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Identification and evaluation of phytochemicals extracted from *Syzygium aromaticum* (L.) and *Cinnamomum zeylanicum* (L.) (L.) on some antibiotic-resistant bacteria

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ABSTRACT

The experiment involved two plants, *Syzygium aromaticum* and *Cinnamomum zeylanicum*, which were used to extract plant parts using 96% ethanol solvent and distilled water for each method. Crude extracts at concentrations of 1000 mg/ml, 500 mg/ml and 100 mg/ml were prepared for the detection of antibacterial activity. Two types of extract are used for treated bacteria studies for inhibition zones. The results of chemical tests for the ethanol and aqueous extracts of the two plants showed positive results for phytochemicals. This effect was shown by the peaks identified by GC-Mass. We determined the antibacterial activity of plant extracts as a criterion for evaluating growth inhibition. The crude extracts were tested against two types of bacteria, which were Gram positive and Gram negative including *Staphylococcus aureus* and *Escherichia coli*, which cause urinary tract infections. The results indicated that the plant extracts with high amounts of phytochemicals are rich sources of antibacterial properties that cause urinary system diseases. All concentrations of extracts inhibited the growth of bacteria, and the effect increased with increasing concentration. There are significant differences between concentration 1000 µg/ml and other concentrations according to the inhibition zone; also, there are significant differences between the effect of all plants on bacteria.

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Introduction

Medicinal plants have been used as a form of treatment for thousands of years, making them one of the oldest sources of medicine. Their therapeutic benefits have been passed down through generations within various human communities across the globe (Petrovska, 2012). Natural products remain crucial as a foundation for drug discovery, and today, many modern pharmaceuticals are derived from traditional herbal remedies, playing a significant role in contemporary pharmacotherapy (Yuan, 2016).

Aromatic medicinal plants are distinguished by their acrid smell and characteristic taste. These plants are also used to enhance the flavor of food, while simultaneously offering numerous medicinal benefits, including anti-fungal, antioxidant, and antibacterial properties (Thomaset al. 2000). Medicinal plants contain chemical compounds called phytochemicals or bioactive compounds, which include alkaloids, phenols, terpenes, volatile oils, glucosides, bitter compounds,

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gums, and mucilaginous substances (Hussein and El-Anssary, 2019).

Syzygium aromaticum and *Cinnamomum zeylanicum,* are considered medicinal plants widely used around the world for various treatments and other applications (Ilodibia et al., 2019; Abdallah, 2016). Urinary tract infections are among the most prevalent diseases caused by Gram-negative anaerobic bacteria and Gram-positive aerobic bacteria. These infections can spread to other parts of the body and pose a significant public health challenge. Bioactive compounds from medicinal plants are increasingly viewed as promising alternatives for treating a wide range of urinary tract infections (Ortega et al., 2023). Some strategies for combating urinary tract infections have advanced through the use of phytochemicals.

S. aromaticum and *C. zeylanicum* are among the most prominent aromatic medicinal plants used against pathogenic bacteria responsible for urinary tract infections due to their rich biochemical content. These plants contain compounds such as cinnamaldehyde, eugenol, proanthocyanidins, and epicatechin, which are known for their potent antimicrobial activity (Rao & Gan, 2014; Ahmed et al., 2021). *C. zeylanicum* also contains trans-cinnamic acid and catechins (Błaszczyk et al., 2021). These bioactive compounds are valued for their antimicrobial properties and their potential in treating various human diseases. The toxicity of active molecules is a critical factor in remedy design, and haemolytic activity provides essential insights into their interactions with biological systems at the cellular level (Amaning et al., 2022; Amer et al. 2024; Jabbar & Abdul Wahid 2025). Haemolytic activity is commonly used to assess general cytotoxicity towards healthy cells (Da Silva et al., 2004).

This study aims to extract and identify effective phytochemicals from the bark, buds, and fruit of *S. aromaticum* and *C. zeylanicum*. It focuses on evaluating the effectiveness of these natural sources as safe and potent alternatives for preventing and treating urinary tract infections caused by bacterial pathogens, and on assessing the free radical scavenging abilities of their phytochemicals through in vitro analysis.

Materials and Methods

Experimental design

The experimental methods were conducted in 2024 at the Biotechnology Laboratory, Faculty of Science, University of Kufa. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. It involved two factors: extraction methods using *Syzygium aromaticum* and *Cinnamomum zeylanicum*, with ethanol (96%) and distilled water (D.W.) as solvents. Each method was evaluated to determine the most effective extraction technique for the leaves and buds of the plants. Phytochemical analysis, both qualitative and quantitative, was performed using GC-MS technology. Crude extracts were prepared at concentrations of 1000 mg/ml, 500 mg/ml, and 100 mg/ml to assess antibacterial activity. Three types of extracts were used in the bacterial inhibition zone study.

Preparation of plant extracts

The plants *Cinnamomum zeylanicum* and *Syzygium aromaticum* were purchased from the Kufa market in the city of Najaf between October and November 2023. The bark and buds of the plants were washed with tap water and cut into smaller pieces. They were then spread in the shade at room temperature to dry. Once dried, the plant parts were ground using an electric grinder for extraction via the maceration method. Leaves and buds were lightly powdered using an electric mill. Ten grams of the powdered *S. aromaticum* and *C. zeylanicum* were each mixed with 200 ml of 70% ethanol or 200 ml of distilled water, respectively. After 24 hours, the mixtures were filtered using filter paper and a glass funnel. The filtrate was transferred to a flask, poured into a glass container, and dried in an oven at 37°C. The resulting powder was collected from the container and used to prepare concentrations of 1000, 500, and 100 mg/ml, according to Harborne (1984).

Preparation of extract concentrations

The samples were ground using an electric grinder and stored in dark, tightly sealed bottles until the extraction process was carried out (Consuelo et al., 2003). The method described by Harborne (1984) was followed for preparing the raw plant extracts. Ten grams of the dry powder from each of the two plants were taken separately, and 100, 500, and 1000 ml of 96% ethanol or distilled water were added. The mixtures were stirred for 30 minutes using a magnetic mixer and then left for 24 hours at room temperature. The solutions were filtered using sieve cloth, and the filtrates were transferred to a centrifuge and spun at 3000 rpm for 10 minutes to precipitate suspended plant materials. The clear supernatant was separated and dried in an electric oven at 40°C. Finally, the extracts were weighed.

Detection of phytochemicals using GC-MS

In this study, the phytochemicals present in two plant parts (buds and leaves) were analyzed using gas chromatography–mass spectrometry (GC-MS). The analysis was performed with a Perkin Elmer Turbo Mass Spectrometer (Norwalk, CT 06859, USA) connected to a Perkin Elmer XLGC system. A Perkin Elmer Elite-5 capillary column was used, measuring 30 × 0.25 mm

with a film thickness of 0.25 mm, composed of 95% dimethylpolysiloxane. Helium served as the carrier gas at a flow rate of 0.5 ml/min, and the injection volume was 1 µl. The inlet temperature was maintained at 250 °C.

The initial oven temperature was set to 110 °C for 4 minutes, then increased to 240 °C, and subsequently programmed to reach 280 °C at a rate of 20 °C/min, with a final hold time of 5 minutes. The total run time was 90 minutes. The MS transfer line temperature was maintained at 200 °C, and the ion source temperature at 180 °C, as detailed in table 1. GC-MS was conducted using electron impact ionization at 70 eV. Compound identification and quantification were based on total ion count (TIC). The spectra of the sample components were compared to those in the GC-MS spectral library. Peak area measurements and data analysis were performed using the WILEY275 and FAME library databases. Accordingly, the names, molecular weights, and structures of the components in the test materials were identified (Ullah et al., 2019).

Table 1. GS-MS conditions

Ion Source	Temp 230 C
Quad Temp	150
Interface Temp.:(MSD Transfer Line)	290
Solvent Cut Time	4.00 min
Start Time	4.00 min
End Time	35.00-40 min
Scan Speed	1562 (N2)
Start	35 m/z
End	650 m/z
Colum Flow	1 ml/min
Purge Flow	3ml/min

Bacterial samples

Staphylococcus aureus and *Escherichia coli* bacterial samples were obtained from the Al-Ameen Center for Research and Advanced Biotechnology in the holy city of Najaf. All collected swabs were incubated in various culture media for 24 hours at 37°C under both aerobic and anaerobic conditions. Bacterial activation and growth were supported using brain heart infusion agar (Lagier et al., 2015). Identification of all bacterial isolates was carried out based on colony morphology—such as color, shape, and size—and confirmed through standard microbiological tests, including hemolysis on blood agar and Gram staining (Habib et al., 2015).

Assessment of plant extract efficacy

The efficacy of the active compounds in *Syzygium aromaticum* buds was evaluated using the agar well diffusion method (Issabeagloo et al., 2012). Between 3–5 bacterial colonies grown on culture media were transferred into a test tube containing 5 ml of distilled water. The turbidity of the bacterial suspension was adjusted to match that of a 0.5 McFarland standard, equivalent to 1.5×10^8 CFU/ml, as described in section 3-6-7 (this procedure was repeated for each bacterial isolate).

A sterile cotton swab was dipped into the bacterial suspension and then used to uniformly inoculate Mueller-Hinton agar plates by swabbing in multiple directions to ensure even bacterial growth. Wells were created in the agar using a sterile cork borer (10 mm diameter), with four wells per plate positioned at equal distances. Three replicates were prepared for each isolate.

Using a micropipette, wells 2, 3, and 4 on each plate were filled with 0.2 ml of the plant extract at concentrations of 1000 mg/ml, 500 mg/ml, and 100 mg/ml, respectively. The first well served as the control and was filled with 0.2 ml of distilled water (D.W.). The plates were then incubated as described in section 3-8.

The antimicrobial activity of the extracts was assessed by measuring the diameter of the inhibition zones (in millimeters) around each well. These measurements were compared among the different concentrations and against the control well, which contained sodium fluoride (Mostafa et al., 2018).

Statistical analysis

Statistical analyses were carried out using SPSS version 25.0; Inc, where data were expressed as the means and standard deviation, too used one–way of variance (ANOVA) test & post hoc by Denken & LSD to find a less significant difference., to compare the results of all groups, P-value ($p \leq 0.05$) was considered statistically significant.

Results and Discussion

Phytochemicals detection of S. aromaticum chromatography

The data presented in figure 1 and table 2 (supplementary) show the chemical constituents of the alcohol extract of *S. aromaticum*, analyzed using GC-MS, which revealed five distinct peaks. These peaks were identified by comparing their mass spectra with those of *C. zeylanicum* alcohol extracts analyzed by GC-MS chromatography.

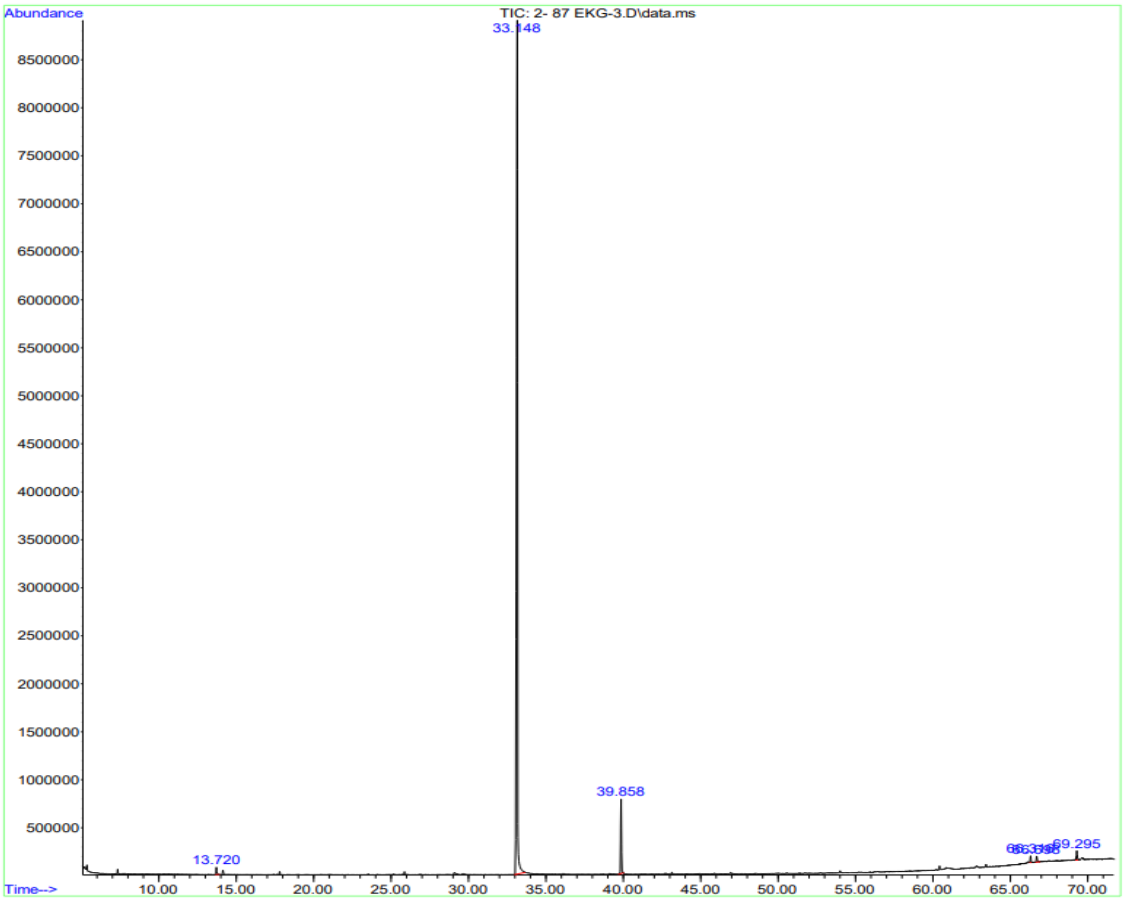

Fig 1. Chemical compounds identified in the alcohol extract of *Syzygium aromaticum* using GC-MS chromatography analysis.

Detection of phytochemicals in Syzygium aromaticum alcohol extracts by GC-MS

Based on the spectra, the identified phytochemicals were characterized. The primary phytochemical constituents are as follows: Phenol, 2-methoxy-4-(2-propenyl)-acetate, comprising 97.66% and known for its antibacterial properties; followed by tetracosane at 0.83%; 1H-Imidazole, 4,5-dihydro-2-(phenylmethyl) at 0.53%; eicosane at 0.46%; and 3-hexanol at 0.52%. The five distinct peaks observed in the GC-MS analysis of the *S. aromaticum* alcohol extract represent the main bioactive compounds, such as eugenol and β-caryophyllene, which are efficiently extracted by alcohol. This limited number of peaks reflects the solvent's selective extraction of the primary volatile compounds from the clove extract.

This study agrees with the work of Gowri and Manimegalai (2019), who reported fourteen compounds in alcohol extracts, with a high percentage of phenol, 2-methoxy-3-(2-propenyl) (64.44%), followed by eugenol (14.97%). Eugenol is the principal component present in the ethanol extract of *S. aromaticum* and has potential applications in developing pharmaceutical drugs. Similarly, Alitonou et al. (2012) identified twenty-one components in alcohol extracts, representing 99.4% of the total constituents of the oil. The essential oil was rich in monoterpenic hydrocarbons, with the major constituents being eugenol (60.4%) and trans-β-caryophyllene (24.0%).

Phytochemicals Detection in Aqueous S. aromaticum Plant Extract by GC-MS Chromatography:

The results presented in Table 3 (supplementary) and Figure 2 show the chemical components identified in the aqueous extract of *Syzygium aromaticum* using GC-MS analysis. Twenty-one peaks were detected, characterized, and identified by comparison with mass spectra. The primary phytochemical constituents include phthalic acid, di(2-propylpentyl) ester (45.97%), followed by bis(2-ethylhexyl) phthalate (22.33%). The third major constituent is 1,2-benzenedicarboxylic acid,

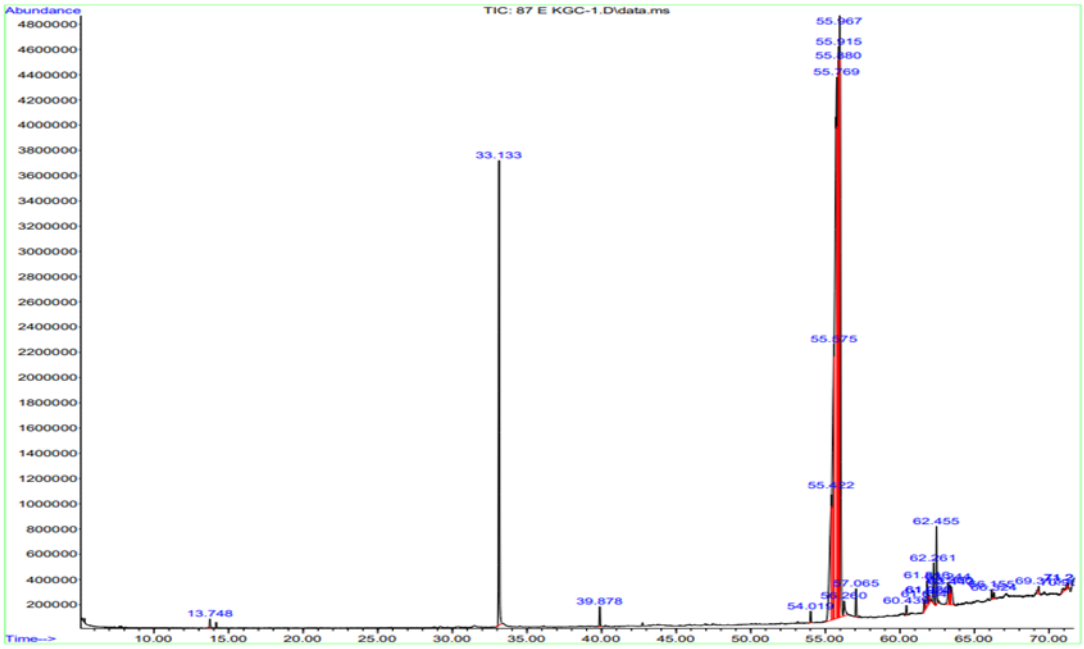

Fig 2. Chemical compounds identified in the alcohol extract of *Syzygium aromaticum* using GC-MS chromatography analysis.

bis(2-ethylhexyl) ester (14.43%), followed by phenol, 2-methoxy-4-(2-propenyl)-acetate (9.57%), ethyl oleate (1.30%), octadec-9-enoic acid (0.80%), ethyl (9Z,12Z)-9,12-octadecadienoate (0.72%), tetradecanoic acid ethyl ester (0.67%), n-hexadecanoic acid (0.53%), and 9,12-octadecadienoic acid (Z,Z)- (0.52%). The proportions of other components were minimal compared to these primary constituents.

The identification of 21 peaks in the GC-MS analysis of the aqueous extract of *Syzygium aromaticum* (clove) indicates the presence of multiple chemical compounds. Each peak corresponds to a distinct component of the extract. This number of peaks reflects the complex composition of the plant, which contains various bioactive compounds such as essential oils, phenolics, tannins, and flavonoids. GC-MS separates these compounds based on their volatility and detects them via mass spectrometry. The aqueous extraction dissolves polar and water-soluble compounds, contributing to the diverse chemical profile observed. The sensitivity and resolution of GC-MS allow for the detection of even minor components, resulting in the identification of 21 distinct peaks.

This study agrees with the findings of Al-Azem et al. (2019), who identified fifty-three compounds in S. aromaticum aqueous extracts. Their components mainly included 21 sesquiterpenes (39.62%), eight monoterpenes (15.09%), and one diterpene (1.88%). Similarly, Selles et al. (2020) identified sixty-five compounds in S. aromaticum aqueous extracts, with eugenol as the major compound (78.72%), followed by β-caryophyllene (8.82%) and eugenyl acetate (8.74%).

Data from the current study indicate that the aqueous extracts of S. aromaticum contain more chemical compounds than the alcohol extracts of the same plant. This difference may be due to the higher polarity of phytochemicals extracted by the aqueous solvent, which has a greater capacity to dissolve these compounds compared to alcohol.

Phytochemicals detection in C. zeylanicum Alcohol Extract used GC-MS Chromatography:

The data presented in Table 4 (supplementary) and Figure 3 demonstrate that the chemical composition of the alcohol extract from *Cinnamomum zeylanicum*, identified through GC-MS analysis, reveals ten distinct peaks. Comparative analysis with mass spectra facilitated the characterization and identification of these phytochemicals. The primary phytochemical constituents are as follows: cinnamaldehyde (E)- with a ratio of 83.56%, followed by 9-octadecenoic acid, 12-hydroxy-, methyl ester, [R-(Z)]- at 5.02%; the third constituent is

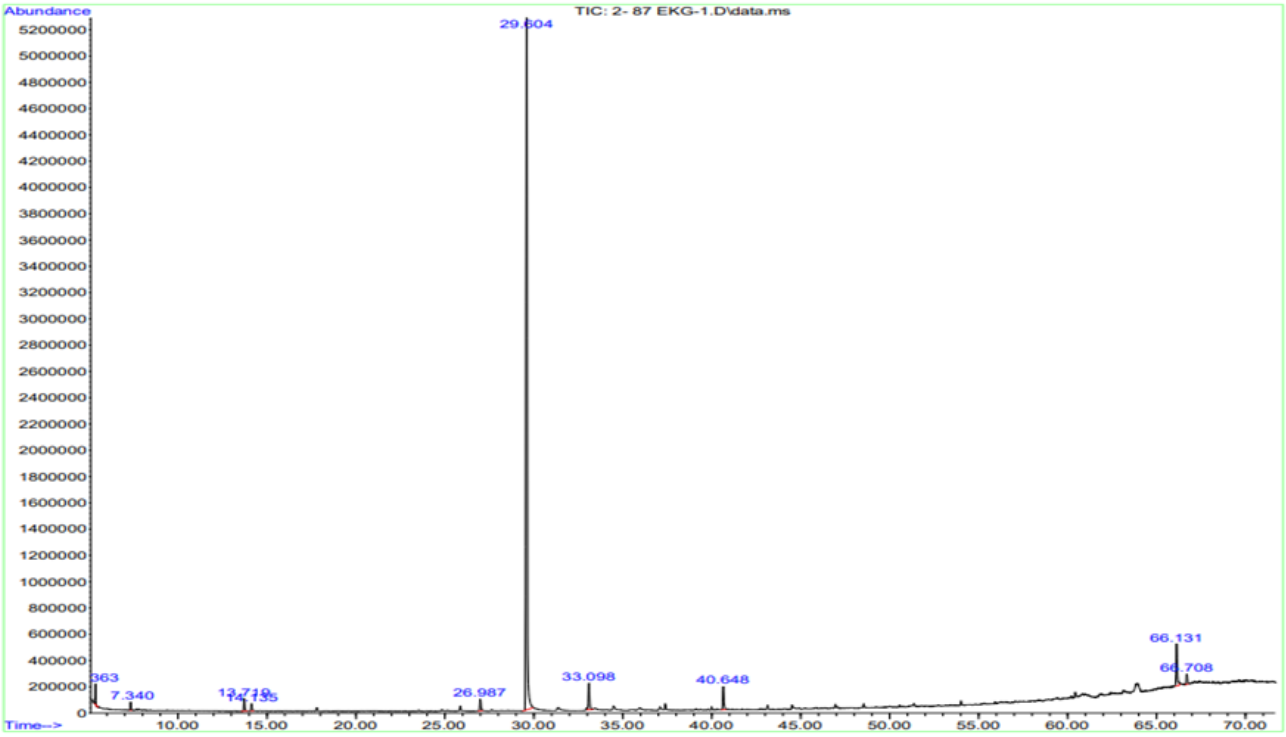

Fig 3. Chemical compounds identified in the alcohol extract of *Cinnamomum zeylanicum* using GC-MS chromatography analysis.

eugenol with 2.92%, then 2-propenal, 3-(2-methoxyphenyl)- at 2.68%, 2-propenal, 3-phenyl- with 1.44%, 3-hexanol (CAS) at 1.13%, and nonanoic acid, dodecyl ester at 1.07%, followed by cyclohexane at 0.99%, and 2-pentene, 3-.

This study agrees with the work of Mutlu et al. (2023), who found twenty-seven compounds in alcohol extracts of C. zeylanicum, with cinnamaldehyde (E) comprising 72.98%, β-caryophyllene at 3.45%, and eugenol at 1.48%. Elumalai et al. (2011) reported four peaks in *C. zeylanicum* ethanolic extracts identified by GC-MS, with the two most intense peaks identified as cinnamaldehyde and cinnamic acid, respectively. Udayaprakash et al. (2015) reported six compounds in GC-MS analysis of C. zeylanicum methanolic extracts, including 4-piperidineacetic acid, 1-acetyl-5-ethyl-2-[3-(2-hydroxyethyl)-1H-indol-2-yl]-α-methyl-methyl ester; pentadecanoic acid, 14-methyl-, methyl ester; 10-octadecenoic acid, methyl ester; cyclopropanebutanoic acid derivatives; and cyclopentaneundecanoic acid, methyl ester.

Radhi and Khashan (2022) also investigated the alcohol (96%) extract of Punica granatum fruit peels, finding the highest concentration of chemical compounds as identified by GC-MS analysis. A total of 42 peaks were detected, with benzoic acid (4-hydroxybenzoic acid) as the primary phytochemical constituent at 13.75%. Similarly, ten distinct peaks were observed in the alcohol extract of *Cinnamomum zeylanicum*, representing the major bioactive compounds extracted by the alcohol solvent and detected by GC-MS. These peaks reflect the solvent's effectiveness in extracting specific chemical components such as cinnamaldehyde, eugenol, and other essential oils and phenolics typical of cinnamon.

The results in Table 5 (supplementary) and Figure 4 show the chemical components identified by GC-MS analysis of the aqueous extract of *C. zeylanicum*, with 30 peaks detected. By comparison with mass spectra, these phytochemicals were characterized and identified. The main phytochemical constituents include cinnamaldehyde (E)- at 37.61%, followed by copaene (8.85%), 1-methoxy-7-methyl-3,4-dihydrobenz (6.58%), alpha-muurolene (6.41%), p-xylene (5.43%), delta-cadinene (4.91%), toluene (3.49%), caryophyllene (3.38%), naphthalene, 1,2,3,4-tetrahydro-1,6-dimethyl-4-(1-methylethyl) (2.67%), phenol, 2-methoxy-4-(2-propenyl)- (2.29%), eugenol (1.81%), 6-alpha-cadina-4,9-diene (-) (1.72%), (Z)-2-methoxycinnamaldehyde (1.63%), 4-tert-butylamphetamine (1.46%), cadina-1,4-diene (1.37%), MDMA methylene homolog (1.34%), benzene, 1,3-dimethyl (1.07%), ethylbenzene (1.03%), (+)-cycloisosativene (1.02%), and atrolactic acid (0.96%). The proportions of other components were minor compared to these main constituents.

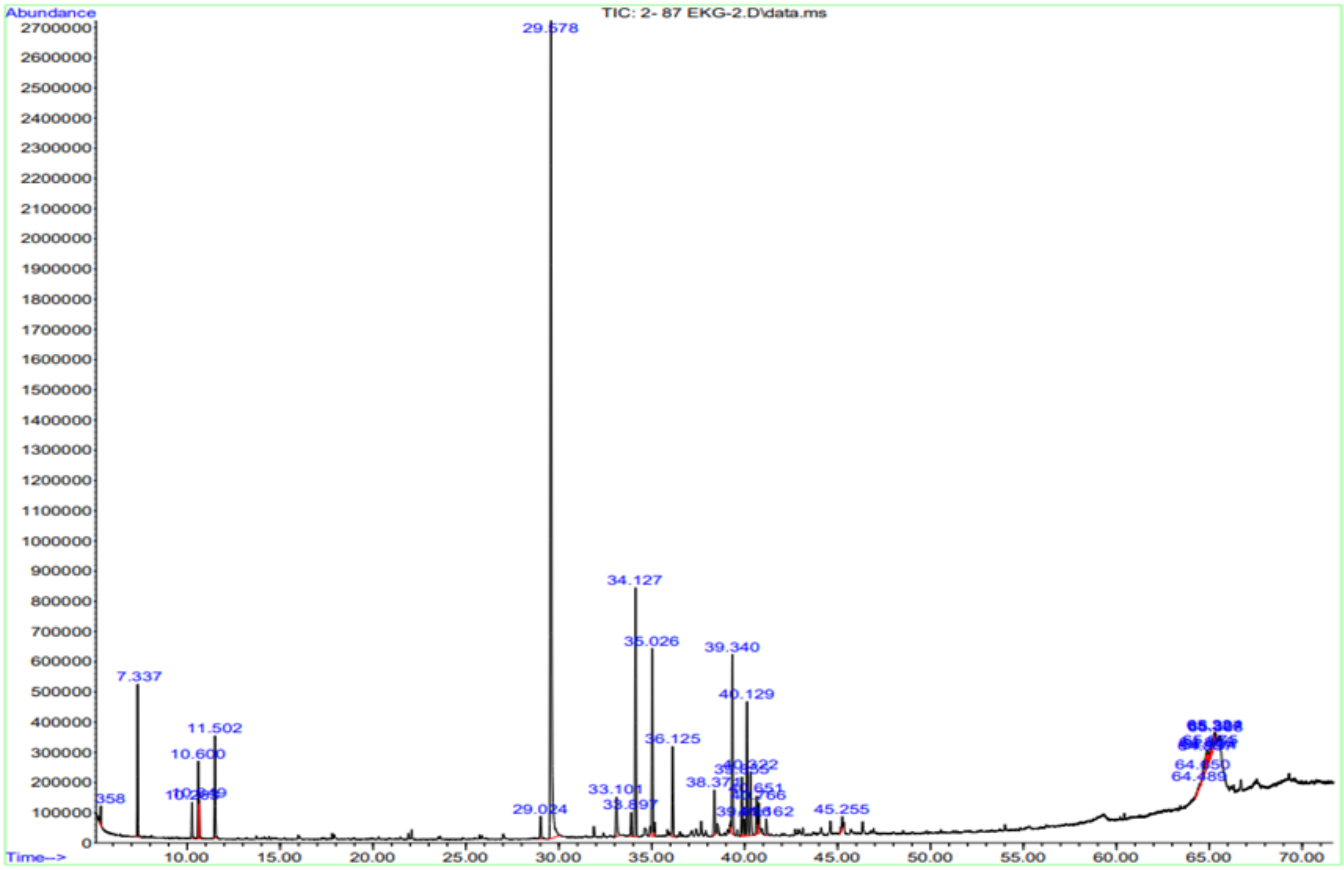

Fig. 4. Chemical compounds identified in the aqueous extract of *Cinnamomum zeylanicum* using GC-MS chromatography analysis.

The 30 peaks observed in the GC-MS analysis of the aqueous extract of *C. zeylanicum* indicate the presence of a wide variety of chemical compounds, including phenolics, flavonoids, tannins, and essential oils, many of which are water-soluble. This diversity reflects the complex nature of the cinnamon extract, capturing both major and minor bioactive constituents.

This study agrees with Ihejirika et al. (2017), who found thirty-eight compounds in *C. zeylanicum* aqueous extracts, with coumarin as the major component (11.41%), followed by hydroxycoumarin (4.97%). Naibaho et al. (2021) identified thirty-four compounds in *C. zeylanicum* aqueous extracts, with 5-(hydroxymethyl)-2-furancarboxaldehyde as the major compound (26.65%).

Data from the current study indicate that *C. zeylanicum* aqueous extracts contain more chemical compounds than the alcohol extracts of the same plant. This result may be due to the higher polarity of phytochemicals extracted by the aqueous solvent, which has a greater capacity to dissolve these compounds compared to alcohol.

Antibacterial activity of aqueous extracts of S. aromaticum and C. zeylanicum

The aqueous extract of *S. aromaticum* plant in table 6 against (*S. aureus*) bacteria present differences inhibition zone were found between all concentrations compared to the control group with an (0 mm), the highest average of the inhibition zone was (25 mm) at a concentration of 1000 µg/ml compared to the other concentrations 500 µg/ml and 100 µg/ml with averages of (23 mm) and (20 mm) respectively as shown in Figure (5), this result was agreement with Al-Mijalli *et al*., (2023) that found The results of the antibacterial study showed how effective essential oils isolated from leaf & flower buds (CEOL & CEOB) are against bacteria. Antibiotic properties were outperformed by these oils, which showed notable zones of inhibition against all tested pathogens, including *S. aureus* ATCC 29213 & *E.coli* ATCC 25922. They also showed low bactericidal nature (MBC/MIC < 4.0) as well as low minimum inhibitory concentrations (MICs) & minimum bactericidal concentrations (MBCs). Time-kill kinetics showed that at sub-MIC dosages, CEOB was more

effective than CEOL in eliminating *S. aureus* in less than 12 hours. The CEOL & CEOB treatment altered *S. aureus's* relative conductivity at both MIC & sub-MIC concentrations, according to the cell membrane permeability test, suggesting that the bacterial membrane was disrupted & affecting the bacteria's capacity to grow & survive. Additionally, the addition of CEOL & CEOB to *S. aureus* cultures resulted in a notable release of proteins from the bacterial cells, as demonstrated by the cell membrane integrity test.

In the same table for the aqueous extract of the same plant on *E.coli* bacteria shows that there are present differences inhibition zone between all concentrations compared to the control group at (0 mm), & the highest average of the inhibition zone was (26 mm) at a concentration of 1000 µg/ml compared to the other concentrations 500 µg/ml & 100 µg/ml with averages of (24 mm) and (21 mm) respectively as shown in Figure (5).This result may be due to the interaction of the plant

extract with DNA molecules, which affects the gene sys Tem Agr and thus reduces gene expression levels or it is possible that the interaction between plant phytochemicals and phosphorylase Agr C in Agr system is one of the main reasons for the inhibition (Li *et al*., 2022), that proved some cells to E. coli were lysed and split because of wrinkle formation after treatment with the aqueous extract of *S. aromaticum*.

Table 6. Antibacterial activity of *S. aromaticum* and *C. zeylanicum* extracts against test strains

	S. aureus				*E. coli*			
Plant	Positive	1000	500	100	Positive	1000	500	100
S. aromaticum	0	25	23	20	0	26	24	21
C. zeylanicum	0	25	23	19	0	24	23	17

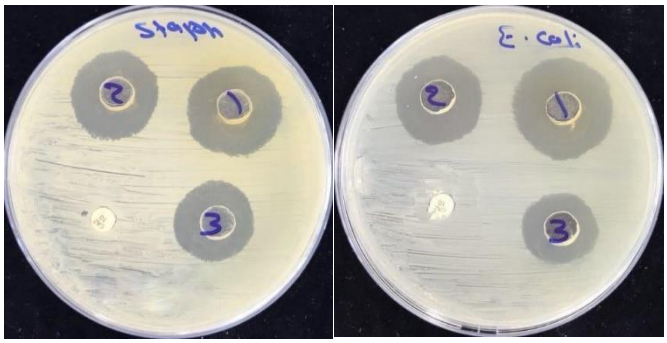

Fig 5. Bacterial growth inhibition zones of *Syzygium aromaticum* extract. (A) Control (distilled water), (1) 1000 µg/ml, (2) 500 µg/ml, (3) 100 µg/ml concentrations of the extract applied using the agar well diffusion method.

Table 6 presents the results of the aqueous extract of *Cinnamomum zeylanicum* against *Staphylococcus aureus*, showing clear differences in the inhibition zones across all tested concentrations compared to the control group (0 mm). The highest average inhibition zone was observed at a concentration of 1000 µg/ml (25 mm), followed by 500 µg/ml (23 mm) and 100 µg/ml (19 mm). These findings are consistent with the study by Saki et al. (2020), which demonstrated a significant antibacterial effect of *C. zeylanicum* on *Enterococcus faecium* and *Pseudomonas aeruginosa*, both Gram-positive bacteria.

Similarly, Khashan and Abbod (2021) reported that methanolic leaf extracts of *Mirabilis jalapa* at concentrations of 1, 5, and 10 mg/ml exhibited strong antimicrobial activity against *S. aureus* and *P. aeruginosa*, both known for their antibiotic resistance.

Additionally, Table 6 presents the results of the aqueous extract of *C. zeylanicum* against *Escherichia coli*, again showing significant differences in the inhibition zones at all concentrations compared to the control group (0 mm). The highest inhibition was recorded at 1000 µg/ml (24 mm), followed by 500 µg/ml (23 mm) and 100 µg/ml (17 mm), as illustrated in Figure 6. These results are in agreement with the findings of Romaniuk and Cegelski (2015) and Mahrous et al. (2023), who reported that clove extract exhibited greater antibacterial activity against *Klebsiella* species than norfloxacin in all tested isolates. This effect was attributed to reduced gene expression associated with biofilm formation, significant leakage of intracellular components, and inhibition of respiratory metabolism—particularly through disruption of the tricarboxylic acid (TCA) cycle.

Furthermore, Pathirana et al. (2019) confirmed the significant antibacterial activity of *C. zeylanicum* at all tested concentrations against seven Gram-negative bacterial strains, with inhibition zones increasing proportionally with concentration.

Finally, a study by Jaber and Khashan (2023) demonstrated that all tested concentrations of essential

oils and crude alcoholic extracts of *Mentha spicata* leaves (ratios of 1:1, 2:1, 5:1, and 10:1 v/v oil to distilled water) exhibited antibacterial activity against *Streptococcus mutans* and *E. coli* isolated from infected gum tissues, showing varying degrees of inhibition.

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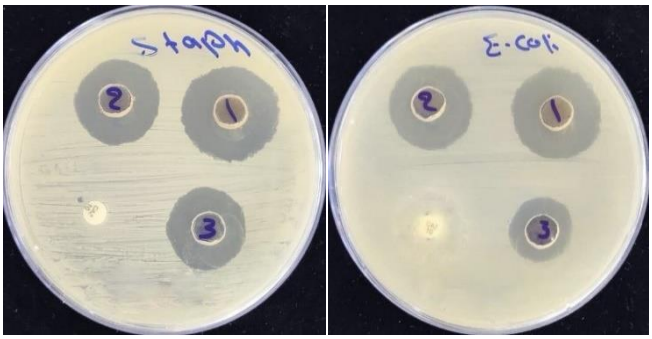

Fig 6. Inhibition zones of bacteria treated with aqueous extract of *C. zeylanicum*. (A) Control; (1) 1000 µg/ml; (2) 500 µg/ml; (3) 100 µg/ml.

Conclusions

Based on the results and findings of this study, it can be concluded that plant extracts exhibit significant antibacterial activity against Staphylococcus aureus and Escherichia coli. The degree of bacterial inhibition was observed to increase proportionally with higher concentrations of the extract, indicating a dose-dependent effect.

Among the tested concentrations, the aqueous extract at 1000 µg/ml demonstrated the highest inhibitory activity against both S. aureus and E. coli. This suggests that aqueous extracts, particularly at higher concentrations, can be effective in controlling bacterial growth.

Furthermore, GC-MS analysis revealed that the percentage of compounds detected was higher in the alcoholic extracts compared to the aqueous extracts for both *Cinnamomum zeylanicum* and *Syzygium aromaticum*. This indicates that alcohol is a more efficient solvent for extracting a greater variety and quantity of phytochemicals from these plants.

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Conflict of interest

Authors declare they have no known conflict of interest.

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