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Determination of Phytochemicals and Antimicrobial Activity of Aqueous Stem Bark Extract of *Boswellia dalzielii against* Some Common Pathogenic Microorganisms

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Abstract
Phytochemical screening by High Performance Liquid Chromatography (HPLC), Fourier Transformed Infrared Spectroscopy (FTIR) and Gas Chromatography- Mass Spectrometry (GCMS) of crude aqueous extract of stem bark of *B. dalzielii* was performed and its antimicrobial activity on *Staphylococcus aureus, Streptococcus pyogenes, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Proteus mirabilis, Salmonella typhi* and *Candida albicans* was evaluated. The result of HPLC analysis revealed 10 components with major ones at peaks 3, 2, 4, 5, 8 and 6 with peak areas of 33.43%, 13.75%, 13.43%, 9.35%, 8.53% and 8.50% respectively; FT-IR revealed 18 functional groups which included amines, amides, α,β-unsaturated aldehydes, ketones, alkanes, alkenes, alkynes, alkyl halides, aromatics, aromatic and aliphatic amines; while the GCMS revealed 9 compounds with major ones as n-Hexadecanoic acid, Stearic acid, 9-Hexadecenoic acid, 1,E-11,Z-13-Octadecatriene with peak areas of 39.40%, 24.28%, 23.38% and 7.73% respectively. The susceptibility test showed that the extract at 50mg/ml to 5mg/ml was active against all the test isolates with higher zones of inhibition of 19±0.00mm for *S. typhi* and 18±0.30mm for *P. mirabilis* and 18±0.41mm for *P. aeruginosa* at 50mg/ml concentration each. Resistance was observed in *E. coli* and *S. pyogenes* at 2.5mg/ml concentration. Similarly, lowest MIC values of 12.5mg/ml were obtained for *S. typhi* and *S. aureus* and 25mg/ml for *C. albicans, P. Mirabilis* and *P. aeruginosa. K. pneumoniae, E. coli, S. pyogenes and E. faecalis* had MIC values of 50mg/ml each. The MBC/MFC values did not exceed the corresponding MIC values by more than a factor of 2. Conclusively, stem bark of *B. dazielii* contains many antimicrobial active compounds which can be purified and used as precursors for new antibiotics.
Key words: Phytochemical, Antimicrobial, Aqueous, MIC, *Boswellia dalzielii*.

INTRODUCTION

Drug resistance has become such an evident issue that it needs no further introduction. Infections due to resistant bacteria are now becoming common, and some pathogens have even become resistant to multiple types or classes of antibiotics. This relentless emergence and spread of antibiotic resistant strains of pathogenic microorganisms has led to the need for finding alternative treatments using among others, plant extracts singly or in combinations.

Medicinal plants have become indispensable in the present age (Meena, 2009). According to Norman (1982), almost 80 percent of the present-day medicines come directly or indirectly from plants. Yet, this 80 percent of the modern drugs comes from less than 15 percent of the plants, which are known to have been pharmacologically, investigated, out of the estimated 250,000 to 500, 000 species of higher plants growing on earth (Fernsworth and Bingel, 1977). According to report of the World Health Organization (WHO), 80% of the World's population relies mainly on traditional therapies which involve the use of plant extracts or their active substances (Pierangeli *et al.*, 2009). It is therefore clear that medicinal plants still remain the most important primary source of many important drugs that are used in orthodox medicine today.

Boswellia dalzielii commonly known as the frankincense tree or by its Hausa names ("Ararrabi", "Basamu" and "Hanu"), is a tree that is commonly found in Northern Nigeria and in some Savannah regions of West Africa (Burkill, 1985). The plant has several medicinal uses. According to Hassan *et al. (2009),* the stem bark is burnt to fumigate cloth and to drive out flies, mosquitoes, etc from rooms. Burkill (1985) and Evans, (1996) reported that the decoction of the stem bark is used to treat rheumatism, septic sores, venereal diseases and gastrointestinal ailments. Phytochemical screening of the plant revealed the absence of alkaloids (Baoua *et al.*, 1976), while saponins, tannins, flavonoids, cardiac glycosides, steroids and terpenes were shown to be present (Alemika and Oluwole, 1991; Adelakun *et al.*, 2001). In another study, the aqueous (dialyzed) extract of the dried gum resin from Cameroon has been shown to possess anti-inflammatory activity in male rats (Duwiejua *et al.*, 1993). Similarly, the methanol and aqueous extracts also showed broad-spectrum antibacterial and antifungal activities (Ntiejumokwu and Alemika, 1991; Adelakun *et al.*, 2001). In addition, Abdulazeez *et al., (*2013), also showed that the aqueous stem bark extract of *B. dalzielii* contain tannins, glycosides, flavonoids, alkaloids, anthracene, saponin and saponin glycosides and its antimicrobial activity against *Staphylococcus aureus, Salmonella typhi, Escherichia coli* and *Shigella dysentriae* showed that it is effective against *Escherichia coli* and *Shigella dysentriae* at 60-80 mg/ml. However, further research is necessary to determine the full identity of the antimicrobial compounds present in the stem bark of the plant using advanced techniques and also to determine their full spectrum of efficacy. The present study aimed at carrying out phytochemical Screening by HPLC, FTIR and GC-MS of the aqueous stem bark extract of *Boswellia dalzielii,* evaluate its antimicrobial activity by agar well diffusion method and to determine the MIC and MBC/MFC of the extract.

MATERIALS AND METHODS

Ethanobotanical Survey

The information on the practice of using *B. dalzielii* by traditional herbalist to cure ailments was gathered through structured questionnaire by means of in-depth interview with the local herbalist in some parts of Katsina State, Nigeria who claimed to have effective medications for common infectious diseases.

Collection, Identification and Authentication of the Plant Material

The stem bark of the plant was collected from the bushes around Kafur, Katsina State, Nigeria in the month of February, 2015. It was identified and authenticated at the Herbarium of the Department of Plant Biology, Bayero University, Kano where a voucher specimen was deposited. The stem bark was washed under running tap water, air- dried at room temperature in the laboratory until brittle, and then pulverized to fine powder and stored in airtight glass containers at room temperature in the dark until use as according to technique of Sunday *et al.* (2010).

Extraction

The powdered sample of the stem bark of the plant was extracted following the method of Gupta *et al.* (2005). Fifty grams (50g) each of the dried powder of the stem bark of the plant was weighed into a glass container and extracted exhaustively with 500ml sterile distilled water by percolation method for one week during which the sealed bottle undergone vigorous shaking at regular intervals. The mixture obtained was filtered through muslin cloth and then re-filtered by passing through Whattman's No.1 filter paper. The filtrate was concentrated by complete evaporation of the solvent on water bath at 45°C. The extract was subsequently transferred into clean sterile airtight glass container and stored in the refrigerator at 4°C until use.

Automated Phytochemical Screening of the Extract

a. High Performance Liquid Chromatography Analysis (HPLC)

The High Performance Liquid Chromatography Analysis (HPLC) was carried out to determine the number of phytochemicals and their percentages in the extract as follows:

Sample Preparation

Stock solution of the extract was prepared in HPLC grade methanol at a concentration of 100µgmL^{-1} and stored in a refrigerator until use. The sample was filtered through Whattman No.1 filter paper before the HPLC analysis.

HPLC Analysis

HPLC was carried out on the extract using an Agilent Zorbax column (Xdb-C18 Type MG 5µm, 4.6 ×250mm). The detection wavelength was 254nm. The analysis was carried out at a constant flow rate of 1.2 mL/ min all throughout, with an average pressure of about 2100 psi. Prior to injection of the sample into the system, the mobile phase was pumped through the column for at least 30 minutes in order to warm up the instrument and achieved equilibration of the column. Elution was carried out with CH CN-H O. The injection volume was 100µml. All chromatographic data were recorded and processed using autochro-3000 software.

a. Fourier Transform Infrared Spectrophotometer (FTIR) Analysis

Fourier Transform Infrared Spectrophotometer (FTIR) Analysis was carried out on the extract using Shimadzu, Japan, FT-IR spectrometer. A 0.1ml of the sample was dropped into an Arsenic selenide (As_2Se_3) aperture plate of 0.1mm thick and loaded in the FTIR spectroscope. The sample was scanned from 650 to 4000 cm^{-1} for 16 times to increase the signal to noise ratio. FT-IR spectra were recorded in the absorption range between 650 and 4000 wave number per centimetre at a resolution of $4cm^{-1}$. The types of chemical bonds/functional groups present in the extract were identified by interpreting the infrared absorption spectrum using IR spectra Table.

b. Gas Chromatography- Mass Spectrometry Analysis (GC-MS)

Gas Chromatography- Mass Spectrometry Analysis (GC-MS) of the extract was carried out to further confirm the identity of the phytocomponents using GC-MS (Model: QP 2010 series, Shimadzu, Japan) equipped with a VF-5ms fused silica capillary column of 30m length, 0.25mm diameter and 0.25µm film thickness. The column oven temperature was programmed from 80^0C to 280^0C min^{-1}. Ionization of the sample components was performed in electron impact mode (EI, 70 eV). The temperature of the injector was fixed to 250^0C and one of the detectors to 200^0C. Helium (99.9995% purity) was the carrier gas fixed with a flow rate of 1.5ml min^{-1}. The mass ranges from 40-1000m/z was scanned at a rate of 3.0 scans/s. 1.0µl of the extract was injected with a Hamilton syringe to the GM-MS manually for total ion chromatographic analysis in split injection technique. Total running time of GC-MS was 35min.

Identification of the Constituents

The identity of the various compounds detected by the GC-MS from the extract was carried out based on the comparison of their retention indices and mass spectra fragmentation patterns with those stored in the computer library (i.e the spectrum of the unknown component was compared with the spectrum of the known components stored in the National Institute of Standards and Technology, NIST Library) and the interpretation of the mass spectrum GC-MS was conducted using data base of National Institute of Standard Technology (NIST 08s), Wiley Registry of Mass Spectral data New York (Wiley 8) and Fatty Acid Methyl Esters Library, version 1.0 (FAME Library) sources were used for matching the detected compounds in the Extract. The molecular weights, molecular formulae and the number of hits used to identify the name of the compounds from NIST and Wiley spectra were also recorded.

Quantification of the Constituents

The relative percentage of each constituent in the extract was expressed as percentage with peak area normalization.

Bioassay

a. Test Organisms

The clinical isolates of bacteria and the fungus used for this study were obtained from Aminu Kano Teaching Hospital, Kano (AKTH). These organisms are as follows: *Staphylococcus aureus, Streptocoocus pyogenes, Enterococcus faecalis, Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi* and *Candida albicans*.

b. Standardization of Inocula

The inocula of the test organisms were standardized using 0.5 McFarland's turbidity standard. Approximately 99.5ml of 1% $BaCl_2$ was added to 0.5ml of 1% v/v H_2SO_4 in order to obtain 100ml of $BaSO_4$ which corresponded to 0.5 McFarland's turbidity standard equivalent to 1.0×10^8 cfu/ml population for bacterial isolates. Bacterial colonies from the 18hours overnight cultures were used to make direct suspension of each bacterial isolate in separate test tubes containing 1ml of sterile physiological saline. The suspensions were adjusted to match the 0.5 McFarland turbidity standard, using saline and a vortex mixer. Similarly, the fungal culture was standardized according to the methods of Murugan *et al*. (2007) by dissolving a loopful of the spore suspension into 10ml of 20% tween 80 solution to obtain 6.0×10^5cfu/ml.

c. Antimicrobial Susceptibility Test

The antimicrobial activity of the extract was tested using agar well diffusion method adopted from CILS (1998). Müeller Hinton, Blood agar and SDA were used for the bacteria and fungus respectively.

The plates were separately inoculated with the suspension of the standardized inocula using sterile swabs. In each case, the sterile swab was submerged in to the suspension, lifted out, and the excess fluid was removed by pressing and rotating the swab against the wall of the test tube. The swab was then used to inoculate the entire surface of the plate three times, rotating the plate 60 degrees between each inoculation. Five wells of 6mm diameter were made in each plate with a central well for the control using 6mm sterile cork borer. The wells were filled with 0.1ml of diluted concentrations (50mg/ml, 25mg/ml, 10mg/ml, 5mg/ml and 2.5mg/ml) of the extract with the aid of sterile pipettes per well.

Similarly, 0.1ml of 10µg/ml Ciprofloxacin was used in to serve as positive control for each organism. Diameters of the zones of inhibition were measured with a transparent ruler and the result was recorded in millimetres after incubating the plates at 37^0C for 24 hours (bacteria) and 25^0C for 48 hours (fungus). The test was replicated in triplicates and the means and standard errors of the zones of inhibitions for each organism at each concentration of the extract were calculated and recorded.

d. Determination of Minimum Inhibitory Concentration (MIC)

The MIC of the extract was determined by standard two-fold serial dilution method adopted from CILS, (1998). A stock solution of the extract was serially diluted in nine test tubes containing 5mls double strength Mueller Hinton broth each (for bacteria) or SD broth (for fungus) and labelled 1-9; to obtain a concentration of 100, 50, 25, 12.5, 6.25, 3.12, 1.56 and 0.78 mg/ml. Tube 9 was the control and had no drug or extract. 0.1ml of the standardized inocula was inoculated in the separate tubes 1-9 for each organism. The various test tube racks were kept at 37°C for 24hours (bacteria) and 25^0C for 48hours (fungus). Then, the MICs were recorded as the lowest concentration of the extract inhibiting the visible growth of the test organisms. This was determined by comparing the tubes with the control against a source of light with white back ground and some contrasting black lines.

e. Determination of Minimum Bactericidal Concentration (MBC) and the Minimum Fungicidal Concentration (MFC)

The MBC and the MFC were determined using the methods of Hugo and Russel (2004). The tubes in each set, which did not show any growth during the MIC and MFC determination, were used. A loop full of the content from each tube was streaked unto fresh nutrient agar plates for the bacteria and SDA plates for the fungus. The plates were incubated for 24 hours at 37°C (bacteria) and for 48 hours at 25^0C (fungus). After the incubation period, the plates were examined for the presence or absence of growth. The MBC and the MFC of the extract were recorded as the smallest concentration of the extract that is capable of killing the entire organism present in the specific inoculum size of test organism.

RESULTS AND DISCUSSION

The ethanobotanical survey on the practices of using *B. dalzielii* to treat different ailments by the Hausa traditional medicinal practitioners revealed that the plant is well known for its various medicinal uses (Table 1). The Hausa name used by most traditional healers when referring to *B. dalzielii* is 'Ararrabi'. Whereas some of them call it 'Hano' and some few others call it 'Basamu' or 'Hararrabi. The result of this survey corroborates the findings of Burkill (1985) and Evans, (1989) who stated that the decoction of the stem bark of *B. dalzielii* is use in the traditional treatment of rheumatism, septic sores, venereal diseases and gastrointestinal ailments.

Table 1: Ethanobotanical information on the practices of using *B. delzielii* to treat different ailments by the Hausa traditional medicinal healers.

Local names	Plant Parts	% of respondents	Traditional medicinal indications	Type of Preparation used	Treatment period
Ararrabi	Stem bark	30	Fever and rheumatism	Water Decoction	Two weeks
Ararrabi	Stem bark	25	Diarrhoaea and other gastrointestinal troubles	Cold infusion or decoction	One week
Hano	Stem bark	15	Wash for antiseptic sores	Decoction	Until healed
Basamu	Stem bark	10	Venereal diseases	Cold infusion or Decoction	Two weeks
Hararrabi	Fresh stem bark	5	Giddiness and palpitations	Ingestion of Fresh stem bark	Few minutes
Ararrabi	Stem bark	5	Snake bite	Cold infusion	24 hours
Ararrabi	Gum	10	Inflammatory diseases	Topical application/ infusion	Until relieved
-	Roots	0	-	-	-
-	Leaves	0	-	-	-
-	Flowers	0	-	-	-

Phytochemicals which possess many ecological and physiological roles are widely distributed as plant constituents (Abdulazeez, *et al.*, 2013). Plants can synthesize and accumulate in their cells a great variety of these phytochemicals (Okwu, 2004). The analyses by GC-MS, HPLC and FTIR of the aqueous extract of *B. dalzielii* stem bark revealed the presence of more than 20 different constituents including fatty acids, heterocyclic compounds, and esters among others (Table 2, Table 3 and Table 4). There were many research works which indicated that the curative properties of medicinal plants are due to the presence of these various complex chemical substances of different composition, which are found as secondary plant metabolites in one or more parts of these plants (Patil *et al.*, 2009).

The HPLC chromatogram and the detailed tabulation of HPLC analysis of the extract are given in figure 1 and Table 2 respectively. From the analysis, the major constituents were at peaks 3, 2, 4, 5, 8 and 6 with corresponding peak areas of 33.43%, 13.75%, 13.43%, 9.35%, 8.53% and 8.50% respectively. While the rest (minor constituents) constitute less than 15% by peak area of the extract.

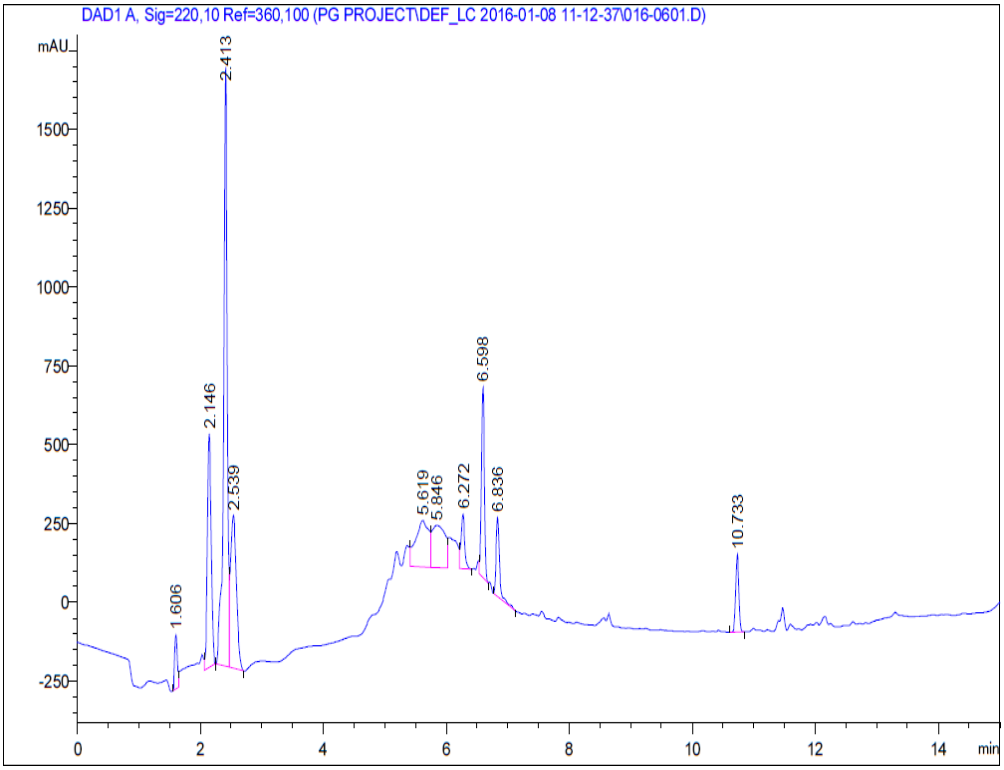


Figure 1: HPLC Chromatogram of the Crude Aqueous Extract of *Boswellia dalzielii*

Table 2: Phytochemical Components of the Aqueous Extract of the Stem Bark of *Boswellia dalzialii* Obtained by HPLC Analysis.

Peak No.	Retention Time (min)	Area (%)
1	1.606	2.11
2	2.146	13.75
3	2.413	33.43
4	2.539	13.43
5	5.619	9.35
6	5.846	8.50
7	6.272	2.98
8	6.598	8.53
9	6.836	4.15
10	10.733	3.74

Fourier Transform Infrared Spectrophotometer (FTIR) is perhaps the most powerful tool for identifying the type of chemical bonds/functional groups present in the phytochemicals. The wavelength of light absorbed is salient feature of the chemical bond as can be seen in the annotated spectrum. By interpreting the infrared absorption spectrum, the chemical bonds in a compound can be determined (Geethu *et al.*, 2014). The FTIR spectrum of the crude aqueous extract of the stem bark of *Boswellia dazielii*, showing the various types of chemical bonds/functional groups were given in Figure 2. On the other hand, Table 3 showed the interpretation of the FTIR spectral data. The result revealed the presence of 1°, 2° amines and amides, α, β -unsaturated aldehydes and ketones, alkanes, alkenes, alkynes, alkyl halides, aromatics, aromatic amines and aliphatic amines. This implies that the plant contain compounds belonging to many functional groups.

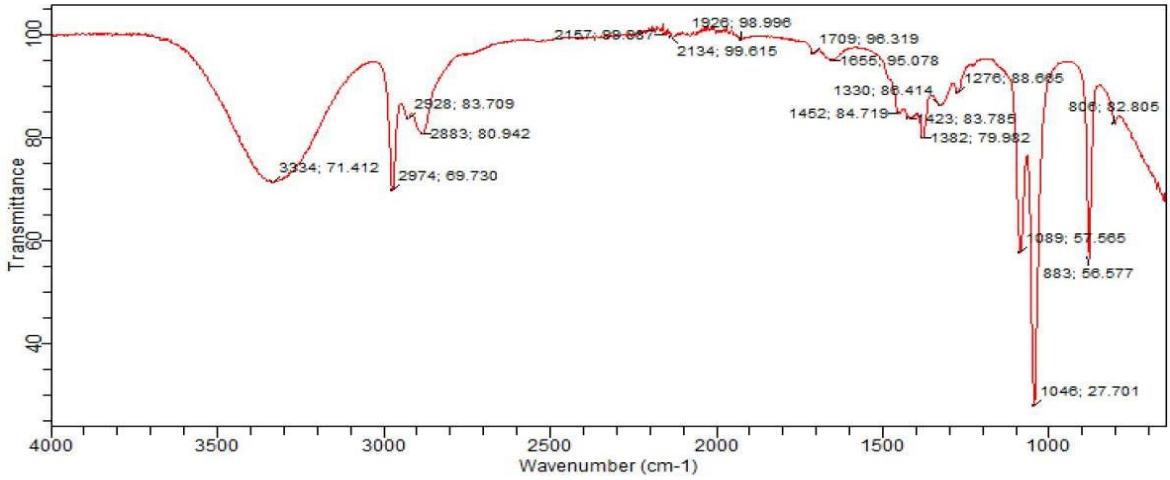


Figure 2: FTIR Spectra of the Crude Aqueous Extract of *Boswellia dalzielii*

Table 3: Various Functional Groups/Chemical Bonds Present in the Aqueous Extract of Stem Bark of *B. dalzielii* Identified by FTIR Analysis.

Peak No.	Wave Length (cm-1)	Transmit-tance (t)	Peak Shape	Type of Bond Identified	Functional Group
1	3334	71.412	Curve	N-H stretch	1°, 2° amines, amides
2	2974	69.730	Sharp	C-H stretch	Alkanes
3	2928	83.708	Narrow	C-H stretch	Alkanes
4	2883	80.942	Sharp	C-H stretch	Alkanes
5	2157	99.087	Weak	-C=_C- stretch	Alkynes
6	2134	99.61	Weak	-C=_C- stretch	Alkynes
7	2134	99.615	Weak	-C=_C- stretch	Alkynes
8	1926	98.996	Weak	-	unknown
9	1709	96.319	Narrow	C=O stretch	α, β -unsaturated aldehydes,ketones
10	1655	95.078	Curve	-C=C- stretch	Alkenes
11	1452	84.719	Narrow	C-H bend	Alkanes
12	1423	83.785	Narrow	C-C stretch (in-ring) C-	Aromatics
13	1330	86.414	Curve	N stretch	Aromatic amines
14	1276	88.665	Sharp	C-N stretch	Aromatic amines
15	1089	57.565	Sharp	C-N stretch	Aliphatic amines
16	1046	27.701	Very sharp	C-N stretch	Aliphatic amines
17	883	56.577	Sharp	C-H "oop"	Aromatics
18	806	82.805	Narrow	C-Cl stretch	Alkyl helides

Similarly, the total ion chromatogram (GC-MS chromatogram) and the detailed tabulation of GC-MS data of the aqueous extract are given in Figure 3 and Table 4 respectively. From the analysis, 9 compounds have been elucidated and effectively matched and identified. The major constituents were at peaks 3 (n-Hexadecanoic acid with peak area 39.40%), Peak 6 (Stearic acid with peak area 24.28%), peak 5 (9-Hexadecenoic acid with peak area 23.38%) and peak 7 (1,E-11,Z-13-Octadecatriene with peak area 7.73%). while the rest had less than 5% composition by peak area.

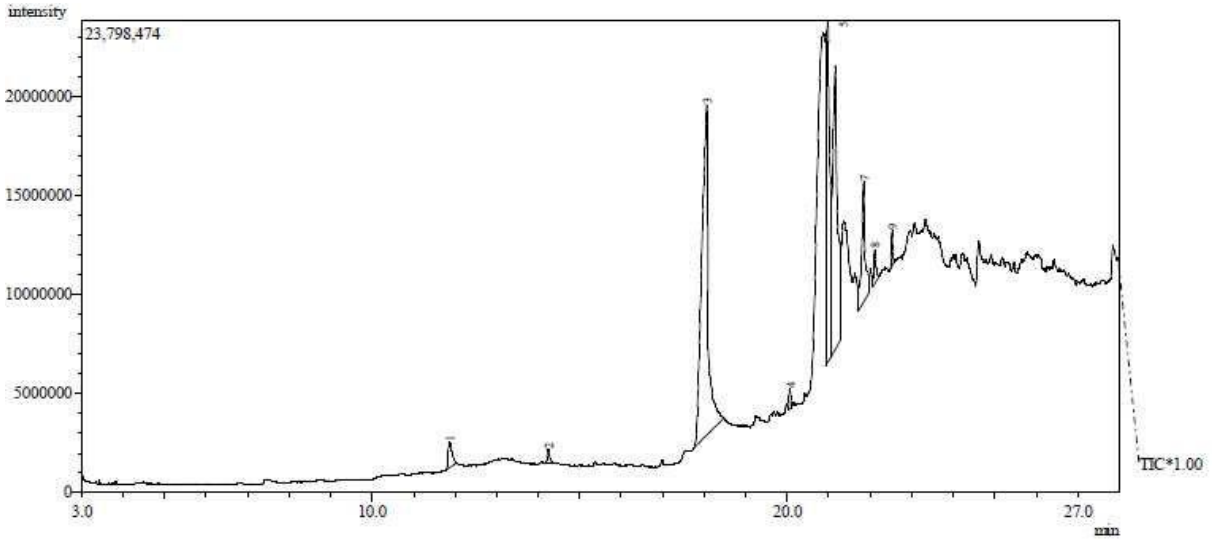
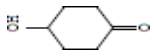
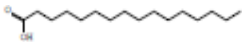
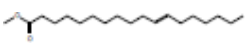
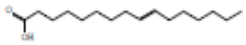
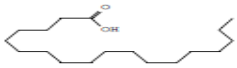
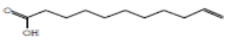


Figure 3: GC-MS Showing Total Ion Chromatogram (TIC) of Aqueous Extract of Stem Bark of *Boswellia dalzielii*

Table 4: Phytochemical components identified from the Aqueous Extract of the Stem Bark of *Boswellia dazielii* by GC-MS Analysis

Peak Number	Retention Time (minutes)	% Composition by Area	Matched compound IUPAC Name	Structure
1	11.865	1.80	4-Hydroxycyclohexanone	
2	14.345	0.53	Tetradecanoic acid (Myristic acid)	
3	18.066	39.40	n-Hexadecanoic acid (palmitic acid)	
4	20.066	0.60	11-Octadecanoic acid	
5	20.979	23.38	9-Hexadecenoic acid	
6	21.157	24.28	Octadecanoic acid (Stearic acid)	
7	21.839	7.73	1,E-11,Z-13-Octadecatriene	
8	22.111	1.32	Undecylenic Acid	
9	22.525	0.94	1-Fluorononane	

The results from the above phytochemical analyses (HPLC, FTIR and GC-MS) support the various ethanobotanical uses of the stem bark of *B. dalzielii* and the observed antimicrobial activity in (Table 5 and Table 6) of this research as the major components identified were reported for their medicinal uses in many research works.

For instance, about 70% of the major components include n-Hexadecanoic acid which is commonly known as Palmitic acid has been reported to have nematicide, pesticide, lubricant, anti-androgenic, flavor, hemolytic 5-alpha reductase inhibitor, antioxidant and hypo-cholesterolemic properties (Komansilan *et al.,* 2012) ; Hexadecenoic acid which is a fatty acid ester also have nematicide, pesticide, lubricant, anti-androgenic, flavor, and has hemolytic 5-alpha reductase inhibitor properties (Sermakkani *et al., 2012*) and (z)-9-Octadecenoic acid commonly known as Oleic acid which is the major component of unsaturated fatty acid found in Olive oil that is responsible for its antimicrobial activity and anticancer activity (David, 2005).

The result of the antimicrobial activity of the extract showing the means and standard error means of the diameters of zones of inhibition produced by the various concentrations of the extract, MIC and MBC/MFC values of the extract for each of the organisms are shown in Table 5. The result showed that the extract is active against all the test isolates with higher zones of inhibition of 19±0.00mm for *S. typhi*, 18±0.30mm for *P. mirabilis* and 18±0.41mm for *P. aeruginosa* at 50mg/ml concentration each. Resistance was only observed in *E.coli* and *S.pyogenes* at 2.5mg/ml concentration. Similarly, lowest MIC values of 12.5mg/ml were obtained for *S. typhi* and *S. aureus* and 25mg/ml for *C. albicans*. *P. Mirabilis* and *P. aeruginosa. K. pneumoniae, E. coli, S. pyogenes and E. faecalis* had MIC values of 50mg/ml each. The MBC/MFC values did not exceed the corresponding MIC values by more than a factor of 2.

Table 5: Antimicrobial Activity of the Crude Aqueous Extract of the Stem Bark of *Boswellia dazielii*

S/N	Test Organisms	Means and Standard Error Means of the Diameters of the Zones of Inhibition Produced by the Various Concentrations of the Extract against the test Organisms (mm)					MIC (mg/ml)	MBC/MFC (mg/ml)
		50 mg/ml	25 mg/ml	10 mg/ml	5 mg/ml	2.5 mg/ml		
1	*S. aureus*	15 ± 0.50	9 ± 0.70	7 ± 0.22	7 ± 0.00	7± 0.00	12.5	25
2	*E. faecalis*	14 ± 0.90	11 ± 0.10	7 ± 0.80	7 ± 0.20	7 ± 0.00	12.5	50
3	*S. pyogenes*	9 ± 0.70	9 ± 0.10	7 ± 0.91	7 ± 0.20	6 ± 0.00*	50	100
4	*P. aeruginosa*	18 ± 0.41	12 ± 0.82	8 ± 0.57	8 ± 0.30	7 ± 0.20	25	50
5	*K. pneumoniae*	13 ± 0.20	12 ± 0.64	9 ± 0.11	9 ± 0.10	8 ± 0.20	25	50
6	*E. coli*	15 ± 0.33	12 ± 0.10	9 ± 0.50	7 ± 0.00	6 ± 0.00*	50	100
7	*S. typhi*	19 ± 0.00	14 ± 0.12	11 ± 0.20	8 ± 0.31	7 ± 0.63	12.5	25
8	*P. mirabilis*	18 ± 0.30	13 ± 0.16	10 ± 0.82	7 ± 0.20	7 ± 0.53	50	100
9	*C. albicans*	15 ± 0.00	14 ± 0.93	11 ± 0.14	7 ± 0.50	7 ± 0.00	25	50

*Values are means plus or minus standard error means obtained from 3 replicas, * indicates resistance.*

The above findings showed that the aqueous stem bark extract of *Boswellia dalzielii* has both antibacterial and antifungal activity and has further supports the earlier reports (Alemika and Oluwole, 1991; Duwiejua *et al.*, 1993; Adelakun *et al.*, 2001 and Abdulazeez *et al.,* 2013) on the antimicrobial activity of the stem bark of the plant.

Conclusion/Recommendation

Stem bark of *B. dalzielii* contains many antimicrobially active compounds. These compounds should be purified and used as precursor for new antibiotics that can be used for effective treatment of many infectious diseases particularly those caused by *S. typhi, S. aureus* and *C. albicans*. In addition, further studies are needed to validate the safety of the stem bark of the plant for consumption as the GC-MS data showed that it contains some few potentially toxic substances.

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