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Fourier Transform Infrared Spectroscopy Analysis of *Allium sativum* L. and *Nymphaea lotus* L.

Adenola Oluwasegun Jesse[1*]

[1]Microbiology Department, Federal University of Technology, Akure, Nigeria.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The use of Fourier Transforms Infrared Spectroscopy (FTIR) in screening secondary metabolites provides valuable information on qualitative, quantitative and the pattern of the biologically active compounds. The present study was carried out to identify functional groups present in water, methanol and n-hexane extracts of *Allium sativum* and *Nymphaea lotus*. It was revealed that *Allium sativum* and *Nymphaea lotus* possess numerous secondary metabolites {*A. sativum* L. (isothiocynate, acid halide, conjugated aldehyde, imine/oxime, halo compound, conjugated amine, alphaticprimary amine, aldehyde, anhydride, α,β-unsaturated ketone, carboxylic acid, nitro compound, aromatic ester) and *N. lotus* L. (aliphatic primary amine, halo compound, anhydride, vinyl ether, cabocylic acid, cyclic alkene, unsaturated ketone, aldehyde, aliphatic primary amine, aldehyde, alkane, benzene derivative, sulphide, alkene, akyl aryl ether, sulfonyl chloride, δ-lactone, imine/oxime, thiocyanate, amine salt, esters, alkene, nitro compound, sulphate, sulphone, akyl aryl ether, aromatic ester, fluoro compound, amine salt, sulphonyl chloride, tertiary alchohol, α,β-unsaturated ketone, alkyne, allene, sulfonic acid, α,β-unsaturated ester, alphatic primary amine, amine, sulfonyl chloride, vinyl ether, aromatic amine, alphatic ketone, isothiocyanate, thiocynate, conjugated alkene and anhydride)} that may be biologically active which could be useful in production of antimicrobials and other medicinal products that can be of high benefits in proffering reliable alternative medicine to human and animal diseases.

**Corresponding author: Email: adenolajesse@gmail.com;*

Keywords: Nymphaea lotus; fourier transform; Allium sativum; animal diseases.

1. INTRODUCTION

Garlic (*Allium sativum* L.) is a common spice with many health benefits, mainly due to its diverse bioactive compounds, such as organic sulfides, saponins, phenolic compounds, and polysaccharides. Garlic is commonly consumed and has a long history of being utilized as a traditional medicine in China [1]. Garlic is one of the universal plants with great healing power and an ability to protect the human body from a wide variety of diseases. It can boost the immune system to fight off potential disease and maintain health [2], has ability to stimulate the lymphatic system which helps in removal of waste products from the body, it is an effective antioxidant that helps in eradicating free radical that may damage the cells. Garlic also help in preventing many kind of cancer, heart disease, strokes and some viral infections. The sulfur-containing compounds present in garlic exerts protection to human body by stimulating the production of certain beneficial enzymes [2]. The garlic serve as a potential sources for discovery and production of new beneficiary drugs to mankind. One of the sulfur - containing compounds, Alliinget converted to the anti-microbial active alliinupon cutting of bruishing of a bulb. Ajoene, a secondary degradation product of alliinpresumed to bethe most active compound responsible for the antithrombotic activity [2]. Garlic is proved to be effective against gastrointestinal neoplasias, blood clots (antiplatelet action) due to the presence of alliin and ajoene which have fibrinolytic activity [3]. *N. lotus* a second plant of this study is an important component of Egyptian vascular aquatic plants and encountered frequently in the irrigation and drainage canals in the Nile delta [3]. The plant is a perennial aquatic plant used in traditional medicine system as an aphrodisiac, anodyne, astringent, cardiotonic, sedative, analgesic and as anti-inflammatory agent [4]. It has been receiving much attention from the ecological, medicinal and environmental points of view, in particular, due to its ability to absorb and accumulate heavy metals from polluted water. Apart from their ecological interest, water lilies appear to have also historical importance worldwide [5]. A lotus (*N. lotus* L.), is a floating aquatic herb with large leaves. This plant has been present in Egypt in ancient times as reported by Herodotus (484-425 B.C) who described the annual harvest of the plant during the flooding of the River Nile plains and especially encountered in the irrigation and drainage canals in the Nile delta. *N. lotus* is not only historically and ecologically important, but medicinally also. The herb is reported to cure liver diseases, as an antiepileptic, used against haematuria and jaundice, as a sedative and as a cooling herb. The roots were used as a stomach-tonic, cough sedative and for diarrhea. The syrup of the roots was used as an anti-inflammatory, in fever, and the seeds were used for hemorrhoids [6]. From the nutritional point of view, the tuberous rhizomes and seeds of the plant could be eaten after boiling or roasting, and also in baking [7]. Afolayan et al. [4] reported that *N. lotus* possess some amount of phytochemicals such as phenols, tannins, saponins, steroids, proanthocyanidins and flavanols. Chemicals obtained from plants are used worldwide for production of vital drugs [8]. Extensive researches has been carried out to evaluate and discover new antioxidant, antimicrobial and antifungal ingredients from different natural sources such as soil, microorganisms, animals, and plants. Systemic screening of these local herbs may result in the discovery of new effective bioactive compounds that may be useful in formulation of new antimicrobial medicine [2]. Amongst the techniques used to screen and fingerprint the bioactive chemical in plants such as HPLC with UV (DAD), ELSD, MS detection or GC-MS, HPLC densitometry, FT-MIR, NIR, NMR or a combination of these, UV-visible spectroscopy which offers a simple, technique to identify the main phytochemicals, discriminating between the lipophilic and hydrophilic molecules in relation to the polarity. Characterization of secondary metabolite fingerprint by chromatography and spectroscopy provide valuable information about qualitative and quantitative constituent of a plant species as well as their pattern of recognition by chemometry. The use of FT-IR spectroscopy technique demonstrated to be very useful in analysis of tissues, plants components, such as membranes, biomolecules like proteins, nucleic acids, polysaccharide as well as complex biological materials such as body fluids or cell cultures. This technique is reliable and widely used to identify chemical constituents, structural compounds in the sample [2]. Fourier transforms infrared spectroscopy is a high resolution analytical technique to identify the chemical constituents and elucidate the structure of compounds [2]. FTIR offers a rapid and nondestructive investigation to fingerprint plant extract or powders. Therefore, the aim of the

present study was to screen functional groups present in water, methanol and n-hexane extracts of *A. sativum* and *N. lotus* using FT-IR spectroscopy.

2. MATERIALS AND METHODS

2.1 Materials Used in the Study

Fresh garlic (*Allium sativum*), water lily (*Nymphaea lotus*), conical flask, spatula, beakers, stirring rods, measuring cylinder, test tubes, test tube racks, hand gloves, cotton wool, paper tape, muslin clothes, ethanol, aluminum foil, Chloroform, syringe, micropipette, ice pack, nitrogen gas, ethanol, distilled water and n-hexane.

2.2 Collection of Garlic (*Allium sativum* L.)

Fresh garlic bulbs were purchased from Oba's market, Akure, Ondo State, Nigeria. The plant was identified and authenticated by experts at the Crop, Soil and Pest Department, Federal University of Technology, Akure, Nigeria. The garlic cloves were separated and kept in a sterile containers, washed with running clean tap water and dried at room temperature. These cloves were milled to a paste, and the paste was stored in an airtight container at 4°C temperature in a refrigerator until use.

2.3 Collection of Water Lily (*Nymphaea lotus* L.)

Water lily was collected from stagnant water body present at Okitipupa local government area of Ondo State, Nigeria. The plant was identified and authenticated by experts at the Crop, Soil and Pest Department, Federal University of Technology, Akure, Nigeria. The leaves, stems and roots were separated and kept in asterile container, washed with running clean tap water and dried at room temperature. The dried leaves, stems and roots were milled to a fine powder, and stored in an airtight container at room temperature until use.

2.4 Preparation of Extracts of *A. sativum*

Apaste obtained from *A. sativum* cloves was extracted with water, ethanol and n-hexane separately using the method described by [9]. *A. sativum* extracts were prepared by chopping the garlic using pestle and mortar and was divided into three equal sizes in 3 sterile plastic containers respectively. Each of the three weighed chopped garlic was homogenized in sterile distilled water, ethanol and N- hexane at 200 g to 1litre of solvent respectively. The homogenate were kept in a covered sterile container for three days. Sterile muslin cloth was used to remove the large particles from the homogenate and then filtered using Whatman No. 1 filter paper. Extracts obtained were then concentrated in a vacuum using rotary evaporator to remove the solvents [10]. The extraction efficiency was quantified by determining and comparing the weight of each of the extracts yield.

2.5 Preparation of Extracts from *N. lotus*

The plants were extracted with water, ethanol and N-hexane using the method described by [9]. Three equal sizes of finely grounded dried *N. lotus* leaves, *N. lotus* stem and *N. lotus* root were measured into 9 sterile plastic containers respectively. Each 200 g portion of the finely grounded *N. lotus* leaves, *N. lotus* stem and *N. lotus* root were homogenized separately in sterile distilled water, ethanol and n- hexane using 1litre of each solvent respectively and then filtered using Whatman No. 1 filter paper. Extracts obtained were then concentrated in vacuum using rotary evaporator to remove the solvents [10]. The extraction efficiency was quantified by determining and comparing the weight of each of the extracts yield.

2.6 Storage of Stock Concentration of *A. sativum* and *N. lotus* Extracts

The 100% stock concentration extracts of *A. sativum* and *N. lotus* thus obtained was stored at 4°C in a well corked universal bottle. The stock was reconstituted with DMSO to a required concentration at each use.

2.7 Determination of the Chemical Properties and Functional Groups of Water, Ethanol and N-hexane Extracts of *A. sativum* and *N. lotus*

The chemical properties and functional groups of water, ethanol and n-hexane extracts of *A. sativum* and *N. lotus* were determined using Fourier Transform Infrared Spectroscopy analysis (FTIR) as described by Nagarajanand Ramesh (2017). A FT-IR spectrometer (Infrared spectrometer Varian 660 MidIR Dual

MCT/DTGS Bundle with ATR) was used to confirm the chemical structure of all samples. Before analysis, the samples were dried in an auto- desiccator for 24 hours. Samples were directly applied to a diamante crystal of ATR and resulting spectra of them were corrected for background air absorbance. Potassium bromide (KBrFT-IR grade, Sigma -Aldrich) disks were prepared from powdered samples mixed with dry KBr in the ratio of 1:100. The spectra were recorded in a transmittance mode from 4000 to 500/400 cm^{-1} at a resolution of 4 cm. Infrared spectrum was Fourier transformed and recorded in the absorption mode. The refractogram obtained from FT-IR spectroscopy between wave number and absorption is tabulated below. IR solution software is employed for getting the spectrum. The region of IR radiation helps to identify the functional groups of the active components present in extract based on the peaks values of the FTIR spectrum. When the extract was passed into the FTIR, the functional groups of the components were separated based on its peaks ratio [2].

3. RESULTS

3.1 Determination of the Chemical Properties and Functional Groups of Water, Ethanol and N-hexane extracts of *A. sativum* and *N. lotus*

The chemical compounds separated from extracts of *A. sativum* and *N. lotus* is represented in Tables 1 to 12 and Figs. 1 to 12 respectively. N-hexane extract of *A. sativum* had the highest number of peak (i.e.24) and compounds in *Allium sativum* extracts, though they all (Alphaticprimary amine, alkane, aldehyde, isothiocynate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, atic ester, isothiocynate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, Aromatic ester, alkene and Halo compound, Acid halide, Conjugated aldehyde, Conjugated amine, alkene, Imine/oxime, alcohol) have similar functional groups.

All the extracts of *N. lotus* had similar functional groups (Aliphatic primary amine, Halo compound, anhydride, Vinyl ether, alcohol, Cabocylic acid, Cyclic alkene, Unsaturated ketone, aldehyde, alkyne, Carbon dioxide, Aliphatic primary amine, aldehyde, alkane, Benzene derivative, Secondary alcohol, sulphide, alkene, Akyl aryl ether, Sulfonyl chloride, Aromatic compound, δ-lactone, Imine/oxime, alkane, alcohol, Thiocyanate, Amine salt, esters, alkene, Nitro compound, Sulphate, Sulphone, Akyl aryl ether, Aromatic ester, Fluoro compound, Amine salt, Sulphonyl chloride, Tertiary alchohol, α,β-unsaturated ketone, alkyne, allene, Sulfonic acid, α,β-unsaturated ester, Alphatic primary amine, amine, Sulfonyl chloride, Vinyl ether, Aromatic amine, Alphatic ketone, isothiocyanate, thiocynate, conjugated alkene and anhydride). Ethanol extract of *Nymphaea lotus* leaves had the highest number of peaks (34) and compounds compare to other extracts of *Nymphaea lotus.*

Table 1. FTIR spectral peak values and functional groups obtained for water extract of *N. lotus* leaves

Run	Peak (cm^{-1})	Functional group	Interpretation
1.	3643.56	O-H Stretching vibration	Alcohol
2.	3351.34	N-H Stretching vibration	Aliphatic primary amine
3.	2917.10	C-H stretching	Alkane
4.	2806.34	H–C=O: C–H stretch	Aldehyde
5.	2445.54	C=O stretching	Unindentified
6.	2347.47	O=C=O stretching	Carbon dioxide
7.	2102.56	C≡C	Alkyne
8.	1741.30	C=O stretching	Aldehyde
9.	1622.20	C=C stretching	Unsaturated ketone
10.	1604.54	C=C stretching	Cyclic alkene
11.	1443.76	O-H bending,	Cabocylic acid
12.	1420.63	O-H bending,	Alcohol
13.	1247.03	C-O stretching	Vinyl ether
14.	1050.29	CO-O-CO stretching	Anhydride
15.	645.22	C-I stretching	Halo compound
16.	601.21	PO_3 Stretching	Unindentified
17.	563.24	C-O Stretching O-H	Unindentified
18.	504.26	C–O stretching	Unindentified

Table 2. FTIR spectral peak values and functional groups obtained for ethanol extract of *N. lotus* leaves

Run #	Peak (cm^{-1})	Functional group	Interpretation
1	3943.02	O-H Stretching vibration (Non bonded)	alcohol
2	3900.23	O-H stretching vibration (Bonded)	alcohol
3	3870.23	O-H stretching vibration (Bonded)	alcohol
4	3723.06	O-H stretching vibration (Bonded)	alcohol
5	3650.54	O-H stretching vibration (Bonded)	Alcohol
6	3457.56	N-H bending vibration	Prmary amine
7	3432.43	O-H stretching	Alcohol
8	2926.07	C-H stretching	Alkane
9	2862.43	O–H stretch, H–bonded	Carboxylic acid
10	2800.75	N-H Stretching	Amine salt
11	2631.17	O-H stretching	Carboxylic acid
12	2432.09	C-N Stretching	unidentified
13	2454.37	O-H bend, alcoholic group	unidentified
14	2296.23	C = C group	unidentified
15	2143.11	S-C≡N stretching	Thiocyanate
16	1844.99	C-H bending	Aromatic compound
17	1742.72	C=O stretch	δ-lactone
18	1641.43	C=N stretching	Imine/oxime
19	1447.64	C-H bending, O–H stretch	Alkane
20	1413.55	O–H bendng	Alcohol
21	1383.63	S=O stretching	Sulfonyl chloride
22	1372.56	S=O stretching	solfonate
23	1230.36	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Akyl aryl ether
24	1100.23	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Secondary alcohol
25	1093.09	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Secondary alcohol
26	1038.71	S=O stretching	sulphide
27	843.72	C-CL	Halo compound
28	832.72	C=c bending	Alkene
29	704.05	C=O stretch	Benzene derivative
30	571.67	–CH (CH2)vibration,	unidentified
31	545.76	PO_3 Stretching	unidentified
32	537.20	C–O stretching	unidentified
33	472.58	O–H bend	unidentified
34	465.21	=C–H bend	unidentified

Table 3. FTIR spectral peak values and functional groups obtained for n-hexane extract of *N. lotus* leaves

Run #	Peak (cm^{-1})	Functional group	Interpretation
1	3945.52	O-H Stretching vibration	unidentified
2	3906.50	O-H stretching	unidentified
3	3825.97	O-H stretching	alcohol
4	3742.13	O-H stretching	O-H stretching
5	3429.93	O-H stretching	alcohol
6	2874.04	C-H Stretching	alkane
7	2107.30	C≡C	alkyne
8	1741.80	C=O stretching	esters
9	1636.67	C=C Stretching, C=O Stretching	alkene
10	1514.49	N-O Stretching	Nnitro compound
11	1432.21	O-H bending	Carboxylic acid
12	1415.61	S=O	Sulphate
13	1306.52	S=O	sulphone
14	1243.30	C-O stretching	Akyl aryl ether
15	1255.71	C-O Stretching O-H	Aromatic ester
16	1013.32	C-F stretching	Fluoro compound
17	843.26	C-CL Stretching	Halo compound
18	571.92	C=O stretch	unidentified
19	562.36	C-O asymmetric , C-O-C Stretching	unidentified
20	542.02	O-H Stretching	unidentified
21	531.41	PO_3 Stretching	unidentified
22	518.32	C–O stretching	unidentified
23	487.05	O–H bend	unidentified
24	475.61	C-I, C-Cl stretch, C-Br stretch	unidentified

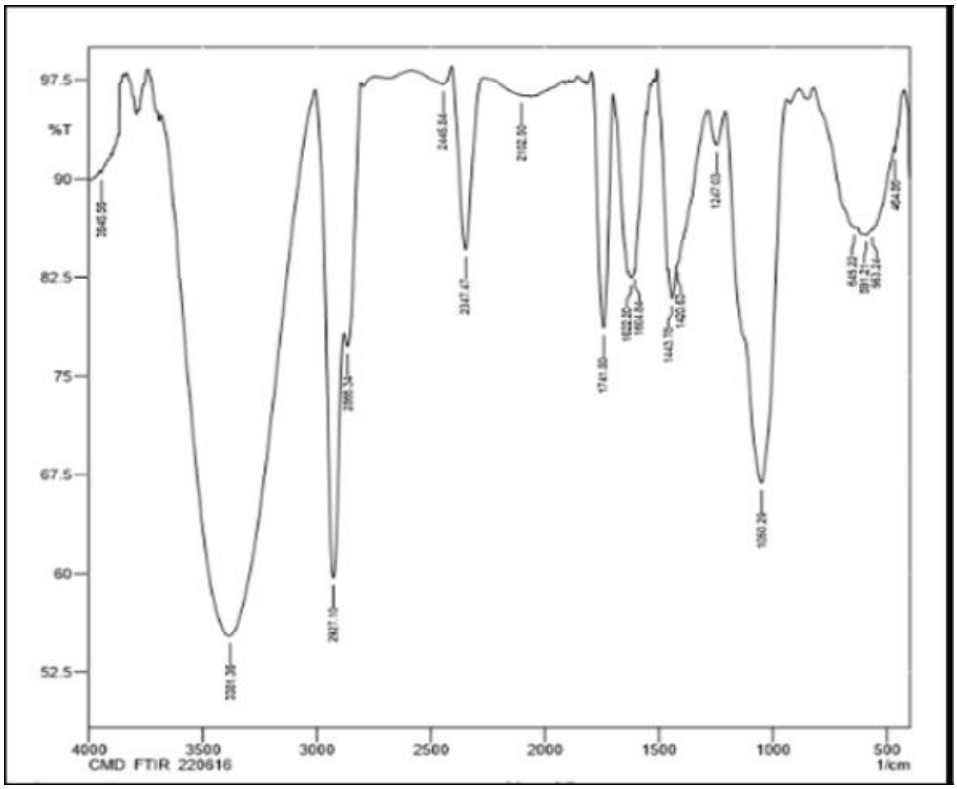

Fig. 1. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of water extract of *N. lotus* leaves

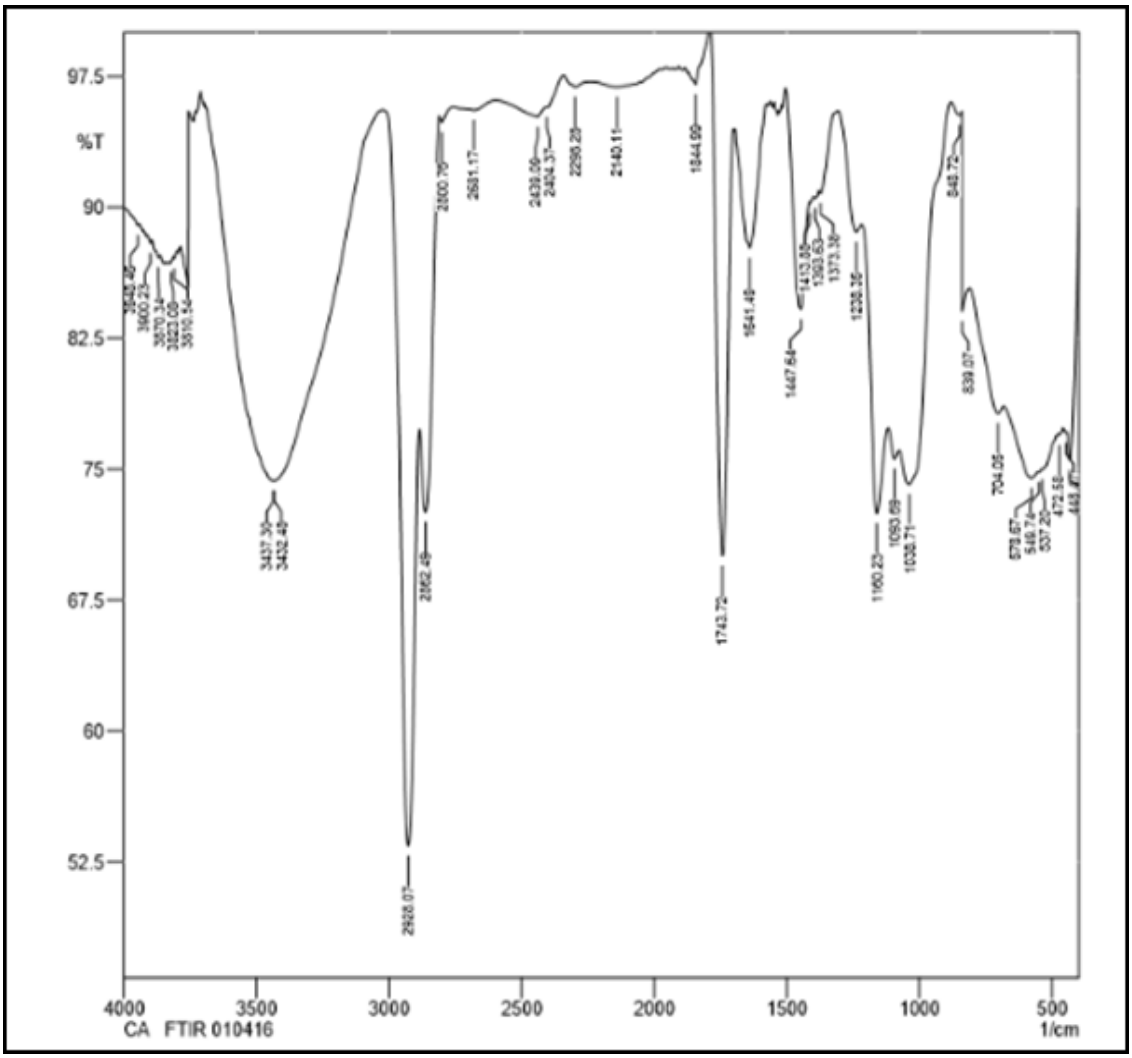

Fig. 2. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of ethanol extract of *N. lotus* leaves

Table 4. FTIR spectral peak values and functional groups obtained for water extract of *N. lotus* stem

Run #	Peak (cm^{-1})	Functional group	Interpretation
1	3918.33	O-H Stretching vibration	alcohol
2	3708.41	O-H Stretching vibration	alcohol
3	2964.28	C-H stretching	alkane
4	2910.50	C-H stretching	alkane
5	2815.71	N-H stretching	Amine salt
6	2735.46	C–H stretch	aldehyde
7	1748.72	C=O stretching	aldehyde
8	1496.13	C=O stretching	
9	1410.65	S=O stretching	Sulphonyl chloride
10	1250.00	C-O stretching	Aromatic ester
11	1108.31	C-O Stretching, O-H	Tertiary alchohol
12	748.96	C-CL	Halo compound

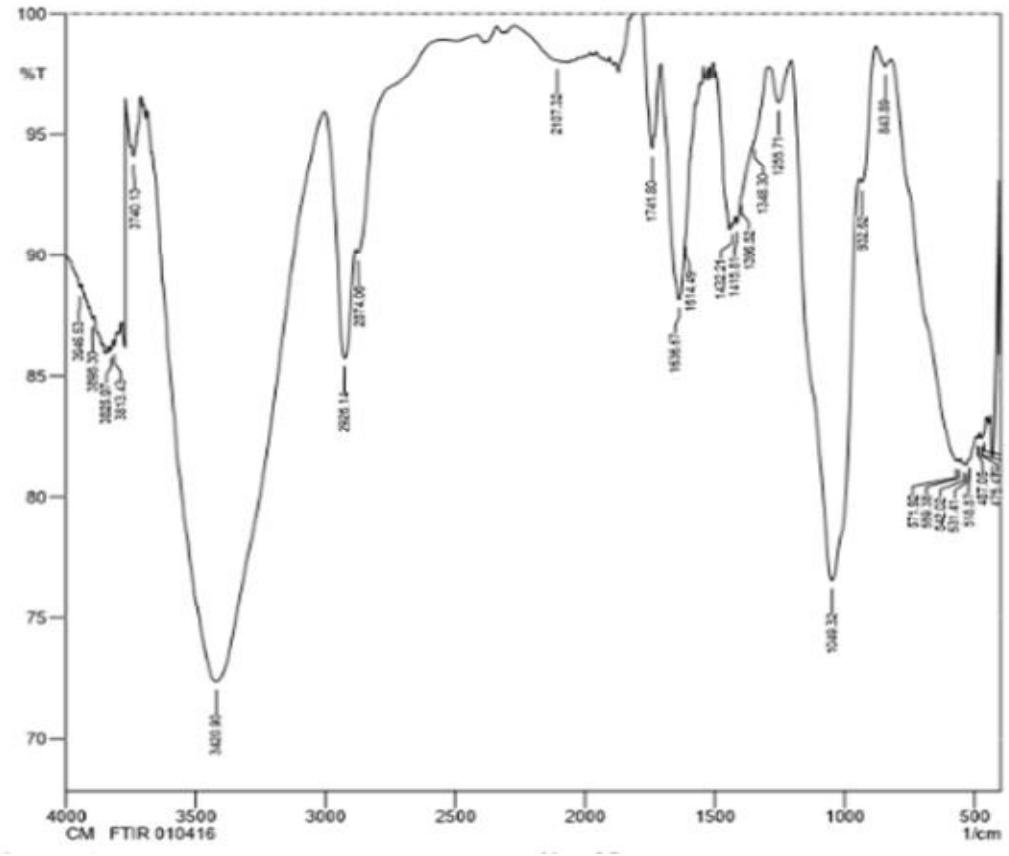

Fig. 3. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of N-Hexane extract of *N. lotus* leaves

Table 5. FTIR spectral peak values and functional groups obtained for ethanol extract *N. lotus* stem

Run #	Peak (cm^{-1})	Functional group	interpretation
1	3924	O-H Stretching vibration	unidentified
2	3758.16	O-H stretching vibration (Bonded)	alcohol
3	3708.63	CH_2 symmetric stretching	alcohol
4	3210.74	O-H Stretching	Carboxylic acid
5	2964.41	C-H stretching	alkane
6	2910.50	N-H bending vibration	Amine salt
7	2812.39	C-O Stretching, O-H bending vibration	unidentified
8	2735.21	C-H Stretching	aldehyde
9	2618.30	C-O asymmetric C-O-C Stretching	unidentified
10	2205.03	C≡C stretching	alkyne
11	1748.81	C=O stretch	unidentified
12	1610.65	C=C stretching	α,β-unsaturated ketone
13	1496.13	C-H bending, O–H stretch	unidentified
14	1250.16	C-O group	Akyl Aryl ether
15	1196.58	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Tertiary alcohol
16	1108.40	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Secondary alcohol
17	748.96	C-CL stretching	Halo compound
18	710.31	C-O stretching	unidentified

Table 6. FTIR spectral peak values and functional groups obtained for n-hexane extract of *N. lotus* stem

Run #	Peak (cm^{-1})	Functional group	interpretation
1	3910	O-H Stretching vibration	alcohol
2	3730.60	O-H stretching	alcohol
3	3425.73	O-H stretching	unidentified
4	2958.40	N-H_4+stretching	unidentified
5	2920.01	C=O stretching	unidentified
6	2832.54	N-H bending vibration	Amine salt
7	2698.77	C-O Stretching, O-H bending vibration	Alcohol
8	1730.26	C=O stretch	α,β-unsaturated ester
9	1610.09	C=C stretching	α,β-unsaturated ketone
10	1482.73	C-O-C asymmetrical Stretching	unidentified
11	1386.25	C-H bending	aldehyde
12	1308.64	S=O Stretching	Sulfonic acid
13	1260.32	C-O asymmetric , C-O-C Stretching	Akyl Aryl ether
14	1955.21	C=C=C Stretching	allene
15	768.74	C-CL Stretching	Halo compound
16	742.00	C-CL stretching	Halo compound
17	700.35	C=C	alkene

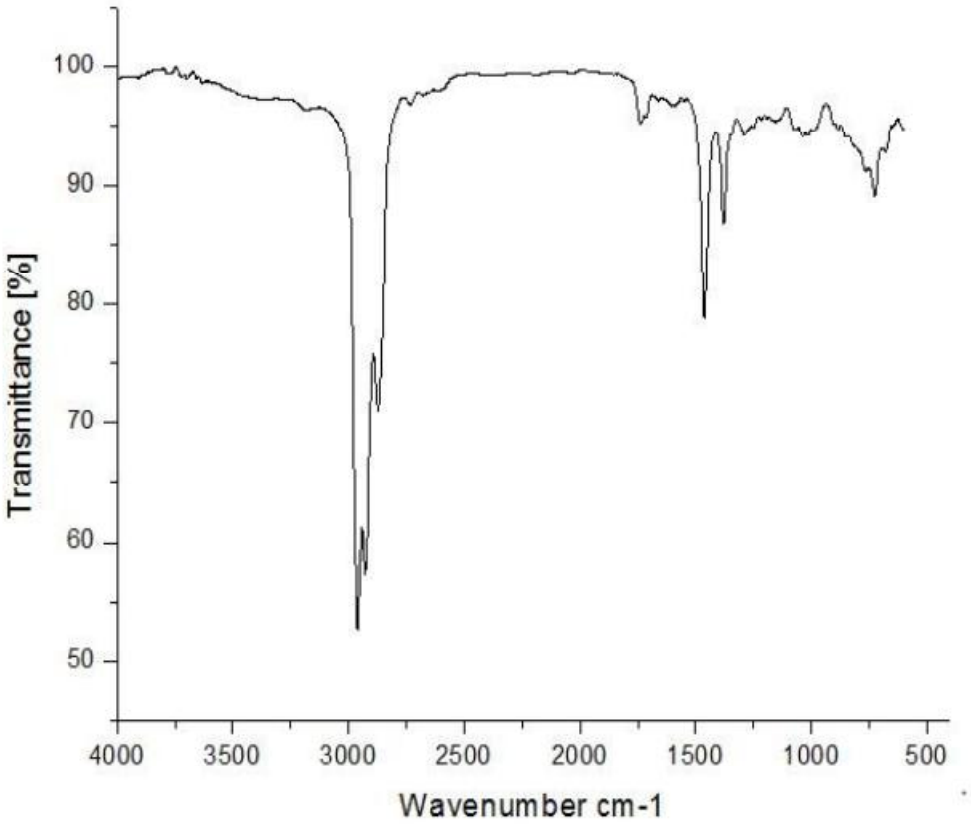

Fig. 4. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of water extract of *N. lotus* stem

Table 7. FTIR spectral peak values and functional groups obtained for water extract of *N. lotus* root

Run #	Peak (cm^{-1})	Functional group	interpretation
1	4633.02	O-H Stretching vibration (Non bonded)	unidentified
2	4538.65	O-H Stretching vibration (Non bonded)	alcohol
3	4343.69	O-H Stretching vibration (Non bonded)	alcohol
4	3984.93	O-H Stretching vibration (Non bonded)	alcohol
5	3873.06	C=O stretching	unidentified
6	3383.14	N-H stretching vibration	Alphatic primary amine
7	2934.66	C-H stretching,	alkane
8	2156.42	S-C≡N stretching	thiocinate
9	1583.56	N–H bend	amine
10	1404.18	S=O stretching	Sulfonyl chloride
11	1072.42	C-O Stretching,	Vinyl ether
12	1047.35	C–O stretch	Vinyl ether
13	754.17	C-CL Stretching	Halo compound
14	607.58	C-CL Stretching	Halo compound
15	557.43	C-CL Stretching	Halo compound

Table 8. FTIR spectral peak values and functional groups obtained for ethanol extract of *N. lotus* root

Run #	Peak (cm^{-1})	Functional group	interpretation
1.	3942.52	O-H Stretching vibration (Non bonded)	Alcohol
2.	3880.76	O-H Stretching vibration (Non bonded)	Alcohol
3.	3765.05	O-H Stretching vibration (Non bonded)	Alcohol
4.	3317.56	O-H stretching	Unidentified
5.	3248.13	N-H bending vibration	Unidentified
6.	3055.34	C-H Stretching	alkene
7.	2924.09	CH_2 asymmetric stretching	Unidentified
8.	2854.65	O–H stretch, H–bonded	Unidentified
9.	2661.77	O-H stretching	Carboxylic acid
10.	2569.59	O-H stretching	Unidentified
11.	2422.18	C-O Stretching, O-H	Unidentified
12.	2353.15	C=O Stretching vibration	Unidentified
13.	2314.59	C-O-H stretching	Unidentified
14.	2175.70	S-C≡N stretching	thiocynate
15.	2056.83	N=C=S stretching	isothiocyanate
16.	1982.82	C=C=C Stretching	allene
17.	1936.53	C-O stretching	Unidentified
18.	1851.68	Aromatic C-H bending	Aromatic compound
19.	1712.29	C=O stretch	Alphatic ketone
20.	1651.07	C=N stretching	Imine/amine
21.	1442.75	C-H bending, O–H stretch	Unidentified
22.	1381.06	S=O stretching	Sulfonyl chloride
23.	1327.03	C–N stretch	Aromatic amine
24.	1265.50	C-O group	Aromatic ester
25.	1195.87	C-O Stretching	ester
26.	1087.85	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Secondary alcohol
27.	1049.23	C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration	Unidentified
28.	879.54	=C–H bend	Unidentified
29.	802.59	para directing benzene ring	Unidentified
30.	709.80	C-H bend, C-Cl Stretching	Unidentified

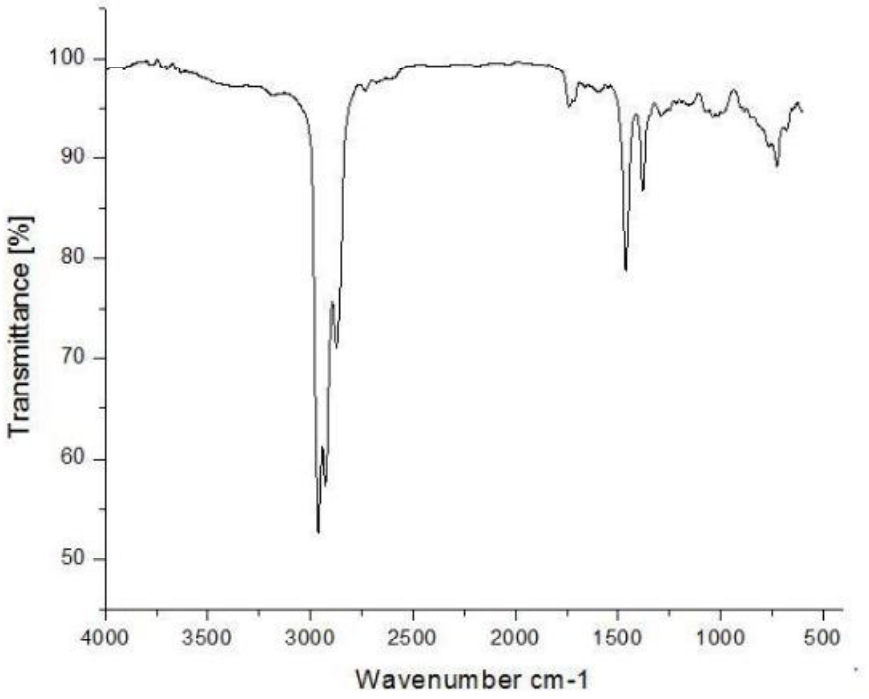

Fig. 5. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of ethanol extract of *N. lotus* stem

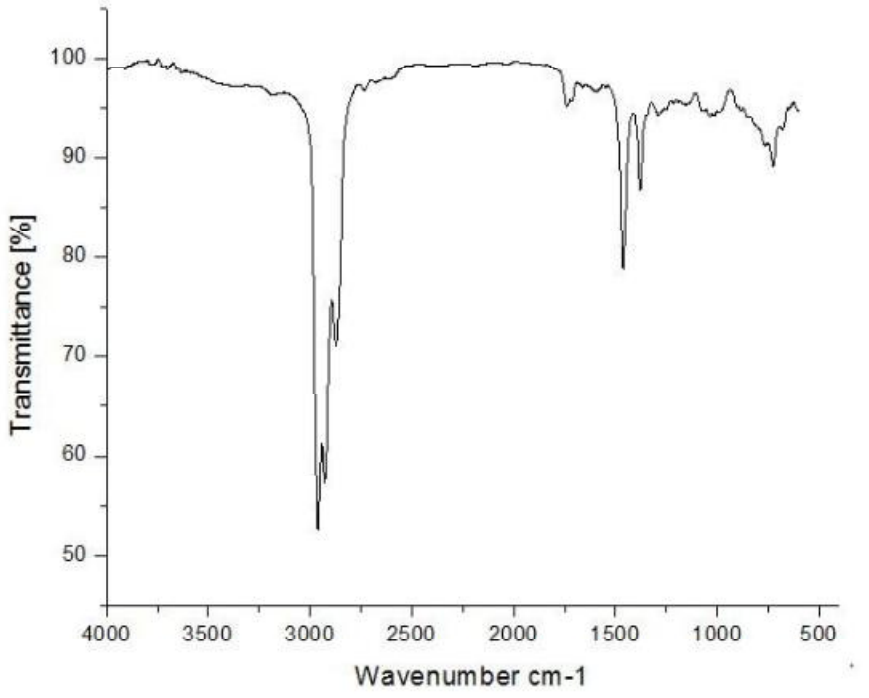

Fig. 6. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of n-hexane extract of *N. lotus* stem

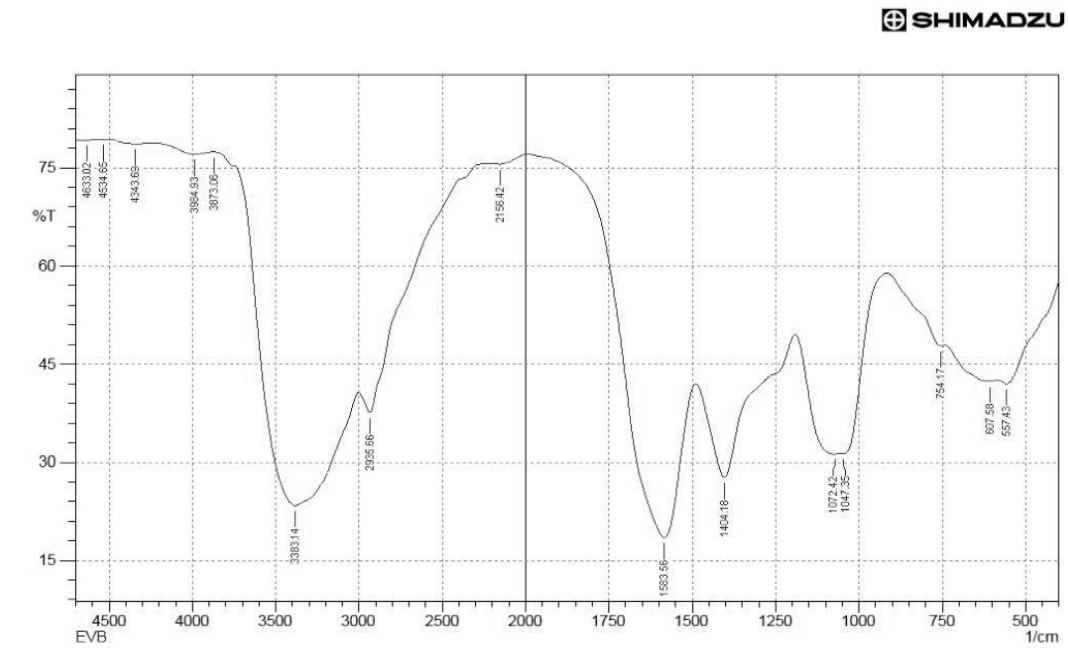

Fig. 7. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of water extract of *N. lotus* root

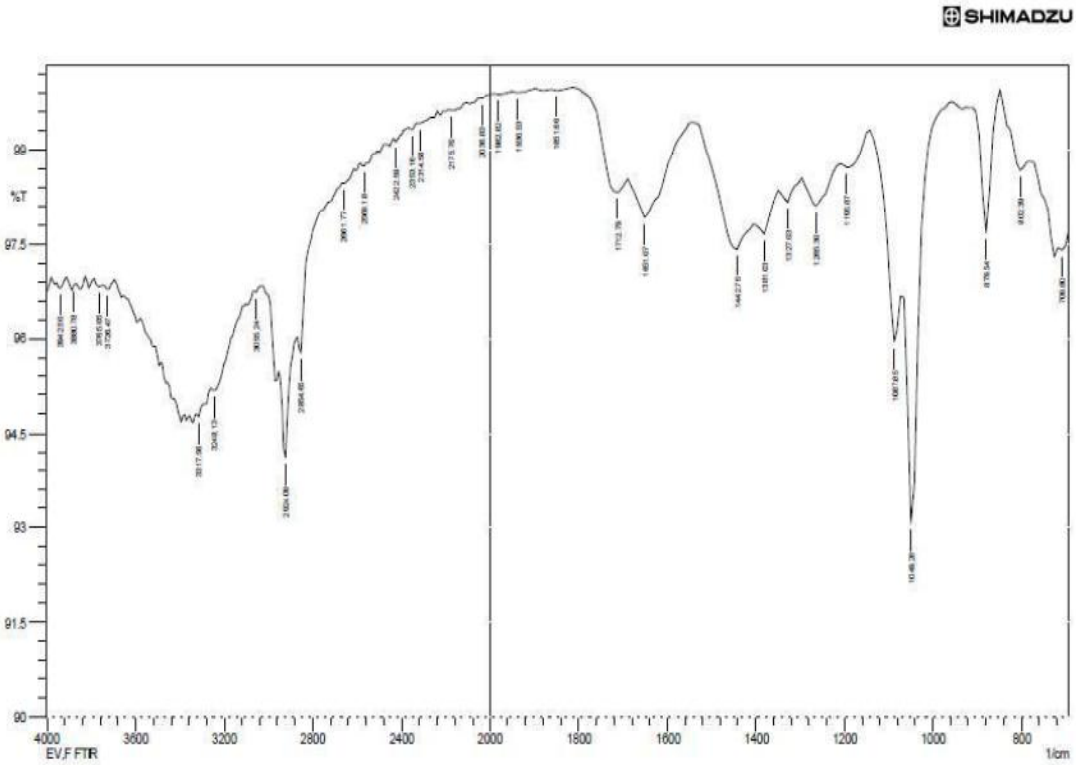

Fig. 8. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of ethanol extract of *N. lotus* root

Table 9. FTIR spectral peak values and functional groups obtained from n-hexane extract of *N. lotus* root

Run #	Peak (cm^{-1})	Functional group	interpretation
1	3888.49	O-H Stretching vibration (Non bonded)	unidentified
2	3348.42	O-H stretching vibration (Bonded)	alcohol
3	2924.08	CH_2asymmetric stretching	alkane
4	2854.66	CH_2 symmetric stretching	unidentified
5	2522.89	O-H Stretching vibration	Carboxylic acid
6	2422.58	O-H Stretching vibration	unidentified
7	2345.34	C= N stretching	unidentified
8	2276.00	C≡N stretch	unidentified
9	2137.13	Triple bond in alkyne	alkyne
10	2090.37	C-O-C asymmetrical Stretching	unidentified
11	1990.54	N-C-S Stretching,	isothiocinate
12	1851.68	C=O Stretching vibration (esters and amino acids)	unidentified
13	1643.30	C=C stretching	conjugated alkene
14	1481.34	C=O stretching, C=CC Aromatics	unidentified
15	1381.11	C-H symmetric stretching	alkane
16	1226.74	C-O Stretching	Aromatic ester
17	1041.62	CO-O-CO Stretching	anhydride

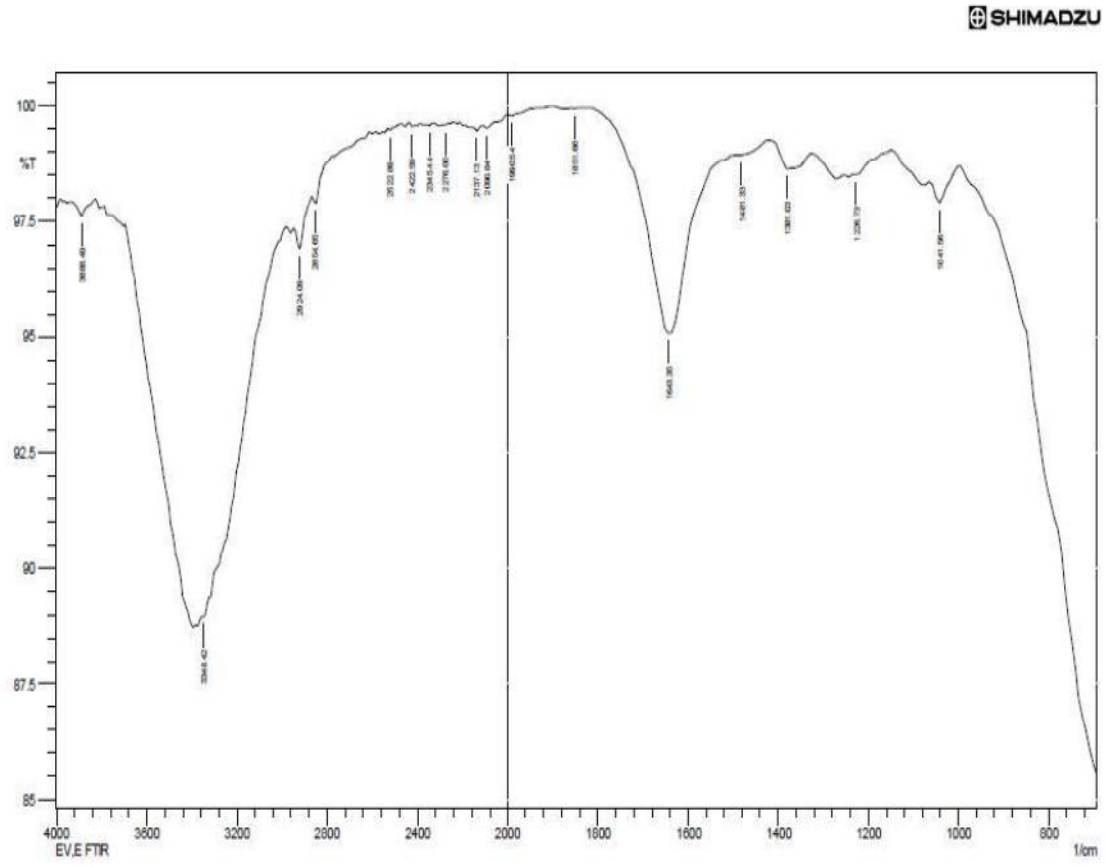

Fig. 9. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of n-hexane extract of *N. lotus* root

Table 10. FTIR spectral peak values and functional groups obtained from water extract of *A. sativum*

Run #	Peak (cm^{-1})	Functional group	Interpretation
1.	3608.37	O-H Stretching vibration	unidentified
2.	2980.31	C-H stretching	alkane
3.	2780.43	O-H stretching	alcohol
4.	2700.36	C≡N stretch	unidentified
5.	2307.52	C= N stretching	unidentified
6.	2055.11	N=C=S stretching	isothiocynate
7.	1812.30	C=O stretching	Acid halide
8.	1703.92	C=O stretching	Conjugated aldehyde
9.	1644.25	C=N stretching	Imine/oxime
10.	1608.43	CH_2 symmetric stretching	unidentified
11.	1543.92	N-O Stretching	Nitro compound
12.	1306.24	C-O stretching	Aromatic ester
13.	1091.12	C-O stretching	Secondary alcohol
14.	1008.26	C-O-H stretch	unidentified
15.	952.99	C-O stretching	unidentified
16.	910.08	C=C bending	alkene
17.	897.95	C-O stretching	unidentified
18.	843.16	C-CL Stretching	Halo compound
19.	620.54	C-Br Stretching	Halo compound

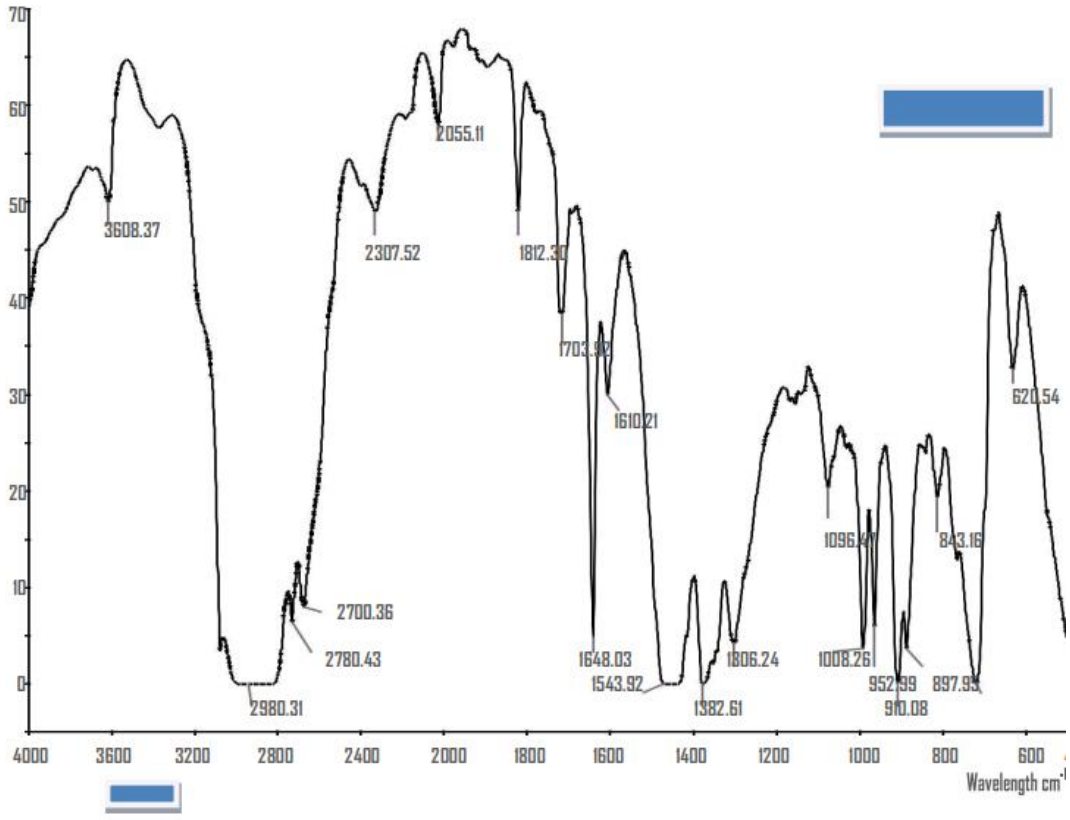

Fig. 10. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of water extract of *A. sativum*

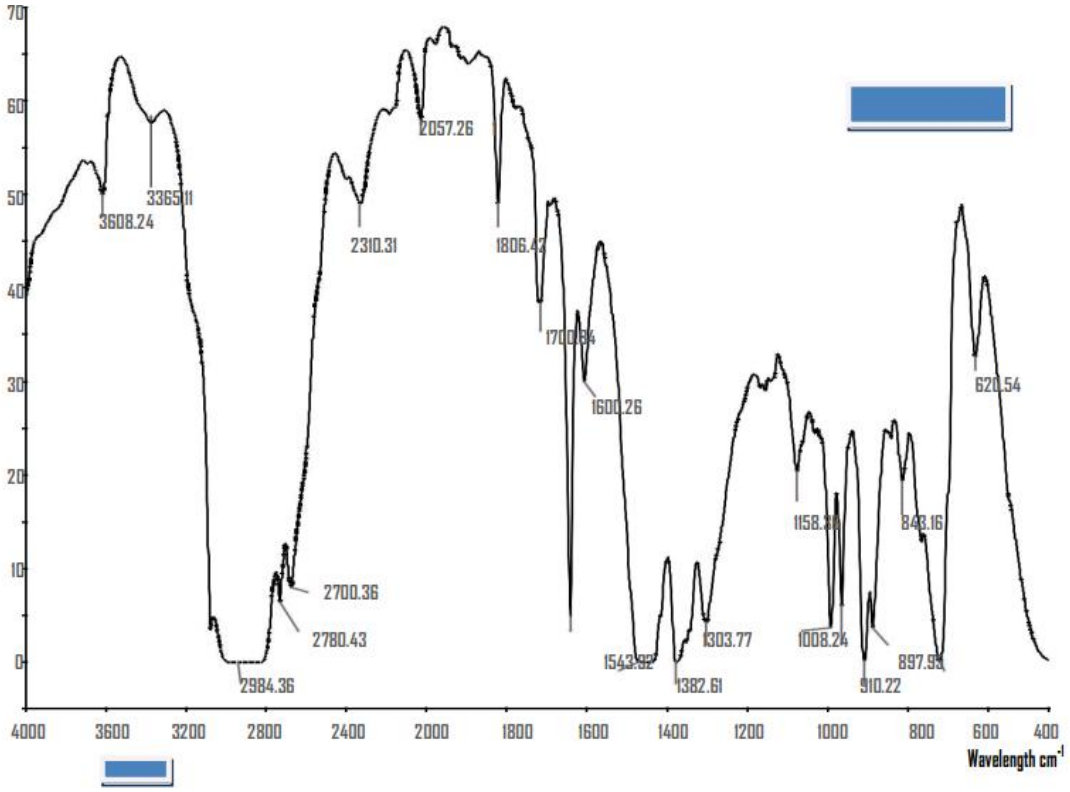

Fig. 11. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of ethanol extract of *A. sativum*

Table 11. FTIR spectral peak values and functional groups obtained for ethanol extract of *A. sativum*

Run #	Peak (cm^{-1})	Functional group	interpretation
1	3608.24	O-H Stretching vibration (Non bonded)	alcohol
2	3365.11	O-H stretching vibration (Bonded)	alcohol
2	2984.36	C-H stretching	alkane
3	2780.43	O–H stretch, H–bonded	alcohol
4	2700.36	O-H stretching	alcohol
5	2310.31	C=O stretching	unidentified
6	2057.26	N=C=S stretching	isothiocynate
7	1806.42	C=O stretching	Acid halide
8	1700.84	C=O stretch	Conjugated aldehyde
9	1600.26	C=N stretching	Conjugated amine
10	1543.92	N–O stretching	Nitro compound
11	1382.61	C-H bending	alkane
12	1303.77	C–N stretch	Aromatic ester
13	1098.36	C-O-H stretching in carboxylic acid	unidentified
14	1008.24	C–O stretch, C-O-H stretching, O-H Stretching vibration	unidentified
15	957.18	C-O stretching	unidentified
16	910.22	C=C Stretching	alkene
17	897.95	=C–H bend	unidentified
18	843.16	C-CL Stretching	Halo compound

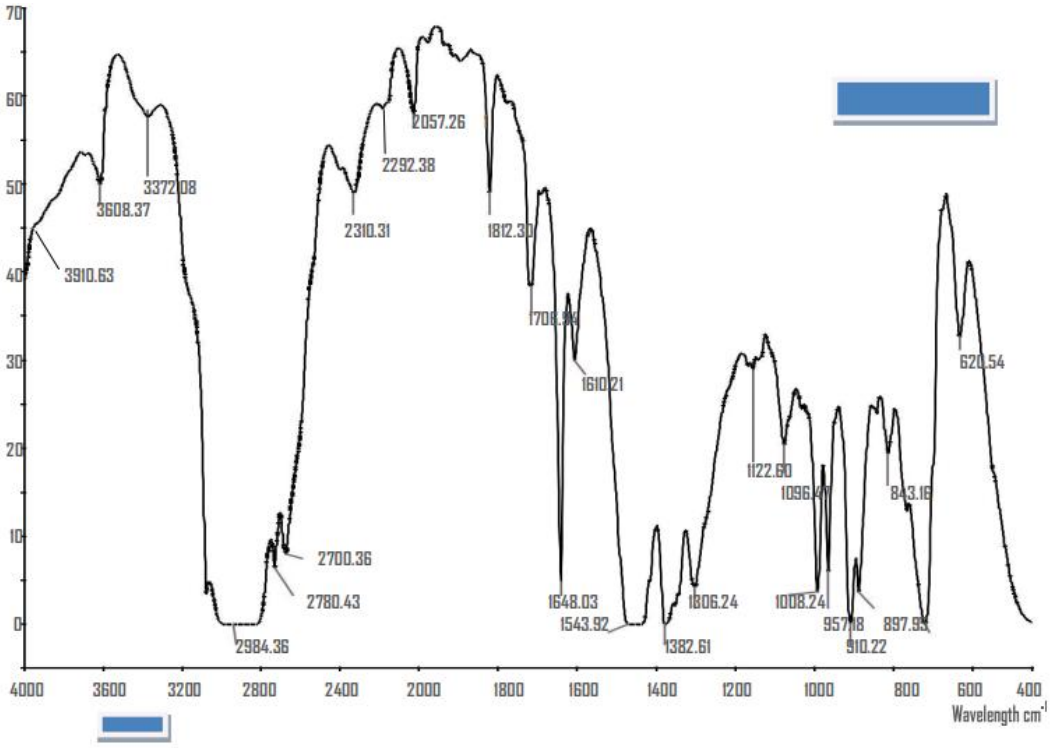

Fig. 12. Fourier Transform Infrared Spectrophotometer (FTIR) spectra of n-hexane extract of *A. sativum*

Table 12. FTIR spectral peak values and functional groups obtained for n-hexane extract of *A. sativum*

Run #	Peak (cm^{-1})	Functional group	interpretation
1	3910.63	O-H Stretching	alcohol
2	3372.08	N-H stretching	Alphatic primary amine
3	2982.61	C-H Stretching	alkane
4	2780.43	C=O stretching	unidentified
5	2707.24	C-H Stretching	aldehyde
6	2310.31	C-O Stretching, O-H bending vibration	unidentified
7	2057.26	N=C=S	isothiocynate
8	1812.30	C=O Stretching	anhydride
9	1706.94	C=O Stretching	carboxylic acid
10	1648.03	C=O Stretching vibration	unidentified
11	1610.21	C=C stretching	α,β-unsaturated ketone
12	1543.92	N-O stretching	Nitro compound
13	1382.74	C-H bending	aldehyde
14	1306.24	C-O stretching	Aromatic ester
15	1008.24	C-OH out of plane bending	unidentified
16	957.18	C=C Stretching	alkene
17	620.54	C-L Stretching	Halo compound

4. DISCUSSION

The results of Fourier Transform Infrared Spectroscopy analysis of *N. lotus and A. sativum* extracts indicates that n-hexane extract of *A. sativum* has the highest number of peak (24) and bioactive compound in *Allium sativum* extracts, though they all (Alphaticprimary amine,

alkane, aldehyde, isothiocynate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, atic ester, isothiocynate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, Aromatic ester, alkene and Halo compound, Acid halide, Conjugated aldehyde, Conjugated amine, alkene, Imine/oxime, alcohol) have similar functional groups. These results are in accordance with the findings of [2]. All the extracts of *Nymphaea lotus* had similar functional groups (Aliphatic primary amine, Halo compound, anhydride, Vinyl ether, alcohol, Cabocylic acid, Cyclic alkene, Unsaturated ketone, aldehyde, alkyne, Carbon dioxide, Aliphatic primary amine, aldehyde, alkane, Benzene derivative, Secondary alcohol, sulphide, alkene, Akyl aryl ether, Sulfonyl chloride, Aromatic compound, δ-lactone, Imine/oxime, alkane, alcohol, Thiocyanate, Amine salt, esters, alkene, Nitro compound, Sulphate, Sulphone, Akyl aryl ether, Aromatic ester, Fluoro compound, Amine salt, Sulphonyl chloride, Tertiary alchohol, α,β-unsaturated ketone, alkyne, allene, Sulfonic acid, α,β-unsaturated ester, Alphatic primary amine, amine, Sulfonyl chloride, Vinyl ether, Aromatic amine, Alphatic ketone, isothiocyanate, thiocynate, conjugated alkene and anhydride). Ethanol extract of *Nymphaea lotus* leaves had the highest number of peaks (34) and compounds. This is in accordance with the findings of [11].

5. CONCLUSION

The findings from this study suggest that the functional groups from extracts of *Allium sativum* and *Nymphaea lotus* may be biologically active which is subjected to further confirmation by other advanced techniques such as NMR ect. Some of the biologically active functional groups are useful in production of antimicrobials and other medicinal products that can be of high benefits in proffering reliable alternative medicine to human and animal diseases caused by multidrug resistant enteric bacteria.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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