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Antimicrobial Activity and Phytochemical Analysis of *Moringa oleifera* against Pathogenic Bacteria

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ABSTRACT

The success of modern medical science depends on drugs obtained from natural resources. This study determined the antimicrobial potentials of *Moringa oleifera* using the leaves, stem-bark, and root extracts against bacterial pathogens *(S. aureus, S. typhi, E. coli, and P. mirabilis).* The parts of *M. oleifera* were extracted by maceration using ethanol, benzene, and water. Qualitative phytochemical identification approaches were adopted to determine the phytochemical constituents of the plants. The agar well diffusion method was used to determine antimicrobial activities of plant extracts against pathogens. Broth dilution method was used to determine the minimum inhibitory concentrations (MIC) of the plant extract against pathogens. Minimum inhibitory and minimum bactericidal concentrations of the plant extract ranges from 6.5-25 mg/mL and 12.5-50 mg/mL respectively. The extracts contained alkaloids, flavonoids, phenols, saponins, tannins, and cardiac glycosides. Aqueous *M. oleifera* leaf extracts had the highest activity against *S. aureus* (23 mm). Similarly, ethanol leaf extract of *M. oleifera* had the highest antibacterial activity against *E. coli* with 29.5 mm. Benzene extract presented a low antibacterial activity with *M. oleifera* leaf showing the highest activity against *S. aureus* (12.5 mm). The presence of bioactive compounds could be used to treat antimicrobial infections.

Keywords: Antibacterial activity, *Moringa oleifera*, minimum bactericidal concentration, minimum inhibitory concentration, phytochemicals

INTRODUCTION

Since ancient times, people have employed natural remedies to improve their health, and modern medicine primarily relies on medications made from natural resources [1]. In the past, a large number of antimicrobial compounds were discovered from synthetic and natural products for the treatment and control of infectious agents. However, only a few of antimicrobial compounds from natural products were reachable to the needy world's market [2]. The emergence of multidrug-resistant bacteria has further compromised the accessibility and affordability of many currently prescribed antibiotics worldwide [3, 4]. As a result, this reduces the effectiveness of the treatment regimens and increases morbidity, mortality, and health care costs [5]. The situation is further complicated in low-income countries by lack of effective surveillance systems, laboratory diagnostics, and access to appropriate antimicrobials in the face of financial limitations [6- 10]. To this effect, the search for an innovative antibiotic from natural products is an important segment of modern medicine to overcome the socio-economic and health impact caused by multidrug-resistant microbes [11].

Traditional medicine is still a preferred primary health care system in many communities, with about 80% in developing countries depending directly on medicinal plants for their medical purposes [12]. Medicinal plants have been a resource for healing in local communities around the world for thousands of years. It still remains of contemporary importance as a primary healthcare mode for approximately 85% of the world's population [13], and as a resource for drug discovery, with 80% of all synthetic drugs deriving from them [14]. This is due to a number of reasons including accessibility and low cost. In the beginning, the trial and error method was used to treat illnesses or even simply to feel better, and in this way, useful plants with beneficial effects were distinguished [15]. The use of these plants has been gradually refined over the generations, and this has become known in many contexts as traditional medicine [16]. The official definition of traditional medicine can be considered as the sum total of knowledge, skills and practices based on the theories, beliefs and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health, as well as in the prevention, diagnosis, improvement or treatment of physical and mental illnesses[16]. It is a fact that all civilizations have developed this form of medicine based on the plants in their own habitats [15]. There are authors who claim that this transmitted knowledge is the origin of medicine and

pharmacy, and today, hundreds of higher plants are cultivated worldwide to obtain useful substances for medicine and pharmacy [17].

Various parts of plants such as leaf, stem-bark, and root are used to prevent, allay symptoms or reverse abnormalities [12]. Since the practice of "herbal remedies" does not adhere strictly to facts accrued using scientific approaches, orthodox medicine sees "herbal medicines" as alternative medicine [12]. However, most pharmaceutical products currently dispensed by physicians have a history of use as herbal remedies, including opium, aspirin, digitalis and quinine, which modern medicine utilizes active compounds isolated from higher plants, and about 80% of their active ingredients indicate a positive correlation between their modern therapeutic use and traditional uses. This study is aimed at determining the antimicrobial potentials of *Moringa oleifera* using their leaf, stem-bark, and root extracts against selected bacterial pathogens *(S. aureus, S. typhi, E. coli and P. mirabilis).*

Moringa oleifera has been reported to possess anti-inflammatory, antioxidant, anti-ulcer, anti-cancer, antihyperlipidaemic, anti-diabetic, anti-asthmatic, hepatoprotective and anti-hypertensive properties [18]. Previous studies reveal that the extracts of different parts of *M. oleifera* have antibacterial activity against species of bacteria that cause water-borne diseases, food-borne diseases, *Staphylococcus aureus, Salmonella typhi,* and *Escherichia coli* [18].There are several reports on the presence of anti-microbial compounds in various *Moringa oleifera* and *Psidium guajava* plant parts like leaves, bark, fruit, root and flowers [18]. Ethanol extracts of *Moringa oleifera* leaves have been reported to have inhibitory activity against *Escherichia coli* and *Staphylococcus aureus* infections, and that the inhibitory effects of the extracts are significantly higher on *Escherichia coli* than on *Staphylococcus aureus* [19].

In West Asia, one of the best-known uses for *Moringa oleifera* is the use of powdered seeds to flocculate contaminants and purify drinking water [20]. The seeds of *Moringa oleifera* also exhibit antimicrobial properties, it purifies water by removing microbes as a result of settling same, as colloids in coagulated and flocculated water. Additionally, these seeds perform their actions directly on microorganisms and cause growth inhibition. The action of antimicrobial peptides produced by this plant parts disrupt the cell membrane or inhibit necessary enzymes [20]. However, variation in plant phytochemical constituents and antimicrobial activities exist, among other factors, due to biochemical reaction within species, geographical location, methods

of extraction and solvent used for extraction. In this case, the biochemical reaction and the solvent used may have been responsible for the observed variations. This study has the potential to contribute to literature and bridge the knowledge gap in the use of *Moringa oleifera* extracts as therapeutic agent for pathogenic bacteria.

This study was aimed to determine the antimicrobial potentials of *Moringa oleifera* using the leaves, stem-bark, and root extracts against bacterial pathogens *(S. aureus, S. typhi, E. coli, and P. mirabilis).* The objectives of the study were to determine the phytochemical constituents of *Moringa oleifera* extract; to compare the antimicrobial effects of the different parts of the plant against *S. aureus, S. typhi, E. coli and P. mirabilis,* determine the minimum inhibitory concentration (MIC) of extracts against each pathogen and to determine the Minimal Bacterial Concentration (MBC) of extracts of the plant against each pathogen.

MATERIALS AND METHODS

Sample Collection and Identification

Moringa oleifera samples were collected from JOSTUM and identified at the Department of Botany, Joseph Sarwuan Tarka University, Makurdi, Benue State- Nigeria.

Preparation of Plant Extracts

The freshly collected plants were carefully washed under tap water, then by distilled water. They were air dried at room temperature (25 ^{0}C) for 14 days, pulverized to a fine powder using a mixer-grinder and stored in air-tight bottles [21].

Extraction of Plant Materials

Fifty grams of the ground plant material were extracted in 200 mL of ethanol, aqueous and benzene for 48 h. The extracts were filtered using Whatman filter paper and evaporated to dryness at 40 ^{0}C (using hot oven) to form the stock solutions.

After evaporation, the extracts were stored in air tight containers at 4 ^{0}C in the refrigerator until ready for use [21].

Qualitative Phytochemical Analysis

Test for Tannins

About 2.0 g of the plant part extract were weighed into a beaker and 10 mL of distilled water was added. The mixture was boiled for five minutes and two drops of 5% $FeCl_3$ were then added. A greenish precipitate indicated the presence of tannins [21].

Test for Flavonoids

Alkaline reagent test. Two drops of sodium hydroxide was added to 2 mL of extract of each plant part. Initially, a deep yellow color appeared but it gradually became colorless by adding few drops of dilute HCl, indicating that flavonoids was present [22].

Test for Alkaloids

Dragendorff's test. By adding 1 mL of Dragendorff's reagent to 2 mL of extract, an orange red precipitate was formed, indicating the presence of alkaloids [22].

Test for Cardiac Glycosides

Keller Killiani test. A solution of 0.5 mL, containing glacial acetic acid and 2-3 drops of ferric chloride, was mixed with 2 mL of extract. After that, exactly 1 mL of concentrated H_2SO_4 was added along the walls of the test tube. The appearance of deep blue color at the junction of two liquids indicated the presence of cardiac glycosides [22].

Test for Saponins

A drop of Na_2CO_3 solution was added to 5 mL of extract in a test tube. After vigorous shaking, it was left to rest for five minutes. Foam formation indicated the presence of saponins [22].

Quantitative Phytochemical Analysis of the Plants

Phenol

The quantity of phenols was determined using the spectrophotometric method. About 0.5 g of the fat-free plant sample was boiled in 50 mL of ether [$(CH_3CH_2)_2O$] for 15 min. Approximately 5 mL of the boiled sample was then pipetted into a 50 mL flask, 10 mL of distilled water was added, and 2 mL of NH_4OH solution and 5 ml of concentrated CH_3 $(CH_2)_3CH_2OH$ was added to the mixture. The sample was made up to the mark and left for 30 min to react for color development and measured at 505 nm wavelength using a spectrophotometer (Model 1280, Montlucon, France). The result was recorded in mg/g [23].

Tannins

Exactly 0.5 g of each plant sample was weighed into a 50 mL plastic bottle. Fifty milliliter of distilled water was added and stirred for 1 h. The sample was filtered in to 50 mL volumetric flask and made up to mark. About 5 mL of the filtered sample was pipetted into test tubes and mixed with 2 mL of $FeCl_3$ in 0.1M HCl and 0.008M $K_4Fe(CN)_6.3H_2O$. The absorbance was measured with a spectrophotometer at 395 nm wave length within 10 minutes [23].

Saponins

The samples were ground and 20 g of each plant sample poured into a conical flask and 100 mL of 20% C_2H_5OH added to the plant sample. The samples were then heated over a hot water bath for 4 h with continuous stirring at 55 ^{0}C. The mixture was then filtered and the residue was re-extracted in another 200 mL of 20% C_2H_5OH. The combined extracts were reduced to 40 mL over a water bath at 90 ^{0}C. The concentrates were then transferred into a 200 mL separator funnel and 20 mL of $(CH_3CH_2)_2O$ added to the extract and shaken vigorously. The aqueous layer was recovered while the $(CH_3CH_2)_2O$ layer was discarded and the purification processes repeated. Sixty milliliters of n-C_4H_9OH was added and the combined n-C_4H_9OH washed twice with 10 mL of 5% NaCl. The remaining solution was heated in a water bath. After evaporation, the sample was dried in the oven to a constant weight at a temperature of 50 ^{0}C for 15 minutes [23].

Flavonoids

Approximately ten grams of plant sample was repeatedly extracted in 100 mL of 80% aqueous methanol at room temperature (25 ^{0}C). The whole solution was then filtered through a whatman filter paper and the filtrates later transferred into a water bath, and the solution evaporated into dryness. The sample was then weighed until a constant weight [23].

Test Organisms

The test organisms were: *Escherichia coli, Salmonella typhi, Staphylococcus aureus and Proteus mirablis.* The identities were confirmed through biochemical tests which included: Simmons' Citrate Agar, MacConkey agar, Coagulase test, Catalase test, Kliger's Iron Agar (KIA), Sulfur Indole Motility media, Glucose broth with Durham tubes and Manitol Salt Agar (MSA).

RESULTS AND DISCUSSION

Table 1 shows the phytochemical composition of aqueous plant extracts. As shown in the Table, *Moringa oleifera* leaf had saponins (18.3 mg/g), followed by flavonoids (7.7 mg/g). Cardiac glycosides were not found. Aqueous *Moringa oleifera* stem-bark had saponins (4.36 mg/g), flavonoids (2.34 mg/g), and cardiac glycosides (0.43 mg/g). The roots had flavonoids (4.83 mg/g) and tannins (4.32 mg/g). Cardiac glycosides were absent.

Table 1: Phytochemical Components (mg/g) of Aqueous Extracts of *Moringa oleifera*

Phytochemical Components	*M. oleifera*		
	Leaf	Stem	Root
Alkaloids	4.0	1.03	3.62
Flavonoids	7.7	2.34	4.83
Phenols	2.9	0.82	3.04
Saponins	18.3	4.36	12.36
Tannins	3.3	1.06	4.32
Cardiac glycol	-	0.43	-

Table 2 shows the phytochemical constituents of ethanol plant extracts. *Moringa oleifera* leaf extracts had the following; flavonoids (8.32 mg/g), saponins (6.23 mg/g). Cardiac glycosides were not detected. The stem-bark had flavonoids (4.23 mg/g), alkaloids (2.33 mg/g), and no cardiac glycosides. Roots had flavonoids (6.71 mg/g), tannins (3.86 mg/g), and no cardiac glycosides.

Table 2: Phytochemical Components (mg/g) of Ethanol Extracts of *Moringa oleifera*

Phytochemical Components	*M. oleifera*		
	Leaf	Stem	Root
Alkaloids	5.23	2.33	3.6
Flavonoids	8.32	4.23	6.71
Phenols	2.93	0.48	3.03
Saponins	6.23	0.32	0.63
Tannins	4.05	2.03	3.86
Cardiac glycosides	-	-	-

Table 3 shows the phytochemical components of Benzene extracts of *Moringa oleifera.* The leaves had tannins (1.23 mg/g) and phenols (0.63 mg/g). Alkaloids, flavonoids and saponins were undetected. The stem-bark of *M. oleifera* had tannins (0.76 mg/g), saponins (0.38 mg/g). Cardiac glycosides and alkaloids were undetected. The roots had only alkaloids (1.2 mg/g), Cardiac glycosides (0.54 mg/g). Saponins were undetected.

Table 3: Phytochemical Components (mg/g) of Benzene Extracts of *Moringa oleifera*

Phytochemical Components	*M. oleifera*		
	Leaf	Stem	Root
Alkaloids	-	-	1.2
Flavonoids	-	0.33	0.38
Phenols	0.63	0.24	0.36
Saponins	-	0.38	-
Tannins	1.23	0.76	1.02
Cardiac glycosides	0.03	-	0.54

Table 4 shows the antibacterial properties of aqueous, ethanol and benzene extracts of *Moringa oleifera*.

Aqueous *Moringa oleifera* leaf extracts had the highest activity against *S. aureus* (23 mm). *E. coli* was next at (22 mm). The least activity detected was against *P. mirabilis* (17 mm). Similarly, the stem-bark had activity against *S. aureus* (18 mm), *P. mirabilis* (15 mm), and *S. typhi* (10 mm). *Moringa oleifera* root extracts had the highest inhibition on *P. mirabilis* (22 mm), *E. coli* (21 mm), and S. *typhi* (16 mm).

Ethanol *Moringa oleifera* leaf extract had highest zone of inhibition against *E. coli* (29.5 mm), and *S. typhi* was next at (24 mm). The least activity detected was against *S. aureus* (18.5 mm). Similarly, stem-bark had the highest activity against *S. typhi* (22.5 mm), *S. aureus* (20.5 mm), and the least action was against *P. mirabilis* and *E. coli* (15.6 mm). The root extracts showed the highest activity against *P. mirabilis* (24 mm), with *E. coli* next at (21 mm). No activity was observed against *S. aureus*.

Benzene *Moringa oleifera* leaves extract only had zones of inhibition against *S. aureus* (12.5 mm). Stem-bark extracts had no inhibition against any of the tested organisms while roots had inhibition against *S. typhi* (9.5 mm), and *E. coli* (8.5 mm).

Table 4: Zones of Inhibition (mm) for Aqueous, Ethanol and Benzene Extract of *Moringa oleifera*

	AQUEOUS			ETHANOL			BENZENE		
	M. oleifera			*M. oleifera*			*M. oleifera*		
Test org.	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
P.mirabilis	17	15	22	20	15.6	24	-	-	-
E.coli	22	12	21	29.5	15.6	21	-	-	8.5
S.typhi	20	10	16	24	22.5	20.5	-	-	9.5
S.aureus	23	18	20	18.5	20.5	-	12.5	-	-

Table 5 shows the MIC of aqueous, ethanol and benzene extracts of *Moringa oleifera*. *Moringa oleifera* leaf extracts had minimum inhibitory concentration (MIC) against *P. mirabilis* (12.5 mg/mL). The remaining organisms all had same inhibition at 6.25 mg/mL. Stem-bark extracts had MIC against *E. coli* and *S. typhi* (25 mg/mL) each and *P. mirabilis* (12.5 mg/mL). The least MIC was against *S. aureus* (6.25 mg/mL). Roots extracts had MIC against *S. typhi* (12.5 mg/mL). The rest of the organisms all had same sensitivity at 25 mg/mL.

Ethanol *Moringa oleifera* leaves extracts had minimum inhibitory concentration (MIC) against *S. aureus* (12.5 mg/mL), and the rest of the organisms all had 6.25 mg/mL MIC. Stem-bark extracts had MIC against *P. mirabilis, E. coli* and *S. aureus* (12.5 mg/mL each). The highest shown was against *S. typhi* (6.25 mg/mL). Lastly, *roots extracts* had MIC against *P. mirabilis, E. coli* and *S. typhi* (6.2 mg/mL each) while no inhibition was observed against *S. aureus*.

Benzene *M. oleifera* leaf extracts showed MIC of 25 mg/mL against *S. aureus*. Stem-bark extracts had no inhibitory activity against any of the test organisms, while roots extracts only had inhibition against *E. coli* and *S. typhi* at 25 mg/mL each.

Table 5: MIC of aqueous, ethanol and benzene extracts of *Moringa oleifera*.

	AQUEOUS			ETHANOL			BENZENE		
	M. oleifera			*M. oleifera*			*M. oleifera*		
Test org.	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
P.mirabilis	12.5	12.5	6.5	6.25	12.5	6.25	-	-	-
E.coli	6.25	25	6.25	6.25	12.5	6.25	-	-	25
S.typhi	6.25	25	12.5	6.25	6.25	6.25	-	-	25
S.aureus	6.25	6.25	6.25	12.5	12.25	-	25	-	-

Table 6 shows the MBC of aqueous, ethanol and benzene extracts of *Moringa oleifera*. Aqueous *Moringa oleifera* leaves extracts showed minimum bactericidal concentration (MBC) against *P. mirabilis* and *S. aureus* at 25 mg/mL each. All other test organisms were inhibited at a MBC of 25 mg/mL. Similarly, *s*tem-bark had the highest MBC against *S.typh* (50 mg/mL) and 25 mg/mL each against *P. mirabilis* and *E. coli*. The lowest (12.5 mg/mL) MBC shown was against *S. aureus,* while the roots extracts showed highest (50 mg/mL) MBC against *S. typhi* (50 mg/mL), *P. mirabilis* and *E. coli* (25 mg/mL each). The lowest shown was against *S.aureus* (12.5 mg/mL). Ethanol *moringa oleifera* leaf had highest MBC against *E. coli* and *S. aureus* (25 mg/mL each). The lowest MBC was against *P. mirabilis* and *S. typhi* (12.5 mg/mL each). Stem-bark had highest MBC against *P. mirabilis*, *E. coli* and *S. aureus* (25 mg/mL each). The lowest MBC was against *S. typhi* (12.5 mg/mL). Roots extracts had highest MBC against *S. typhi at* 25 mg/mL and 12.5 mg/mL each against *P. mirabilis* and *E. coli*. There was no bactericidal effect against *S. aureus.* Benzene *Moringa oleifera* leaf had highest MBC (50 mg/mL) against *S. aureus*. Stem-bark extracts had no activity against any of the test organisms while the roots extracts only had activity (50 mg/mL each) against *E. coli and S. typhi*.

Table 6: Minimum Bactericidal Concentration (mg/mL) for Aqueous, Ethanol and Benzene Extracts of *Moringa oleifera*

	AQUEOUS			ETHANOL			BENZENE		
	M. oleifera			*M. oleifera*			*M. oleifera*		
Test org.	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
P.mirabilis	25	25	25	12.5	25	12.5	-	-	-
E.coli	12.5	25	25	25	25	12.5	-	-	50
S.typhi	12.5	50	50	12.5	12.5	25	-	-	50
S.aureus	25	12.5	12.5	25	25	-	50	-	-

The presence of phytochemicals in aqueous *Moringa oleifera* leaves show that the plant leaves have medicinal value. *Moringa oleifera* leaves had high antibacterial activity. This could be because it has phytochemicals (saponins) in large quantities. Soetan *et al*., [24] reported that purified saponin extract of *Sorghum* bicolor showed anti-bacterial activity against three pathogenic microbes; *Escherichia coli, Staphylococcus aureus and Candida albicans*. It was concluded that saponins have inhibitory effect on Gram-positive organisms, but not Gram negative organisms, or fungi. The findings of Isitua *et al*. [25] also state that the leaf extracts of *Moringa oleifera* contain proteins that have varying antibacterial activities. The organisms may have been inhibited due to the presence of the phytochemicals.

Ethanol extracts of *Moringa oleifera* leaves produced flavonoids in higher quantities compared to other phytochemicals. This review that in the ethanol extracts, flavonoids are more concentrated in the leaves of this plant. This further suggests that respective plant parts with higher phytochemical of certain extracts could be the preferred plant part for therapy.

The variations in antimicrobial properties of extracts used in this study can be attributed to the presence of different phytochemical constituents as previously researched by Chitia *et al*. [26] and Biswas *et al*. [27]. This finding is in agreement with that of Moore *et al.* [28] who reported that variations in plant phytochemical constituents and antimicrobial activities exist, among other factors, due to biochemical reaction within species, geographical location, methods of extraction and solvent used for extraction. In this case, the biochemical reaction and the solvent used may have been responsible for the observed variations. The results from this study reveal that benzene extract of leaves of *Moringa oleifera* only had good concentration of tannins. The result however, showed that benzene may not be the preferred solvent as compared to ethanol and aqueous solvent.

Aqueous *Moringa oleifera* leaves had the highest inhibition against *S. aureus*. Possibly, leaves of *Moringa* extracts had phytochemicals (saponins) more active against Gram positive bacteria than Gram negative bacteria as stated Gayanthri *et al.,* [29] that *M. oleifera* leaf extracts showed significant inhibitory activity against *Staphylococcus aureus*.

Ethanol extracts of the plant produced zones of inhibition in almost all the parts of the plant used against all the test organisms, except for ethanol *Moringa oleifera* roots which failed to inhibit the growth of *S. aureus.* It may have been that ethanol *Moringa oleifera* roots lack the basic

phytochemicals to inhibit the growth of *Staph. aureus.* The highest zone of inhibition observed by *Moringa oleifera* leaf was against *E. coli* infections. This result reveals that the ethanol leaf extracts of *Moringa oleifera* were effective on *E. coli* and may be used to effectively treat *E. coli* infections. This is in accordance with the findings of Ehab *et al.* [30] who stressed *that M. oleifera* is a medicinal plant, a rich source of bioactive compounds and is used in the treatment of certain infections such as caused by *Staphylococcus aureus and Escherichia coli*.

However, ethanol *Moringa oleifera* roots could not inhibit the growth of *S. aureus*. Benzene stem bark plant extracts produced very weak zones of inhibition with different parts of the plant extracts, and no zones of inhibition with most of the plant parts. *Moringa oleifera* stem bark extract had no inhibition against any of the test organisms. It was however observed that *Moringa oleifera* leaves had minimum inhibition against *S. aureus infections*. This finding differs from that obtained by Wasem *et al*. [18] that minimum inhibition zone for *Moringa oleifera* leaves extracts was observed against *Salmonella* species. This difference may be attributed to variation of solvent applied. This is an indication that benzene may not be a good solvent for extraction, compared to the other solvents used in this study. However, this studies show that benzene *Moringa oleifera* leaves can be used to treat *S. aureus* infections effectively. With this result, it is clear that the type of solvent use for extraction also has a role to play in the activity of the extract. It is so because various solvent turn to have different chemical structure and polarities.

This study however, agrees with Kinghorn *et a*l. [17] that the extraction of essential compounds of a plant using water and ethanol had highest content of bioactive compounds in its extract. This assertion is true because benzene extracts had few bioactive compounds as reflected in this study

Aqueous stem bark extracts of *Moringa oleifera* displayed a MIC against all the test organisms. *Moringa oleifera* leaves produced the lowest MIC against *Proteus mirabilis infections*. This work perfectly aligns with the findings of Gomes *et al*., [31] which states that the antibacterial activity of *Moringa oleifera* was seen against several bacteria namely *Escherichia Coli*, *Staphylococcus aureus, and Proteus* spp. In this case, *Proteus mirablis* infections has been inhibited by aqueous *Moringa oleifera leaf* while *Moringa oleifera* root produced the lowest minimum inhibitory concentration against *S. typhi*. This shows that the aqueous extracts of this

plant produced a better inhibition on *P. mirablis*. With this result, *Moringa oleifera* leaves can be comfortably use to treat *P. mirabilis* infections, while the roots are better on *S. typhi*.

Similarly, aqueous extracts of the plant showed good results for minimal bactericidal concentration against all organisms. Aqueous *Moringa oleifera* stem and aqueous *Moringa oleifera* roots had good minimal bactericidal effect against *S. typhi infections*. Aqueous *Moringa oleifera* stem and aqueous *Moringa oleifera* roots can be preferably used against *S. typhi* infections. This finding varies with that obtained by Al-Farsi *et al*., [32] that the minimum bactericidal concentration extract for *M. oleifera* leaves was observed against *Salmonella paratyphi*. Ethanol extracts of *Moringa oleifera* also had inhibitory effects against all the test organisms, except for ethanol *Moringa oleifera* roots which showed no inhibition against *S. aureus infections*. Saponins, seemingly more effective on *S. aureus* infections was in low concentration in ethanol *Moringa oleifera* root extract. Therefore ethanol *Moringa oleifera* roots may not be effective against *S. aureus infections*. The leaves of *Moringa oleifera* seemed effective against *E. coli* infections. This may have been so due to the solvent and the variations in phytochemicals distribution in *Moringa oleifera* plant. Ethanol *Moringa oleifera* stem can be effectively use for the treatment of *P. mirabilis* and *E.col* infections. Similar findings were reported by Amabye *e t* al., [33] on screening and the antibacterial activity of *Moringa oleifera* leaves and seeds extract against selected bacteria.

Benzene solvent extracts also had bactericidal effects in few parts of *Moringa oleifera* plant. The roots were effective against *E. coli* and *S.typhi infections,* while the leaves were effective against *S. aureus* infections. The differences in activity may have been attributed to variations in the bioactive concentration in different parts of the plant. The plant solvent used had little effect on most test organisms in this research work. Therefore, benzene may not really be a good solvent compared to other solvents used in this research work.

CONCLUSION

Crude extracts of *Moringa oleifera* (leaf, stem-bark and roots) showed good antimicrobial activity against both gram-positive and gram-negative bacteria. Aqueous and ethanol extract of the plant presented a better antimicrobial activity than the benzene extract. It is concluded that antimicrobial activity of the extracts is due to the presence of phytochemicals including alkaloids,

flavonoids, phenols, saponins, tannins and cardiac glycosides. MIC ranged from 6.5-50.00 mg/mL while MBC range from 12.5 to 50.00 mg/mL. This work recommends the use of *M. oleifera* leaves, stem bark and roots in traditional medicine.

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