pure cinnamon bark (*Cinnamomum burmannii*) powder, ethanol 96%, Aquadest, and ciprofloxacin (as the positive control). The culture media used consisted of Nutrient Agar (NA) and Mueller-Hinton Agar (MHA). The equipment used included Petri dishes, Erlenmeyer flasks, pipettes, an incubator, an analytical balance, an autoclave, and a digital caliper for measuring inhibition zones.

Preparation of Cinnamon Extract

The cinnamon bark was cleaned, dried at room temperature, and ground into a fine powder. The extraction process was carried out using maceration with 96% ethanol for 72 hours with occasional stirring. The macerate was filtered using Whatman paper No. 1, and the filtrate was evaporated using a rotary evaporator at 40–50°C until a concentrated extract was obtained. The extract was stored in sterile containers at 4°C until further testing.

Preparation of Bacterial Culture

A pure culture of *E. coli* was reactivated on Nutrient Agar and incubated at 37°C for 24 hours. A bacterial suspension equivalent to 0.5 McFarland standard (approximately 1.5×10^8 CFU/mL) was prepared by diluting the culture in sterile saline solution.

Antibacterial Activity Test

The antibacterial potential of *Cinnamomum burmannii* extract was evaluated using the Kirby–Bauer disc diffusion method. Four concentrations of the extract—25%, 50%, 75%, and 100%—were prepared, and each experimental and control group was tested in six times ($n=6$) to ensure data accuracy. Sterile paper discs measuring 6 mm in diameter were infused with each concentration of the extract and carefully placed on Mueller–Hinton Agar (MHA) plates previously inoculated with an *Escherichia coli* suspension. Ciprofloxacin discs served as the positive control to benchmark antibacterial activity, while ethanol-soaked discs were used as the negative control to exclude solvent influence. The plates were incubated at 37°C for 24 hours under aseptic conditions. Following incubation, the inhibitory zones around each disc were measured in millimeters using a digital caliper, providing quantitative evidence of the cinnamon extract’s inhibitory effect on *E. coli* growth.

Research Results

The measurement results will indicate the diameter of the inhibition zone in millimeters (mm) produced by the cinnamon (*Cinnamomum burmannii*) extract. Measurements will be conducted using a caliper.

Table 1. Inhibition zone diameter of *Escherichia coli* against *Cinnamomum burmannii* extract

Replication	Cinnamon Bark Extract (<i>Cinnamomum burmannii</i>)				Negative control (-)	Positive control (+)
	100%	75%	50%	25%		
1	16.35	18.86	13.47	9.36	0	16.59
2	18.47	17.92	12.76	12.22	0	18.81
3	17.19	16.28	15.13	8.78	0	21.55
4	15.88	18.98	14.61	10.89	0	19.50
5	12.08	17.08	14.00	12.75	0	18.55
6	13.11	16.03	13.67	13.20	0	17.20

Table 1 presents the measurement results of the inhibition zones formed by *Cinnamomum burmannii* (cinnamon bark) extract against *Escherichia coli* at various concentrations (100%, 75%, 50%, and 25%). The inhibition zones were measured in millimeters (mm) for six replications. The negative control (–) showed no inhibition zone (0 mm), indicating no antibacterial effect. In contrast, the positive control (+) produced inhibition zones ranging from 16.59 mm to 21.55 mm. Overall, the cinnamon bark extract exhibited antibacterial activity against *E. coli*, with the highest inhibition observed at concentrations of 75% and 100%, and progressively smaller zones at lower concentrations (50% and 25%).

Table 2. Inhibition Zone Diameter (mm)

Group	Mean±SD	p-value
<i>Cinnamomum burmannii</i> extract 25%	11.84 ± 1.83	0.001
<i>Cinnamomum burmannii</i> extract 50%	13.94 ± 0.84	
<i>Cinnamomum burmannii</i> extract 75%	17.52 ± 1.26	
<i>Cinnamomum burmannii</i> extract 100%	15.79 ± 2.44	
Ciprofloxacin	18.37 ± 1.76	
Distilled water (Aquadest)	0.00 ± 0.00	

The results presented in Table 2 show that *Cinnamomum burmannii* extract exhibits a clear antibacterial effect that generally increases with concentration, as reflected by the progressively larger inhibition zones observed at 25%, 50%, and 75% extract levels. The 75%

extract demonstrates the strongest antibacterial activity (17.52 ± 1.26 mm), although the inhibition zone slightly decreases at the 100% concentration (15.79 ± 2.44 mm), suggesting a possible plateau or reduced effectiveness at full extract strength. When compared to the positive control, ciprofloxacin (18.37 ± 1.76 mm), all concentrations of the extract show lower activity, although the 75% extract approaches its inhibitory effect, indicating notable antibacterial potential. Meanwhile, the negative control (distilled water) shows no inhibition zone, confirming the validity of the experimental procedure. The statistically significant p-value (0.001) indicates that the differences in inhibition zones among the groups are meaningful and not due to chance. Overall, these findings demonstrate that *Cinnamomum burmannii* extract possesses significant, concentration-dependent antibacterial activity, with the 75% extract showing the most promising effect.

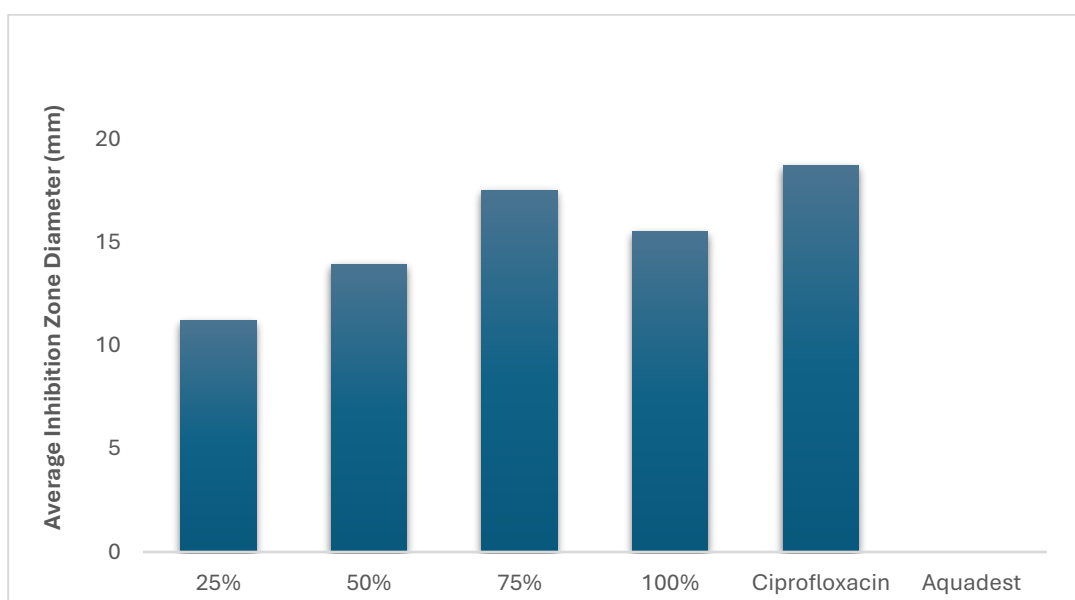


Figure 1. Average Inhibition Zone Diameter (mm)

This figure illustrates the average inhibition zone diameter (mm) of *Cinnamomum burmannii* extract against *Escherichia coli* at various concentrations (25%, 50%, 75%, and 100%), compared with the positive control (Ciprofloxacin) and the negative control (Aquadest). The results show that the largest inhibition zone was produced by Ciprofloxacin, with an average diameter close to 18 mm, confirming its strong antibacterial activity. Among the extract concentrations, the 75% concentration demonstrated the highest inhibitory effect (approximately 17 mm), followed by 100% (around 15–16 mm), 50% (about 14 mm), and 25% (around 11 mm). The Aquadest (negative control) did not produce any inhibition zone,

indicating the absence of antibacterial activity. These findings suggest that *Cinnamomum burmannii* extract possesses antibacterial potential against *E. coli*, with the 75% concentration showing optimal effectiveness, although it is still lower than Ciprofloxacin, the standard antibiotic control.

Table 3. Post Hoc Bonferroni Test Results of Cinnamon Bark (*Cinnamomum burmannii*) Extract Against the Growth of *Escherichia Coli*

Group Comparison	Extract Concentration	n	p-value
Ciprofloxacin vs Cinnamon Extract	100%	6	0.021
	75%	6	1.000
	50%	6	0.000
	25%	6	0.000
	Aquadest	6	0.000
Aquadest vs Cinnamon Extract	100%	6	0.000
	75%	6	0.000
	50%	6	0.000
	25%	6	0.000
Cinnamon Extract 25% vs Other Concentrations	50%	6	0.076
	75%	6	0.000
	100%	6	0.000
Cinnamon Extract 50% vs Other Concentrations	75%	6	0.006
	100%	6	1.000
Cinnamon Extract 75% vs 100%	100%	4	0.511

The post hoc Bonferroni analysis revealed that cinnamon bark (*Cinnamomum burmannii*) extract exhibited significant antibacterial activity against *Escherichia coli*, particularly at higher concentrations. A statistically significant difference was noted between ciprofloxacin and the 100% extract concentration ($p = 0.021$), indicating that although ciprofloxacin was more effective overall, the 100% extract still produced a measurable inhibitory effect. However, ciprofloxacin did not show a significant difference from the 75%, 50%, and 25% extract concentrations (all $p = 1.000$), suggesting that these lower concentrations did not achieve antibacterial effects comparable to the positive control. When aquades (negative control) was compared with all cinnamon extract concentrations (100%, 75%, 50%, and 25%), consistent and highly significant differences were observed (all $p = 0.000$), confirming that even the lowest concentration of the extract demonstrated antibacterial activity, while aquades exhibited no inhibitory effect. Further intragroup comparisons among the extract concentrations revealed a clear concentration-dependent trend, where increasing extract concentration was associated with stronger antibacterial activity. Although the comparison between the 25% and 50% concentrations approached significance ($p = 0.076$), this suggests an emerging increase in

effect. More pronounced differences were observed when comparing 25% to the 75% and 100% concentrations (both $p = 0.000$), reinforcing that higher concentrations are markedly more effective. Additionally, the 50% extract showed a significant difference from the 75% concentration ($p = 0.006$), but no significant difference from the 100% concentration ($p = 1.000$), suggesting that the antibacterial effect begins to plateau between 50% and 100%. Finally, the absence of a significant difference between the 75% and 100% concentrations ($p = 0.511$) indicates that the maximum antibacterial effect is likely achieved at the 75% extract concentration.

Discussion

The findings of this study revealed that the concentration of *Cinnamomum burmannii* extract exerted a significant influence on its antibacterial activity against *Escherichia coli*. The varying concentrations (25%, 50%, 75%, and 100%) demonstrated a concentration-dependent inhibition pattern when compared with the negative control (distilled water) and the positive control (ciprofloxacin). The results indicate that *C. burmannii* extract effectively inhibited the growth of *E. coli*, with the most pronounced antibacterial effect observed at a concentration of 75%.

The extract exhibited a progressive increase in inhibition zone diameter corresponding to the rise in concentration: 11.84 mm at 25%, 13.94 mm at 50%, and reaching the maximum inhibition zone of 17.52 mm at 75%. However, a slight decline was observed at 100% concentration, with an average inhibition zone of 15.79 mm. By contrast, ciprofloxacin, used as the positive control, produced a larger inhibition zone (18.37 mm), while the negative control (distilled water) showed no inhibition at all. These findings confirm that *C. burmannii* extract possesses substantial antibacterial potential, although its inhibitory activity remains slightly below that of ciprofloxacin. Post Hoc Bonferroni analysis further demonstrated that the differences in antibacterial activity among the treatment groups were statistically significant based on the concentration of the extract. Significant differences ($p < 0.05$) were identified between the 25%, 75%, and 100% concentrations, indicating that the antibacterial effect varied significantly across these levels. Conversely, no significant differences were observed between the 25% and 50% concentrations ($p = 0.076$) or between the 75% and 100% concentrations ($p = 0.511$), suggesting that beyond 75%, increasing the extract concentration did not enhance the inhibitory activity. Thus, the optimal antibacterial concentration of *C. burmannii* extract against *E. coli* was determined to be 75%.

The gradual increase in the diameter of the inhibition zone from 25% to 75% indicates that higher concentrations of *C. burmannii* extract exhibit greater antibacterial potency. This enhancement is likely attributed to the increased diffusion and concentration of bioactive compounds—such as cinnamaldehyde, tannins, flavonoids, and alkaloids within the agar medium, thereby strengthening the inhibitory effect against *E. coli*. However, the observed decline at the 100% concentration may be related to the physicochemical properties of the extract itself. At high concentrations, *C. burmannii* extract becomes highly viscous and dense, reducing the diffusion rate of its active compounds through the agar medium. This increased viscosity limits the ability of molecules like cinnamaldehyde to spread evenly, resulting in a smaller effective contact area with bacterial cells. Additionally, excessive concentration may cause compound aggregation or precipitation, lowering solubility and decreasing the release of active constituents. Intermolecular interactions among phenolic compounds may also lead to partial binding or inactivation of active groups, diminishing their antibacterial potential. Hence, even though the total amount of bioactive compounds is higher, their reduced diffusion and bioavailability at 100% concentration likely explain the slight decline in inhibition zone diameter. These findings align with previous studies demonstrating that *C. burmannii* extract exhibits a dose-dependent inhibitory effect against *E. coli*. Parisa et al. (2019) reported that concentrations of 5%, 10%, 20%, and 40% produced inhibition zones ranging from 3.75 mm to 17.25 mm, confirming that antibacterial activity increases with higher extract concentrations (7). Similarly, Reppi et al. (2016) found that *C. burmannii* extract produced inhibition zones of 14.3 mm against *E. coli* and 25 mm against *Streptococcus pyogenes*. The difference in susceptibility is likely due to the structural characteristics of the bacterial cell wall: *E. coli*, a Gram-negative bacterium, possesses a thick lipopolysaccharide layer that reduces permeability to antimicrobial agents, whereas *S. pyogenes*, a Gram-positive species, lacks such a barrier, making it more susceptible.

The antibacterial properties of *C. burmannii* are mainly attributed to its bioactive constituents, including cinnamaldehyde, flavonoids, tannins, and alkaloids. Cinnamaldehyde disrupts bacterial cell membrane integrity, leading to ion leakage and impaired cellular function (9). Flavonoids alter cell wall permeability and cause structural damage, leading to cell death (10). Tannins bind to bacterial cell wall proteins, inhibiting the formation of new cell walls, while alkaloids, being basic compounds, interact with amino acids in bacterial cell walls and DNA, compromising genetic stability and replication, resulting in cell lysis (11). Beyond structural damage, these bioactive compounds also interfere with essential physiological

processes. Previous research suggests that the active components of *C. burmannii* may inhibit biofilm formation and disrupt the bacterial electron transport chain (12). Therefore, the antibacterial activity observed in this study is likely the result of synergistic interactions among multiple bioactive compounds that simultaneously target the structural and metabolic functions of *E. coli*.

Moreover, technical factors inherent to the disc diffusion method may also influence the inhibition zone measurements. Variables such as the rate of compound diffusion in agar, agar density, bacterial inoculum size, growth rate, and incubation duration can all affect the diameter of the inhibition zone (13). The positive control, ciprofloxacin, produced a significantly larger inhibition zone than all concentrations of *C. burmannii* extract. This is attributed to its well-defined and specific mechanism of action on bacterial genetic processes. Ciprofloxacin, a fluoroquinolone antibiotic, inhibits bacterial DNA gyrase and topoisomerase IV enzymes essential for DNA replication and transcription, causing DNA fragmentation and bacterial cell death (14). Its high efficacy stems from this specific molecular targeting, resulting in broader inhibition zones compared to natural extracts like *C. burmannii*.

This study demonstrates that *Cinnamomum burmannii* extract effectively inhibits the growth of *Escherichia coli* at a concentration of 75%, whereas its antibacterial activity slightly decreases at 100%. While ciprofloxacin remains the most potent antibacterial agent due to its specific molecular mechanism, the significant antibacterial activity of *C. burmannii* highlights its potential as a promising natural antibacterial agent that may complement conventional therapies. The limitation of this study lies in its in vitro design; thus, further in vivo and phytochemical analyses are recommended to determine the specific active compounds responsible for antibacterial activity.

Conclusions and Suggestions

The findings of this study demonstrate that *Cinnamomum burmannii* (cinnamon bark) extract exhibits significant antibacterial activity against *Escherichia coli* in vitro and shows promising potential as a natural antibacterial agent. The formation of clear inhibition zones around the test discs at concentrations of 25%, 50%, 75%, and 100% confirms the antibacterial properties of the extract. This study revealed a significant difference in antibacterial activity among the treatment groups, indicating that variations in extract concentration influence the inhibitory effect on *E. coli*. Further analysis using the Post Hoc Bonferroni test identified the optimal concentration for inhibiting *E. coli* growth as 75%, as increases beyond this level did

not produce a significant improvement in antibacterial activity. Although *C. burmannii* extract produced smaller inhibition zones compared to ciprofloxacin as the positive control, its substantial inhibitory effect highlights its potential as a natural antibacterial agent. These findings suggest that *Cinnamomum burmannii* could be further developed as a complementary or alternative antibacterial compound to support conventional therapeutic approaches.

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