GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

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Bioactive compositions and identification of functional groups of selected medicinal plants

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GSC Biological and Pharmaceutical Sciences, 2024, 27(01), 008–027

Publication history: Received on 21 February 2024; revised on 30 March 2024; accepted on 01 April 2024

Article DOI: https://doi.org/10.30574/gscbps.2024.27.1.0106

Abstract

Medicinal plants, either as standardized extracts or in their pure forms, offer countless propects for new drug leads and also possess a good range of nutritional benefits due to the presence of bioactive organic chemical compounds called phytochemicals that act as a defense against a variety of diseases. This study focus was to investigate the bioactive compounds, and identification of functional groups of three medicinal plants; *Monodora myristica*, *Parkia biglobosa*, and *Azadirachta indica*. The solvents used were methanol, water and ethanol respectively. Gas Chromatography- Mass Spectroscopy (GC-MS) assay was used for the analysis of bioactive compounds and Fourier-Transform Infrared Spectroscopy (FTIR) method was used for the identification of functional groups in the plant extracts. Results revealed several bioactive compounds at different peaks that were confirmed by their retention time, compound name, structure and percentage composition. FTIR analysis revealed different functional groups with distinct characteristic wave numbers, peak intensity, peak shape and bonds in the plant extracts. Among the identified phytocompounds of *Monodora myristica*, phenol, dodecanoic acid, hexadecane, n-hexadecanoic acid, 1-octadecene, and 1-eicosanol possess antioxidant property. Similarly, some of the identified phytocompounds of *Parkia biglobosa*; dodecanoic acid, hexadecanoic acid, 9-octadecene, naphthalene, 3-eicosene and n-hexadecanoic acid possess antioxidant property. Likewise, Hexadecane, hexadecenoic acid, 3-eicosene and n-hexadecanoic acid are phytocompounds of *Azadirachta indica* with antioxidant property. This study demonstrated these plants as a great source of naturally occurring bioactive compounds with therapeutic value, which supports their application in medicine to treat a variety of diseases.

Keywords: Bioactive compounds; Functional groups; Phytochemical analysis; *Monodora myristica*; *Parkia biglobosa*; *Azadirachta indica*

1. Introduction

Plants with medicinal properties have been extensively used in medicine. Research on medicinal plants' effectiveness is conducted worldwide, and some of the data obtained has provided insight on how to make plant-based compounds with therapeutic uses [6]. Plants are the most plentiful natural primary source of active medications and are extremely useful in the ethnomedical treatment of a wide range of illnesses [14].

The bioactive compounds found in medicinal plants, also known as phytochemicals, are found in grains, vegetables, fruits, and other plant products. They are known to play a protective role against major chronic diseases in both host-metabolic or genetic dysfunctional disease and infectious disease [11, 13, 8, 10]. The application of ethnomedical knowledge in biosciences to investigate novel bioactive chemicals and the poly-pharmacological formulation of plant extracts for use in primary healthcare has been the major focus of plant study [1].

Data from the study of the medicinal uses of *Parkia biglobosa* showed that it possessed wide-ranging pharmacological actions, including anti-diarrhoea, antimicrobial, antihypertensive, anti-inflammatory, analgesic, and antiplasmodial

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activities. All the parts of the plants are used for care. Phytochemical investigations revealed that some compounds such as tannins, saponins, flavonoids, steroids, phenols, terpenes, isoquinoline alkaloids, indole alkaloids, cardiac glycoside and reducing sugars are present [5]. The use of *P. biglobosa* as herbal remedies in African countries and the reports on the toxicity of the plant further showed that the plant is non-toxic to humans [9].

Research on the medicinal importance of *Azadirachta indica* reviews that it possesses powerful antidermatonic, anthelmintic, anti-bacterial, anti-viral, anti-septic, anti-inflammatory, anti-fungal, anti-ulcer, insect repellent, properties and boosts the body's overall immune responses. It was found to be widely used in treating chronic malaria, bed bugs ulcer, bad teeth, syphilis, leprosy, spermicidal in preventing pregnancies and other diseases. Externally, the oil is applied as an antiseptic for urticaria and chronic skin diseases like eczema, scabies, ring worm and maggot infested wounds. It is also used for killing lice, fleas, ticks' insecticide, and bacterial growth in mouth [7]. By boosting lipid peroxidation and elevating ascorbic acid (Vitamin C) levels in the brain, antioxidant chemicals found in *Azadirachta indica* can reduce brain damage in patients with stroke [16].

Study by Agiriga and Siwela [2] demonstrated that several parts of *Monodora myristica* including the seeds, bark, and flowers, are rich sources of various phenolics, vitamins, carotene, protein, and they also contain vital minerals. They also contain bioactive substances with antioxidant, anti-diabetic, anti-inflammatory, antispasmodic, diuretic, antihypertensive, hepatoprotective, cholesterol-lowering, antibacterial, and antifungal properties, as well as stimulant effects on the heart and circulatory system. In the traditional system of medicine, the plant's crude extracts are used to cure various diseases.

This research investigated the bioactive constituents and the identification of the functional groups present in three selected plants with medicinal value. The three selected medical plants are shown in the table below:

Table 1 Selected Medicinal Plants

Botanical name	**English name**	**Common name**
Azadirachta indica	Neem leaf	Dogo yaro
Parkia biglobosa	African locust bean	Ogiri /Iru/Dawa dawa
Monodora myristica	African nutmeg/Calabash nutmeg	Ehuru

2. Material and methods

2.1. Plant collection and Identification

Leaves of *Azadirachta indica* were collected from the premises of Federal University of Technology Owerri (FUTO), while seeds of *Parkia biglobosa and Monodora myristica* were harvested from Obaji farm at Orogwe Owerri West Local Government Area, Nigeria and identified by Mr. Udoka Obiajunwa Peter, a Taxonomist in the Department of Forestry, Faculty of Natural Sciences Michael Okpara University of Agriculture, Umudike. Voucher specimen with voucher numbers MOUAU/ZEB/HERB/22/005, MOUAU/ZEB/HERB/22/006 and MOUAU/ZEB/HERB/22/007 respectively were deposited at the University Herbarium.

Freshly collected plants materials were air-dried for 14 days after collection, pulverized to powder, weighed and stored for extraction.

2.2. Chemicals

96% ethanol, 96% methanol, 10% ethanol, anhydrous Sodium sulphate. Other chemicals were of analytical grades.

2.3. Extraction

Exactly 50 g of each sample was macerated in 1000 ml of its appropriate solvent, 96% methanol for *Monodora myristica*; water for *Parkia biglobosa* and 96% ethanol for *Azadirachta indica*. Each sample was turned intermittently for 72 h and thereafter filtered, first with clean handkerchief, then with filter paper to obtain a filtrate which was dried at low room temperature (60^0C) under pressure in a rotary vacuum evaporator (Thermotech, buchi type model th-012) and then concentrated at 40^oC in a hot air oven. Extracts obtained were dark brown in colour, oily in consistency with a yield of 3.65%, 4.22% and 3.98% for *Monodora myristica, Parkia biglobosa* and *Azadirachta indica* respectively.

2.4. Methods for GC-MS and FT-IR

2.4.1. GC–MS analysis

The phytochemical analysis of the extract was carried out using the method as described by Association of Official Analytical Chemists (A.O.A.C) [3]. One gramme (1 g) of the extract was weighed and transferred in a test tube and 25 ml of ethanol was added and allowed to react in a hotplate at 60^0C for 90 mins. After the reaction time, the reaction product contained in the test tube was transferred to a separatory funnel. The tube was washed successfully with 20 ml of ethanol, 10 ml of cold water, 10 ml of hot water and 3 ml of hexane, which was all transferred to the funnel. This extracts were combined and washed three times with 10 ml of 10%v/v ethanol aqueous solution. The solution was dried with anhydrous sodium sulfate and the solvent was evaporated. The sample was solubilized in 1000 µl of pyridine of which 200 µl was transferred to a vial for analysis.

Agilent Technologies GC systems with GC-220 model (Varian, Santa Clara, CA, USA) equipped with HP-5MS column (30 m in length × 250 µm in diameter × 0.25 µm in film thickness) were used for the GC–MS analysis of bioactive compounds from different extracts. High energy electrons (70eV) were used in an electron ionization device for spectroscopic detection by GC-MS. The carrier gas, which had a flow rate of 1 mL/min, was pure helium gas (99.995%). The initial temperature range of 50 to 150°C was chosen, and it was held there for roughly ten minutes at an increase of 3°C per minute. Lastly, the temperature was raised to 300°C at a rate of 10°C per minute. Splitless injection of one microliter of the prepared 1% extracts diluted with the appropriate solvents was performed. The percentage of the chemical components present in each extract was calculated by looking at the peak area that was created in the chromatogram.

2.4.2. Identification of chemical constituents

Based on the GC retention time on an HP-5MS column and the comparison of the spectra with standard computer software data (Replib and Mainlab data of GC–MS systems), bioactive compounds isolated from various extracts were identified. These identifications were done using the method of Buss & Butler [4].

2.4.3. FTIR analysis

FTIR analysis was done according to the method of Vander-Weerd, Heeren & Boon [17]. Buck scientific M530 USA FTIR was used for the analysis. This device has a beam splitter of potassium bromide and a detector of deuterated triglycine sulphate. The software of the Gram A1 was used to obtain the spectra and to manipulate them. Approximately 1.0g of samples, 0.5ml of nujol was added, properly mixed and placed on the salt pellet. FTIR spectra were acquired during the measurement in frequency ranges of 4,000–600 cm^{-1}, co-added at 32 scans, and resolved at 4 cm^{-1}. Transmitter values were used to display FTIR spectra.

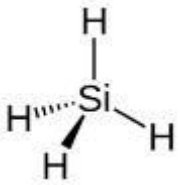
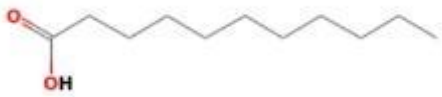
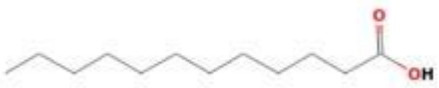
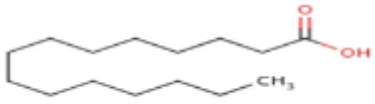
3. Results

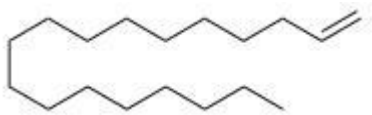
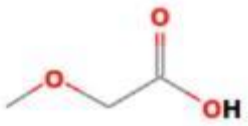
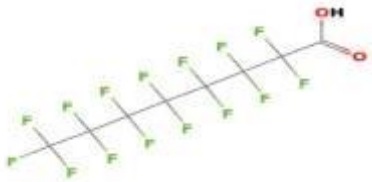
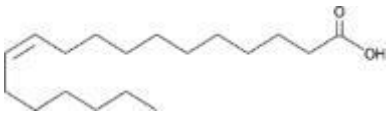
3.1. GC-MS Results for Plant Extracts

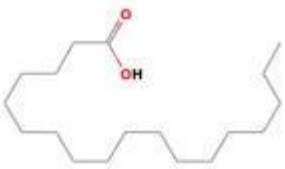
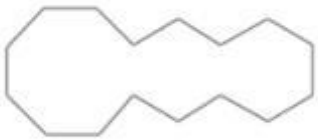
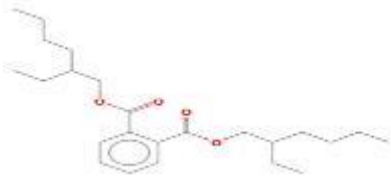
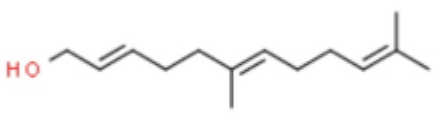
3.1.1. Bioactive compounds of Monodora myristica extract

A total of fourty-one (41) compounds were identified in the methanolic extract of *Monodora myristica.* The bioactive compounds with their peak values, retention time (RT), structural formula and percentage composition are shown in Table 2.

Table 2 GC-MS result of *Monodora myristica* extract

PEAK	RT	COMPOUND NAME	STRUCTURE	% COMPOSITION
1	6.959	Decane		0.19
2	9.634	Dodecane		0.61
3	14.674	Cyclopentane		0.39
4	14.947	Tetradecane		1.75
5	16.519	3-heptafluorobutyroxydodecane		0.28
6	16.541	Silane		0.31
7	17.406	Phenol		2.42
8	17.664	Undecanoic acid		1.11
9	19.124	Dodecanoic acid		13.43
10	19.563	9-Eicosene		0.39
11	19.811	hexadecane		0.72
12	21.542	Dodecyl acrylate		0.22
13	23.464	Tetradecanoic acid		2.14
14	24.003	9-Eicosene		0.38
15	24.215	Octadecane		0.37
16	26.496	Pentadecanoic acid		0.47

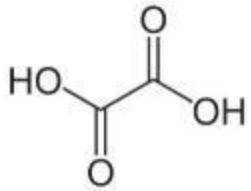
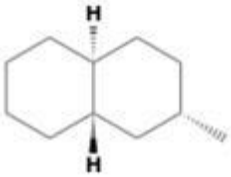
17	27.601	n-Hexadecanoic acid		11.73
18	28.043	1-Octadecene		1.11
19	28.207	Methoxyacetic acid		0.26
20	28.669	Pentadecafluoroctanoc acid		0.43
21	28.796	9-Octadecenoic acid		2.02
22	29.042	Cyclohexane		0.40
23	29.140	1-Eicosanol		0.22
24	29.253	Cis-13-Octadecenoic acid		0.52
25	29.319	Cis-Vaccenic acid		0.25
26	29.578	Methyl stearate		0.24
27	29.762	9-Octadecenoic acid		16.80
28	29.870	Cyclohexadecane		2.03
29	29.935	9-Octadecenoic acid		0.91

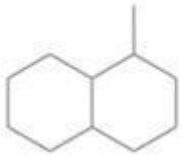
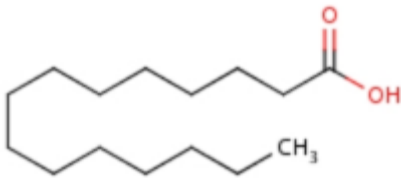
30	29.981	Octadecanoic acid		9.78
31	30.094	Oleic acid		4.74
32	30.159	Oleic acid		1.79
33	30.243	1-Docosene		9.57
34	30.307	Cycloeicosane		4.34
35	30.392	Cyclohexadecane		4.85
36	30.582	5-Eicosene		1.63
37	30.789	3-Eicosene		0.27
38	31.482	Heptadecyl heptafluorobutyrate		0.35
39	32.063	Bis(2-ethylhexyl)phthalate		0.31
40	32.437	Nonadecyl trifluoroacetate		0.12
41	33.502	6,11-Dimethyl-2,6,10-dodecatrien-1-ol		0.16

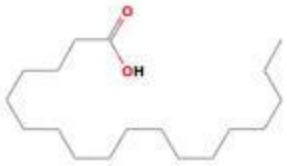
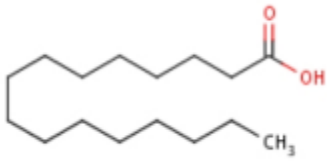
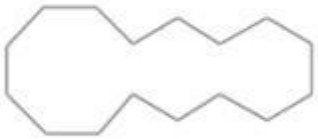
3.1.2. Bioactive compounds of Parkia biglobosa extract

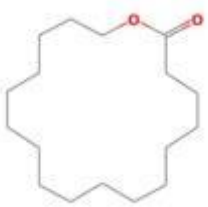
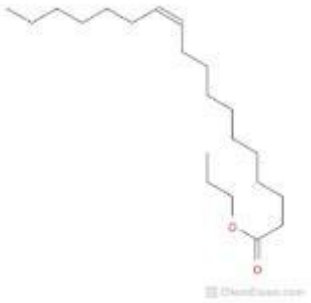
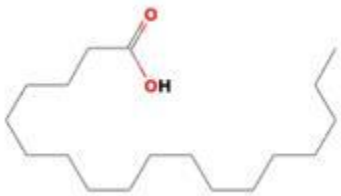
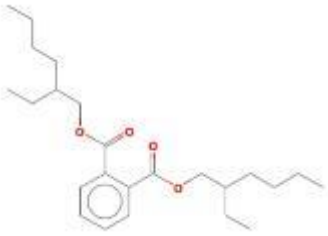
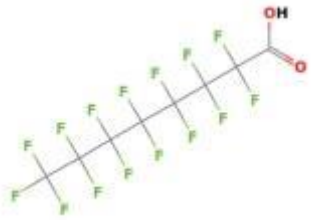
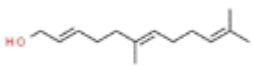
Forty-six (46) bioactive compounds were identified from the GC-MS analysis of the aqueous extract of *Parkia biglobosa* and the result is presented in Table 3 showing their different peaks, retention time (RT), compound name, structural formula and percentage composition.

Table 3 GC-MS result of *Parkia biglobosa* extract

PEAK	RT	COMPOUND NAME	STRUCTURE	% COMPOSITION
1	5.339	Oxalic acid		0.30
2	5.422	Naphthalene		0.63
3	5.501	Benzene		0.22
4	5901	Decane		0.48
5	5.974	Decane		0.77
6	6.067	Decane		0.93
7	6.209	Decane		0.66
8	6.360	Cyclohexanone		0.60
9	6.440	Cis-2-Ethylcyclopentanecarboxaldehyde		0.53
10	6.803	Trans-Decalin		0.70
11	6.961	Decane		1.70

12	7.191	1-Methyldecahydronaphthalene		0.41
13	7.601	Glutaric acid		0.23
14	9.631	Dodecane		0.71
15	14.943	Tetradecane		0.40
16	19.276	Dodecanoic acid		4.48
17	19.563	9-Octadecene		0.42
18	19.811	Hexadecane		0.46
19	23.491	Tetradecanoic acid		3.21
20	24.002	3-Eicosene		0.57
21	24.217	Octadecane		0.53
22	26.471	Pentadecanoic acid		0.44
23	27.501	n-Hexadecanoic acid		7.18
24	27.637	Butyl myristate		0.42
25	28.035	1-Docosene		1.27
26	28.205	Eicosane		0.40

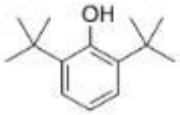
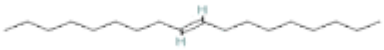
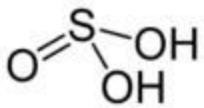
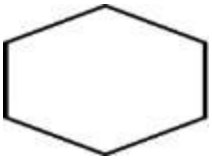
27	28.712	n-Butyl laurate		0.20
28	28.815	1-Hexadecanol		0.40
29	29.038	Cyclohexane		0.45
30	29.139	1-Docosene		0.39
31	29.251	Cis-13-Octadecenoic acid		0.79
32	29.579	Methyl stearate		0.54
33	29.756	Trans-13-Octadecenoic acid		23.04
34	29.874	Butyl 9-hexadecenoate		10.51
35	29.976	Octadecanoic acid		14.46
36	30.087	Hexadecanoic acid		16.07
37	30.243	Cyclohexadecane		1.30
38	30.308	3-Eicosene		0.22

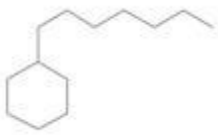
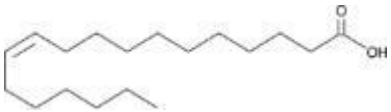
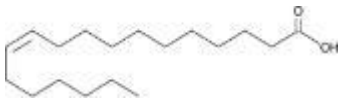
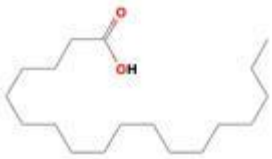
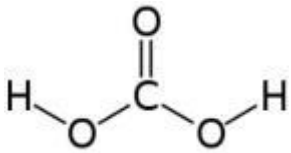
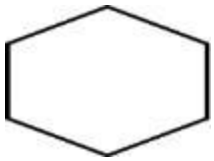
39	30.680	Heptadecanolide		0.99
40	31.152	9,17-Octadecadienal		0.23
41	31.244	n-propyl 11-octadecenoate		0.40
42	31.277	Octadecanoic acid		0.16
43	31.483	17-pentatriacontene		0.31
44	32.064	Bis(2-ethylhexyl) phthalate		0.55
45	32.437	Pentadecaflorooctanoic acid		0.15
46	33.503	6,11-Dimethyl-2,6,10-dodecatrien-1-ol		0.20

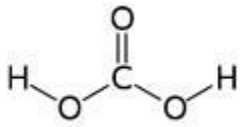
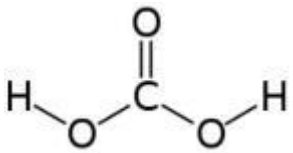
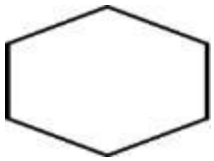
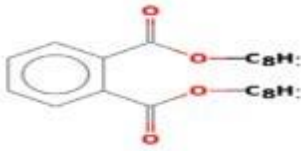
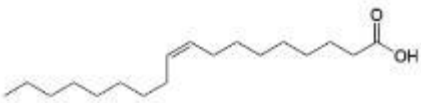
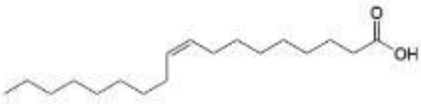
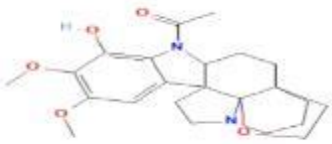
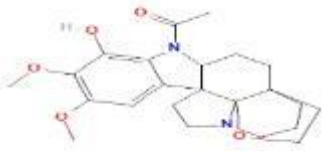
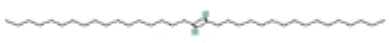
3.1.3. Bioactive compounds of Azadirachta indica extract

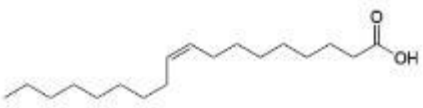
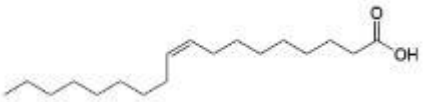
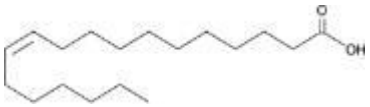
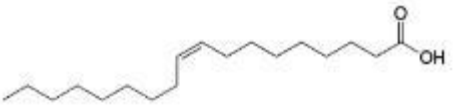
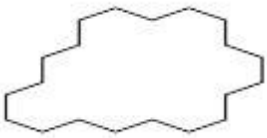
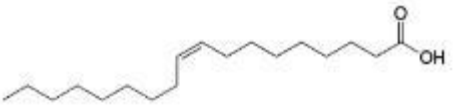
A total of sixty-five (65) bioactive compounds were identified from the GC-MS analysis of the ethanol extract of *Azadirachta indica.* These bioactive compounds are presented in Table 4 with their different peaks, retention time (RTS), compound name, structural formula and percentage composition.

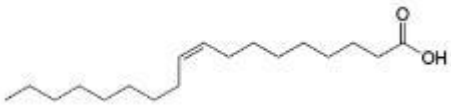
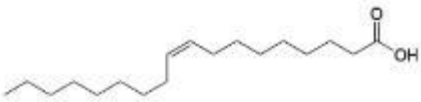
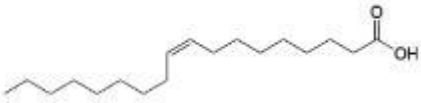
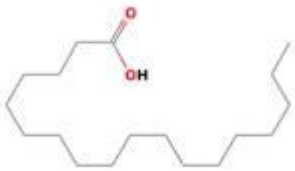
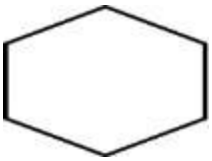
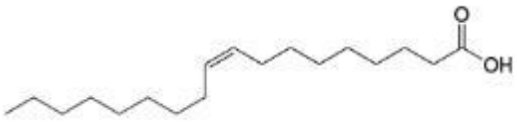
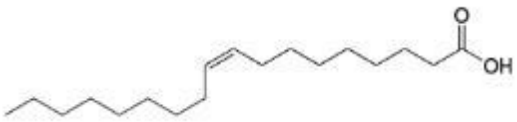
Table 4 GC-MS analysis result of *Azadirachta indica* extract

PEAK	RT	COMPOUND NAME	STRUCTURE	%COMPOSITION
1	9.630	Dodecane		1.28
2	14.943	Tetradecane		0.38
3	17.410	2,4-di-tert-butylphenol		1.23
4	19.257	Dodecanoic		3.11
5	19.566	9-octadecene		1.33
6	19.812	Hexadecane		1.46
7	23.480	Tetradecanoic acid		2.47
8	24.002	9-Eicosene		0.43
9	24.213	Sulfurous acid		1.47
10	25.286	Cyclohexane		0.23
11	26.466	Hexadecenoic acid		0.22
12	27.497	N-hexadecanoic acid		3.30
13	28.205	1-docosene		1.74
14	28.205	Heptacosane		1.21

15	29.040	Heptyl cyclohexane		0.15
16	29.252	9-octadecenoic acid		0.34
17	29.575	Methyl stearate		0.13
18	29.750	Cis-vaccenic acid		5.95
19	29.868	9-octadecenoic acid		0.42
20	29.890	Cis-vaccenic acid		0.28
21	29.972	Octadecanoic acid		0.77
22	30.087	Hexadecenoic acid		0.62
23	30.242	1-docosene		1.07
24	30.308	Carbonic acid		0.20
25	30.394	5-eicosene		0.12
26	30.678	9-octadecenoic acid		0.12
27	30.787	Cyclohexane		0.17
28	31.482	1-docosene		0.99

29	31.525	Carbonic acid		0.21
30	31.623	Carbonic acid		0.13
31	31.746	12-Methyl-E,E-2,13-octadecadien-1-ol		0.18
32	31.923	Cyclohexane		0.23
33	32.023	1-decanol		0.24
34	32.063	Diisooctyl phthalate		2.19
35	32.181	Tricosane		0.38
36	32.224	Oleic acid		0.29
37	32.257	Oleic acid		0.34
38	32.296	Aspidospermidin-17-ol		0.59
39	32.359	Aspidospermidin-17-ol		0.60
40	32.438	17-pentatriacotene		1.30
41	32.471	3-Eicosene		0.62

42	32.506	Oleic acid		0.37
43	32.581	Cyclotetracosane		0.94
44	32.618	1-Nonadecane		0.94
45	32.757	Oleic acid		3.82
46	32.789	Cis-vaccenic acid		1.97
47	32.883	9-octadecenoic acid		1.95
48	32.921	Tetracosane		2.20
49	32.971	Oleic acid		1.39
50	33.045	9-octadecenoic acid		3.97
51	33.090	Cycloeicosane		3.14
52	33.142	Oleic acid		2.27
53	33.191	Trans-13-octadecenoic acid		4.46
54	33.235	9-octadecenoic acid		3.33

55	33.297	9-octadecenoic acid		2.52
56	33.297	Oleic acid		2.21
57	33.333	Oleic acid		3.07
58	33.396	1-Hexacosene		6.46
59	33.434	Eicosane		4.06
60	33.502	6,11-Ddimethyl-2,6,10-dodecatrien-1-ol		14.67
61	36.821	Oleic acid		0.01
62	36.821	Octadecenoic acid		0.02
63	37.022	Cyclohexane		0.03
64	37.081	Oleic acid		0.02
65	37.140	Oleic acid		0.01

3.2. FTIR Results of Plant Extracts

3.2.1. Funtional groups of Monodora myristica extract

From the result of FTIR analysis, the presence of absorptions in the 3800 to 3100 cm^{-1} region indicates that the compound contains O-H or N-H groups, indicating hydrogen bond (O–H) group due to the vibration of water molecules. The compound must have one or more Carbon-Carbon (C-C) double bonds, which are attributable to the existence of aliphatic C-H stretch of CH, CH2, and CH3 groups. The bands in the 3100 to 3000 cm^{-1} regions show the presence of hydrogens linked to sp2-hybridized carbons.Absorptions in the 3000–2850 cm^{-1} region indicate the compound contains

hydrogens bound to sp3-hybridized carbons. Examination of the triple-bond region shows no indications of the presence of triple bonded functional group.

Moving on to the double-bond region, a carbonyl group is present as shown by the significant absorption at 1721 cm^{-1}.This is not part of a carboxylic acid (no O-H) or an aldehyde (absence of absorptions in the 2830–2700 cm^{-1} region). Nor does the unknown appear to be an amide (no N-H, carbonyl absorption too high), or an acyl chloride (carbonyl position too low). This indicates ketone possibility. The strong absorption at 1397cm^{-1} suggests that the unknown contains an alcohol, see Table 5.

Table 5 FTIR result of *Monodora myristica* extract

Wave number	Peak intensity	Peak shape	Bond	compound
690.8756	Strong	Sharp	C-H out of plane bending	Cis disubstituted alkene
815.566	Medium	Broad	Sp2 CH bending	1,4 disubstituted aromatic compound
1030.659	Medium	Sharp	C-N stretching	Amine
1236.255	Medium	Broad	C-O stretching	Alkyl aryl ether
1397.019	Medium	Sharp	O-H bending	Alcohol, carboxylic acid
1590.293	Medium	Sharp	N-H bending	Amine
1721.021	Strong	Broad	C=O stretching	Aliphatic ketone
1817.417	Medium	Sharp	C=O stretching	Anhydride
1950.449	Medium	Broad	C-H bending	Aromatic compound
2083.711	Strong	Sharp	N=C=S stretching	Isothiocyanate
2278.126	Medium	Very sharp	N=C=O stretching	Isocyanate
2518.308	Strong	Sharp	S-H stretching	Thiol
2738.125	Strong	Sharp	O-H stretching	Carboxylic acid
3014.04	Strong	Sharp	C-H stretching	Alkene
3244.576	Strong	Sharp	O-H stretching	Carboxylic acid
3346.233	Strong	Sharp	N-H stretching	Aliphatic primary amine
3542.772	Strong	Sharp	O-H stretching	Intermolecular bonded Alcohol
3833.605	Strong	Very sharp	O-H stretching	Free alcohol

3.2.2. Funtional groups of Parkia biglobosa extract

The different functional groups found in the aqueous extract of *Parkia biglobosa* is presented in Table 6. Single bond areas ranged from 2500 to 4000 cm^{-1} in the peaks. A wide absorption band was identified, indicating the presence of hydrogen bonds in the substance. A strong bond between 3400 and 3800 cm^{-1} indicates the presence of bonding related to oxygen, which may be N-H or O-H. Peaks between 3000 and 3200 cm^{-1} were identified, indicating that the compound contain an aromatic structure. Strong bond at less than 3000 cm^{-1} responded to the C-C bond. The presence of absorptions in the 3000 to 2850 cm^{-1} region indicates that there are hydrogens bonded to sp3-hybridized carbons in the compound. This indicates the presence of alkene in the compound. Aldehyde was found to have a specific peak between 2700 and 2800 cm-1. The absence of a triple bond region (2000-2500 cm^{-1}) indicates that there are no C≡C bonds in the material. Regarding the double bond region (1500-2000 cm^{-1}). Peak at about 1839 cm^{-1}, shows the presence of a carbonyl group in the compound.

Table 6 FTIR result of *Parkia biglobosa* extract

Wave number	Peak intensity	Peak shape	Bond	compound
827.8279	Very strong	Broad	C-H out of plane bending	Trisubstituted alkene, para disubstituted aromatic compound
1097.611	Medium	Sharp	C-O stretching	Secondary alcohol
1279.721	Strong	Sharp	C-N stretching	Aromatic amine
1383.936	Strong	Very sharp	O-H stretching	Phenol, alcohol
1541.907	Medium	Broad	N-O stretching	Nitro compound
1839.551	Medium	Broad	C=O stretching	Anhydride
1932.285	Weak	Broad	C-H bending	Aromatic compound
2066.473	Medium	Broad	N=C=S stretching	Isothiocyanate
2310.194	Medium	Sharp	O=C=O stretching	Carbon dioxide
2530.145	Strong	Sharp	O-H stretching	Carboxylic acid
2702.572	Medium	Sharp	C-H stretching	Aldehyde
2840.261	Medium	Sharp	C-H stretch	Alkanes
2992.879	Strong	Sharp	N-H stretch	Amine salt
3182.727	Medium	Broad	O-H stretching	Intramolecular bonded alcohol
3305.789	Medium	Broad	N-H stretch	Aliphatic primary amine
3522.591	Medium	Sharp	O-H stretching	Intermolecular bonded alcohol
3627.504	Medium	Sharp	O-H stretching	Alcohol
3793.298	Medium	Sharp	O-H stretching	Free alcohol

3.2.3. Funtional groups of Azadirachta indica extract

Table 7 FTIR result of *Azadirachta indica* extract

Wave number	Peak intensity	Peak shape	Bond	Compound
853.8417	Strong	Broad	C-Cl bending	Halo compound
1277.997	Medium	Sharp	C-O stretching	Aromatic ester
1370.808	Strong	Broad	O-H bending	Phenol
1621.763	Strong	Sharp	C=C stretching	Alkene
1893.239	Strong	Sharp	C=O stretching	Anhydride
2016.346	Weak	Broad	C-H bending	Aromatic compound
2105.062	Medium	Broad	C≡C stretching	Alkynes
2213.934	Medium	Sharp	C≡N stretching	Nitrile
2298.079	Medium	Sharp	N=C=O stretching	Isocyanate
2451.352	Medium	Sharp	O=C=O stretching	Carbon dioxide
2630.584	Strong	Broad	O-H stretching	Carboxylic acid
2717.996	Strong	Broad	O-H stretching	Carboxylic acid

3086.353	Strong	Sharp	C-H stretching	Alkene
3274.454	Medium	Sharp	C-H stretching	Alkynes
3430.844	Strong	Sharp	O-H stretching	Intermolecular bonded alcohol
3591.458	Strong	Sharp	O-H stretching	Alcohol
3823.469	Medium	Broad	O-H stretching	Free alcohol

From the FTIR analysis result presented in Table 7, in the single bond area (2500-4000cm^{-1}), several peaks were detected. A broad absorption band between 3823 and 33400 cm^{-1} indicates the presence of an O-H hydrogen bond group as a result of water molecules vibrating. Peaks at between 3000 and 3200cm^{-1}, replying the aromatic ring. Peaks at below 3000cm^{-1}, responding the single bond of carbon. The absorptions in the region of 3000 to 2850cm^{-1} attributed to presence of aliphatic C–H stretch of CH, CH2 and CH3 groups. Aldehyde peak was not detected between 2700 and 2800cm^{-1}. Regarding the triple bond region (2000-2500cm^{-1}), the peak observed at 2105cm^{-1} arises due to the presence of C≡C groups. The peak at 2213cm^{-1} is related to the C≡N stretching vibrations. In the double bond region (1500-2000 cm^{-1}), the peak which is presented at 1622cm^{-1} can also be corresponded to C = C stretching of alkene observed at about 3273cm^{-1}. The strong absorption at 1893 cm^{-1} indicates the presence of a anhydride. A weak absorption band was also detected at 2023cm^{-1} indicating the presence of aromatic compound. In the fingerprint region (600-1500 cm^{-1}), strong. The band found at 854 cm^{-1} is related to the stretching vibrations of C–H out-of-plane band.

4. Discussion

Gas chromatography-mass spectroscopy (GC-MS), according to Vishwakarma [18], is an important method for the identification and quantification of organic compounds in plant extracts. The GC-MS instrument functions based on the principle of molecular component identification (the MS component) and chemical mixture separation (the GC component). This study showed the identification of bioactive compounds at different peaks that were confirmed by their retention time, compound name, structure and percentage composition. The identified compounds are shown in Table 2, Table 3 and Table 4 for *Monodora myristica, Parkia biglobosa* and *Azadirachta indica* respectively.

Fourty-one bioactive compounds were identified in the methanolic extract of *Monodora myristica* some of which are decane, phenol, tetradecane, n-hexadecanoic acid, cyclopentane, cis-vaccenic acid, methyl stearate, 9-octadecenoic acid, e.t.c, (see Table 2). Among the identified phytocompounds, phenol, dodecanoic acid, hexadecane, n-hexadecanoic acid, 1-octadecene, and 1-eicosanol have antioxidant property. GC-MS analysis carried out by Miediegha, *et al*. [12] on the oil of *Monodora myristica* revealed that it contained fatty acids such as n-hexadecanoic acid, cis-vaccenic acid and 9,12-octadecadienoic acid; as well as terpinoids such as alpha-terpineol and alpha-cadinol. Forty-six bioactive compounds were identified in the aqueous extract of *Parkia biglobosa*, these compounds are listed in Table 3. Similarly, some of the identified phytocompounds, dodecanoic acid, hexadecanoic acid, 9-octadecene, naphthalene, 3-eicosene and n-hexadecanoic acid have antioxidant property. Likewise, sixty-five identified compounds of the ethanol extract of *Azadirachta indica* are shown in Table 4. Hexadecane, hexadecenoic acid, 3-eicosene and n-hexadecanoic acid are the phytocompounds with antioxidant property.

Fourier transform infrared (FTIR) spectroscopy was employed in determining the functional groups present in the plant extracts revealing different characteristic peak values, distinct wavelength, and bonds in the extracts. The FTIR analyses of methanol extract of *Monodora myristica* showed the presence of alkene, aromatic compound, amine, alkyl aryl ether, alcohol carboxylic acid, aliphatic ketone, anhydride, isothiocyanate, isocyanate, alphatic primary amine, and free alcohol (Table 5). The aqueous extract of *Parkia biglobosa* showed alkene, secondary alcohol, aromatic amine, phenol, alcohol, nitro compound, anhydride, aromatic compound, isothiocyanate, carbondioxide, carboxylic acid, aldehyde, alkanes, amine salt, aliphatic primary amine and free alcohol (Table 6)

Also, the ethanol extract of *Azadirachta indica* leaf showed the presence of halo compounds, aromatic ester, phenol, alkene, anhydride, alkynes, nitrile, isocyanate, carbondioxide, carboxylic acid, intramolecular bonded alcohol and free alcohol functional groups (Table 7) which could be responsible for some of the pharmacological activities observed. This technique has been used to investigate the functional groups found in some medicinal plants. For example, phenols, alkanes, carboxylic acids, aldehydes, ketones, alkenes, alkyl halides, primary amines, aromatics, amide, alcohols, esters, ethers, and aliphatic amine compounds were found in the methanol and chloroform leaf extracts of *Wedelia biflora*, which demonstrated significant peaks [15].

5. Conclusion

From the results obtained, it can be concluded that the extracts of *Monodora myristica, Parkia biglobosa* and *Azadirachta indica* possess therapeutic activities as a result of the bioactive compounds found in them. Therefore, these plants extracts could be useful in drug production or as a therapy in the treatment of several diseases.

The use of these plants in medicine is recommended and additional research should be done to identify, isolate, and purify the bioactive constituents that give these plants their action. Further research is also encouraged to clarify these extracts' potential mechanism of action

Compliance with ethical standards

Disclosure of conflict of interest

There was no conflict of interest recorded in this research.

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