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ANTIBACTERIAL ACTIVITY OF *ADANSONIA DIGITATA* (BAOBAB) LEAVES USING GAS CHROMATOGRAPHY-MASS SPECTROMETRY: A PUBLIC HEALTH APPLICATION FROM ENVIRONMENTAL AND MEDICAL PERSPECTIVE

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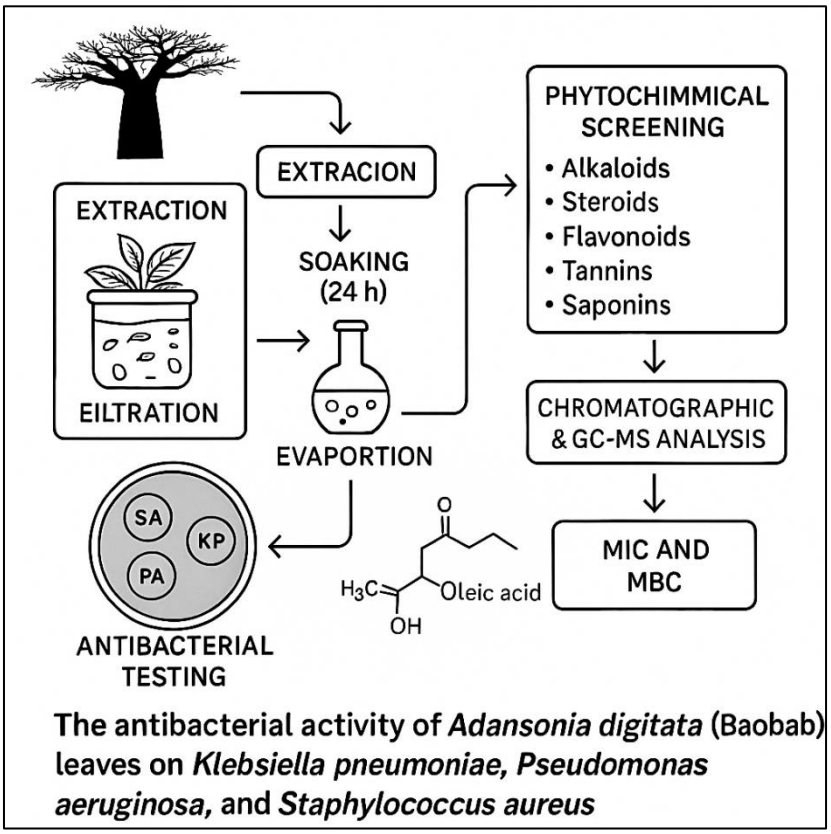
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ABSTRACT

This research investigated the antibacterial activity of *Adansonia digitata* (Baobab) leaf extracts against *Klebsiella pneumoniae* (ATCC 13883), *Pseudomonas aeruginosa* (ATCC 27853), and *Staphylococcus aureus* (ATCC 6538). *Adansonia digitata* (Baobab) leaves were extracted through 24-hour aqueous soaking, filtrated and evaporated using water bath. Phytochemical screening, thin layer chromatography (TLC), column chromatography, and gas chromatography–mass spectrometry (GC-MS) were used to qualitatively analyze the extracts. The antibacterial activity was determined by using the agar well diffusion method, while minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were determined by broth dilution. technique The ethanolic extracts yielded 11.56% and confirm the presence of alkaloids, steroids, flavonoids, tannins, and saponins, both ethanol and aqueous extracts showed significant antibacterial sensitivity against *S. aureus* and *K. pneumoniae*, with inhibition zones exceeding 18 mm, though lower ($p < 0.05$) compared to those produced by standard antibiotics (24.0 ± 2.0 to 30.0 ± 2.0 mm). The Minimum Inhibitory Concentration for ethanol extracts against *S. aureus* was 31.3 mg/ml, significantly lower ($p < 0.05$) compared with *P. aeruginosa* and *K. pneumoniae* (62.5 mg/ml each). Minimum Bacteriacidal Concentration values were 250 mg/ml for *S. aureus* and 500 mg/ml for both *K. pneumoniae* and *P. aeruginosa*. Antibacterial eficacy of the extracts increased with increase in concentration, and specific fractions of the ethanol leaf extract-containing oleic acid-exhibited significantly higher ($p < 0.05$) activity against tested strains. These findings suggest potential for *A. digitata* leaf extracts in antimicrobial therapy and health intervention.

Keyword: *Adansonia digitata*, ethanol, GC-MS, *Klebsiella pneumonia, Pseudomonas aeruginosa.*

Graphical Abstract



1 INTRODUCTION

Microorganisms (Bacteria, Fungi, Virus) have over time developed resistant many conventional antibiotics which have necessitated the use of alternatives therapy as antimicrobial agents (1). Several plant that contain metabolites which have effect against the pathogens are being utilized. There are research on the utilization of antimicrobial peptides and compounds from plants and animals (2), imitating the natural lipopeptides of bacteria and fungi (3) and using the uncultivated portion of microbiota through the meta-genomic approach (4). Other ways include drugs bio-engineered to possess double target activities, such as a rifamycin–quinolone hybrid antibiotic. The less complicated/expensive approach of all the aforementioned is the use of plants which have helped many researchers to focus on phytomedicine (i.e. use of plant for treatment of infections). Many plant parts such as leaves, stem, roots, seeds and fruit pulps have been utilized against infectious microorganisms; among them are *Adansonia digitata* (Baobab), *Grewia trichocarpa*, *Launaea cornuta* and *Zanthoxylum* among many others (5, 6). Resistance of several species of microbes to a wide range of antibiotics has been a major problem faced by clinicians. The resistance could be due to frequent mutation of the organisms which has led to increase in spread of bacterial infections between man and animals (7). *Adansonia sdigitata* is known as Baobab, the plant belongs to the family of Bombacaceae and genus *Adansonia* (8). *A. digitata* is found in West Africa and Asia, its family comprises of 30 genera and 250 species (8). The name baobab was derived from Arabic word bu – hibab meaning "fruit with many seeds" (9]). Baobab tree is found in Savannah area of African compared to other trees due to its huge size. Many communities have traditions that prohibits the inhabitants from cutting down the tree, places where extensive deforestation takes place, the baobab trees still survives (4). The plant parts are the leaves, fruit pulp, seeds and bark of stem and roots as recorded by (10). Due to its high nutritional value, the leaves can be used to prepare soups while the seeds are used as a thickener for locally made soup. They are raw material for making ropes, hats, bags amongst others. It has been recorded that the plant leaves are used to treat diseases of the kidney, inflammations, asthma, diarrhoea etc. (11). Studies by (12) have also shown that the effectiveness of the plant against pathogenic bacteria is real.

The plant has been attracting many pharmaceutical companies due to its numerous traditional uses in treatment of various forms of ailment (13). Report has shown that the European commission has authorized essentiality of *Adansonia digitata* fruit pulp as novel food (4, 14). In West Africa the plant bark is used for treatment of fever and as an antidote (9).

1.1 Justification of the Study

Medicinal plants are increasingly gaining ground, probably due to increase rate of resistance to modern drugs and antibiotics by the pathogens responsible for causing gonorrhea, tuberculosis and other diseases and high cost of drugs for maintenance of health (10). People in developing countries still rely on traditional healing method and medicinal plants for their daily healthcare, in spite of the advancement in modern medicine (15). Baobab is an important medicinal plant in tropical Africa and India, all parts of the plant have been reported to be used in treatment of various forms of ailment such as antiviral, anti- inflammatory, antioxidant, antipyretic, antimicrobial and anti-trypanosoma activities (8). Quite a number of research has been executed on the antibacterial activities of different parts of *Adansonia digitata* on clinical isolates and its comparative effect has not been sufficiently studied, hence the need to study the antibacterial activities of the leaves and stem bark effects on some selected bacteria.

Aim of the study

The aim of this study is to determine the antibacterial activity of *Adansonia digitata* (Baobab) leaves on some selected bacteria.

Objectives of study

The objectives of this study are to;

- Carryout phytochemical screening of *Adansonia digitata* (Baobab) leaves.
- Determine the antibacterial activity of *Adansonia digitata* (Baobab) leaves against *Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Staphylococcus aureus* using Agar well diffusion.
- Determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of *Adansonia digitata* (Baobab) leaves against *Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Staphylococcus aureus*
- Determine some of the active phytochemical components of *Adansonia digitata* (Baobab) leaves.
- Carryout column chromatography on the stem bark and leaves of *Adansonia digitata.*
- Carryout Gas chromatography– mass spectrometry (GC-MS) analysis of the fractions of *Adansonia digitata.*
- Determine the antibacterial effects of the fractions of *Adansonia digitata* (Baobab) leaves against *Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Staphylococcus aureus.*
- Determine the minimum inhibitory concentration (MIC) and minimum bacteria concentration (MBC) of the column fractions of *Adansonia digitata* (Baobab) leaves and against *Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Staphylococcus aureus*.

2 MATERIALS AND METHODS

2.1 Study Area

This study was conducted in the Department of Microbiology's Microbiology Laboratory at the University of Abuja in Abuja, Nigeria. Nigeria's Federal Capital Territory is Abuja. The domain spans a large area of land, around 8000 squares, and is centrally positioned. The majority of Abuja's population is made up of immigrants, Gbagi, Nupe, and Gwari. The average annual rainfall in this area is between 1403 and 1632 millimeters. Between March and November, when the average lowest and maximum temperatures were 30 and 37 degrees Celsius, respectively, this rain was observed. There should be six to ten hours of sunshine every day, with a relative humidity of roughly 50% for wet conditions and 20% for dry conditions. The primary economic pursuits of the indigenous people consist of cultivating arable crops, raising livestock, and fish aquaculture. Among the five local government area councils in Nigeria's federal capital territory is Gwagwalada. In addition to Abaji, Kuje, Bwari, and Kwali, Abuja is also a part of the Federal Capital Territory. The primary town in the region, Gwagwalada, with a population of 157, 770 as of the 2018 Census and a total area of 1,043 km2. Located at longitude 7, 0919 and latitude 9, 9414 (lat (DMS) 80 560 29N, long (DMS) 70 51 31E).

2.2 Preparation and Sterilization of Media

Mueller Hinton agar (Himedia), peptone water (Himedia), nutrient agar (Himedia M001-500G), and mannitol salt agar (Himedia) were the media utilized in this investigation, and they were prepared in accordance with the manufacturer's instructions.

2.3 Sample collection and identification

From Kwali Area Council FCT-Abuja, healthy *Adansonia digitata* leaves was collected, and they was sent to the University of Abuja Herbarium for identification. The extracts from the kernels were extracted mechanically after the *Adansonia digitata* leaves was separated, dehulled, cleaned, and dried at room temperature to consistent weights.

2.4 Extraction and sterilization of *Adansonia digitata* leaves and stem bark

Adansonia digitata leaves was extracted using the technique described by (16). Thus, 700 milliliters of ethanol, hexane, and distilled water were added to each of the three 1000 milliliter Erlermeyer flasks after two hundred grams (200gm) of *Adansonia digitata* leaves powder were weighed into each. After thoroughly mixing the material, the bioshaker was left for a full day. After 48 hours, the content in each flask was filtered using Whattman no.1 filter paper and then concentrated by evaporation in water bath at 45^0C. Ultimately, the extracts were kept in sterile bijoux bottles at 4^oC after being sterilized using membrane filtration in accordance with (16).

2.5 Authentication of Test Organisms

The Diagnostic Division of NIPRID, Abuja provided the test organisms, which were *Klebsiella pneumonia* (ATCC13883), *Pseudomonas aeruginosa* (ATCC 9027), and *Staphylococcus aureus* (ATCC 6538). The test organisms were resuscitated and authenticated by streak inoculation on Nutrient agar and incubated for 24 hours at 37^0C, and then placed on their various selective medium. After Gram staining, they were evaluated for purity by microscopy and put through other standard procedures. Finally, they were kept on fresh nutrient agar slants in a refrigerator at 4^oC.

2.6 Identification of test organisms

Microscopy was employed to identify the test organisms after Gram Staining. Visual exams were performed to detect growth patterns, colony characteristics, color, shape, arrangement, and the complete surface of pure isolates.

The IMViC series of assays was applied to isolates from Nutrient Agar using both blue-pigmented colonies and mucoid colonies. These provide more proof that *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* were identified. It consists of Indole Production, Methyl red test, Voges Proskauer test and the citrate utilization test while *Staphylococcus aureus* was isolated on mannitol salt agar (MSA). Additionally, coagulase and catalase assays were performed on *Staphylococcus aureus* (17).

2.7 Indole Test

Each isolate was injected with an 18-hour culture in bijoux bottles holding 3 milliliters of sterile tryptone water, and the bottles were then incubated for 48 hours at 37^oC. In order to check for indole, 0.5 milliliter of Kovac's reagent was added, and after 10 minutes, the surface layer was gently shook to look for a red coloring. A positive indole test was shown by a red surface ring layer (17).

2.8 Citrate Utilization Test

To conduct this test, an agar slant was inoculated with the test organism, then a 5ml Simmon's citrate agar was stabbed in the butt. For every case, an unvaccinated control group was put up. After being cultured for 48 hours at 37^oC, the medium turned vivid blue and the growth showed that the organism could use citrate as its only carbon source (17).

2.9 Catalase Test

A sterile test tube was filled with three (3) milliliters of hydrogen peroxide solution. Using a glass rod, multiple colonies of the test organism that had been cultured for eighteen hours were selected and submerged in the hydrogen peroxide solution. Positive results were shown by the immediate bubbling that was noticed (17).

2.10 Methyl Red Test and Voges-proskauer test

This examination was conducted in accordance with (17). To create a broth culture, the test organism was injected into sterile peptone water and cultured for a full day. After sterilizing and cooling, 0.5g of D glucose and 0.5g of potassium pallidium were added to prepared 5% peptone water. 2.5ml of the broth culture was then added, and the mixture was cultured at 4^0C for a whole day. The emergence of red hue with methyl red addition denotes a favorable methyl red reaction. After adding 5 drops of 40% potassium hydroxide and 15 drops of 5% α-naphtha in ethanol, the remaining 4ml of broth in the stock bottle was shaken. In less than an hour of standing, the bottle's cap came loose and slanted. Bright pink appearance suggested a favorable response. No color shift suggested a negative response to the Voges-proskauer test.

2.11 Coagulase Test

A drop of distilled water was placed on a clean grease free slide and a colony of the test organism was picked and emulsified on the drop of water to make a thick suspension. A loopful of plasma was added to the suspension and mixed gently to observe for clumping of the organism within 10 seconds (17).

2.12 Qualitative Phytochemical Screening

In less than an hour of standing, the bottle's cap came loose and slanted. Bright pink appearance suggested a favorable response. No color shift suggested a negative response to the Voges-proskauer test.

2.13 Tests for Tannins

The ferric chloride test was used to check for tannins, and a 5ml solution of the extract was placed in a test tube. Next, a 5% ferric chloride solution was added in 1 milliliter. There was a precipitate that turned greenish black, which suggested the presence of tannins (18).

2.14 Test for Flavonoids

A tiny quantity of the plant material extract was mixed with a few drops of strong hydrochloric acid. The presence of flavonoids is indicated by the rapid development of a red tint (18).

2.15 Test for Saponins

After diluting one milliliter (1ml) of the extract with twenty milliliters of distilled water, the mixture was agitated for fifteen minutes within a graduated cylinder. Saponnins are present when a layer of foam one centimeter thick is present (18).

2.16 Test for Steroids

To test for steroids, one milliliter of the extract solution was taken, and one milliliter of sulfuric acid was added. Steroids are indicated by the color red (18).

2.17 Test for Alkaloids

Utilizing Wagner's technique, check for alkoids by placing 0.2 milliliters of diluted hydrochloric acid and 2 milliliters of the extract solution in a test tube. Wagner's reagent, or 1 milliliter of iodine solution, was then added. The formation of a reddish-brown precipitate suggested the presence of alkaloids (18).

2.18 Preparation of *Adansonia digitata* leaves extract concentrations

In screw-capped bijoux bottles, stock solutions of the ethanolic, hexane, and aqueous extracts of the leaves of *Adansonia digitata* were made. According to (18) but modified, six distinct concentrations of each extract were generated at 500mg/ml, 250mg/ml, 125mg/ml, 62.5 mg/ml, and 31.25mg/ml. Using dimethyl sulfoxide (DMSO) as the diluent, five-fold doubling dilutions of the *Adansonia digitata* leaves extract stocks were prepared in screw-capped bijoux bottles. A sterile bijoux container holding 1.0 ml of dimethyl sulfoxide (DMSO) was aseptically pipetted with about 1.0ml of the stock sample. Everything was well combined. After that, 1.0 ml of the dilution sample and 1.0 ml of dimethyl sulfoxide (DMSO) were aseptically pipetted into the following sterile bijoux bottle. Everything was well combined. Other three-fold dilutions of solutions were similarly made up to 31.3mg/ml (18).

2.19 Standardization of the Test Bacteria

Pseudomonas aeruginosa, *Staphylococcus aureus*, and *Klebsiella pneumoniae* test bacteria were standardized using Mcfarland turbidity standards number 0.5. In 100 milliliters of distilled water, barium chloride (1.175g) was dissolved. 100 milliliters of water were mixed with one milliliter of sulfuric acid. To achieve the turbidity standard of 0.5, 99.5 ml of H2SO4 solution was mixed with 0.5ml of barium chloride solution. This corresponds to a density of 108 colonies of bacteria per milliliter. After diluting the isolate with sterile water in test tubes, the Mcfarland turbidity was compared (19).

2.20 Antibacterial Assay

Using the agar well diffusion method as reported by (20), the antibacterial activity of the ethanolic, hexane, and aqueous extracts of *Adansonia digitata* against the test organisms was ascertained. Each test organism was aseptically seeded with 1ml of an 18-hour broth culture using a sterile pipette on the sterile, solidified Mueller Hinton Agar plate. Any surplus was then aseptically drained. After the plates were left undisturbed for approximately fifteen minutes, three wells were formed on each seeded agar plate using a sterile cork borer with a diameter of five millimeters. The wells were kept sufficiently apart, kept away from the plate's edge, and spaced 25mm apart from one another to prevent zone overlap. Mueller Hinton agar that had been melted was used to seal the base of each well two times. Two drops (0.4ml) of a known concentration of each extract were added to well 1, well 2 and well 3 of the plates seeded with *Pseudomonas aeriginosa, Staphylococus aureus,* and *Klebsiella pneumoniae*, respectively, while ampicillin was added to well 2 of the plates seeded with *Staphylococcus aureus* using sterile Pasteur pipettes. The diluent (DMSO) was utilized as the negative control, while the positive controls were ampicillin and chloramphenicol. The plates were incubated at 37°C for 24

hours after being left undisturbed for approximately 30 minutes at room temperature to allow the extracts to diffuse. Using a transparent metric ruler, the diameters of the zones of inhibition surrounding the wells were measured and recorded after a 24-hour period. The mean zone diameters of inhibition (mm) were calculated for the antibacterial investigation, which was conducted in triplicate. Results were interpreted using the 10 mm standard for antibacterial susceptibility testing, as stated by (20).

2.21 Determination of Minimum inhibitory concentration (MIC)

The technique outlined by (21) was used to calculate the minimum inhibitory concentration (MIC). The MIC was measured against five distinct concentrations (500mg/ml, 250mg/ml, 125mg/ml, 62.5mg/ml, and 31.3mg/ml) of each extract generated through double dilution using DMSO as the diluent in this assay, which used the broth dilution technique. Every test organism had its broth culture diluted after 18 hours, and the number of organisms was found to be 0.5 Mac Farland standard. For this test, 100µL of the various amounts of extract was combined with 10 ml of nutrition broth. Next, 10µL of a standardized bacterial culture was added to each tube, and they were all incubated at 37°C for a 24 hours. After a day, the turbidity of each tube was compared to that of the control tubes. Ampicillin and chloramphenicol served as positive controls, and DMSO served as the negative control. The minimum inhibitory concentration (MIC) was determined by taking the lowest dose at which there was no visible increase in turbidity (nor an increase in optical density) using a spectophometer (21).

2.22 Determination of Minimum bactericidal concentration (MBC)

According to (22), the extracts' minimum bactericidal concentration (MBC) was ascertained. The broth dilution obtained from the minimum inhibitory concentration (MIC) tubes was used to determine this. Samples were removed from tubes that showed no increases in optical density and visibly in the minimum inhibitory concentration (MIC) test. Sterile wire loops were used to inoculate newly made nutrient agar plates, and the plates were then incubated for 24 hours at 37°C. The minimum bactericidal concentration (MBC) was determined by taking the lowest concentration of the extracts that did not exhibit any bacterial growth (22).

2.23 Fractionation of *Adansonia digitata* leaves extracts

The antibacterial activity of the *Adansonia digitata* leaf extracts was assessed both singly and in combination after the fractions were separated using thin layer chromatography and column chromatography. In order to determine which active ingredients were in charge of the observed activities, the fractions were further subjected to Gas Chromatography-Mass Spectrometry (GC-MS) analysis (18).

2.24 Thin Layer chromatography of *Adansonia digitata* leaves extracts

The thin layer chromatography (TLC) was performed using (18) method as a guide. *Adansonia digitata* leaves extracts were subjected to a TLC profile on a pre-coated TLC plate using a mixture of hexane/ethyl acetate and petroleum ether in a ratio of 6:3:1 for the leaves. The mixture was kept in a beaker with a cover to maintain the concentration. The TLC plates were used; their measurements were 5.0cm in width and 10cm in length. Using a ruler and pencil, a line was drawn across the width of the plates 1.0cm from the bottom as a starting point. The extracts were then placed in the middle of the line formed on the TLC plate using a capillary tube. The plates were placed in a chromatography chamber, and the plates were watched until the solvent ascended to the solvent front, which was marked by 6.1cm on the TLC plate. The TLC plates were carefully taken out of the chromatography chamber, and each component was marked with a pencil before being examined under a UV lamp set at 254/366nm to see the separated components. In order to achieve the color and persistent spot on the TLC plate, the plates were additionally sprayed with a solution of 90 mg/ml ethanol and 10 mg/ml sulfuric acid, then heated on a hot plate (18).

The resolution front (RF) value was calculated for each of the fractions using the formula:

$$\mathrm{Rf} = \frac{\text{Distance travelled by solute}}{\text{Distance travelled by solvent}} \qquad \text{Equ. (1)}$$

2.25 Column chromatography of *Adansonia digitata* leaves extracts

After being cleaned and dried, the flash column was clamped vertically onto a retort stand. 30g of absorbent silica gel was added to the clean, dry column after a piece of cotton wool. To achieve consistent packing, a gentle tap was applied to the column. After weighing and adding about 15g of *Adansonia digitata* leaves extract to the column, solvent was added. For both *Adansonia digitata* leaves, solvent elution was initiated with 100% hexane and proceeded with hexane/ethyl acetate (80:20%, 60:40%, 40:60%, 20:80% v/v, 100% ethyl acetate and 100% methanol, respectively). The fractions were gathered and allowed to evaporate in 50ml beakers. The fractions were further refined by thin layer chromatography (TLC), with 10% sulphuric acid (H_2SO_4) used as a spray reagent for both extracts and 100% chloroform

for *Adansonia digitata* leaves. According to (18), this was carried out. The bactericidal activity of the fractions was examined both singly and in combination.

2.26 Methylation of *Adansonia digitata* leaves Extracts for GC-MS analysis

This research was performed using the methodology outlined by (18). Sodium metal that had been stored in paraffin oil was cleaned using hexane. Next, dry methanol was made by re-distilling distilled methanol with magnesium turnings added. One gram of sodium metal was added to ten milliliters of dried methanol to create sodium methoxide.

Adansonia digitata leaves sample, each weighing about 10ml, were measured and placed in flasks with a circular bottom. Antibumping granules, 0.5ml sodium methoxide, 0.5ml methanol, and 1 drop of phenolphthalein were added. In a water bath, the mixture was refluxed for five minutes at 45^0C. One milliliter of sodium hydrogen sulphate (NaHSo4) was used to neutralize the content. After transferring the liquid into a separating funnel, 0.5ml of hexane was added in order to extract the free fatty acids and fatty acid methyl esters (FFA & FAME). Two layers emerged from the shaking of the substance. For GC-MS Analysis, around 1 milliliter of the liquid from the top layer was taken (18).

2.27 Gas chromatography-mass spectrometry analysis

GC-MS was used to determine the extracts' chemical composition using the methodology outlined by (18). The following parameters were used for the GC-MS Clarus 500 Perkin Elmer system, which included an AOC-20i autosampler and a gas chromatograph interfaced to a mass spectrometer, to analyze the extracts: The Restek RtxR-5 (30 meter x 0.25mm) used a split ratio of 10:1 and an injection volume of 1.0µl (or 5% diphenyl / 95% dimethyl polysiloxane) with an electron impact mode operating at 70 eV. Helium (99. 999%) was used as the carrier gas, with a constant flow of 1.80 mL/min; the injector temperature was 250^0C. The oven was set to start at 40°C (isothermal for 5 minutes), climb by 60°C each minute to 280°C, and then finish at 280°C for 15 minutes of isothermal operation. Mass spectra were obtained at 70eV with pieces ranging from 40 to 550Da with a scan interval of 0.5 seconds. The GC ran for sixty minutes in total (18).

2.28 Identification of compounds

Interpretation on mass spectrum GC-MS was carried out utilizing the National Institute of Standards and Technology (NIST) database and the (23) method. The known components' spectra that were kept in the NIST library were compared to the mass spectra of the unknown components.

3 RESULTS

3.1 Percentage yield of *Adansonia digitata* leaves

The leave yields 11.56%, 8.64% and 6.16% for the ethanolic, aqueous and hexane extracts as seen in Table 1.

Table 1: Physical characteristics of the *Adansonia digitata* leaves and stem bark extracts

Physical characteristics	Plant Extracts Leaves
Ethanolic Extract	
Weight of Plant Powder (g)	250
Weight of Extracts (g)	28.9
Yield (%)	11.56
Colour	Dark brown
Texture	Gummy
Aqueous Extract	
Weight of Plant Powder (g)	250
Weight of Extracts (g)	21.6
Yield (%)	8.64
Colour	Dark brown
Texture	Gummy
Hexane Extract	

Weight of Plant Powder (g)	250
Weight of Extracts (g)	15.4
Yield (%)	6.16
Colour	Reddish brown
Texture	Gummy

3.2 Phytochemical components of *Adansonia digitata* leaves extracts

Table 2 shows the results of phytochemical screening of *Adansonia digitata* leaves extracts and the phytochemical tested were flavonoids, steroids, alkaloids, saponins and tannins. Among the phytochemical tested for *Adansonia digitata* leaves, alkaloids, tannins. and steroids were present in the ethanolic extract and flavonoids, tannins, saponins and steroids were present in the hexane extracts while in the aqueous extracts, alkaloids, flavonoids, tannins and saponins were the phytochemicals present.

Table 2: Qualitative phytochemical constituents of *Adansonia digitata* leaves and stem bark extracts

Phytochemical Components	Ethanol	Hexane	Aqueous
A. digitata leaves			
Alkaloids	+	-	+
Flavonoids	-	+	+
Tannins	+	+	+
Saponins	-	+	+
Steroids	+	+	-

Key: += Present, -=Negative

3.3 Antibacterial Activity of *Adansonia digitata* Leaves

Table 3 shows the antibacterial activities of *Adansonia digitata* leaves extracts against *Staphylococcus aureus* (ATCC 6538), *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853) respectively. Zone diameter of inhibition of ethanolic extract of *Adansonia digitata* leaves at 500mg/ml against *Staphylococcus aureus* 20.0±1.0mm, *Klebsiella pneumoniae* 19.0±0.0mm, and *Pseudomonas aeruginosa* 16.0±1.0 mm while for aqueous extract of *Adansonia digitata* leaves, against *Staphylococcus aureus* had 19.0±0.00mm, *Klebsiella pneumoniae* 18.0±0.5mm and *Pseudomonas aeruginosa* 15.0±0.0mm and the zone diameter of inhibition of hexane extract of *Adansonia digitata* leaves at the same 500mg/ml against *Staphylococcus aureus* had 15.0±1.0mm, *Klebsiella pneumoniae* 13.5±0.0mm, and *Pseudomonas aeruginosa* 11.0±1.0mm.

Zone diameter of inhibition of the controls (Ampicillin against *Staphylococcus aureus* was 30.0±2.0mm and Chloramphenicol against *Klebsiella pneumoniae* was 26.0±1.0mm, *Pseudomonas aeruginosa* 24.0±2.0mm) were significantly ($P<0.05$) higher than that of the extracts of both *Adansonia digitata* leaves at all concentrations of 31.3mg/ml, 62.5mg/ml, 125mg/ml, 250mg/ml and 500mg/ml as shown in Table 3.

Both the ethanolic, aqueous and hexane extracts of *Adansonia digitata* leaves and had antibacterial effects on all the test organisms but the effect of ethanolic extract is significantly higher ($P< 0.05$) than the aqueous and hexane respectively. The antibacterial activity of leaves extracts *of Adansonia digitata* against all the test organisms also increased as the concentration increased.

Table 3: Antibacterial activity of *Adansonia digitata* leaves extracts showing mean zones of inhibition in millimeter

Test Organisms/ Extracts	Concentrations in mg/ml				
	500	250	125	62.5	31.3
Ethanol					
P. aeruginosa	16.0±1.0	12.0±0.0	7.5±1.00	5.0±0.0	NA

S. aureus	20.0±0.0	18.5±1.0	13.0±.00	11.0±0.0	8.0±0.5
K. pneumonia	19.0±1.0	17.0±0.0	9.0±1.00	6.5±0.50	NA
Hexane					
P. aeruginosa	11.0±0.0	7.0±0.0	5.0±1.0	NA	NA
S. aureus	15.0±1.0	12.0±0.0	9.0±.0	6.5±0.0	NA
K. pneumonia	13.5±0.5	9.0±1.0	6.0±1.0	NA	NA
Aqueous					
P. aeruginosa	15.0±0.0	7.5±0.0	6.5±0.0	NA	NA
S. aureus	19.0±1.0	15.0±0.0	11.5±0.0	10.0±1.0	6.0±0.0
K. pneumonia	18.0±0.5	14.0±1.0	7.0±0.0	6.0±0.0	NA
Controls					
P. aeruginosa (CH)	24.0±2.0	21.0±1.0	14.0±1.0	10.0±1.0	5.0±1.0
S. aureus (AMP)	30.0±2.0	28.0±2.0	19.0±1.0	12.0±1.0	6.0±0.0
K. pneumoniae (CH)	26.0±1.0	25.0±1.5	17.0±0.0	11.5±0.5	5.0±1.0

Each value represents Mean± standard deviation from three replicate values.; Keys: Chl= Chloramphenicol, Amp= Ampicillin; Clinical and Laboratory Standards Institute Guidelines (CLSI, 2018), ZONE ≥ 18mm = Active, ≤ 6mm = Inactive, ≤ 15mm = Moderate.

3.4 Minimum Inhibitory Concentration of *Adansonia digitata Leaves* Extracts

The minimum inhibitory concentrations of *Adansonia digitata* leaves extract against *Staphylococcus aureus* (ATCC 6538), *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853) are represented in Table 4.

The minimum inhibitory concentrations of ethanolic extracts of *Adansonia digitata* leaves against *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* was 62.5mg/ml while *Staphylococcus aureus* was 31.3mg/ml. Also, the MIC for the hexane extract of *Adansonia digitata* leaves, against *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* was 125mg/ml while MIC of 62.6mg/ml was recorded against *Staphylococcus aureus*. The MBC for aqueous extracts of *Adansonia digitata* leaves against *Staphylococcus aureus* and *Klebsiella pneumoniae* was 62.5mg/ml while *Pseudomonas aeruginosa* was 125mg/ml.

The MIC for the Ampicillin (control) against *Staphylococcus aureus* and Chloramphenicol (control) against *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* was 31.3mg/ml each. The minimum inhibitory concentration of *Adansonia digitata* leaves extracts against all the test organisms were significantly different ($P< 0.05$) from the controls.

Table 4: Minimum inhibitory concentration (MIC) of *Adansonia digitata* leaves extracts against test organisms

Test Organisms/ Extracts	**Concentrations in mg/ml**				
	500	250	125	62.5	31.3
Ethanol					
P. aeruginosa	-	-	-	-*	+
S. aureus	-	-	-	-	-*
K. pneumonia	-	-	-	-*	+
Hexane					
P. aeruginosa	-	-	-*	+	+
S. aureus	-	-	-	-	+
K. pneumonia	-	-	-*	+	+
Aqueous					
P. aeruginosa	-	-	-*	+	+
S. aureus	-	-	-	-*	+

K. pneumonia	-	-	-	-*	+
Controls					
P. aeruginosa (CH)	-	-	-	-	-*
S. aureus (AMP)	-	-	-	-	-*
K. pneumoniae (CH)	-	-	-	-	-*

Each value represents Mean± standard deviation from three replicate values.; Keys: Chl= Chloramphenicol, Amp= Ampicillin, + = Growth, - = No growth, -* = MIC.

3.5 Minimum Bactericidal Concentration of *Adansonia digitata Leaves* Extracts

The minimum bactericidal concentrations of *Adansonia digitata* leaves extract against *Staphylococcus aureus* (ATCC 6538), *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853) are represented in Table 5. The minimum bactericidal concentrations of both ethanolic and aqueous extracts of *Adansonia digitata* leaves against *Staphylococcus aureus* and *Klebsiella pneumoniae* was 250mg/ml while *Pseudomonas aeruginosa* was 500mg/ml. Also, the MBC for the hexane extract of *Adansonia digitata* leaves, against *Staphylococcus aureus* and *Klebsiella pneumoniae* was 500mg/ml while no MBC was recorded against *Pseudomonas aeruginosa*.

The minimum bactericidal concentration of *Adansonia digitata* leaves and extracts against all the test organisms were significantly different (P< 0.05) from the controls.

Table 5: Minimum Bactericidal Concentration (MBC) of *Adansonia digitata* leaves extracts against test organisms

Test Organisms/ Extracts	**Concentrations in mg/ml**				
	500	250	125	62.5	31.3
Ethanol					
P. aeruginosa	-*	+	+	+	+
S. aureus	-	-*	+	+	+
K. pneumonia	-	-*	+	+	+
Hexane					
P. aeruginosa	+	+	+	+	+
S. aureus	-*	+	+	+	+
K. pneumonia	-*	+	+	+	+
Aqueous					
P. aeruginosa	-*	+	+	+	+
S. aureus	-	-*	+	+	+
K. pneumonia	-	-*	+	+	+
Controls					
P. aeruginosa (CH)	-	-*	+	+	+
S. aureus (AMP)	-	-	-*	+	+
K. pneumoniae (CH)	-	-	-*	+	+

Each value represents Mean± standard deviation from three replicate values.; Keys: Chl= Chloramphenicol, Amp= Ampicillin, + = Growth, - = No growth, -* = MBC.

3.6 Antibacterial effects of fractions of Ethanolic extract of *Adansonia digitata* leaves

Tables 6 show the effects of column fractions of *Adansonia digitata* leaves bark extracts respectively against *Staphylococcus aureus* (ATCC 6538), *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853).

At 500mg/ml the zone diameter of inhibition of the fraction of the ethanolic extract of *Adansonia digitata* leaves was *Staphylococcus aureus* (20.0±0.0mm), *Klebsiella pneumoniae* (18.0±1.0mm) and *Pseudomonas aeruginosa* (16.0±1.0mm). From the same Table 4.9, fraction 1 of the ethanolic extract of *Adansonia digitata* leaves was active at

concentrations 500mg/ml, 250mg/ml and 125mg/ml against *Staphylococcus aureus* (19.0±1.0mm, 13.0±0.0mm and 9.0±0.0mm), but active at 500mg/ml and 250mg/ml against *Klebsiella pneumoniae* (11.0±1.0mm and 7.0±0.0mm) and only shown activity at 500mg/ml against *Pseudomonas aeruginosa* (8.0±0.0mm).

Table 6: Antibacterial Activity of Fractions of Ethanolic Extract of *Adansonia digitata* Leaves showing mean zones of inhibition in millimeter

Fractions	**Test Organisms/ Extracts**	**Concentrations in mg/ml**				
		500	250	125	62.5	31.3
Fraction 1	*P. aeruginosa*	8.0±0.0	NA	NA	NA	NA
	S. aureus	19.0±1.0	13.0±0.0	9.0±.00	NA	NA
	K. pneumoniae	11.0±1.00	7.0±0.0	NA	NA	NA
Fraction 2	*P. aeruginosa*	16.0±1.0	12.0±0.0	7.5±1.00	5.0±0.0	NA
	S. aureus	20.0±0.0	18.5±1.0	13.0±.00	11.0±0.0	8.0±0.5
	K. pneumoniae	18.0±1.0	16.0±0.0	9.0±1.00	6.5±0.50	NA
Fraction 3	*P. aeruginosa*	NA	NA	NA	NA	NA
	S. aureus	5.0±0.0	NA	NA	NA	NA
	K. pneumoniae	NA	NA	NA	NA	NA
Fraction 4	*P. aeruginosa*	NA	NA	NA	NA	NA
	S. aureus	5.5±0.0	NA	NA	NA	NA
	K. pneumoniae	NA	NA	NA	NA	NA
Control	*P. aeruginosa* (CH) *S. aureus* (AMP) *K. pneumoniae* (CH)	24.0±2.0 30.0±2.0 26.0±1.0	21.0±1.0 28.0±2.0 25.0±1.5	14.0±1.0 19.0±1.0 17.0±0.0	10.0±1.0 12.0±1.0 11.5±0.5	5.0±1.0 6.0±0.0 5.0±1.0

Each value represents Mean± standard deviation from three replicate values.; Keys: Ch= Chloramphenicol, Amp= Ampicillin; Clinical And Laboratory Standards Institute Guidelines (CLSI, 2018), ZONE ≥ 18mm = Active, ≤ 6mm = Inactive, ≤ 15mm = Moderate.

3.7 Minimum inhibitory concentration of ethanolic fractions of *Adansonia digitata leaves* extract.

The minimum inhibitory concentration of *Adansonia digitata leaves* extract for fraction against *Staphylococcus aureus* was 125mg/ml, *Klebsiella pneumoniae* (250mg/ml) and *Pseudomonas aeruginosa* (500mg/ml). For fraction 2, *Staphylococcus aureus* (ATCC 6538) was 31.3mg/ml while *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853) was 62.5mg/ml as seen in Table 7.

Table 7: Minimum Bactericidal Inhibitory of fractions of Ethanolic extract of *Adansonia digitata* leaves showing mean zones of inhibition in millimeter

Fractions	Test Organisms/ Extracts	Concentrations in mg/ml				
		500	250	125	62.5	31.3
Fraction 1	*P. aeruginosa*	-*	+	+	+	+
	S. aureus	-	-	-*	+	+
	K. pneumoniae	-	-*	+	+	+
Fraction 2	*P. aeruginosa*	-	-	-	-*	+
	S. aureus	-	-	-	-	-*
	K. pneumoniae	-	-	-	-*	+
Fraction 3	*P. aeruginosa*	+	+	+	+	+

	S. aureus	-*	+	+	+	+
	K. pneumoniae	+	+	+	+	+
Fraction 4	*P. aeruginosa*	+	+	+	+	+
	S. aureus	-*	+	+	+	+
	K. pneumoniae	+	+	+	+	+
Control	*P. aeruginosa* (CH)	-	-	-	-	-*
	S. aureus (AMP)	-	-	-	-	-*
	K. pneumoniae (CH)	-	-	-	-	-*

Keys: + = Growth, - = No growth, Fraction 1= 100mg/ml Methanol, Fraction 2 = 80: 20mg/ml Hexane/Ethyl acetate, Fraction 3 = 60: 40mg/ml Hexane/Ethyl acetate, Fraction 4 = 20: 80mg/ml Hexane/Ethyl acetate, -* = MIC.

3.8 Minimum bactericidal concentration of fractions of *Adansonia digitata leaves* extract.

The minimum bactericidal concentration of *Adansonia digitata leaves* extract for fraction against *Staphylococcus aureus* and *Klebsiella pneumoniae* was 250mg/ml while *Pseudomonas aeruginosa* had MBC of 500mg/ml as seen in Table 8.

Table 8: Minimum Bactericidal Concentration of fractions of Ethanolic extract of *Adansonia digitata* leaves showing mean zones of inhibition in millimeter

Fractions	Test Organisms/ Extracts	Concentrations in mg/ml				
		500	250	125	62.5	31.3
Fraction 1	*P. aeruginosa*	+	+	+	+	+
	S. aureus	+	+	+	+	+
	K. pneumoniae	+	+	+	+	+
Fraction 2	*P. aeruginosa*	-*	+	+	+	+
	S. aureus	-	-*	+	+	+
	K. pneumoniae	-	-*	+	+	+
Fraction 3	*P. aeruginosa*	+	+	+	+	+
	S. aureus	+	+	+	+	+
	K. pneumoniae	+	+	+	+	+
Fraction 4	*P. aeruginosa*	+	+	+	+	+
	S. aureus	+	+	+	+	+
	K. pneumoniae	+	+	+	+	+
Control	*P. aeruginosa* (CH)	-	-*	+	+	+
	S. aureus (AMP)	-	-	-*	+	+
	K. pneumoniae (CH)	-	-	-*	+	+

Keys: + = Growth, - = No growth, Fraction 1= 100mg/ml Methanol, Fraction 2 = 80: 20 mg/ml Hexane/Ethyl acetate, Fraction 3 = 60: 40mg/ml Hexane/Ethyl acetate, Fraction 4 = 20: 80mg/ml Hexane/Ethyl acetate, -* = MBC.

3.9 The GC-MS fragments of Adansonia digitata leaves and Adansonia digitata

From Tables 15, 2-Hexanone, 3,3-dimethyl, Pentanal,2,2-dimethyl, n-Hexadecanoic acid, Oleic acid, Octadecanoic acid, Decane, 1 –fluoro-, 9 -Octadecenaland vitamin E were present in Fraction of *Adansonia digitata leaves* while the Fraction of *Adansonia digitata*

3.10 GAS CHROMATOGRAPHY-MASS SPECTROMETRY ANALYSIS

Shimadzu QP2010 plus series gas chromatography + Shimadzu QP2010 plus mass spectroscopy detector (GC-MS) system

Chromatogram: Chromatogram Agada Sample A:/GCMSolution/AGABA.5gl

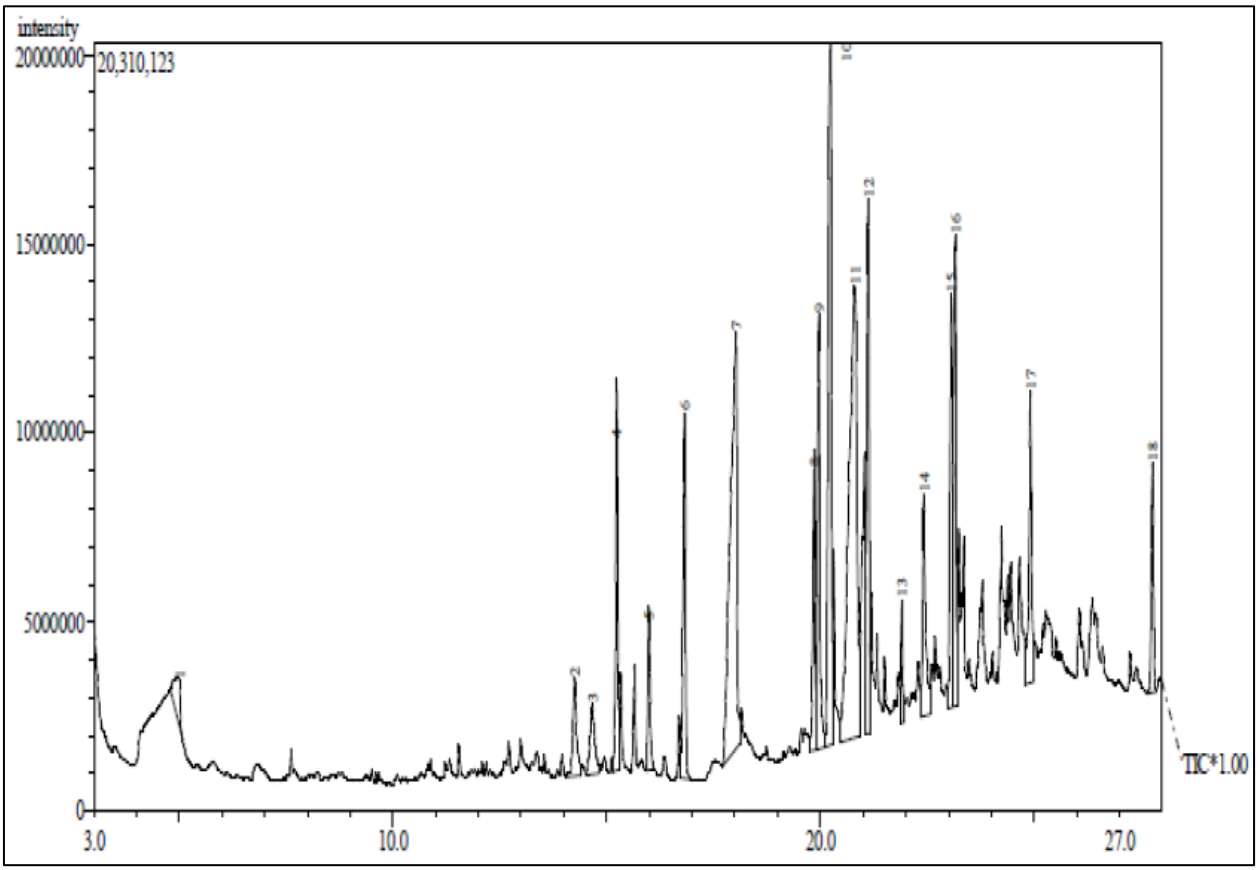


Figure 1: GAS CHROMATOGRAM: Typical GC-MS total ionic chromatogram (TIC) SAMPLE A: Fraction 1

- GC-MS parameters
- Programmed Temp: 40°C to 280°C
- Carrier gas: Helium.
- Injection volume: 1 µL at 250^{0}C
- Column flow: 1.80mL/min for the GC.
- Mass spectroscopy scanner: ACQ mode
- Range: 30-700 amu
- Speed: 1478.

Table 9: Major Phytochemical components from Ethanolic extract of leaves of *Adansonia digitata* by GC-MS Analysis

S/N	Compound name	Molecular eight	Retention Time	Area%
1	2-Hexanone,dimethyl	128	3.129	35.93
2	Pentanal,2,2-dimethyl	144	3.217	9.64
3	n-Hexadecanoic acid	256	17.586	16.16
4	Oleic acid	282	20.493	25.22
5	Octadecanoic acid	284	20.765	4.46
6	Decane, 1 –fluoro-	160	22.329	1.66
7	9 -Octadecenal	266	24.152	2.52
8	Vitamin E	430	24.928	4.40

4 DISCUSSION

Qualitative phytochemical analysis of the plant confirm the presence of organic compounds in the plant including flavonoids, steroids, etc which agrees with (24) and (25) also reported the presence of organic compounds which include reducing sugar, flavonoids, steroids, phenol and cardiac active glycosides. In this research, the phytochemical tested for *Adansonia digitata* leaves, alkaloids, tannins and steroids were confirmed in the ethanolic extract and flavonoids, tannins, saponins and steroids were confirmed in the hexane extracts while in the aqueous extracts, alkaloids, flavonoids, tannins and saponins were the organic compounds confirmed which align with the findings of. (26, 27). The qualitative and quantitative phytochemical analysis of the leaves of *A. digitata* confirms the plant contain organic compounds. Tannins are also used as antiseptic and the activity is due to the presence of the phenolic group. Flavonoids are important group of polyphenols that are constituents of many plant parts. They are soluble in water and have different functions which can account for the antibacterial activity of the plant. According to reports by (11) and (28), bioactive compounds like flavonoids, tannins, alkaloids e.t.c. are responsible for antimicrobial activities in the plant.

The antibacterial activities of *Adansonia digitata* leaves extracts against *Staphylococcus aureus* (ATCC 6538), *Klebsiella pneumoniae* (ATCC 13883) and *Pseudomonas aeruginosa* (ATCC 27853) shows that the zone the diameter of inhibition of ethanolic, aqueous and hexane extract of *Adansonia digitata* leaves at all concentrations against *Staphylococcus aureus* is higher than that of *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. The ethanolic, aqueous and hexane extracts of *Adansonia digitata* leaves has antibacterial effects on all the test bacteria but the effects of ethanolic and aqueous extracts were significantly higher ($P< 0.05$) than that of the hexane. The reports by (29) also with the fact that ethanolic and aqueous extracts of *A. digitate* exhibited a greater inhibition than hexane on *Staphylococcus aureus*.

This study has also shown that the higher the concentration of the extracts, the more effective the antimicrobial activities. This is align with the study of (30) who concluded that the effectiveness of an extract is dependent on its concentration.

The zone diameter of inhibition of the controls (Ampicillin against *Staphylococcus aureus* was 30.0±2.0mm and Chloramphenicol against *Klebsiella pneumoniae* was 26.0±1.0 mm, *Pseudomonas aeruginosa* 24.0±2.0mm) were significantly ($P<0.05$) higher than that of the extracts of *Adansonia digitata* leaves at all concentrations of 31.3mg/ml, 62.5mg/ml, 125mg/ml, 250mg/ml and 500mg/ml. The susceptibility of test organisms to antibiotics confirms the effectiveness of Chloramphenicol against *P. aeruginosa* and *K. pneumoniae* and Ampicillin against *S. aureus* which is in agreement with the findings of (31). The antibacterial effect of broad and narrow spectrum antibiotics against several bacteria cannot be over emphasized and have been reported by many researchers (32). Plant extracts and antibiotics have been reported to have antibacterial properties against bacterial pathogens, howbeit plant extracts are gaining new grounds in phytomedicine (33, 34).

5 CONCLUSION

Results obtained from this research has revealed that ethanol and aqueous extracts of leaves of *Adansonia digitata* posses antimicrobial properties against *Staphylococcus aureus, Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. This property may because of the presence of significant number of phytochemicals such as saponins, tannins, flavonoids, alkaloids and steroids present in the leaves of the plant. This also implies that leaves extracts of *A. digitata* has potentials to be used as an antimicrobial agent.

Recommendations

Following the results and observations of this study, it is recommended that:

i. The leaves of *Adansonia digitata* might be a good substitute for standard antibacterial medications for the many people who live in rural parts of developing countries e.g. Nigeria and for those that do not have enough money to buy them.
ii. After purification and standardization, the leaves of *Adansonia digitata* can be used as an effective and reasonably priced alternative in a situation where standard antibiotics are becoming less effective against diseases caused by *S. aureus, K. pneumoniae,* and *P. aeruginosa.*
iii. *Adansonia digitata* leave contain certain active phytochemical elements that point to the plant's potential use in the creation of antibacterial soaps and lotions sold in stores.

Contribution of this study to knowledge

This research has made some contributions to the scientific knowledge in the subject, as follows:

i. *Adansonia digitata* leaves exhibited broad spectrum action against *S. aureus*, *K. pneumoniae*, and *P. aeruginosa*, the three bacteria that were chosen.
ii. While the majority of common antibacterial agents are ineffective against *S. aureus*, *K.* pneumoniae, and *P. aeruginosa* species, the leaves and stem bark of *Adansonia digitata*, which were employed in this study, demonstrated antibacterial activity against these organisms with MIC as low as 31 mg/ml, suggesting that they could be useful substitutes.
iii. This study's solid findings support the usefulness of plant materials in the treatment of bacterial illnesses, particularly in isolated rural locations where access to traditional medications is limited or prohibitive for the underprivileged.
iv. The high antibacterial activities shown by the fractions of leaves and stem bark of *Adansonia digitata* against *P. aeruginosa, K. pneumoniae* and *S. aureus* is an indication that the plants are potential source of standard antibacterial principles that would be cost effective.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

There is no conflict of interest

Authors contribution

All authors were in involved fully and actively in the research and write up.

REFERENCES

[1] Tarin-Pello, A., Suay-Garcia, B. and Perez-Gracia, M. T. (2022). Antibiotic resistant bacteria: current situation and treatment options to accelerate the development of a new antimicrobial arsenal. *Expert review of anti-infective therapy*, *20*(8), 1095-1108.

[2] Touré, S.F., Michalet-Doreau, B., Traoré, E., Friot, D. and Richard, D. (2016). Occurrence of digestive interactions in tree forage-based diets for sheep. *Animal Feed Science Technology*, 74: 63-78.

[3] Blomhoff, R., Carlsen, M., Halvorsen, B., Holte, K., Bohn, S., Dragland, S., Sampson, L., Willey, C., Senoo, H., Umezono, Y., Sanada, C., Barikmo, I., Berhe, N., Willett, W., Phillips, K. and Jacobs, D. (2017). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal*, 9: 1353-1356.

[4] Besco, E., Braccioli, E., Vertuani, S., Ziosi, P., Brazzo, F., Bruni, R., Sacchetti, G. and Manfredini, S. (2017). The use of photochemiluminescence for the measurement of the integral antioxidant capacity of baobab products. *Food Chemistry*, 102: 1263-1266.

[5] Rana, H., Kumar, R., Chopra, A., Pundir, S., Gautam, G. K. and Kumar, G. (2022). The various pharmacological activity of Adansonia digitata. *Research Journal of Pharmacology and Pharmacodynamics*, *14*(1), 53-59.

[6] Ajiboye, A. E., Sadiq, S. O. and Adedayo, M. R. (2020). Antimicrobial activity and phytochemical screening of Adansonia digitata stem bark extract on some clinical isolates. *Ife Journal of Science*, *22*(2), 035-044.

[7] Urban-Chmiel, R., Marek, A., Stępień-Pyśniak, D., Wieczorek, K., Dec, M., Nowaczek, A. and Osek, J. (2022). Antibiotic resistance in bacteria-A review. *Antibiotics*, *11*(8), 1079.

[8] Sidibe, M. and Williams, J.T. (2016). Baobab: *Adansonia digitata* fruit for the future. *International centre for underutilized crops, Southampton,* 66: 1400–1408.

[9] Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R. and Van Boekel, M.A.J.S. (2016). Baobab food products: A review on their composition and nutritional value. *Critical Reviews in Food Science and Nutrition*, 49: 254 -274.

[10] Shukla, Y.N., Dubey, S., Jain, S.P. and Kumar, S. (2016). Chemistry, biology and uses of *Adansonia digitata* – A review. *Journal of Medicinal and Aromatic Plant Science*, 23: 429-434.

[11] Kubmarawa, D., Ajoku, G.A., Enwerem, N.M. and Okorie, D.A. (2017). Preliminary phytochemical and antimicrobial screening of 50 medicinal plants from Nigeria. *African Journal of Biotechnology*, 6: 1690-1696.

[12] Datsugwai, M.S.S. and Yusuf, A.S. (2020). Phytochemical analysis and antimicrobial activity of baobab (*Adansonia digitata*) leaves and stem bark extracts on *Staphylococcus aureus* and *Escherichia coli*. *Journal of Bioscience and Biotechnology*, 6(1): 9-16.

[13] Süntar, I. (2020). Importance of ethnopharmacological studies in drug discovery: role of medicinal plants. *Phytochemistry Reviews*, *19*(5), 1199-1209.

[14] Kamatou, G. P. P., Vermaak, I. and Viljoen, A. M. (2011). An updated review of Adansonia digitata: A commercially important African tree. *South African Journal of Botany*, *77*(4), 908-919.

[15] Hudson, J.B., Anani, K., Lee, M.X., De Souzâ, C., Arnason, J.T. and Gbeassor, M. (2016). Further investigations on the antiviral activities of medicinal plants of Togo. *Pharmaceutical Biology*, 38: 46-50.

[16] Halilu, E. M. and Muhammad, N. K. (2024). Physicochemical and free radical scavenging activity of Adansonia digitata seed oil. *Physical Sciences Reviews*, *9*(5), 2137-2151.

[17] Shoaib, M., Muzammil, I., Hammad, M., Bhutta, Z. A. and Yaseen, I. (2020). A mini-review on commonly used biochemical tests for identification of bacteria. *International Journal of Research Publications*, *54*(1), 1-7.

[18] Akinmusire, O. A., Dahunsi, A. A. and Dahunsi, A. E. (2025). Chemical characterization of Dichrostachys cinerea extracts using GC-MS and column chromatography. *Microbiology Independent Research Journal (MIR Journal)*, *12*(1), 19-29.

[19] Tordesillas, P. A. B., Patawaran, N., Aparente, A., Veloso, L. E., Bautista, J. N., Berches, D. M. and Rañada, K. M. (2025). Determining the Effect on the Crude Extract of Psophocarpus tetragonolobus (Winged Bean) as Protein Source Replacement for Tryptic Soy Broth. *Journal of Interdisciplinary Perspectives*, *3*(8), 369-379.

[20] Yadav, A. and Mohite, S. (2020). Screening of In-vitro anti-inflammatory and Antibacterial assay of Malvastrum Coromandelianum. *International Journal of Pharma Sciences and Research*, *11*(4), 68-70.

[21] Akin-Osanaiye, B.C. and Dahunsi, A.A. (2024). Antibacterial Activity of Emperor Scorpion (Pandinus imperator) Venom against Some Selected Bacteria. *GVU Journal of Science, Health and Technology GVU J-SHT*, *9*(1), 1-17.

[22] Dahunsi, A. A. and Akin-Osanaiye, B.C. (2024). Assessment of antibacterial efficacy and toxicological implications of emperor scorpion (Pandinus imperator) venom using animal model. *World*, *6*(01), 001-011.

[23] Freiberger, K., Enzinger, H. and Vogel, C. (2017). A noise power ratio measurement method for accurate estimation of the error vector magnitude. *IEEE Transactions on Microwave theory and techniques*, *65*(5), 1632-1645.

[24] Abiona, D.L., Adedapo, Z. and Suleiman, M.K. (2018). Proximate analysis, phytochemical screening and antimicrobial activity of baobab (*Adansonia digitata)* leaves. *Journal of Applied Chemistry*, 32: 803-906.

[25] Magashi, A. M. and Abdulmalik, U. (2021). Antibacterial activity and phytochemical screening of stem bark extracts of *Adansonia digitata* on some clinical isolates. *Umaru Musa Yar'Adua University Journal of Microbiology Research*, 3(1): 1-7.

[26] Bashir, M., Ibrahim, A., Bilyaminu, M., Ali, R. I., Isa, H., Sambo, K. H. and Ishaq, I. (2022). Phytochemical screening and antibacterial activity of leaf and stem bark extracts of *Adansonia digitata* on *E. coli*, *S. aureus* and *S. typhi*. *Microbes and Infectious Diseases*, *3*(1), 217-223.

[27] Thompson, P. T., Boamah, V. E. and Badu, M. (2024). In-vitro antioxidant, antimicrobial and phytochemical properties of extracts from the pulp and seeds of the African baobab fruit (Adansonia digitata L.). *Heliyon*, *10*(8).

[28] Agbafor, K.N. and Nwachukwu, N. (2018). Phytochemical analysis and antioxidant property of leaf extracts of *Vitex doniana* and *Mucuna pruriens*. *International Journal of Biochemistry Research*, 2: 7-9.

[29] Yang, R.Y., Tsou, S.C.S., Lee, T. C., Chang, L.C., Kuo, G. and Lai, P.Y. (2017). Moringa, a novel plant rich in antioxidants, bioavailable iron, and nutrients. *American Chemical Society Symposium Series*, 925(17): 224-239.

[30] Akintobi, O. A., Bamkefa, B. A., Adejuwon, A. O., Obayemi, O. S. and Ologan, B. L. (2019). Evaluation of the anti-microbial activities of the extracts of the leaf and stem bark of Alstonia congensis on some human pathogenic bacteria. *Advances in Bioscience and Bioengineering*, *7*(1).

[31] Ajiboye, A.E., Babatunde, S.K., Adedayo, M.R., Adetumbi, M.A., Ajuwon, I.B. and Ajasegun, T.A. (2019). Antibacterial potency and phytochemical screening of the bark of *Terminalia catappa* against some clinical isolates. *International Journal of Phytomedicine*, 8: 193- 201.

[32] Alm, R. A. and Lahiri, S. D. (2020). Narrow-spectrum antibacterial agents—benefits and challenges. *Antibiotics*, *9*(7), 418.

[33] Abdallah, E. M., Alhatlani, B. Y., de Paula Menezes, R. and Martins, C. H. G. (2023). Back tonature: Medicinal plants as promising sources for antibacterial drugs in the post-antibiotic era. *Plants*, *12*(17), 3077.

[34] Adegoke, O.S., Owoicho, I., Obekpa, Nnamso, J., Ibuotenang,D. and Shaibu, S.E. (2025). Phytogenic Synthesis of Copper Nanoparticles Using Hibiscus Rosa- Sinensis Flower Extract and Assessment of their Antibacterial and Antioxidant Potentials. *UMYU Journal of Microbiology Research*, 10 (2) 188 – 200