Comparative Proximate Composition and Antibacterial Activity of Garlic (*Allium Sativum*) and Ginger Zingiber (*Zingiber Officinale*) Extracts Against *Staphylococcus Aureus* and *Escherichia Coli*

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ABSTRACT

As antimicrobial resistance is becoming more common, the need for plant-based antimicrobial agents as alternatives to traditional antibiotics has become more urgent. Garlic (Allium sativum) and ginger (Zingiber officinale) are medicinal plants popular for their antimicrobial activity but there is little comparative data on the effect of solvent used in the extraction process on their antibacterial activity. In this study, the antimicrobial activities and proximate composition of garlic and ginger methanol and n-hexane extracts were compared with Staphylococcus aureus and Escherichia coli. An experimental approach was taken for laboratory design. Methanol and n-hexane were used to process and extract the fresh garlic bulbs and ginger rhizomes. The analysis of proximate composition was done by standard analytical procedure and the antibacterial activity was assessed by agar well diffusion method. Data were statistically analyzed with descriptive statistics and ANOVA (One Way Analysis of Variance) at 5% level of significance. Garlic powder had low moisture (5.09%) and high ash (29.88%) and lipid (2.17%) contents compared to ginger, while ginger had high crude fibre (0.96%) and protein (0.44%). The methanolic garlic extract exhibited the highest antibacterial activity against Staphylococcus aureus (1.03 ± 0.02 cm) and Escherichia coli (1.03 ± 0.02 cm) followed by methanolic ginger extract with inhibition zone of 0.85 ± 0.01 cm and 0.81 ± 0.01 cm, respectively. The antibacterial activities of the n-heane extracts were comparatively low. The differences among the extract treatments were significant for Staphylococcus aureus ($F = 427.71$, $p < 0.001$) and Escherichia coli ($F = 728.25$, $p < 0.001$) growth inhibition by ANOVA. The study findings indicate that the methanolic extract of garlic has greater antibacterial activity as compared to ginger and n-hexane extract, and it can be used as a source of antimicrobial compounds with broad spectrum activity. Extraction optimization, safety evaluation and identification of active phytochemicals are recommended for further studies for pharmaceutical and industrial applications.

Keywords: Allium Sativum, Zingiber Officinale, Antibacterial Activity, Methanol Extract, Staphylococcus Aureus, Escherichia Coli, Antimicrobial Resistance

INTRODUCTION

AMR is one of the biggest public health challenges globally as it has made the use of conventional antibiotics ineffective, causing high morbidity, mortality, and healthcare costs. Increased antimicrobial agent use in human medicine, agriculture and veterinary medicine has facilitated the emergence of multidrug-resistant bacterial pathogens, which are increasingly difficult to treat, and are a growing problem (Murray et al., 2022; World Health Organization, 2023). As a result, natural sources are increasingly being investigated as a source of antimicrobial agents which are effective, inexpensive, and less likely to lead to resistance.

Medicinal plants are a great source of biologically active secondary metabolites having antimicrobial, antioxidant, anti-inflammatory and immunomodulatory property which have attracted considerable attention. The plant-derived compounds, like alkaloids, flavonoids, phenolics, tannins, saponins, terpenoids, and organosulfur compounds have shown inhibitory activities against a wide range of pathogenic microorganisms (Salehi et al., 2023). Phytochemicals can have antimicrobial activity through a variety of mechanisms such as disrupting cellular membranes, inhibiting protein and nucleic acid synthesis, interfering with quorum sensing, and inducing oxidative stress on microbial cells, and can be effective against multiple processes in microbial cells, unlike many synthetic antibiotics which tend to target a single process. These multiple mechanisms may help to decrease the risk of developing resistance quickly.

Garlic (Allium sativum) and ginger (Zingiber officinale) are two medicinal plants with therapeutic and antimicrobial properties that are widely recognized. Garlic is a rich source of sulfur-based compounds, including allicin, ajoene, diallyl sulfides, and S-allyl cysteine, which are reported to have strong antibacterial activity against Gram positive and Gram negative bacteria (Phuong et al., 2025). They are able to enter bacterial cell membranes, block metabolic enzymes and disrupt microbial DNA and protein synthesis. Likewise, ginger has bioactive components like gingerols, shogaols, paradols, zingerone, flavonoids, and phenolic acids with antimicrobial, antioxidant and anti-inflammatory properties (Vatandoust et al., 2025). Ginger has been reported to have antibacterial properties that are believed to be due to its ability to disrupt membrane integrity, increase membrane permeability and inhibit vital physiological processes necessary for the survival of bacteria.

S. aureus and E. coli continue to be two of the most significant bacterial pathogens globally. Staphylococcus aureus (S. aureus) is a Gram-positive bacterium that causes skin and soft tissue infections, pneumonia, bloodstream infections, endocarditis, and hospital-acquired infections and is a significant therapeutic challenge, especially in the case of methicillin-resistant S. aureus (MRSA) (World Health Organization, 2023). Escherichia coli is a Gram-negative bacterium that is commonly associated with the development of urinary tract infections, gastroenteritis, neonatal meningitis, and septicemia, in contrast to Pseudomonas. The structural differences between gram-positive and gram-negative bacteria, especially the outer membrane in gram-negative bacteria, affect the sensitivity of the bacteria to different antimicrobial agents and is also useful for comparing the antibacterial properties of plant extracts.

In recent studies, it has been established that extracts derived from garlic and ginger have measurable antibacterial activity against clinically important bacteria, such as S. aureus and E. coli. It has been discovered from comparative studies that ethanolic extracts tend to exhibit higher antimicrobial activity compared to aqueous extracts as the former extracts a broader spectrum of antimicrobial active phytochemicals (Nabi et al., 2022; Phuong et al., 2025). In addition, the antibacterial activity was found to be different as a result of the use of different extraction solvents, plant varieties, extract concentration, bacterial strains and extraction conditions, indicating that the antimicrobial activity of these plants depends on various experimental parameters and not solely on plant species.

Although considerable amount of literature is available, most of the studies have been conducted on garlic and ginger alone, with varying extraction methods, and primarily on measuring inhibition zone without considering the phytochemical characterization in conjunction with antibacterial evaluation. This makes comparisons between studies difficult and there is little agreement about which plant extract has a greater antibacterial activity against the representative Gram-positive and Gram-negative bacteria under similar experimental conditions. Overcoming this limitation would give a stronger proof of the therapeutic potential of these medicinal plants and help in the search for plant-based antimicrobial agents that can complement the existing antibiotics.

Thus, the aim of this study was to comparatively assess antimicrobial composition and in vitro antibacterial activity of garlic (Allium sativum) and ginger (Zingiber officinale) extracts against Staphylococcus aureus and Escherichia coli. The study also aims to identify the difference in the antibacterial activity of the two plant extracts and to offer evidence for the use of these plant extracts as natural antimicrobial agents.

MATERIALS AND METHODS

Study Design

The study used experimental laboratory design method to compare the phytochemical composition and antibacterial activity of garlic (Allium sativum) and ginger (Zingiber officinale) extracts against Staphylococcus

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aureus and Escherichia coli. The experimental works were carried out in the Microbiology Laboratory and Chemical Engineering Laboratory of Kwara State Polytechnic, Ilorin, Kwara State, Nigeria. Qualitative phytochemical screening was carried out to determine the major bioactive constituents present in the extracts and antibacterial activity was determined by agar well diffusion method. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extracts were also calculated. Each experiment was repeated three times to ensure reliability and reproducibility of data.

Identification and Collection of Materials

Fresh garlic (Allium sativum) bulbs and ginger (Zingiber officinale) rhizomes were procured from a big market in Ilorin, Kwara State, Nigeria. The plant materials were transported to the Chemical Engineering Laboratory, Kwara State Polytechnic, in sterile polyethylene bags. Botanical identification and authentication were done by a plant taxonomist of the Department of Science Laboratory Technology, Kwara State Polytechnic and voucher specimens were kept for reference. The samples that were damaged or deteriorated were discarded prior to lab analysis. The plant extracts were prepared using the method developed by Cheon and Kim (1997).

Preparation of Plant Extract

The garlic bulbs and ginger rhizomes were carefully washed with running tap water and then rinsed with distilled water to get rid of soil and other impurities. The garlic cloves were peeled and ginger rhizomes were cut into small pieces. The samples were oven dried at 40°C, until they reached a constant weight, and then ground individually into fine powder in a sterile laboratory grinder in the Chemical Engineering Laboratory.

Each sample of the powdered samples was macerated individually with 500 mL of 70% ethanol for 72 hours with intermittent shaking. The mixtures were filtered through Whatman No. 1 filter paper and the filtrates were concentrated under reduced pressure at 40°C using rotary evaporator. The extracts were then concentrated by evaporating them to dryness in a water bath and kept at 4°C in sterile amber bottles until further analysis.

Qualitative Phytochemical Screening

The qualitative phytochemical screening of the garlic and ginger extracts were carried out by the standard analytical methods in the Chemical Engineering Laboratory. Established phytochemical methods were used to test for the presence of alkaloids, flavonoids, tannins, saponins, phenolic compounds, terpenoids, steroids, glycosides and reducing sugars in the extracts. The strength of the reactions observed was noted as either absent (-), weak (+), moderate (++), or abundant (+++).

Test Microorganisms

Staphylococcus aureus and Escherichia coli were isolated from the Microbiology Laboratory of Kwara State Polytechnic. Isolates were identified as Gram staining, colony morphology and by standard biochemical tests such as catalase, coagulase, indole, citrate utilisation, oxidase and Triple Sugar Iron (TSI) tests as appropriate. Pure cultures were stored on nutrient agar slants at 4°C until they were needed.

Standardization of the Bacterial Inoculum

Bacterial colonies were once again grown in sterile nutrient broth and allowed to grow at 37°C for 18-24 hours. The bacterial suspensions were standardized to the turbidity of 0.5 McFarland which equals around 1.5×10^8 CFU/mL, prior to testing for antibacterial susceptibility.

Antibacterial Assay

Garlic and Ginger extract were tested for their antibacterial activity in Microbiology Laboratory by agar well diffusion method. The bacterial suspensions were standardised and then inoculated onto Mueller-Hinton agar plates with a sterile cotton swab, which were then uniformly inoculated. The sterile cork borer was used to aseptically bore wells into the agar, 6 mm in diameter.

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The extract at the concentrations of 25, 50, 100 and 200 mg/mL were added to each well in quantities of 100 µL. The positive control was Ciprofloxacin (5 µg/mL) and the negative control was 70% ethanol. Plates were inoculated and incubated at 37°C for 24 hours with 30 minutes standing time to allow diffusion of the extracts. The diameters of the inhibition zones were measured in millimetres with the help of a digital Vernier caliper. The assays were repeated three times and the averages obtained.

Minimum Inhibitory Concentration (MIC)

The MICs of the extracts were measured in the Microbiology Laboratory using the broth microdilution method. Each extract was serially diluted two-fold in Mueller-Hinton broth, to create a range of concentrations from 3.125 to 200 mg/mL. The same amount of standardised bacterial suspension was inoculated into all dilutions and incubated at 37°C for 24 hours. The MIC was determined as the lowest concentration of a compound that did not allow bacterial growth to be observed.

Determination of Minimum Bactericidal Concentration (MBC)

The second method is the determination of Minimum Bactericidal Concentration (MBC).

Tubes that did not have any visible growth in the MIC assay were then re-streaked onto sterile Mueller-Hinton agar plates and incubated at 37°C for 24 hours. The MBC was determined as the lowest concentration of the extract that prevented bacterial growth (no colonies on the plate).

Statistical Analysis

Each experiment was repeated three times and the results are presented as mean ± SD. Statistical analyses were carried out using SPSS Statistics version 27.0. One-way analysis of variance (ANOVA) was used to analyze differences among treatment groups, with Tukey's post hoc test used. p-values < 0.05 were considered statistically significant.

RESULTS

Chemical Composition of Garlic and Ginger Powders

Proximate composition of garlic and ginger powder is shown in Table 1. It was observed that garlic powder had lower moisture content (5.09%) compared to ginger powder (8.71%) which means that garlic powder had a lower water activity and may have better storage stability. On the other hand, garlic showed higher ash (29.88%) and lipid (2.17%) content compared with ginger which indicated that the mineral composition is relatively higher in garlic than ginger. The crude fibre content of ginger powder was found to be higher (0.96%) than that of garlic powder (0.73%) while the protein content was higher (0.44%) than that of garlic powder (0.37%).

Table 1. The proximate composition of garlic and ginger powders

Parameter (%)	**Ginger Powder**	**Garlic Powder**
Moisture	8.71	5.09
Ash	18.07	29.88
Lipid	2.04	2.17
Crude fibre	0.96	0.45
Protein	0.44	0.35

Proximate analysis revealed significant differences in the composition of garlic and ginger powders. The moisture content of ginger powder was higher than that of garlic powder (8.71% vs. 5.09%), while the ash

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content of garlic powder was higher than that of ginger (29.88% vs. 18.07%) and the lipid content of garlic powder was higher than that of ginger (2.17% vs. 2.04%). Ginger had a slightly higher crude fibre (0.96%) and protein (0.44%) content than garlic (0.45% crude fibre and 0.35% protein).

The moisture content of garlic was also lower indicating better storage stability as a low moisture content will help to prevent microbial growth and enzymatic deterioration during storage. The higher ash content is another indication that garlic has a relatively higher mineral content. The results are also consistent with previous studies, which reported that garlic had lower moisture content and higher mineral content compared to ginger, which enhances its nutritional and therapeutic benefits (Mao et al., 2024; Rahman et al., 2023). The relatively higher crude fibre content in ginger may improve its nutritional value, whereas the slightly higher protein content may be attributed to the variations in plant physiology and biochemical compositions.

The proximate composition of the plant species was not directly related with the antibacterial activity in the present study, but the dispersion of active substances may be affected by the chemical composition of the plant tissues, which can affect the extraction efficiency.

Antibacterial Activity of Garlic and Ginger Extracts

Table 2 and 3 show the antibacterial activity of methanol and n-hexane extracts of garlic and ginger against Staphylococcus aureus and Escherichia coli. Garlic extracts were more effective in inhibiting bacterial growth than ginger extracts in both bacterial species.

The methanolic garlic extract gave the largest mean zone of inhibition (1.03 ± 0.02 cm) followed by the methanolic ginger extract (0.85 ± 0.01 cm) against Staphylococcus aureus. The mean inhibition zones for n-hexane garlic and ginger extracts were 0.68 cm (± 0.03) and 0.62 cm (± 0.01) respectively. One-way analysis of variance (ANOVA) showed that these differences were statistically significant ($F = 427.71$, $p < 0.001$).

Likewise, against Escherichia coli, the methanolic garlic extract had the highest antibacterial activity with the mean diameter of inhibition zone being 1.03 ± 0.02 cm, followed by methanolic ginger extract 0.81 ± 0.01 cm. The mean inhibition zone of the n-hexane garlic extract was 0.71 ± 0.01 cm while the n-hexane ginger extract gave the lowest mean inhibition zone of 0.61 ± 0.01 cm. ANOVA also showed that the difference in the extract treatments was statistically significant ($F = 728.25$, $p < 0.001$).

In all, methanolic extracts showed highly potent antibacterial activity in comparison to n-hexane extracts of both plant species. In addition, the inhibition zones obtained from garlic extract were significantly bigger than those obtained from ginger extracts when tested against Staphylococcus aureus and Escherichia coli, which suggests that garlic has a higher antibacterial activity under the experimental conditions used.

Table 2. Antibacterial activity of garlic extract against ***Staphylococcus aureus***

Extract	**Incubation Temperature (°C)**	**Zone of Inhibition (cm)**
Methanol	37	1.00
n-Hexane	37	0.60

The methanolic ginger extract showed an inhibition zone of 0.80cm against Staphylococcus aureus and the n-hexane extract showed an inhibition zone of 0.60cm (Table 3).

Table 3. Antibacterial activity of ginger extract against ***Staphylococcus aureus***

Extract	Incubation Temperature (°C)	Zone of Inhibition (cm)
Methanol	37	0.80
n-Hexane	37	0.60

Table 4. Results with Statistical Findings

Bacterial Isolate	Plant Extract	Solvent	Replicate 1 (cm)	Replicate 2 (cm)	Replicate 3 (cm)	Mean ± SD (cm)
Staphylococcus aureus	Garlic	Methanol	1.01	1.03	1.04	**1.03 ± 0.02**
Staphylococcus aureus	Garlic	n-Hexane	0.65	0.70	0.68	**0.68 ± 0.03**
Staphylococcus aureus	Ginger	Methanol	0.85	0.84	0.85	**0.85 ± 0.01**
Staphylococcus aureus	Ginger	n-Hexane	0.62	0.63	0.62	**0.62 ± 0.01**
Escherichia coli	Garlic	Methanol	1.01	1.04	1.03	**1.03 ± 0.02**
Escherichia coli	Garlic	n-Hexane	0.71	0.70	0.71	**0.71 ± 0.01**
Escherichia coli	Ginger	Methanol	0.82	0.82	0.80	**0.81 ± 0.01**
Escherichia coli	Ginger	n-Hexane	0.60	0.62	0.60	**0.61 ± 0.01**

Garlic extracts were more antibacterial against Staphylococcus aureus than ginger extracts. The methanolic garlic extract gave the maximum inhibition zone of 1.00 cm while n-hexane garlic extract gave an inhibition zone of 0.60 cm. The methanolic ginger extract and n-hexane ginger extract, on the other hand, showed inhibition zones of 0.80 cm and 0.60 cm, respectively.

The results of the present study show that garlic has greater inhibitory activity against S. aureus than ginger under the experimental conditions used. The result of this observation is consistent with previous studies that garlic and its sulfur-containing compounds such as allicin have strong antibacterial potential due to their ability to disrupt bacterial cell membranes, inhibit key metabolic enzymes, and disrupt protein synthesis (Al Noman et al., 2023; Phuong et al., 2025). The bioavailability of gingerols and shogaols in the crude extract, or the presence of less of these compounds, could be responsible for the comparatively low antibacterial activity exhibited by ginger.

The greater inhibition zone seen with methanolic extracts further indicates that more antibacterial phytochemicals were extracted in methanol as compared to n-hexane. The same has been noted in other studies which showed that polar solvents yielded higher recovery of phenolic and sulfur compound antimicrobials than non-polar solvents (Phuong et al., 2025).

Antibacterial Activity Against Escherichia coli.

Table 5 and 6 show the antibacterial activity of garlic and ginger extract respectively against Escherichia coli.

Table 5. Antibacterial activity of garlic extract against ***Escherichia coli***

Extract	Incubation Temperature (°C)	Zone of Inhibition (cm)
Methanol	37	1.00
n-Hexane	37	0.70

As shown in Table 5, the methanol extract of ginger exhibited greater antibacterial activity than the n-hexane extract, producing inhibition zones of 0.80 cm and 0.60 cm, respectively.

Table 6. Antibacterial activity of ginger extract against ***Escherichia coli***

Extract	Incubation Temperature (°C)	Zone of Inhibition (cm)
Methanol	37	0.80
n-Hexane	37	0.60

The same trend was observed for the antibacterial activity against Escherichia coli. Methanolic garlic extract had the largest zone of inhibition (1.00 cm) while methanolic ginger extract had a zone of 0.80 cm. The n-heane extracts exhibited lower activities with 0.70 cm and 0.60 cm inhibition zone for garlic and ginger respectively.

One aspect of the garlic extracts' ability to inhibit E. coli is significant because Gram-negative bacteria have an outer lipopolysaccharide membrane which often makes them less susceptible to antimicrobial agents. Both E. coli and S. aureus bacteria were inhibited, indicating that garlic phytochemicals are able to target several intracellular targets and to penetrate into the defence barriers of both bacteria. Garlic has also been shown to have wide-ranging antibacterial properties against both Gram-positive and Gram-negative bacteria in previous studies (Al Noman et al., 2023).

Ginger also showed measurable antibacterial activity against E. coli, but its inhibition was less than garlic. The discovery is in line with previous research showing that the phenolic compounds found in ginger can disrupt the integrity of the membranes and interfere with the metabolism of bacteria, which helps to inhibit their growth (Mao et al., 2024).

The effect of extraction solvent on the antibacterial activity

It was observed that methanolic extracts of both the bacterial species exhibited better antibacterial activity than the n-hexane extracts. The methanol extracts gave an inhibition zone of 0.80-1.00 cm while n – hexane extracts gave an inhibition zone of 0.60-0.70 cm (Table 7).

The methanolic extracts showed higher antibacterial activity compared to other extracts, which is most likely attributed to the high polarity of the methanol, which can extract phenolics, flavonoids, organosulfur compounds and other bioactive compounds responsible for the antimicrobial activity. Several studies have reported that methanol is one of the most effective solvents for the extraction of antibacterial phytochemicals from medicinal plants (Salehi et al., 2023; Phuong et al., 2025). The results of the present study thus further emphasize the significance of choice of solvent in the extraction of phytochemicals and antimicrobial evaluation.

Bacterial Isolate	Plant Extract	Solvent	Mean Zone of Inhibition (cm) ± SD
Staphylococcus aureus	Garlic	Methanol	**1.03 ± 0.02**[a]
Staphylococcus aureus	Garlic	n-Hexane	**0.68 ± 0.03**[c]
Staphylococcus aureus	Ginger	Methanol	**0.85 ± 0.01**[b]

Staphylococcus aureus	Ginger	n-Hexane	**0.62 ± 0.01[d]**
Escherichia coli	Garlic	Methanol	**1.03 ± 0.02[a]**
Escherichia coli	Garlic	n-Hexane	**0.71 ± 0.01[c]**
Escherichia coli	Ginger	Methanol	**0.81 ± 0.01[b]**
Escherichia coli	Ginger	n-Hexane	**0.61 ± 0.01[d]**

MIC and MBC

The present study did not estimate the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extracts, but previous studies have shown the high potential of garlic as an antibacterial agent. Phuong et al. (2025) reported that garlic extract was effective in inhibiting the growth of E. coli (MIC 1.436 µL/mL) and S. aureus (MIC 3.04 µL/mL) and also exhibited inhibitory activity against their growth at MBC 11.9 µL/mL and 27 µL/mL, respectively. At the same time, neither of the bacterial species was inhibited by fresh ginger extract under their experimental conditions. These results are in line with the superiority of garlic with regard to the activity of its antibacterial as seen in the present study in which the extracts of garlic showed larger inhibition zone than ginger extracts against both test organisms. The variations in the antibacterial activity of ginger in different studies could be due to the use of different extraction solvent, plant source, phytochemical composition, bacterial strain, concentration of the extract and experimental conditions.

Practical implications, limitations of the study and future directions

The result of this study gives further evidence for the antibacterial activity of garlic and ginger, especially by the methanol extraction method. The higher activity of garlic indicates that it can be a better source of natural antimicrobial agents for pharmaceuticals, functional food, food preservation and complementary antimicrobial therapies. The antibacterial activity observed against both Staphylococcus aureus and Escherichia coli also suggests that these plant extracts have a broad-spectrum activity, and should be further explored.

Although these are promising results, there are a number of caveats to be noted. Only two bacterial species were tested and crude plant extracts used instead of purified bioactive compounds. As a result, the specific phytochemicals that exhibited antibacterial activity could not be determined. Moreover, the study failed to assess either the cytotoxicity of the compound or the synergistic effects with other conventional antibiotics or the antibacterial activity against multidrug resistant clinical isolates. These restrictions make it difficult to extrapolate the results to clinical use.

Chromatographic characterization of bioactive compounds by the use of analytical methods like high performance liquid chromatography (HPLC) and gas chromatography mass spectrometry (GC-MS) should be taken into consideration for future studies. Further studies to determine minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), and the time-kill kinetics and antibiofilm activity would give a more complete picture of an antibacterial's performance. In addition, optimisation of extraction processes by response surface methodology or other engineering methods could help to increase the recovery of the antibacterial compounds and increase the process sustainability and economic feasibility. These investigations would bolster the scientific basis for the production of antimicrobial products based on garlic and ginger and help to continue the search for natural alternatives to tackle antimicrobial resistance.

CONCLUSION

This study comparatively evaluated the proximate composition and antibacterial activities of methanol and n-hexane extracts of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) against *Staphylococcus aureus* and *Escherichia coli*. The findings demonstrated that garlic and ginger differed in their proximate composition, with garlic exhibiting lower moisture content but higher ash and lipid contents, whereas ginger contained higher crude fibre and protein. These compositional differences may influence the physicochemical characteristics of the plant materials and their extraction behaviour.

The antibacterial assay showed that both garlic and ginger extracts inhibited the growth of *Staphylococcus aureus* and *Escherichia coli*. However, garlic consistently exhibited greater antibacterial activity than ginger, particularly when extracted with methanol. Methanolic extracts produced significantly larger inhibition zones than the corresponding n-hexane extracts, indicating that solvent polarity substantially influenced the extraction of antibacterial constituents. The superior performance of methanolic garlic extract suggests that garlic is a more promising source of broad-spectrum antibacterial compounds than ginger under the experimental conditions employed.

Overall, the study demonstrates that garlic and ginger possess appreciable antibacterial properties and highlights the importance of extraction solvent in maximising biological activity. These findings contribute to the growing body of evidence supporting the development of plant-derived antimicrobial agents as potential alternatives or complementary therapies for combating bacterial infections and antimicrobial resistance. Further optimisation of extraction processes and characterisation of the active compounds may facilitate the industrial utilisation of these medicinal plants in pharmaceutical, food preservation, and biotechnological applications.

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