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

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**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, aliphatic primary 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, cabocyclic acid, cyclic alkene, unsaturated ketone, aldehyde, aliphatic primary amine, aldehyde, alkane, benzene derivative, sulphide, alkene, akyr aryl ether, sulphonyl chloride, δ-lactone, imine/oxime, thiocyanate, amine salt, esters, alkene, nitro compound, sulphate, sulphone, akyr aryl ether, aromatic ester, fluoro compound, amine salt, sulphonyl chloride, tertiary alcohohol, α,β-unsaturated ketone, alkyne, allene, sulfonic acid, α,β-unsaturated ester, aliphatic primary amine, amine, sulphonyl chloride, vinyl ether, aromatic amine, aliphatic 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.
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 the 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 radicals that may damage the cells. Garlic also helps in preventing many kinds of cancer, heart disease, strokes and some viral infections. The sulfur-containing compounds present in garlic exert protection to human body by stimulating the production of certain beneficial enzymes [2]. The garlic serves as a potent source for discovery and production of new beneficiary drugs to mankind. One of the sulfur-containing compounds, Allinigen converted to the anti-microbial active alliinupon cutting of bruising of a bulb. Ajoene, a secondary degradation product of allin presumed to be the 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 its 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 flavonols. 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

**Keywords:** *Nymphaea lotus; fourier transform; Allium sativum; animal diseases.*
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. The garlic 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 a sterile 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*

A paste 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 1 litre 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 1 litre 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 absorbance mode. The refractogram obtained from FT-IR spectroscopy between wave number and absorption is tabulated below. IR solution software is employed for getting the number and absorption is tabulated below. IR spectroscopy between wave numbers and their absorption is tabulated below. IR spectroscopy between wave numbers and their absorption is tabulated below.

The chemical compounds separated from extracts of Nymphaea lotus leaves had the highest number of peak (i.e. 24) and compounds in Allium sativum extracts, though they all (Aliphatic primary amine, alkane, aldehyde, isothiocyanate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, 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, Cabocyclic acid, Cyclic alkene, Unsaturated ketone, aldehyde, alkyn, Carbon dioxide, Aliphatic primary amine, aldehyde, alkane, Benzene derivative, Secondary alcohol, sulphide, alken, Akyl aryl ether, Sulfonyl chloride, Aromatic compound, -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 alcoho, α,β-unsaturated ketone, alkyne, allene, Sulfonyl acid, α,β-unsaturated ester, Aliphatic primary amine, amine, Sulfonyl chloride, Vinyl ether, Aromatic amine, Aliphatic ketone, isothiocyanate, thiocynate, conjugated alkene and anhydride).

### 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     | Unidentified                 |
| 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,       | Cabocyclic 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      | PO₂ Stretching     | Unidentified                 |
| 17  | 563.24      | C-O Stretching O-H | Unidentified                 |
| 18  | 504.26      | C-O stretching     | Unidentified                 |
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     | N-H bending vibration | Primary amine |
| 6     | 3457.56     | N-H stretching | Alcohol |
| 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 | sulphonate |
| 23    | 1230.36     | C–O stretch, C-O-H stretching in carboxylic acid, O-H Stretching vibration | Amyl 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      | PO₂ 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=O Stretching, C=C Stretching    | alkene                       |
| 10    | 1514.49     | N-O stretching                    | Nitro 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      | PO₃ 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 alcohol     |
| 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     | CH₂ 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 | alkynne  |
| 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-H₁+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     | 4334.69     | 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 stretch 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.    | 2924.95     | CH₂ 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.   | 2314.99     | C=O-H stretching Unidentified |
| 14.   | 2175.70     | S-C≡N stretching thioynate |
| 15.   | 2066.38     | 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     | CH₂ asymmetric stretching             | alkane                           |
| 4     | 2854.66     | CH₂ 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 alkene                | alkene                           |
| 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     | CH₂ 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                                      | isothiocyanate            |
| 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         | unidentified              |
|       |             | vibration                                             |                           |
| 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*

| 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                                      | isothiocyanate          |
| 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 (Alphatic primary amine, ...
alkane, aldehyde, isothiocynate, anhydride, carboxylic acid, α,β-unsaturated ketone, Nitro compound, aldehyde, atic ester, isotheiocynate, 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, Cabocyclic 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, β-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 alcohols, α,β-unsaturated ketone, alkyne, allene, Sulfonic acid, α,β-unsaturated ester, Alphatic primary amine, amine, Sulfonyl chloride, Vinyl ether, Aromatic amine, Alphatic ketone, isothiocynatate, 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 etc. 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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