Analysis of Bioactive Chemical Compounds of Leaves Extracts from *Tamarindus indica* Using FT-IR and GC-MS Spectroscopy

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Authors’ contributions

This work was carried out in collaboration among all authors. Author MAHM designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MAHM, GMNO, AZAT and FYSA managed the analyses of the study. Author VP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

*Tamarindus indica* is one of the medicinal plants used in the treatment of various diseases traditionally.  
**Aims:** This study was conducted to identify the phytochemical constituents of *T. indica* leaf extracts.  
**Methods:** Using Fourier-transform infrared spectroscopy (FT-IR) and gas chromatography-mass spectrometry (GC-MS) to identification of bioactive compounds in extracts of *T. indica*.  
**Results:** The FT-IR spectrum confirmed the presence of alcohol group, alkene group, amine group, carbonates, ethers, carboxylic acid and disulfides in both extracts.

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A total of 22 and 38 bioactive phytochemical compounds were identified in the ethanolic and aqueous extracts of *T. indica*, respectively. The major bioactive compounds of the ethanolic extract of *T. indica* leaves were cis-Vaccenic acid, trans-13-Octadecenoic acid, Oleic Acid, Octadecanoic acid, Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester, Eicosanoic acid and Eicosane, 1-Iodo-2-methylundecane, 10-Methylmonadecane. While the major bioactive compounds of the aqueous extract were 3-O-Methyl-d-glucose, Myo-Inositol, 4C-methyl-, Myo-Inositol, 2-C-methyl-, Propane, 2,2-dimethoxy-, 1,3-Dioxolane, Ethanol, 2-(1-methylethoxy)-, and 2-Pentanone, 4-hydroxy-4-methyl-, 2-Hexanol, 2-methyl-, Ethanamine, N-methyl.

Keywords: Tamarindus indica; bioactive chemical compounds; FT-IR; GC-MS.

1. INTRODUCTION

The relationship between humans and plants started from the beginning of the emergence of humans on earth. Plants as a source of medicinal drugs have continued where they play an important role in the maintenance of human health since ancient times [1]. The world population depended on traditional remedies, especially plants, in treating many diseases, where there are about three-quarters of people are treated with traditional medicine [2]. India is the birthplace of the renewed system of indigenous medicine such as Ayurveda, Unani and Siddha [3]. Studies showed that traditional healers in India use 2500 plant species of which100 species are used which serves as regular sources of medicine [4].

Higher plants are sources of bioactive compounds continue to play a dominant role in the maintenance of human health. Reports available on the green plants to represent a reservoir of effective chemotherapeutics, which are non-phytotoxic, more systemic and easily biodegradable [11,12]. Plants are rich source of secondary metabolites with interesting biological activities. In general, these secondary metabolites are important source with a variety of structural arrangements and properties [13]. However, the FT-IR has been used because of the presence of many compounds of secondary metabolites within the extracts. FT-IR is used for the screening of the extracts' constituents, where it is a simple technique and sensitive in evaluating the presence of functional groups which are present in extracts [17]. Where it proved that FT-IR spectroscopy is a reliable and sensitive method for detecting biomolecular composition which is present in plant extracts [18].

GC-MS analysis is a breakthrough in the analysis of phytoconstituents and structure elucidation of these compounds as they have a sensitivity of detecting compounds as low as 1ng [19]. Because of the development of chromatographic techniques like GC-MS, analysis has become easier in analyzing small amounts of chemicals [20].

Due to is lack of sufficient literature on the phytochemical profile and its pharmacological activity for this plant, the present study was
carried out to evaluate GC-MS and FT-IR analysis of extracting this plant in this study.

2. MATERIALS AND METHODS

2.1 Plant Material

*T. indica* leaves were collected from the campus of Dr. Rafiq Zakaria College for Women-Aurangabad. The leaves were washed under tap water. Then they were dried in the laboratory at room temperature (25-30°C) for two weeks. The leaves were grinded with the mechanical grinder until they became soft powder. The powder was kept in an airtight container to protect the powder from moisture and light.

2.2 Preparation of Plant Extracts

The ethanolic and aqueous extracts of *T. indica* leaves were prepared out using the Soxhlet apparatus for ethanolic extract and magnetic stirrer for aqueous extract as described by earlier researches [21-23].

2.3 FT-IR Analysis of *T. indica* Extracts

FTIR (Bruker, USA) was used for identifying functional groups and the types of chemical bonds that present in extracts. Dried powders of extracts of each plant material were used for FT-IR analysis. Where 10 mg of the dried extract powder was encapsulated in 100 mg of KBr pellet, in order to prepare the translucent disc (3 mm diameter). The powdered sample of each plant was loaded in FT-IR, with a scan range from 400 to 4000 cm⁻¹ with a resolution of 4 cm⁻¹.

2.4 GC-MS Analysis of *T. indica* Extracts

GC-MS analysis of the ethanolic and aqueous extracts of *T. indica* leaves performed using Thermo Scientific Triple Quadrupole GC-MS (Trace 1300 GC, Tsq 8000 triple quadrupole MS) equipped with TG 5MS (30 m X 0.25 mm, 0.25 μm) column. Helium was used as the carrier gas at a flow rate of 1 ml/min. using an injection volume of 1.0 μL. Injector temperature was kept at 250°C and ion source temperature was 230°C. The oven temperature was maintained at 50°C isothermal at 280°C, Mass Spectra transfer line temperature. The spectrum of the unknown component was compared with the spectrum of the known components stored in the NIST library.

3. RESULTS

3.1 Functional Group Analysis by FT-IR of Ethanolic Extract of *T. indica* Leaves

The absorption spectra of ethanolic extract for *T. indica* are shown in the region of 4000-400 cm⁻¹ are 12 peaks are derived. The peaks represented the ranges from 3851.78 to 1454.36 peaks were shown in Table 1 and Fig. 1. The peaks at 3851.78, 3740.97 and 3672.72 cm⁻¹ represent alcohol compounds. The peaks at 3614.59 and 2359.59 cm⁻¹ represents amines. The peak at 2173.79 cm⁻¹ represents Alkynes. The peak at 1916.82 cm⁻¹ represents carbonyl compounds. The peak at 1743.34 cm⁻¹ represents Carboxylic acids compounds. The peaks at 1696.11, 1650.16 and 1520.55 cm⁻¹ represent alkenes. The peak at 1454.36 cm⁻¹ represents aryl compounds. Interpretation of FT-IR spectra of the isolated compound of ethanolic extract for *T. indica* is presented in Table 1.

3.2 Functional Groups Analysis by FT-IR of Aqueous Extract of *T. indica* Leaves

The absorption spectra of the aqueous extracts of *T. indica* leaves were shown in Fig. 2, which appears the highest number of peaks (14). The peaks at 3815.62, 3741.26, 3367.28 and 3614.03 cm⁻¹ represent alcohol. The peak at 2358.97 cm⁻¹ represents amines. The peak at 2174.19 cm⁻¹ represents alkynes. The peak at 1916.55 cm⁻¹ represents carbonyl compounds. The peak at 1743.36 cm⁻¹ represents carboxylic acids compounds. The peaks at 1696.09, 1649.97, 1520.63 and 1415.86 cm⁻¹ represent alkenes. The peak at 1464.12 cm⁻¹ represents aryl compounds. The peak at 1062.08 cm⁻¹ represents alkyl-substituted ether compounds. Interpretation of FT-IR spectra of the isolated compound of ethanolic extract for *T. indica* is presented in Table 2.

3.3 GC-MS Analysis of *T. indica* Leaves Ethanolic Extract

Chromatogram GC-MS analysis of *T. indica* ethanolic leaves extract showed the presence of twenty-two peaks Fig. 3. The chemical compound, molecular formula and molecular weight were as shown in Table 3. The major phytochemical constituents were cis-Vaccenic acid, trans-13-Octadecenoic acid,
Oleic Acid, Octadecanoic acid, Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester, Eicosanoic acid, and Eicosane, 1-Iodo-2-methylundecane, 10-Methylnonadecane. Interpretation of GC-MS spectra of the identified compounds of ethanolic extract for *T. indica*. The detailed results are summarized in Table 3.

### 3.4 GC-MS Analysis of *T. indica* L. Leaves Aqueous Extract

GC-MS analysis of compounds was carried out in aqueous leaves extract of *T. indica* shown in Table 4. The GC-MS chromatogram of the 38 peaks of the compounds detected as shown in Fig 4. The major phytochemical constituents were 3-O-Methyl-D-glucose, Myo-Inositol, 4C-methyl-, Myo-Inositol, 2-C-methyl-, Propane, 2,2-dimethoxy-, 1,3-Dioxolane, Ethanol, 2-(1-methylethoxy), and 2-Pentanone, 4-hydroxy-4-methyl-, 2-Hexanol, 2-methyl-, Ethanamine, N-methyl-. Interpretation of GC-MS spectra of the identified compounds of aqueous extract for *T. indica*. The detailed results are summarized in Table 4.

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**Table 1. FT-IR spectral peak values and functional groups obtained from ethanolic extract of *T. indica* leaves**

| No. | Peak values (cm⁻¹) | Bond | Functional group            |
|-----|-------------------|------|-----------------------------|
| 1.  | 3851.78           | O-H  | Alcohol                     |
| 2.  | 3740.97           | O-H  | Alcohol                     |
| 3.  | 3672.72           | O-H  | Alcohol                     |
| 4.  | 3614.59           | N-H  | Aliphatic secondary amine   |
| 5.  | 2359.59           | N-H  | Amine                       |
| 6.  | 2173.79           | C≡C  | Alkynes                     |
| 7.  | 1916.82           | C=O  | Carbonyl group              |
| 8.  | 1743.34           | COOH | Carboxylic acids            |
| 9.  | 1696.11           | C=C  | Alkene group                |
| 10. | 1650.16           | C=C  | Alkene group                |
| 11. | 1520.55           | C=C  | Alkene group                |
| 12. | 1454.36           | C=C-C| Aryl (Aromatic ring)        |

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**Fig. 1. FT-IR spectrum of ethanolic extract of *T. indica***
Table 2. FT-IR spectral peak values and functional groups obtained from aqueous extract of *T. indica* leaves

| No. | Peak values (cm⁻¹) | Bond | Functional group              |
|-----|-------------------|------|------------------------------|
| 1.  | 3815.62           | O-H  | Alcohol                      |
| 2.  | 3741.26           | O-H  | Alcohol                      |
| 3.  | 33672.89          | O-H  | Alcohol                      |
| 4.  | 3614.03           | H-OH | Alcohol                      |
| 5.  | 2358.97           | N-H  | Amine                        |
| 6.  | 2174.19           | C≡C  | Alkynes                      |
| 7.  | 1916.55           | C=O  | Carbonyl group               |
| 8.  | 1743.36           | COOH | Carboxylic acids             |
| 9.  | 1696.09           | C=C  | Alkene group                 |
| 10. | 1649.97           | C=C  | Alkene group                 |
| 11. | 1520.63           | C=C  | Alkene group                 |
| 12. | 1464.12           | C=C-C| Aryl (Aromatic ring)         |
| 13. | 1415.86           | C-H  | Alkene                       |
| 14. | 1062.08           | C-O-C| Alkyl-substituted ether      |
Table 3. Gas chromatography-Mass spectrometry analysis of bioactive components of ethanolic extracts of T. indica leaves

| S No. | RT  | Area (%) | Name of the compound                                                                 | Molecular formula          |
|-------|-----|----------|--------------------------------------------------------------------------------------|----------------------------|
| 1.    | 4.88| 0.09     | 2-Pentanone, 4-hydroxy-4-methyl-                                                     | C₆H₁₀O₂                    |
|       |     |          | 2-Hexanol, 2-methyl-                                                                  | C₇H₁₀O                     |
|       |     |          | 2-Pentanol, 2,4-dimethyl-                                                             | C₂H₄O                      |
| 2.    | 16.93| 0.37     | 3-O-Methyl-d-glucose                                                                  | C₆H₁₀O₆                    |
|       |     |          | 3,4-Bis-(2-deoxy-3-deoxynanosyl) α-D-Manofuranoside, 1-O-decyl-                       | C₁₀H₂₂O₆                   |
|       |     |          | L-Glucose                                                                            | C₆H₁₀O₆                    |
| 3.    | 19.52| 1.65     | Eicosane, 10-methyl-                                                                  | C₁₃H₂₈O₃                   |
|       |     |          | Tetradecane, 2,6,10-trimethyl-                                                        | C₁₃H₃₂O₆                   |
|       |     |          | Methoxyacetic acid, 2-tridecyl ester                                                  | C₁₃H₃₂O₆                   |
|       |     |          | Methoxyacetic acid, 2-tridecyl ester                                                  | C₁₃H₃₂O₆                   |
| 4.    | 19.74| 0.57     | Cyclopropanebutanoic acid, 2-[[2-[[2-(pentylcyclopropyl)methyl]cyclopropyl]methyl]cyclopropyl]methyl, methyl ester | C₂₅H₄₂O₂                   |
|       |     |          | Cyclopentanetridecaneic acid, methyl ester                                            | C₁₉H₃₈O₂                   |
|       |     |          | Tridecaneic acid, 4,8,12-trimethyl-, methyl ester                                      | C₁₉H₃₈O₂                   |
|       |     |          | n-Hexadecanoic acid                                                                   | C₁₈H₃₂O₂                   |
|       |     |          | l-(+)-Ascorbic acid 2,6-dihexadecanoate                                              | C₁₈H₃₂O₈                   |
|       |     |          | Pentadecanoic acid                                                                    | C₁₈H₃₂O₂                   |
| 5.    | 20.08| 7.4      | Hexadecanoic acid, ethyl ester                                                        | C₁₈H₃₂O₂                   |
|       |     |          | Ethyl 14-methyl-hexadecanoate                                                         | C₁₈H₃₂O₂                   |
|       |     |          | Ethyl hydrogen dodecadienoate                                                         | C₁₈H₃₈O₄                   |
| 6.    | 20.45| 0.23     | Eicosane                                                                              | C₂₀H₄₂                     |
|       |     |          | Eicosane, 10-methyl-                                                                  | C₂₀H₄₄                     |
|       |     |          | Tetradecane, 2,6,10-trimethyl-                                                        | C₁₇H₃₈                     |
| 8.    | 21.25| 0.18     | 9,10-Secocholesta-5,7,10(19)-triene-3,24,25-triol,(3α,5Z,7E)-                         | C₂₇H₄₄O₃                   |
|       |     |          | 2-Bromotetradecanoic acid                                                             | C₁₁H₂₇BrO₂                  |
|       |     |          | Corynan-17-ol, 18,19-didehydro-10-methoxy-, acetate (ester)                           | C₂₂H₂₈N₂O₃                  |
| 9.    | 21.41| 5.53     | 9,12-Octadecadienoic acid, methyl ester                                              | C₁₉H₃₄O₂                   |
|       |     |          | 9,12-Octadecadienoic acid (Z,Z)-, methyl ester                                        | C₁₉H₃₄O₂                   |
|       |     |          | Methyl 9-cis,11-trans-octadecadienoate                                                | C₁₉H₃₄O₂                   |
| 10.   | 21.51| 7.34     | Eicosane                                                                              | C₂₀H₄₂                     |
|       |     |          | 1-Iodo-2-methylundecane                                                               | C₁₂H₂₅I                    |
|       |     |          | 10-Methylundecane                                                                    | C₁₂H₂₅I                    |
| 11.   | 21.74| 0.89     | [1,1'-Bicyclopropyl]-2-octanoic acid, 2'-hexyl-, methyl ester                         | C₂₁H₃₈O₂                   |
|       |     |          | Cyclopropaneoctanoic acid,2-[[2-[[2-(ethylcyclopropyl)methyl]cyclopropyl]methyl]cyclopropyl]methyl, methyl ester | C₂₂H₃₈O₂                   |
| 12.   | 21.81| 35.23    | cis-Vaccenic acid                                                                     | C₁₉H₃₂O₂                   |
|       |     |          | trans-13-Octadecenoic acid                                                            | C₁₉H₃₂O₂                   |
|       |     |          | Oleic Acid                                                                            | C₁₉H₃₂O₂                   |
| 13.   | 21.88| 20.28    | Octadecanoic acid                                                                     | C₁₉H₃₂O₂                   |
|       |     |          | Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester                                    | C₂₀H₄₂O₄                   |
|       |     |          | Eicosanoic acid                                                                       | C₂₀H₄₂O₂                   |
| 14.   | 22.03| 2.13     | Octadecanoic acid                                                                     | C₁₉H₃₂O₂                   |
|       |     |          | 9,12,15-Octadecatrienoic acid,2-[[trimethylsilyl]oxy]-1-[(trimethylsilyl)oxy]methyl[ethyl ester, (Z,Z,Z)- | C₂₂H₅₂O₄S₄₂                  |
|       |     |          | i-Propyl 16-methyl-heptadecanoate                                                     | C₂₂H₅₂O₄S₄₂                  |
| S No. | RT   | Area (%) | Name of the compound                                                                 | Molecular formula |
|-------|------|----------|--------------------------------------------------------------------------------------|-------------------|
| 15.   | 22.09| 0.61     | 6,9,12,15-Docosatetraenoic acid, methyl ester                                        | C_{23}H_{38}O_{2} |
|       |      |          | 9-Octadecenoic acid (Z)-2-hydroxy-1-(hydroxymethyl)ethyl ester, cis-Vaccenic acid     | C_{21}H_{40}O_{4} |
| 16.   | 22.45| 3.03     | Methoxyacetic acid, 2-tridecyl ester                                                | C_{18}H_{32}O_{3} |
|       |      |          | Eicosane                                                                             | C_{16}H_{34}O_{3} |
| 17.   | 22.91| 2.57     | Benzene, 1,1'-sulfonylbis[4-chloro-2,4'-Dichlorodiphenylsulfone, di-n-Nonyl sulfide | C_{17}H_{34}S     |
| 18.   | 23.5 | 2.52     | Aspidospermidin-17-ol,1-acetyl-19,21-epoxy-15,16-dimethoxy-Tetradecane, 2,6,10-trimethyl-1-Hexadecanol, 2-methyl-1-Heptatriacotanol, 1-methylene, (3â,5â)-Isoaromadendrene epoxide | C_{23}H_{36}N_{2}O_{5} |
| 19.   | 24.25| 2.77     | Cholestan-3-ol, 2-methylene-, (3â,5â)-Cholestan-3-ol, 2-methylene-, (3â,5â)-         | C_{17}H_{36}O      |
|       |      |          | Cholestan-3-ol, 2-methylene-, (3â,5â)-                                              | C_{17}H_{36}N_{2}O_{3} |
| 20.   | 24.76| 0.64     | Corynan-17-ol, 18,19-didehydro-10-methoxy-6-Octadecenoic acid, (Z)-Corynan-17-ol, 18,19-didehydro-10-methoxy-acetato (ester) | C_{22}H_{28}N_{2}O_{3} |
|       |      |          | 9,12,15-Octadecatetraenoic acid,2,3-bis [(trimethylsilyl)oxy] propyl ester, (Z,Z,Z)-Dasycarpidan-1-methanol, acetate (ester) | C_{22}H_{28}O_{2} |
|       |      |          | [2-(5-Hydroxypent-2-enyl)-3-oxocyclopentyl] thioetic acid, S-t-butyl ester, i-Propyl 9-tetradecenoate | C_{24}H_{38}O_{4} |
| 21.   | 26.34| 0.43     | Phthalic acid, di(2-propylpentyl) ester                                             | C_{22}H_{38}O_{4} |
| 22.   | 26.84| 2.62     | Phthalic acid, di(oct-3-yl) ester                                                   | C_{22}H_{38}O_{4} |
|       |      |          | Diisooctyl phthalate                                                               | C_{22}H_{38}O_{4} |

Fig. 4. GC-MS profile of aqueous extract of *T. indica* L. leaves
Table 4. Gas chromatography-mass spectrum analysis of bioactive components of the aqueous extracts of *T. indica* leaves

| S.No | RT  | Area (%) | Name of the compound                                                                 | Molecular formula |
|------|-----|----------|--------------------------------------------------------------------------------------|-------------------|
| 1.   | 3.12 | 8.93     | Propane, 2,2-dimethoxy-1,3-Dioxolane, Ethanol, 2-(1-methylethoxy)-                  | C₈H₁₄O₂, C₈H₁₄O₂ |
| 2.   | 3.67 | 0.38     | Silanediol, dimethyl-Trimethylsilyl fluoride, 1,5-Hexadiene, 3,3,4,4-tetrafluoro-     | C₄H₈O₃Si, C₆H₁₂F₄ |
| 3.   | 4.46 | 1.10     | 3-Penten-2-one, 4-methyl-3-Hexen-2-one, 2,4-Azetidinedione, 3,3-diethyl-            | C₈H₁₀O, C₈H₁₀O, C₈H₁₀O |
| 4.   | 4.85 | 2.24     | Furfural, 3-Furaldehyde, 3,5-Dimethylpyrazole                                       | C₅H₈O₂, C₆H₈N₂ |
| 5.   | 5.02 | 7.87     | 2-Pentanone, 4-hydroxy-4-methyl-2-Hexanol, 2-methyl-Ethanol, N-methyl-             | C₆H₁₂O₂, C₆H₁₀O, C₆H₁₂N |
| 6.   | 7.00 | 0.38     | 2-Furancarboxaldehyde, 5-methyl-Pyrazole-4-carboxaldehyde, 1-methyl-               | C₈H₁₂O₂, C₈H₁₂O₂ |
| 7.   | 8.41 | 0.34     | Benzeneacetaldehyde, 2,4,6-Cycloheptatrien-1-one, 4-methyl-4,5-Dihydro-2(1H)-pentalenone | C₈H₁₂O, C₈H₁₂O |
| 8.   | 11.18| 0.95     | 6-Acetyl-á-d-mannose, 12,15-Octadecadiynoic acid, methyl ester, 1-Hexen-3-ol, 5-nitro-1-phenyl-, (R*,R*)- | C₈H₁₄O₇, C₁₉H₂₃O₂, C₁₂H₁₈NO₃ |
| 9.   | 15.09| 0.22     | 2H-Indeno[1,2-b]furan-2-one, 3,3a, 4,5, 6,7, 8,8b-octahydro-8,8-dimethyl 1,3-Dithiane, 2-[4-(1-ethoxyethoxy)butyl] 1-(3-Cyano-4,5,6,7-tetrahydro-2-benz[c] thienyl)-3-(3,4-dimethoxycinnamoyl)-2-thioure | C₁₃H₁₈O₂, C₁₂H₂₃O₂S₂, C₂₁H₂₁N₂O₃S₂ |
| 10.  | 15.16| 0.57     | Malonodinitrile, 2-(5-dimethylaminopenta-2,4-dienyliden)-1-tert-Butyl-3-(3-methoxyphenyl)-bicyclo [1.1.1] pentan | C₁₀H₁₁N₃, C₁₈H₂₂O |
| 11.  | 15.66| 0.76     | Oct-3-ene-1,5-diyne, 3-t-butyl-7,7-dimethyl-1-Fluoro-1-hex-1-yl-2,2-dimethylcyclopropane 2-Cyclohexen-1-one,2-hydroxy-6-methyl-3-(1-methylthyl)- | C₁₄H₂₀, C₁₁H₁₇F, C₁₀H₁₆O₃ |
| 12.  | 15.88| 3.79     | 3-O-Methyl-d-glucose, 2-Acetylamino-3-hydroxy-propionic acid, 6-Ethoxy-6-methyl-2-cyclohexenone | C₈H₁₄O₆, C₈H₁₄O₄, C₈H₁₄O₂ |
| 13.  | 16.11| 0.47     | 3-O-Methyl-d-glucose, à-Methyl mannofuranoside, 3-Methylmannoside | C₈H₁₄O₆, C₈H₁₄O₆, C₈H₁₄O₆ |
| 14.  | 16.21| 1.10     | 3-O-Methyl-d-glucose, à-Methyl mannofuranoside, 3-Methylmannoside | C₈H₁₄O₆, C₈H₁₄O₆, C₈H₁₄O₆ |
| 15.  | 16.58| 2.10     | 3-O-Methyl-d-glucose, Myo-Inositol, 4-C-methyl-à-d-Mannofuranoside, methyl | C₈H₁₄O₆, C₈H₁₄O₆, C₈H₁₄O₆ |
| S.No | RT  | Area (%) | Name of the compound                                | Molecular formula |
|------|-----|----------|-----------------------------------------------------|-------------------|
| 16.  | 17.03 | 0.13 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 17.  | 17.17 | 9.54 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 18.  | 17.46 | 0.80 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | á-d-Mannofuranoside, methyl                         | C₇H₁₄O₆          |
| 19.  | 17.68 | 0.62 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 20.  | 17.78 | 0.35 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 21.  | 17.82 | 0.23 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 22.  | 17.86 | 0.52 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 23.  | 17.89 | 0.12 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 24.  | 17.92 | 0.23 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 25.  | 17.94 | 0.14 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 26.  | 17.99 | 0.86 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 27.  | 18.06 | 2.44 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 28.  | 18.11 | 0.52 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 29.  | 18.17 | 1.13 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 30.  | 18.23 | 1.79 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 31.  | 18.32 | 33.55 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 4-C-methyl-                           | C₇H₁₄O₆          |
|      |      |        | Myo-Inositol, 2-C-methyl-                           | C₇H₁₄O₆          |
| 32.  | 19.12 | 0.82 | 3-O-Methyl-d-glucose                                | C₇H₁₄O₆          |
|      |      |        | d-Mannose                                           | C₆H₁₂O₅           |
|      |      |        | d-Glycero-l-gluco-heptose                           | C₉H₁₄O₇           |
| 33.  | 20.10 | 5.84 | n-Hexadecanoic acid                                 | C₁₆H₃₂O₂          |
|      |      |        | l(+)-Ascorbic acid 2,6-dihexadecanoate              | C₃₉H₆₉O₆          |
|      |      |        | Pentadecanoic acid                                  | C₁₅H₃₀O₂          |
Secocholesta

Pentanone, 4 present in higher amounts were Pyrene and ethanolic extract. The prevailing compounds and presence of twenty leaves flowers by GC

The study on the active principles of carboxilic acids are used as antioxidants and alkenes had antimicrobial effects, and the manufacture of safe drugs, which are used as Some aliphatic amines have entered the manufacture of safe drugs, which are used as effective anti-malarial drugs [25]. Also, alkanes and alkenes had antimicrobial effects, and the carboxilic acids are used as antioxidants [26].

**4. DISCUSSION**

**4.1 Functional Group Analysis by FT-IR of Extracts of T. indica Leaves**

FT-IR analysis of ethanolic and aqueous extracts of T. indica leaves revealed that functional group components of alcohols, amino acids, carboxylic acid, alkanes, alkenes, organic hydrocarbons, aryl (Aromatic ring), thiols group and ethers compounds. Correa et al. [24] analyzed the aqueous leaf extract of T. indica by FT-IR and reported that the aromatic ring compounds, alkenes, amines, alcohols and alkyl halides were only present in the extract.

Some aliphatic amines have entered the manufacture of safe drugs, which are used as effective anti-malarial drugs [25]. Also, alkanes and alkenes had antimicrobial effects, and the carboxilic acids are used as antioxidants [26].

**4.2 GC-MS Analysis of T. indica Leaves Ethanolic Extract**

The study on the active principles of T. indica leaves flowers by GC-MS analysis exhibited the presence of twenty-two major peaks in the ethanolic extract. The prevailing compounds and present in higher amounts were Pyrene and Fluoranthe in the extract. While the compounds found in smaller amount were 2-Pentanone, 4-hydroxy-4-methyl- and 9,10- Secocholesta-5,7,10(19)-triene-3,24,25-triol, (3a, 5Z,7E)-. Some of these compounds identified through GC-MS are known to have many important biological and formulation functions, such as 2-Pentanone, 4-hydroxy-4-methyl- is used as antimicrobial [27]. 3-O-Methyl-d-glucose is used as anti-cancer and anti-inflammatory [28]. Tetradecane, 2,6,10-trimethyl- is used as antifungal, antibacterial and nematicidal [29]. n-Hexadecanoic acid is used as antimicrobial and antioxidant [30]. Eicosane has the antioxidant activity as reported by earlier workers [31]. Octadecanoic acid act as antimicrobial, anti-inflammatory, hepatoprotective and nematicide [32]. Cholestan-3-ol, 2-methylene- (3a,5a)- have activities such as anti-inflammatory and cytotoxic activities [33]. Corynan-17-ol, 18,19-didehydro-10-methoxy-, acetate (ester) is used as anti-diarrhoeal activity [34]. Dasycarpidan-1-methanol, acetate (ester) has pharmacological activity such as antimicrobial, antioxidant and anti-inflammatory [28]. Diisooctyl phthalate act as antimicrobial, antifungal, antiviral and antioxidant activities [27].

**4.3 GC-MS Analysis of T. indica Leaves Aqueous Extract**

The GC-MS analysis of a crude aqueous extract of T. indica showed the presence of twenty-six (26) different compounds in it. Some of which have never been reported as constituents of T. indica. The prevailing compounds and present in higher amounts were Myo-Inositol, 2-G-methyl-, Propane, 2,2-dimethoxy-, 2-Pentanone, 4-hydroxy-4-methyl- present in the extract. While the compounds which found in smaller amount were 1,3-Dithiane, 2-[4-(1-ethoxyethoxy) butyl], Benzenacetaldehyde. Most of the phytochemicals mentioned in Table 4. had pharmacological action and many important
biologials such as furfural act as anti-inflammatory activity and analgesic activity [28]. 12,15-Octadecadiynoic acid, methyl ester act as anti-inflammatory [32]. n-Hexadecanoic acid acts as antioxidant and anti-inflammatory [35]. cis-Vaccenic acid act as anti-asthmatic, anti-inflammatory and lowers total cholesterol and triglycerides levels [28,36]. Octadecanoic acid is used hypercholesterolemic, antiarthritic, anti-inflammatory, hepatoprotective, nematicide and antimicrobial [28]. Hexadecanoic acid,2-hydroxy-1-(hydroxymethyl)ethyl ester act as antioxidant [29].

5. CONCLUSION

The results of this study revealed that extracts of T. indica contains pharmacologically active substances with antimicrobial, anti-inflammatory, and antioxidant activity. Therefore, the crude extracts of T. indica leaf could be new sources of development of new plant-based therapy for management of several diseases.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kirbag S, Zengin F, Kursat M. Antimicrobial activities of extracts of some plants. Pak J Bot. 2009;41(4):2067-2070.
2. Koduru S, Grierson DS, Afolayan AJ. Ethnobotanical information of medicinal plants used for treatment of cancer in the Eastern Cape Province, South Africa. Curr Sci. 2007;906-908.
3. Sahayaraj PA, Gowri J, Dharmalingam V, Shobana R, Prema AA. Phytochemical screening by FTIR spectroscopic analysis of leaf and stem extracts of Wedelia biflora. Int J Nano Corros Sci Eng. 2015; 2(5):322-334.
4. Nithyadevi J, Sivakumar R. Phytochemical screening and GC–MS, FT-IR analysis of methanolic extract leaves of Solanum torvum sw. Int J Res Stud Biosci. 2015; 3(9):61-66.
5. Christenhusz MJ, Byng JW. The number of known plants species in the world and its annual increase. Phytotaxa. 2016;261(3): 201-217.
6. Wink M. Evolution of secondary metabolites in legumes (Fabaceae). Sou Afr J Bot. 2013;89:164-175.
7. Bhadoriya SS, Ganeshpurkar A, Narwaria J, Rai G, Jain AP. Tamarindus indica: Extent of explored potential. Pharma Rev. 2011;5(9):73–81.
8. Mabberley DJ. Mabberley’s plant-book: A portable dictionary of plants, their classifications and uses (No. Ed.3). Cambridge University Press; 2008.
9. Zohrameena S, Mujahid M, Bagga P, Khalid M, Noorul H, Nesar A, Saba P. Medicinal uses & pharmacological activity of Tamarindus indica. World J Pharm Sci. 2017;5(2):121-133.
10. Gupta R. Investigation of anti diarrhoeal activity of ethanolic extract of Tamarindus indica L. seeds in albino Wistar rats. Asian J Pharm. 2016;10(04):492-496.
11. Mehdi MAH, Pradhan V, Salem KNQ, Omar GMN, Alarabi FY. Effect of ethanol extract of Pancratium maximum bulbs on Entamoeba histolytica in vivo. European Journal of Biomedical. 2020;7(12):317-322.
12. Mehdi MAH, Alarabi FY, Farooqui MI, Pradhan V. Phytochemical screening and antiamebic studies of Tamarindus indica of leaves extract. Asian J Pharm Clin Res. 2019;12(2):507-512. Available:http://dx.doi.org/10.22159/ajpcr.2019.v12i2.29684
13. Mehdi MAH, Alarabi FY, Farooqui M, Pradhan V. Phytochemical screening and antiamebic studies of Tamarindus indica of leaves extract. Asian J Pharm Clin Res. 2019;12(2):507-512. Available:http://dx.doi.org/10.22159/ajpcr.2019.v12i2.29684
14. Al-Arabi FY, Omar GM, Mehdi MA, Pradhan V. The effect of Tamarindus indica extracts on larval stage of Echinococcus granulosus parasite In vivo and In vitro study. Pharma Innov J. 2018;7(11):22-28.
15. Satpute S, Vanmare DJ. In vitro antifungal activity of Tamarindus indica L. extract against pathogenic fungi. International
22. Al-Ahdbab MA. Anti-Hyperglycemic effect of Tamarindus indica extract in Streptozotocin-induced diabetes in male rats. World Appl Sci J. 2015;33(12):1940-1948.

23. Mehdi MAH, Pradhan V. The antiamoebic potential of aqueous extract of Tamarindus indica leaves. Mukt Shabd Journal. 2020;9(6):457-466.

24. Correa SN, Naranjo AM, Herrera AP. Biosynthesis and characterization of gold nanoparticles using extracts of Tamarindus indica L. leaves. J Phys. 2016;687(1):012082.

25. Pérez B, Teixeira C, Albuquerque IS, Gut J, Rosenthal PJ, Prudêncio M, Gomes P. PRIMACINS, N-cinnamoyl-primaque conjugates, with improved liver-stage antimalarial activity. Med Chem Comm. 2012;3(9):1170-1172.

26. Buzhko OO, Zavygorodny MP, Kruglyak OS, Omeljanchik LO, Shapoval GA. Antioxidant activity of alkoxy derivatives of (quinoline-4-ythio) carboxylic acids. Ukr Biochem J. 2015;87(2):95-102.

27. Phuong TV, Lam V, Diep CN. Bioactive compounds from Marine streptomyces Sp. by Gas Chromatography-Mass Spectrometry. Pharm Chem J. 2018;5(1):196-203.

28. Hussein JH, Ubaid JM, Hameed IH. Gas chromatography–mass spectrum analysis of volatile components of methanolic leaves extract of Cordia myxa. Int J Curr Pharm Res Rev. 2017;7(6):16-22.

29. Arora S, Kumar G. Phytochemical screening of root, stem and leaves of Cenchrus biflorus Roxb. J Pharmacog Phytochem. 2018;7(1):1445-1450.

30. Abdullah BM, Mehdi MAH, Khan AR, Pathan JM. Gas chromatography-mass spectrometry (GC-MS) Analysis of Ajwain (Trachyspermum ammi) Seed Extract. International Journal of Pharmaceutical Quality Assurance. 2020;11(2):228-231. Available:https://doi.org/10.25258/ijpqa.11.2.6

31. Godara P, Dulara BK, Barwer N, Chaudhary NS. Comparative GC-MS analysis of bioactive phytochemicals from different plant parts and callus of Leptadenia reticulata wight and am. Pharmacog J. 2019;11(1):129-140.

32. George LO, Radha HR, Somasekariah BV. In vitro anti-diabetic activity and GC-MS analysis of bioactive compounds present in the methanol extract of Kalanchoe pinnata. Indian J Chem. 2018;1213-1221.

33. Shareef HK, Muhammed HJ, Hussein HM, Hameed IH. Antibacterial effect of ginger (Zingiber officinale) roscoe and bioactive chemical analysis using gas chromatography mass spectrum. Orient J Chem. 2016;32(2):20-40.

34. Hussein HM, Hameed IH, Ibrahim OA. Antimicrobial Activity and spectral chemical analysis of methanolic leaves extract of Adiantum capillus-veneris using GC-MS and FT-IR spectroscopy. Int J
Pharmacog Phytochem Res. 2016;8(3): 369-385.

35. Patel J, Reddy V, Kumar G, Satyasai D, Bajari B. Gas chromatography and mass spectroscopy analysis of bioactive components on the leaf extract of *Terminalia coriacea*: A potential folklore medicinal plant. Int J Green Pharm. 2017; 11(01):143.

36. Yakubu EO, Oritoju O, Onwuka J. Gas chromatography- mass spectrometry (GC-MS) analysis of aqueous extract of *Daniellia oliveri* stem bark. Pharm Anal Acta. 2017; 8(568):1-8.