



Antibacterial Activity of Combined Garlic (*Allium sativum*) and Ginger (*Zingiber officinale*) extracts on Bacterial Strains Associated with Urinary Tract Infections in Women

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Abstract	Article History
Background: The increasing prevalence of antibiotic-resistant uropathogens necessitates the search for alternative therapeutic agents. Ginger (<i>Zingiber officinale</i>) and garlic (<i>Allium sativum</i>) have shown documented antibacterial activity against infectious diseases, yet their combined antibacterial activity against urinary tract infection (UTI)-associated pathogens remains inadequately characterized. Objective: This study investigated the antibacterial activity of aqueous and ethanolic extracts of ginger and garlic and their combined effects against uropathogenic <i>Escherichia coli</i>, <i>Staphylococcus aureus</i>, and <i>Streptococcus</i> species. Methods: Agar well diffusion assay was used to determine the zones of inhibition at concentrations ranging from 25 to 400 mg/mL. The Minimum inhibitory concentration (MIC) was determined using broth dilution method, while minimum bactericidal concentration (MBC) was assessed by subculturing from wells showing no turbidity onto fresh agar and checking for colony growth with gentamicin (20 mg/mL) used as the positive control. Results: Ethanolic extracts showed a superior antibacterial activity compared to aqueous extracts. The ethanolic ginger-garlic combination exhibited the highest antibacterial activity, producing a 26.00 mm zone of inhibition against <i>E. coli</i> at 400 mg/mL, approaching the gentamicin control (30.00 mm). Against <i>S. aureus</i>, the aqueous combination yielded 20.00 mm compared to individual extracts (ginger: 10.00 mm; garlic: 18.00 mm). The ethanolic garlic extract showed remarkable potency with MIC of 25.00 mg/mL against <i>E. coli</i>. The combined ethanolic extract demonstrated bactericidal activity (MBC: 200 mg/mL) against all isolates. For comparison, the MBC of individual ethanolic garlic extract against <i>S. aureus</i> was recorded at 400 mg/mL. <i>Streptococcus</i> species exhibited intermediate susceptibility, while <i>S. aureus</i> required higher concentrations for inhibition. Conclusion: The synergistic interaction between ginger and garlic extracts produced an enhanced antibacterial activity against uropathogens, with the ethanolic combination demonstrating bactericidal effects. These findings support the potential development of standardized ginger-garlic formulations as complementary therapeutic options for managing urinary tract infections amidst rising antibiotic resistance. Keywords: <i>Zingiber officinale</i>, <i>Allium sativum</i>, urinary tract infections, antibacterial activity, synergistic effect, minimum inhibitory concentration	Received: 29 Apr 2026 Accepted: 25 May 2026 Published: 11 Jun 2026  Scan QR code to view* License: CC BY 4.0*  Open Access article.
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Introduction

Urinary tracts infections (UTIs) are among the most frequently encountered bacterial infections in clinical practice globally (Mancuso *et al.*, 2023). Research has shown that nearly 50-60% of women will experience at least one UTI in their lifetime (Al Lawati *et al.*, 2024). The primary causative agents of UTIs are pathogenic *Escherichia coli* (UPEC), which account for approximately 80-90% of community-acquired infections (Rubini *et al.*, 2020). Other significant pathogens include *Klebsiella*

pneumoniae, *Proteus mirabilis*, and *Staphylococcus saprophyticus* (Flores-Mireles *et al.*, 2015). The extensive use and misuse of antibiotics have given rise to the emergence of multidrug-resistant (MDR) strains, leading to complication in treatment protocols and intermittent infections (Gupta *et al.*, 2017). According to the World Health Organization (WHO), antibiotic resistance is one of the biggest threats to global health, food security, and development today (WHO, 2020). This alarming trend indicates that there is an urgent need for alternative

therapeutic strategies. Natural products, particularly those derived from medicinal plants; offer a promising avenue for developing new antibacterial agents (Abdallah *et al.*, 2023). Historically, in traditional medicine plants extracts have been utilized to treat various infections due to the presence of antimicrobial compound (Breijyeh and Karaman, 2024). Garlic has been used for centuries in various cultures for its medicinal properties, including its antibacterial, antiviral, antifungal, and anti-inflammatory effects (Sahidur *et al.*, 2023). The bioactive compounds in garlic, such as allicin, alliin and ajoene, contribute to its broad spectrum antimicrobial activity against Gram-positive and negative bacteria (Borlinghaus *et al.*, 2014; Nakamoto *et al.*, 2020). Similarly, ginger is renowned for its medicinal properties, which include antimicrobial, anti-inflammatory, and antioxidant activities. The primary active compounds in ginger, such as gingerols and shogaols, have been shown to possess significant antibacterial properties (Ali *et al.*, 2008). Garlic extract has been shown to exhibit strong antibacterial activity against both Gram-positive and Gram-negative bacteria while ginger extract has demonstrated antibacterial activity against Uropathogenic *Escherichia coli* (UPEC) (Onianwah & Ho, 2018; Iotsor *et al.*, 2019).

Despite these promising findings, there is a need for more comprehensive research to evaluate the potential of the combined effect of garlic and ginger extracts as an alternative treatment for UTIs. This study aims to fill this gap by investigating the synergistic antibacterial activity of these extracts against UTI-causing pathogens for their potential as natural alternative in the treatment of UTI amongst women.

Materials and Methods

Test material

Garlic (*Allium sativum*) and ginger (*Zingiber officinale*) were purchased from Bokkos local market and taken to the Department of Plant Science and Biotechnology, University of Jos for identification and confirmation. Garlic was kept in oven at 60°C for 2 days for drying and then made into a fine powder, while ginger was peeled, washed, coarsely minced, air dried and pulverized with a blender to a fine powder.

Test Microorganism

The clinical isolates were obtained from the Department of Microbiology, National Veterinary Research Institute (NVRI) Vom Plateau State, Nigeria. Biochemical tests were used to identify and confirm the test organisms as *Escherichia coli*, *Streptococcus* species, and *Staphylococcus aureus*. Ethical approval for the use of clinical isolates was obtained from Plateau State Ministry of Health with registration number MOH/MIS/202/VOL 1/2049.

Laboratory preparation of plant materials and extraction

Cold maceration method of extraction as described by Sankeshwar *et al.* (2018) was used to obtain the various extracts employed in this study. Each dried extract was packed in a well labeled sterile sample container and stored in the refrigerator at 4°C until further use.

Evaluation of in-vitro antibacterial activity of plant extracts

Evaluation of antibacterial activity was done using agar well diffusion method as described by Balouiri *et al.* (2016). The plates were allowed to stand for one hour for proper diffusion of extracts

before incubation at 37°C for 24 hours. The diameters of zones of inhibition observed were measured and recorded in millimeters.

Determination of Minimum Inhibitory Concentration (MIC)

The MIC was determined by checking for the minimum concentration of the extract that inhibited the growth of the test organisms according to the method described by Doughari *et al.* (2007). Concentration of each bacterial strain was adjusted to 0.5 MacFarland standards, OD at 600nm to obtain the recommended bacterial population. All the test tubes were inoculated at 37°C for 24 hours after which the test tubes were observed for turbidity. The lowest concentration of the extract that showed no observed turbidity was recorded as MIC for the extract.

Determination of Minimum Bactericidal Concentration (MBC)

The MBC was determined by sub-culturing the broth dilutions that inhibited the growth of the test organisms (i.e., those at or above the MIC) on a Nutrient agar plate according to a method described by (Iotsor *et al.*, 2019). The broth dilutions were streaked onto nutrient agar plates and incubated at 37°C for 24 hours. The lowest concentration of the extracts that prevented the growth of the test organisms on the agar plates were recorded as the MBC indicating that only non-viable microorganisms were present.

Results

The antibacterial activities of aqueous extracts in table 1 showed that *Escherichia coli* and *Streptococcus* species exhibited the highest susceptibility (15.00mm) at concentration of 400mg/ml while a low susceptibility was recorded in *Staphylococcus aureus* (10.00mm) also at 400mg/ml for ginger. Garlic showed a significantly higher antibacterial activity observed against *Staphylococcus aureus* (18.00mm), and *Escherichia coli* (14.50mm) at 400mg/ml. The combined ginger and garlic aqueous extract showed an enhanced antibacterial activity with *Staphylococcus aureus* showing susceptibility of 20.00mm at 400mg/ml.

The result in table 2 shows that the antibacterial activities of ethanolic extracts for ginger against *Escherichia coli* (16.50mm), *Staphylococcus aureus* (16.00mm) and *Streptococcus* species (16.00mm) at 400mg/ml. Garlic extract displayed a considerable antibacterial activity especially against *Escherichia coli* (16.00mm). However, its potential against *Streptococcus* species was the weakest measuring 13.50mm at 400mg/ml. The results also showed the combined extract, established the highest antibacterial activity, especially against *E. coli* (26.00mm) at 400mg/ml, suggesting a synergistic effect in a combined state.

The MIC result for the aqueous extracts in table 3 suggest that *Escherichia coli* exhibited susceptibility at 200.00mg/ml, *Streptococcus* species at 100.00mg/ml and *Staphylococcus aureus* at 400.00mg/ml ginger. The result also indicated that *Escherichia coli* and *Streptococcus* species were both inhibited by the garlic at 400.00mg/ml, while *Staphylococcus aureus* was inhibited at 200.00mg/ml, suggesting a more sensitivity in *Staphylococcus aureus* to the extract. The combined extract inhibited *Escherichia coli* and *Streptococcus* species at 200.00mg/ml, while *Staphylococcus aureus* required 400.00mg/ml.

Table 4 shows the MBC of garlic extract (Aqueous) recorded for *Staphylococcus aureus* at 200.00mg/ml. The MBC of the combined extracts for *Escherichia coli* and *Streptococcus* specie

was 200.00mg/ml, while *Staphylococcus aureus* was 100.00mg/ml. *Staphylococcus aureus* and *Streptococcus* species at 400.00mg/ml.

The result in table 5 showed that *Escherichia coli* was inhibited at 200.00mg/ml, while *Streptococcus* species require 100.00mg/ml for ginger. Garlic shows an order of inhibition with *Escherichia coli* at 25.00mg/ml, *Staphylococcus aureus* at 50.00mg/ml while *Streptococcus* species requires 100.00mg/ml. The combined extract inhibited *Escherichia coli* at 200.00mg/ml, In table 6, ginger did not show any bactericidal effect against the test isolates at the concentrations used. However, garlic showed some effect against *Staphylococcus aureus* recorded at 400.00mg. The combined extracts exhibited bactericidal effect at 200.00mg/ml for all the isolates.

Table1: Antibacterial Activities of Aqueous Extracts

Isolates	Concentrations of extracts (mg/ml) diameter of zones of inhibition (mm)					Extract	Control (Gentamicin 20mg/mL)
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	15.00	13.00	9.00	0.00	0.00	Ginger	30.00
	14.50	11.50	0.00	0.00	0.00	Garlic	30.00
	16.00	12.00	0.00	0.00	0.00	Ginger/Garlic combo	30.00
<i>Staphylococcus aureus</i>	10.00	0.00	0.00	0.00	0.00	Ginger	26.00
	18.00	14.00	0.00	0.00	0.00	Garlic	26.00
	20.00	18.00	16.00	8.00	0.00	Ginger/Garlic combo	26.00
<i>Streptococcus sp</i>	15.00	12.00	10.00	0.00	0.00	Ginger	28.00
	15.00	12.00	10.00	0.00	0.00	Garlic	28.00
	12.00	8.00	0.00	0.00	0.00	Ginger/Garlic combo	28.00

Table 2: Antibacterial activities of Ethanolic Extracts

Isolates	Concentrations of extracts (mg/ml) diameter of zones of inhibition (mm)					Extract	Control (Gentamicin 20mg/mL)
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	16.50	13.50	11.00	9.50	0.00	Ginger	30.00
	16.00	13.00	11.00	0.00	0.00	Garlic	30.00
	26.00	23.00	12.00	8.00	0.00	Ginger/Garlic combo	30.00
<i>Staphylococcus aureus</i>	16.00	12.00	10.00	0.00	0.00	Ginger	26.00
	14.00	10.00	0.00	0.00	0.00	Garlic	26.00
	21.00	18.00	10.00	0.00	0.00	Ginger/Garlic combo	26.00
<i>Streptococcus sp</i>	16.00	14.00	12.00	10.00	0.00	Ginger	28.00
	13.50	10.50	0.00	0.00	0.00	Garlic	28.00
	15.00	12.00	0.00	0.00	0.00	Ginger/Garlic combo	28.00

Table 3: MIC of Aqueous Extract

Isolates	Extract concentrations (%)					Extract	MIC concentration mg/ml
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	-	-á	+	+	+	Ginger	200.00
	-á	+	+	+	+	Garlic	400.00
	-	-á	+	+	+	Ginger/Garlic combo	200.00
<i>Staphylococcus aureus</i>	-	-	-á	+	+	Ginger	100.00
	-	-á	+	+	+	Garlic	200.00
	-á	+	+	+	+	Ginger/Garlic combo	400.00
<i>Streptococcus sp</i>	-á	+	+	+	+	Ginger	400.00
	-á	+	+	+	+	Garlic	400.00
	-	-á	+	+	+	Ginger/Garlic combo	200.00

Key: á = MIC; + = Turbidity; - = No turbidity

Table 4: MBC of Aqueous Extract

Isolates	Extract concentrations (%)					Extract	MBC concentration mg/ml
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	+	+	+	+	+	Ginger	0.00
	+	+	+	+	+	Garlic	0.00
	-	-μ	+	+	+	Ginger/Garlic combo	200.00
<i>Staphylococcus aureus</i>	+	+	+	+	+	Ginger	0.00
	-	-μ	+	+	+	Garlic	200.00
	-μ	+	+	+	+	Ginger/Garlic combo	400.00
<i>Streptococcus sp</i>	+	+	+	+	+	Ginger	0.00
	+	+	+	+	+	Garlic	0.00
	-	-μ	+	+	+	Ginger/Garlic combo	200.00

Key: μ = MBC; + = Turbidity; - = No turbidity

Table 5: MIC of Ethanolic Extracts

Isolates	Extract concentrations (%)					Extracts	MIC concentration (mg/ml)
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	-	-á	+	+	+	Ginger	200.00
	-	-	-	-	-á	Garlic	25.00
	-	-á	+	+	+	Ginger/Garlic combo	200.00
<i>Staphylococcus aureus</i>	+	+	+	+	+	Ginger	0.00
	-	-	-	-á	+	Garlic	50.00
	-	-	-á	+	+	Ginger/Garlic combo	100.00
<i>Streptococcus species</i>	-	-	-á	+	+	Ginger	100.00
	-	-	-á	+	+	Garlic	100.00
	-	-	-á	+	+	Ginger/Garlic combo	100.00

Key: á = MIC; + = Turbidity; - = No turbidity

Table 6: MBC of Ethanolic Extracts

Isolates	Extract concentrations (%)					Extracts	MBC concentration (mg/ml)
	400.00	200.00	100.00	50.00	25.00		
<i>Escherichia coli</i>	+	+	+	+	+	Ginger	0.00
	+	+	+	+	+	Garlic	0.00
		-μ				Ginger/Garlic combo	200.00
<i>Staphylococcus aureus</i>	+	+	+	+	+	Ginger	0.00
		+	+	+	+	Garlic	400.00
		-μ				Ginger/Garlic combo	200.00
<i>Streptococcus species</i>	+	+	+	+	+	Ginger	0.00
	+	+	+	+	+	Garlic	0.00
		-μ				Ginger/Garlic combo	200.0

Key: μ = MBC; + = Turbidity; - = No turbidity

Discussion

The increasing challenge of antibiotic resistance, particularly among uropathogens, necessitates the search for alternative therapeutic agents for the treatment of UTI (Ayman, 2025). The finding in this study revealed that the ethanolic extract of ginger exhibited superior activity compared to its aqueous counterpart, producing inhibition zones of 16.50 mm against *E. coli* and 16.00 mm against both *S. aureus* and *Streptococcus sp.* at 400 mg/mL. In contrast, the aqueous ginger extract produced a 15.00 mm zone against *E. coli* and only 10.00 mm against *S. aureus* at the same concentration. This observation aligns with previous reports demonstrating that organic solvents, particularly ethanol, are more efficient at extracting bioactive phytochemicals such as flavonoids, tannins, and alkaloids from plant materials compared to water (Aliyu *et al.*, 2017; Bello *et al.*, 2023). The enhanced extraction of these non-polar antimicrobial

compounds likely accounts for the superior performance of ethanolic preparations.

For garlic, however, the aqueous extract demonstrated notable activity against *S. aureus* (18.00 mm), surpassing the ethanolic extract's effect (14.00 mm) at 400 mg/mL. This differential susceptibility suggests that the water-soluble antimicrobial components of garlic, primarily allicin and other sulfur-containing compounds, are highly effective against Gram-positive organisms. Bello *et al.* (2023) similarly reported that aqueous garlic extracts produced zones of inhibition ranging from 14 to 16 mm against clinical isolates, supporting the present findings in this study.

The most striking observation was the enhanced antibacterial activity when ginger and garlic extracts were combined. For ethanolic extracts against *E. coli*, the combination produced a

26.00 mm inhibition zone at 400 mg/mL, representing a 58% increase compared to ginger alone (16.50 mm) and 62.5% compared to garlic alone (16.00 mm). Similarly, against *S. aureus*, the aqueous combination yielded 20.00 mm compared to 10.00 mm (ginger) and 18.00 mm (garlic) individually. This pattern of enhanced activity strongly indicates synergistic interaction between the two plant extracts. The synergistic mechanism likely involves complementary phytochemical profiles. Ginger contains gingerols, shogaols, and zingerone, while garlic provides allicin, ajoene, and other organosulfur compounds (Ayman, 2025). These compounds may target different bacterial cellular processes simultaneously disrupting cell wall synthesis, interfering with protein function, and inhibiting nucleic acid synthesis, thereby producing an effect greater than the sum of individual contributions (Ali *et al.*, 2016). The combination of ginger and garlic enhances the pharmacological properties of each, leading to improved antimicrobial, antioxidant, and anti-inflammatory activities, a synergism attributed to the interaction of phytochemicals present in both plants (Hartfield, 2023).

The Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) data showed that ethanolic garlic extract have an MIC of 25.00 mg/mL against *E. coli* representing a remarkable potency, substantially lower than previously reported values of 125 mg/mL for similar preparations (Bello *et al.*, 2023). This discrepancy may reflect variations in extraction methodology, garlic cultivar, or bacterial strain susceptibility.

The MBC data revealed that while individual extracts demonstrated predominantly bacteriostatic activity, the combination achieved bactericidal effects. The combined ethanolic extract exhibited MBC values of 200 mg/mL against all three isolates, whereas ginger alone showed no bactericidal activity at the concentrations tested, and garlic only demonstrated MBC against *S. aureus* at 400 mg/mL. This observation is clinically significant, as bactericidal agents are generally preferred for treating urinary tract infections, particularly in immunocompromised patients.

Urinary tract infections remain among the most common bacterial infections in women, with *E. coli* accounting for approximately 75-80% of cases, followed by *S. aureus* and *Streptococcus* species (Faris *et al.*, 2024; Ali *et al.*, 2016). The rising resistance to conventional antibiotics such as gentamicin, as evidenced by the discrepancy between control (26-30 mm) and extract inhibition zones, underscores the urgent need for alternative strategies. The finding that the ginger-garlic combination produced a 26.00 mm zone against *E. coli*—approaching the 30.00 mm gentamicin control, indicates that this botanical combination holds promise as an adjunctive or alternative therapeutic option. Furthermore, the concentration-dependent activity observed across all extracts supports the feasibility of developing standardized formulations for clinical application. The fact that the combination maintained activity at lower concentrations (200 mg/mL and 100 mg/mL) indicates potential for dose optimization, which could minimize adverse effects while maintaining therapeutic efficacy.

Conclusion

In conclusion, these findings underscore the potential of combining natural plant extracts to enhance their antibacterial properties and offer a promising alternative to conventional antibiotics, especially in the treatment of UTIs caused by pathogens such as *E. coli*, *S. aureus*, and *Streptococcus* species. This study provides valuable preliminary data on the synergistic antibacterial activity of combined ginger and garlic extracts against selected uropathogens. However, the absence of statistical replication, unidentified bacterial strains, lack of cytotoxicity assessment, and exclusive reliance on in vitro methods limit the generalizability and clinical applicability of the findings. Future studies should address these limitations through rigorous experimental design including statistical validation, strain identification, safety profiling, and in vivo confirmation.

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Conflict of Interests

No conflict of interest

Authors Contributions

All authors contributed significantly to the study design, sample collection, analysis, and interpretation. They also gave immense contribution to the article's writing, revising, or critical evaluation and gave final approval for the version to be published.

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