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Antibacterial activity of cinnamon bark extract against multidrug-resistant bacterial isolates

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ABSTRACT

Background: Multidrug-resistant organisms are becoming a major healthcare challenge, making infections difficult to treat. This study aimed to determine the antimicrobial activity of cinnamon bark extract on multidrug resistant organisms which include *Escherichia coli*, *Klebsiella pneumonia Pseudomonas aeruginosa and Salmonella typhi*.

Methods: The isolates identity were confirmed using cultural, morphological and biochemical tests. The isolates were then subjected to antibiotic susceptibility test (AST) using Kirby-Bauer method. Antibacterial activity was evaluated through well diffusion method while the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) of the plant extracts were determined using broth diffusion and plating methods respectively. Analysis of variance (ANOVA) was employed for statistical significance (p-values <0.05).

Results: The result of AST revealed that all isolates were resistant to most antibiotics, except for some *Pseudomonas* species that were susceptible. The MAR indices of all enterobacteriaceae ranged between 0.8 and 1 and were adjudged to be multidrug resistant (MDR) bacteria (MAR index ≥0.2), while that of Pseudomonadaceae ranged between 0 and 0.3. Cinnamon bark extracts displayed significant antibacterial activity by producing clear zones of inhibition against test organisms. Ethanolic extract was more effective than aqueous extract at various concentrations. The ethanolic extract of cinnamon bark exhibited bactericidal effects against *Pseudomonas* sp. at 20mg/ml and against other organisms at 40mg/ml, whereas the aqueous extract was only effective against *Pseudomonas* sp. at 40mg/ml.

Conclusion: The findings of this study revealed that cinnamon bark extract exhibit antibacterial activity against multidrug-resistant bacteria, suggesting it potential for developing treatment against MDR infections.

Keywords: Cinnamon bark, Aqueous and Ethanolic Solvent, Antibacterial Activity, Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

1. INTRODUCTION

The escalating issue of multi-drug resistant bacteria poses a significant threat to global health, resulting in approximately 700,000 deaths annually, according to the World Health Organization [1]. Antimicrobial resistance (AMR) occurs when microbes evolve mechanisms to evade or counteract the effects of antimicrobials (drugs used to treat infections). Its emergence is largely linked to the overuse and misuse of antimicrobials, leading to increased healthcare costs and mortality rates. In response to this challenge, researchers are exploring alternative methods to combat AMR. Plants, which have been a cornerstone of traditional medicine, offer promising antimicrobial properties. A systematic review of 958 plant species from 142 families found that many plants exhibit antibacterial properties, particularly those in the Lamiaceae, Fabaceae and Asteraceae families [2]. Cinnamon is a nutrient-rich spice, comprising primarily carbohydrates, with smaller amounts of protein and fat. It is a rich source of essential minerals like calcium, iron, and vitamin K. Cinnamon contains various resinous compounds, including cinnamaldehyde, eugenol, and cinnamic acid, which contribute to its distinctive taste, fragrance, and potential health benefits [3]. It also possesses many bioactive compounds like secondary metabolites, which are defensive

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compounds against competitors and pathogens [4]. The chemical composition and properties of cinnamon can vary significantly depending on factors such as the plant part used, extraction method, and solvent employed [5]. Building on this understanding, the present study aimed on evaluating the antibacterial efficacy or activity of cinnamon bark against selected bacterial isolates that are multidrug resistant.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Biological Materials

The study utilized plant material from Cinnamon bark (Cinnamomum cassia) and bacterial isolates, including *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Salmonella typhi*.

2.1.2 Equipment and Apparatus

The equipment used included an autoclave, incubator, microscope, refrigerator, water bath, spectrophotometer, and laminar flow hood, while the apparatus included petri dishes, inoculating loops, test tubes, micropipettes, cock borer, and antibiotic discs.

2.1.3 Chemical and Reagents

The study utilized various chemical solvents and reagents, including water and ethanol for plant extraction and dimethyl sulfoxide (DMSO) for dissolving and preparing stock solutions. Reagents such as hydrogen peroxide, tetramethyl-p-phenylenediamine dihydrochloride, barritt's reagents A and B, bromocresol purple, crystal violet, iodine, 70% alcohol, seferanin and sugars like glucose, lactose, and sucrose were used for biochemical testing. Additionally, various media including nutrient agar, mueller hinton agar, simmons' citrate agar, christensen's broth, and peptone water broth were also utilized.

2.2 Methods

2.2.1 Collection of Plant Material

Cinnamon bark (*Cinnamomum cassia*) was sourced from the local market in Owo, Nigeria. Plant material authentication was conducted by the Department of Biological Science at Achievers University in Owo, Nigeria. The bark underwent a series of processing steps, including cleaning, washing, and shade drying. It was then pulverized into a fine powder using a mechanical grinder and filtered through a 250 µm mesh sieve. The resulting powder was stored in a sterile, dry container [6].

2.2.2 Extraction of Plant Material

The extraction of bioactive compounds from cinnamon bark was carried out using two solvents of different polarities, ethanol and water, as previously described [7]. The Soxhlet extraction method, a technique employed in earlier studies [8, 9], was utilized to extract the plant constituents. Specifically, 100g of dried cinnamon bark was weighed and placed in two separate conical flasks, followed by the addition of 1000ml of water and 100% ethanol, respectively. Each flask received anti-bumping granules, followed by vigorous shaking for 10 minutes. The mixtures were then left to stand at room temperature for 48 hours. The resulting extracts were filtered, concentrated through evaporation at a temperature range of 45-50°C and stored at 4°C for further analysis.

2.2.3 Preparation of Extract stock solutions

The crude extracts were dissolved in 5.0 ml of 10% v/v Dimethyl Sulfoxide (DMSO) to create stock solutions with concentrations of 100, 50, 25, and 12.5mg/ml. These solutions were then stored in sample bottles at 15°C for subsequent analysis [10].

2.2.4 Collection of Bacterial Cultures

The study utilized clinical isolates of *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *and Salmonella typhi*, which were sourced from the Microbiology Laboratory's collection at Achievers University. The microorganisms underwent rigorous testing, including morphological, cultural, and biochemical examinations, to confirm their purity and viability. Regular subculturing maintained the microorganisms' health and stability throughout the study.

2.2.5 Confirmation of Test Organisms

The physical morphology of the isolates was examined macroscopically, considering characteristics such as size, color, pigmentation, texture, odor, and consistency. Additionally, a microscopic examination was performed using Gram staining to differentiate between Gram-positive and Gram-negative isolates [11].

2.2.5.1 Biochemical Identification of Isolates

The bacterial isolates were further characterized and identified using a comprehensive panel of biochemical tests, as previously described [11, 12]. The tests included Gram staining, catalase, motility, sugar fermentation, methyl red, voges-proskauer, indole, urease, oxidase, coagulase, triple sugar iron (TSI) and citrate assays, which were done after subculturing. The results of these biochemical tests, combined with growth on selective media, enabled the identification of the bacterial isolates.

2.2.6 Antibiotic Susceptibility Testing

The isolates underwent antibiotic susceptibility testing using the standardized Kirby-Bauer disk diffusion method, as outlined by the Clinical Laboratory Standards Institute [13]. A range of conventional antibiotics was evaluated against the Gram-negative isolates, including Septrin (30µg), Chloramphenicol (30µg), Ciprofloxacin (30µg), Sparfloxacin (10µg), Amoxicillin (30µg), Augmentin (10µg), Pefloxacin (30µg), Gentamicin (30µg), Tarivid (10µg), and Streptomycin (30µg).

2.2.6.1 Standardization of Inoculum

Bacterial cultures were incubated on nutrient agar plates at 37°C for 24 hours. A 0.1ml aliquot of bacterial cells was suspended in sterile normal saline and adjusted to match the turbidity of a 0.5 McFarland standard, as recommended by CLSI guidelines. The resulting bacterial suspension was inoculated onto Mueller-Hinton agar plates. Antibiotic discs were applied to the agar surface, and the plates were incubated at 37°C for 16 hours. Zone of inhibition diameters were measured and interpreted according to CLSI standards, categorizing the isolates as sensitive, intermediate, or resistant [13].

2.2.6.2 Multiple Antibiotics Resistant Index

This was used to determine multidrug resistant isolates (MDR). It was calculated as follows:
MAR index for isolates = a/b
Where “a” is the number of antibiotics to which the isolate is resistant while “b” represents the number of antibiotics tested [14].

2.2.7 Antibacterial susceptibility assay

The antibacterial effectiveness of the extracts was evaluated using the agar well diffusion method, following CLSI guidelines [15]. The selected bacterial isolates with the highest multiple antibiotic resistance (MAR) index were inoculated onto Mueller Hinton Agar plates, and five wells were subsequently created in each plate. A 50-µl sample of each extract concentration was added to the wells, and the plates were incubated at 37°C for 24 hours. The antibacterial activity was assessed by measuring the diameter of the inhibition zones around each extract, with results reported in millimeters.

2.2.7.1 Determination of Minimum Inhibitory Concentration (MIC)

The Minimum Inhibitory Concentration (MIC) of the extracts was determined using a serial dilution technique [9]. The extracts were diluted in a series of concentrations, ranging from 80 mg/ml to 5 mg/ml, using nutrient broth at a 1% concentration. Each dilution was then combined with 0.5 ml of the test organism and incubated at 37°C for 24 hours. To ensure accurate results, two control groups were established: one with the test organism and no extract, and another with the extract and no test organism. After incubation, the samples were checked for signs of bacterial growth, indicated by turbidity. The lowest extract concentration that showed no visible growth, compared to the control groups, was identified as the MIC.

2.2.7.2 Minimum Bactericidal Concentration (MBC) Determination

Samples from the minimum inhibitory concentration (MIC) tubes with no visible growth were subcultured onto nutrient agar and incubated at 37°C for 24 hours. The MBC was defined as the lowest concentration of extract resulting in no bacterial growth after incubation.

2.3 Statistical Analysis

The Statistical tool employed to carry out the data analysis of this study was Microsoft Excel 2007. Each experiment was conducted in triplicate. Experimental results were computed as mean and standard deviation. Analysis of variance (ANOVA) was used to determine the significant difference among the mean of the concentrations of various extract at $p \leq 0.05$.

3. RESULTS

3.1 Confirmation of Bacterial Isolates

The biochemical test results of 11 bacterial isolates suggest they belong to four probable organisms: *Pseudomonas* sp (Fm1, Fm7, Fm10), *Salmonella* sp (Fm2, Fm11), *Escherichia coli* (Fm3, Fm5, Fm9) and *Klebsiella* sp (Fm4, Fm6, Fm8) based on their Gram reaction, cellular morphology, and biochemical reactions (Table 1). *Pseudomonas* was characterized by its oxidase-positive nature and distinct metabolic versatility. In contrast, *Salmonella* was typically lactose-negative and hydrogen sulfide-positive. *Escherichia coli* was identifiable by its lactose fermentation and indole production, whereas *Klebsiella* species were lactose-positive.

3.2 Antibiotic Susceptibility Test

Table 2 revealed the antibiotic susceptibility and resistance profile, and multiple antibiotic resistance (MAR) index, of bacterial isolates from clinical origin. The isolates were classified as susceptible (S), intermediate (I) and resistance (R) according to CLSI standard. The MAR index of Pseudomonas spp ranged between 0 and 0.3 while the organisms belonging to the family of enterobactericaea ranged between 0.8 and 1 (Table 2). The percentage susceptibility and resistance profile shows that *Pseudomonas* species were highly susceptible to the antibiotics investigated with 100% susceptibility to Chloranphenicol Sparfloxacin, Ciprofloxacin, Amoxacillin, Augmentin, Tarivid and Streptomycin. Also *Pseudomonas* spp exhibited 33.33% intermediate and resistance to Septrin and Gentamycin while 66.67% susceptibility was shown to Perfloxacin. Both *Klebsiella* spp and *Salmonella* spp exhibited 100% resistance to the antibiotics investigated. *Escherichia coli* showed 66.67% to ciprofloxacin and tarivid while *Klebsiella* spp showed 33.33 % susceptibility to ciprofloxacin and amoxicillin (Table 3).

3.3 Antibacterial Activity of Cinnamon Bark

Cinnamon bark extracts exhibited antibacterial activity against the test organisms, with varying zones of inhibition. For ethanolic extract, *Pseudomonas* sp (21 mm) showed the highest sensitivity, followed by *Klebsiella* sp (17 mm), while *Salmonella* sp and *E. coli* had the same zone of inhibition (14 mm) (Table 4). For Aqueous extraction, *Pseudomonas* sp has the highest zone of inhibition of 13 mm followed by *Klebsiella* sp (8 mm), while both *E.coli* and *Salmonella* exhibited zone of inhibition of 7mm at concentration of 100 mg/ml. *Pseudomonas* sp was the only organism that exhibited zone of inhibition of 6 mm at concentration of 50 mg/ml (Table 5). The antibacterial activity of ethanolic and aqueous cinnamon bark extracts was compared based on zone of inhibition at different concentrations, as depicted in Figures 1 and 2. The antibacterial activity of the ethanolic extract against *Escherichia coli* is shown in Figure 1, with zones of inhibition measuring 14 mm, 11 mm, and 6 mm at concentrations of 100, 50, and 25 mg/ml, respectively. In contrast, Figure 2 shows the antibacterial activity of the aqueous extract against *Escherichia coli*, with a minimal zone of inhibition of 7 mm at a concentration of 100 mg/ml.

3.3.1 Minimum Inhibitory Concentration

Table 6 showed the minimum inhibitory concentration of ethanolic extract of cinnamon bark against test organisms. *Pseudomonas* sp and *Klebsiella* sp recorded MIC value of 10 mg/ml while *Salmonella* sp and *E. coli* exhibited minimum inhibition at a concentration of 20 mg/ml. For aqueous extracts, the MIC values were recorded at higher concentration. *Pseudomonas* sp exhibited minimum inhibition at concentration of 40 mg/ml, while *Salmonella* sp, *E. coli* and *klebsiella* sp exhibited minimum inhibition at concentration of 80mg/ml.

3.3.2 Minimum Bactericidal Concentration

For ethanolic extracts, bactericidal effect was recorded in *Pseudomonas* sp at minimum concentration of 20 mg/ml while other organisms exhibited MBC at 40 mg/ml. Only the *Pseudomonas* spp was killed at concentration of 40mg/ml while other organisms were resistant to various concentration used by aqueous extracts (Table 7)

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Table 1: Morphological and Biochemical Characteristics of bacterial Isolates

Isolates Codes	Gram reaction	Cellular Morphology	Tripple Sugar Iron		Indole	Methyl Red (MR)	Voges Proskauer (VP)	Citrate	Urease	Motility	Oxidase	Catalase	Lactose Fermentation	H_2S	Gas	Probable organisms
			Slant	Butt												
Fm1	-ve	R	Alk	Alk	-	-	-	+	-	+	+	+	-	-	+	*Pseudomonas* sp
Fm2	-ve	R	Alk	Acid	-	+	-	-	-	+	-	+	-	+	-	*Salmonella sp*
Fm3	-ve	R	Acid	Acid	+	+	-	-	-	+	-	+	+	-	+	*Escherichia coli*
Fm4	-ve	R	Acid	Acid	-	-	+	+	+	-	-	+	+	-	+	*Klebsiella* sp
Fm5	-ve	R	Acid	Acid	+	+	-	-	-	+	-	+	+	-	+	*Escherichia coli*
Fm6	-ve	R	Acid	Acid	-	-	+	+	+	-	-	+	+	-	+	*Klebsiella* sp
Fm7	-ve	R	Alk	Alk	-	-	-	+	-	+	+	+	-	-	+	*Pseudomonas* sp
Fm8	-ve	R	Acid	Acid	-	-	+	+	+	-	-	+	+	-	+	*Klebsiella* sp
Fm9	-ve	R	Acid	Acid	+	+	-	-	-	+	-	+	+	-	+	*Escherichia coli*
Fm10	-ve	R	Alk	Alk	-	-	-	+	-	+	+	+	-	-	+	*Pseudomonas* sp
Fm11	-ve	R	Alk	Acid	-	+	-	-	-	+	-	+	-	+	-	*Salmonella sp*

Table 2: Antibiotic Susceptibility and Resistance Profile of Bacterial Isolates

Codes	Septrin	Chloramphenicol	Sparfloxacin	Ciprofloxacin	Amoxacillin	Augmentin	Gentamycin	Pefloxacin	Tarivid (Ofloxacin)	Streptomycin	Isolates	MAR Index
Fm1	15I	20S	25S	25S	17I	20S	16S	22S	19S	20S	*Pseudomonas* sp	0
Fm2	18S	10R	19S	10R	8R	0R	0R	0R	0R	10R	*Salmonella* sp	0.8
Fm3	0 R	0R	18S	0R	0R	0R	19S	0R	0R	0R	*Escherichia coli*	0.8
Fm4	0R	0R	10R	10R	11R	0R	10R	0R	0R	0R	*Klebsiella* sp	1
Fm5	0R	0R	0R	0R	0R	0R	0R	0R	0R	0R	*Escherichia coli*	1
Fm6	10R	10R	10R	14I	10R	10R	10R	0R	10R	10R	*Klebsiella* sp	0.9
Fm7	25S	20S	25S	25S	17I	25S	14I	35S	35S	20S	*Pseudomonas* sp	0
Fm8	8R	11R	8R	16S	16S	6R	0R	0R	6R	8R	*Klebsiella* sp	0.8
Fm9	0R	2R	4R	19S	10R	6R	0R	0R	18S	0R	*Escherichia coli*	0.8
Fm10	10R	19S	21S	22S	19S	19S	8R	6R	21S	18S	*Pseudomonas* sp	0.3
Fm11	0R	8R	8R	7R	10R	6R	0R	0R	6R	0R	*Salmonella* sp	1

Table 3: Percentage Susceptibility and Resistance Profile of Bacterial Isolates

Bacteria		Septrin	Chloramphenicol	Sparfloxacin	Ciprofloxacin	Amoxacillin	Augmentin	Gentamycin	Pefloxacin	Tarivid (ofloxacin)	Streptomycin
Pseudomonas spp (n=3)	S	(1) 33.33%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(1) 33.33%	(2) 66.67%	(3) 100%	(3) 100%
	I	(1) 33.33%	0	0	0	0	0	(1) 33.33%	0	0	0
	R	(1) 33.33%	0	0	0	0	0	(1) 33.33%	(1) 33.33%	0	0
Salmonella spp (n=2)	S	(1) 50%	0	(1) 50%	0	0	0	0	0	0	0
	I	0	0	0	0	0	0	0	0	0	0
	R	(1) 50%	(2) 100%	(3) 50%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(3) 100%
Escherichia coli (n=3)	S	0	0	(1) 33.33%	(1) 33.33%	0	0	(1) 33.33%	0	(1) 33.33%	0
	I	0	0	0	0	0	0	0	0	0	0
	R	(3) 100%	(3) 100%	(2) 66.67%	(2) 66.67%	(3) 100%	(3) 100%	(2) 100%	(3) 100%	(2) 66.67%	(3) 100%
Klebsiella sp (n=3)	S	0	0	0	(1) 33.33%	(1) 33.33%	0	0	0	0	0
	I	0	0	0	0	0	0	0	0	0	0
	R	(3) 100%	(3) 100%	(3) 100%	(2) 66.67%	(2) 66.67%	(3) 100%	(3) 100%	(3) 100%	(3) 100%	(3) 100%

Table 4: Antibacterial activity of ethanolic cinnamon extract

Bacterial Isolates	Concentration of extract/ Zones of inhibition (mm)				Control CPX 10µg
	100 mg/ml	50 mg/ml	25 mg/ml	12.5 mg/ml	
Pseudomonas spp	21±0.8	16±0.7	13±0.9	05±0.3	31
Salmonella spp	14±0.9	10±2	5±0.7	0	24
Escherichia coli	14±0.8	11±0.9	6±0.6	0	30
Klebsiella spp	17±0.5	12±0.3	7±0.4	04±0.9	27

Table 5: Antibacterial activity of aqueous cinnamon extract

Bacterial Isolates	Concentration of extract/ Zones of inhibition (mm)				Control CPX
	100 mg/ml	50 mg/ml	25 mg/ml	12.5 mg/ml	10µg
Pseudomonas spp	13±0.7	6±0.5	0	0	33
Salmonella spp	7±0.6	0	0	0	24
E.coli	7±0.4	0	0	0	24
Klebsiella spp	8±1.3	0	0	0	21

Key: CPX - Ciprofloxacin

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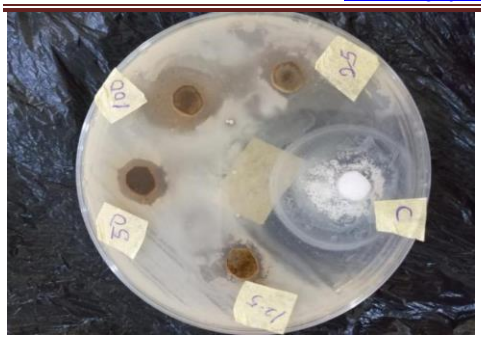

Figure 1: Antibacterial activity of ethanolic extract against *Escherichia coli* with greater zones of inhibition (14 mm, 11 mm and 6mm at concentrations of 100, 50 and 25 mg/ml)

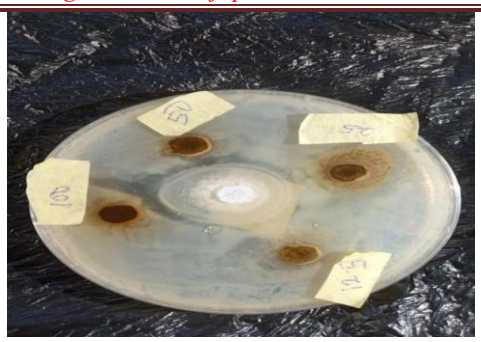

Figure 2: Antibacterial activity of aqueous extract against *Escherichia coli* with minimal zone of inhibition (7mm at a concentration of 100mg/ml)

Table 6: Minimum inhibitory concentration of cinnamon extracts

Bacterial Isolates	Minimum Inhibitory Concentration (mg/ml)	
	Ethanol	Aqueous
Pseudomonas spp	10	40
Salmonella spp	20	80
E.coli	20	80
Klebsiella spp	10	80

Table 7: Minimum bactericidal concentration of cinnamon extract

Bacterial Isolates	Minimum Bactericidal Concentration (mg/ml)	
	Ethanol	Aqueous
Pseudomonas sp	20	40
Salmonella sp	40	-
E.coli	40	-
Klebsiella sp	40	-

4. DISCUSSION

The emergence of multidrug-resistant (MDR) bacteria, which are highly pathogenic, poses a significant and escalating threat to global health. Initially confined to hospital-acquired infections, these resistant strains are now increasingly prevalent in community settings, underscoring a pressing public health concern. In this study, antibiotic susceptibility test (AST) result revealed and confirmed that all isolates investigated were multidrug-resistant organisms with MAR indices ≥ 0.2 except for some *Pseudomonas* species with 33.33% susceptibility. The susceptibility of *Pseudomonas* to various antibiotics in this study correlates with data generated from 2000 to 2017 where *Pseudomonas aeruginosa* displayed 85% susceptibility to amikacin, penicillins and cephalosporins, for tobramycin and meropenem, it was 76% and 75%, respectively [16]. The resistant of bacteria isolates that include the enterobactericea family, observed in this study correlates with Abo-state *et al* [17], they observed that all enterobacteriaceae isolates exhibited 100% resistance to ampicillin, carbicillin, methicillin, vacomycin, erythromycin, clindamycin, trimethroprim/sulfamethoxazole and tetracycline. The emergence of antibiotic resistance due to overuse and misuse of drugs makes a bacterial infection too difficult to treat, hence the need for alternative medicine to subdue the spread of resistance. Plant extracts are now considered a superior choice to control different plant and animal pathogens, as reported by several previous studies [18,19, 20, 21]. The results of antibacterial activity of cinnamon back extracts against test organisms by ethanolic and aqueous extraction observed in this study displayed high efficacy. This correlates with the study of Idris and Habibu, in which both ethanolic and hexane extracts of cinnamon bark had the highest activity against *Klebsiella pneumoniae* and *Pseudomonas aeuginosa* [22]. The antibacterial activity of plant extracts can be attributed to the presence of various phytochemicals, including alkaloids, saponins, tannins, and flavonoids [23]. These compounds exhibit antimicrobial properties through different mechanisms. Flavonoids work by complexing with extracellular proteins and bacterial cell walls, disrupting microbial membranes and leading to antimicrobial effects [24]. Alkaloids intercalate with bacterial DNA, inhibiting microbial growth and replication [25]. Saponins form pores in microbial membranes, exerting a bactericidal effect [26]. Tannins inactivate microbial adhesions, enzymes, and cell envelope transport proteins, and complex with polysaccharides, ultimately inhibiting microbial growth [27]. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values recorded in this study, revealed that cinnamon bark extract possess inhibitory and bactericidal effect against antibiotic-resistant bacteria pathogens. It has been reported previously that extracts from several plants such as oregano, cumin, sage, and other spices possessed significant ($P < 0.05$) antibacterial and antifungal activities against wide range of pathogenic bacteria (Gram-positive and Gram-negative), as well as yeast and mold [28, 29]. Furthermore, the MBC of each plant extracts were observed at higher concentrations compared to the MIC values, this supports previous findings in the literature that the antimicrobial activities have a direct relation to increasing the extracts concentration (%) [30]. This study observed higher efficacy of ethanolic extract against test organisms while low efficacy was obtained with aqueous extract of cinnamon bark. This was in agreement with Abkhoo and jahani, where aqueous extracts of cinnamon showed no activity against pathogenic strains [31]. In addition, this finding also aligns with Pinelo *et al*. They suggested that solvent type and extraction method influence efficacy [32]. The response of multidrug resistant organisms that were investigated in this study to plant extracts of cinnamon bark had their growth inhibited by ethanolic extract at different concentrations, such result are very interesting because these bacteria were from clinical source and their control are very difficult by therapeutic means considering their multidrug resistant nature. However, the study's in vitro design, limited number of bacterial isolates and concentration range, potential variability in cinnamon composition and quality, and short exposure duration may limit the generalizability of the findings.

5. CONCLUSION

This study showcases the antibacterial potential of cinnamon bark extracts against multidrug-resistant pathogens, with efficacy varying based on solvent polarity. Future research directions include identifying key bioactive compounds, promoting awareness of natural antimicrobials, optimizing extraction methods, and utilizing molecular techniques for more accurate pathogen identification.

DECLARATIONS

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Conflict of Interest
The Authors declare no conflict of interest

Authors contribution
Ayodeji S. Adedeji: Conceptualization, Laboratory Analysis, Manuscript Writing and Proofreading
Christiana O. Aderotiba: Laboratory Analysis; Abiodun Omolara Akinkugbe: Plant Identification and Manuscript Proofreading

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