Phytochemical Investigations of the Medicinal Plant Swertia Chirata Ham

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Abstract

The fresh stem of the plant *Swertia chirata* Ham was extracted by rectified spirit. The crude rectified spirit extract was fractionated by using standard chromatographic techniques, on alumina gave several fractions (A, B, C, D, E, and F). Fraction D, when subjected to column chromatographic analysis on neutral alumina, yielded a compound, tentatively known as compound AJ-1 m.p. 178°C. In this research work only one compound is isolated. From the spectral evidences, the compound is an alkaloid containing 37 carbon atoms with 52 hydrogen along with secondary or tertiary nitrogen and several OH groups in the molecule. The pure compound AJ-1 has found anti-diabetic, analgesic, anti-inflammatory and other different bioactivity tests can be performed for the pure compounds AJ-1. The plant is being used as folk medicine in the treatment of diabetes, jaundice and skin diseases.

Keywords: Gentianaceae; *Swertia chirata* Ham; Spectral characteristics; Pure Compound AJ-1

Introduction

Natural product chemistry is an ancient science. Different medicinal compounds such as antitumor, anticancer, anti AIDS etc were isolated from natural plants. Isolation of any compound from any plants is uncertain. None can assure it before investigation. But generally secondary metabolites are obtained by proper investigation. Plants are unique in their ability to synthesize fats, carbohydrates, proteins that constitute three major food classes for human race [1]. The array of medicines derived from them is impressive and includes hypotensive drugs, analgesics, anaesthetics, antitumor and antiparasitic compounds, anti-inflammatory drugs, steroids, laxatives, diuretics and many others [2]. Theophrastus [3] a student of Plato, in his historia plantarum described the use of nearly 500 medicinal plants. A vast compilation of ancient knowledge of medicinal plant, can be seen in the natural history of pliny [4], the famous Roman physician. The Chinese Emperor Shen Nung (3000 BC) [5] compiled a treatise on medicinal plants. The medicinal plants that have been used since ancient time, many have yielded most useful drugs that are very much in use in current medicine. Such as - the most isolated natural analgesic, morfine [6] was isolated from opium poppy (latex of Papaver somniferum fruit). Quinine [6], an antimalarial alkaloid, was isolated from cinchona bark (Cinchona succirubra) which was used by the South Americans and the Indians. Emetine [7], which is considered as an important medicine for amoebiasis, is the main alkaloid obtained from the root of ipecacuanha (Cephaelis ipecacuana) was used in Brazil and Far east for dysentery and diarrhoea. Reserpine [8], used as a hypotensive drug and tranquilizer was isolated from the plant Rauwolfia serpentina, considered to be a common remedy for mental illness and snake bite in the Indian sub continent. Bronchodilating effect of ephedrine from Ephedra vulgaris [6].

Curare used as arrow poison by the South American natives has now given as tubocurarine [9], a quaternary alkaloid now being used as an adjunct to anesthesia for surgery. Anti-spasmodic effect of atropine [6], from Atropa belladonna. Anaesthetic effect of strychnine [6] from Nux vomica and pelletierine, from pomegranate. Antileprotic effect of chaulmoogra fruit [6] was well known to the ancient Indians. At present thousands of plant metabolites are also now being successfully used in the treatment of a variety of diseases. A few striking examples of plant metabolites are as follow: Taxol [10], from *Taxus brevifolia*. Vin-cristine [11] and Vinblastine [11] from *Vinca rosea* Linn. (Periwink Plant), all of which are important anticancer drugs. Arrow poison of foxglove [12] consisting of digitalis glycosides is cardiotonic for man. The root bark of Mexican yam [13] is used in making cortisone and other steroidal drugs. Salicylic acid [14] isolated from willow bark has a variety of pharmacological effects on platelet aggregation, pain and immune system. Artemisinin, a new antimalarial from Chinese herbal medicine [15].

The plant under investigation is *Swertia chirata* Ham which belongs to the family Gentianaceae. The Gentianaceae is a tropical family of small trees, herb and bitter tonic. It consists of 180 species. About 8-10 species exist in India [16]. This plant is indigenous to temperature Himalayas at altitudes above 4000 feet from Kashmir, Nepal and Bhutan [17]. In this family all plants are use as medicine. In the present investigation the plant *Swertia chirata* Ham was selected for phytochemical and biological studies.

The plant *Swertia chirata* (Family: Gentianaceae) Ham was chosen for investigation since it has a folkloric reputation. So far literature surveyed, *Swertia chirata* Ham has tremendous uses in traditional medicines. It has anti-microbial activity against Gram positive and Gram negative bacteria. All the plant are used as astringent, unani-tonic to heart, liver, eyes, cough, scanty-urine, melancholia, dropsy, sciatia, skin diseases, the plant is used as a bitter tonic in gastrointestinal disorders, like dyspepsia/anorexia, it is used as digestive, febrifuge and laxative. It is used to prevent malaria, particularly useful in fever. The plant is also effective against intestinal worms burning of the body, bronchial asthma, regulating the bowels [18] (Figure 1).

Materials and Methods

Dried stem of *Swertia chirata* Ham (Locally known as chirata) were collected from Bhangura Kabirajni Shop of Rajshahi Shahab Bazar. The stems of the plant were cut into small pieces by a sharp knife. About 650
The crude rectified spirit extract was subjected to an alumina column for fractionation. The column containing 10 gm of alumina was prepared as described before. Crude extract (2.5 gm) for the purpose was mixed with a little rectified spirit in a mortar to get a free following mass. The sample was then placed carefully on the top of the prepared column and was successively eluted with n-hexane, n-hexane with increasing portions of petroleum ether; ethyl acetate and finally with methanol (Table 1). A number of colour bands were observed during the development of the column. The subsequent eluants were collected in 100 ml beakers (Table 2).

Examination of the combined fractions

**Fraction A:** Fraction A gave no spot on TLC examination and was discarded.

**Fraction B:** The residue (35 mg) from fraction B did not give any discrete spot with different solvent system and tailed badly and was not worked out further.

**Fraction C:** The fraction showed two spots on the TLC, placed with solvent system n-Hexane: Ethyl acetate (3:1). The spots were pink in color under UV light. The band were contains R value=0.67 and 0.583, respectively. The residue from fraction C was subjected to a small chromatographic column fitted with a cotton-plug, using Ethyl acetate: Toluene (1:4). The two eluants were collected and evaporated to get small amount of compounds C1 and C2. The compounds C1 and C2 were insufficient quantities and were not worked out further.

**Fraction D:** The fraction showed two spots (Rf=0.53 and 0.73) on TLC plate using the solvent system Petroleum ether: Ethyl acetate (1:2). The spot having Rf=0.73 showed a violet fluorescence under UV light and yellowish spot in iodine vapour. While the other spot having Rf=0.53 was pink under UV light and yellow in iodine vapor. The components on chromatoplate did not react with potassium permanganate reagent and reacted with vanillin sulfuric acid reagent giving bluish violet spots.

The residue (110 mg) from fraction D was subjected on alumina to a small chromatographic column using petroleum ether: ethyl acetate (1:1). The two eluants were colleted and evaporated to get two compounds designated as AJ-1 (45 mg) and AJ-2 (8 mg).

The compound AJ-1 was crystalline but the compound AJ-2 was not crystalline. The compound AJ-2 was insufficient quantities and was not worked out further.

**Fraction E and F:** These two fractions appeared to be a mixture of components, which had R values very close to each other and could not be separated. The fractions were therefore preserved for further studies in future.

<table>
<thead>
<tr>
<th>Eluants</th>
<th>Amount of solvent (in ml)</th>
<th>No. of collected beakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% n-hexane</td>
<td>300</td>
<td>1-3</td>
</tr>
<tr>
<td>25% Petroleum ether in hexane</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>50% Petroleum ether in hexane</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>100% Petroleum ether</td>
<td>200</td>
<td>6-7</td>
</tr>
<tr>
<td>2.5% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>5% Ethyl acetate in petroleum ether</td>
<td>300</td>
<td>9-11</td>
</tr>
<tr>
<td>7.5% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>10% Ethyl acetate in petroleum ether</td>
<td>300</td>
<td>13-15</td>
</tr>
<tr>
<td>12.5% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>15% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>17</td>
</tr>
<tr>
<td>20% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>18</td>
</tr>
<tr>
<td>25% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>19</td>
</tr>
<tr>
<td>30% Ethyl acetate in petroleum ether</td>
<td>200</td>
<td>20-21</td>
</tr>
<tr>
<td>40% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td>50% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>23</td>
</tr>
<tr>
<td>60% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td>70% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>80% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>26</td>
</tr>
<tr>
<td>90% Ethyl acetate in petroleum ether</td>
<td>100</td>
<td>27</td>
</tr>
<tr>
<td>100% Ethyl acetate</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>5% Methanol in ethyl acetate</td>
<td>200</td>
<td>29-30</td>
</tr>
<tr>
<td>15% Methanol in ethyl acetate</td>
<td>100</td>
<td>31</td>
</tr>
<tr>
<td>50% Methanol in ethyl acetate</td>
<td>200</td>
<td>32-33</td>
</tr>
<tr>
<td>100% Methanol wash</td>
<td>100</td>
<td>34</td>
</tr>
</tbody>
</table>

The fractions were combined on the basis of their preliminary TLC examination to give combined fractions A, B, C, D, E, F (Table 2). Each combined fraction was evaporated to dryness under reduced pressure.

<table>
<thead>
<tr>
<th>Beaker number</th>
<th>Yield of residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>9 mg</td>
</tr>
<tr>
<td>7-11</td>
<td>35 mg</td>
</tr>
<tr>
<td>12-17</td>
<td>60 mg</td>
</tr>
<tr>
<td>18-21</td>
<td>110 mg</td>
</tr>
<tr>
<td>22-25</td>
<td>25 mg</td>
</tr>
<tr>
<td>26-30</td>
<td>45 mg</td>
</tr>
</tbody>
</table>

**Table 2:** Name of the fraction obtained from column chromatography.
Isolation of the compound AJ-1 from small chromatographic column

From the TLC analysis of the fraction obtained from small column chromatography, it was observed that the compound AJ-1 contained only one compound. This was recrystallized from methanol-ethyl acetate mixture.

Purification of the compound AJ-1: The compound AJ-1 was further recrystallized dissolving in petroleum ether: ethyl acetate (1:1) and the crystals were washed with different solvents of varying polarity when needle-shaped crystals were obtained.

Purity Test: This isolated compound AJ-1 was tested in different solvent systems for its purity. The compound showed a single spot on TLC examination. So this compound is pure. Finally its Rf values were determined using the various solvent systems (Table 3).

Spectral characteristics of the compound AJ-1

Infrared (IR) Spectrum of the compound: Infrared (IR) spectrum (Figure 2) of the compound in KBr (spectroscopic grade) pellet was recorded with a pye-unicam SP³-300 spectrophotometer. The samples were put in an agate mortar and thoroughly powdered with KBr and then transferred in a disc holder and a disc was made by hydraulic press. The KBr pellet was mounted in the sample cavity of the machine.

The infrared (IR) spectrum of the compound had nine characteristic bands in the functional group region at 3509 (OH-streching); 2993, 2971, 2938 (CH-streching); 1762, 1744; 1705 (>C=O); 1502 (NH) and 1150 (CH-streching) cm⁻¹, respectively.

¹H-NMR Spectrum of the compound AJ-1: ¹H-NMR spectrum of the compound was recorded on NMR spectrophotometer (500MHz) at the Faculty of Pharmaceutical Sciences, Nagoya City University, Tanbe-dori, Mizuho-Ku, Nagoya 467, Japan. Pyrd₅ is was used as solvent and the chemical shifts are given in δ-values.

¹H-NMR data of the compound

<table>
<thead>
<tr>
<th>Solvent system and ratio</th>
<th>Rf value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum ether: Ethyl acetate (1:2)</td>
<td>0.73</td>
</tr>
<tr>
<td>Chloroform: Ethyl acetate (49:1)</td>
<td>0.92</td>
</tr>
<tr>
<td>Ethyl acetate: Chloroform (19:1)</td>
<td>0.79</td>
</tr>
<tr>
<td>Toluene: Ethyl acetate (3:1)</td>
<td>0.88</td>
</tr>
<tr>
<td>Ethyl acetate: Pyridine: Water (5:1:4)</td>
<td>0.98</td>
</tr>
<tr>
<td>Ethyl acetate: Chloroform: Methanol (2:2:1)</td>
<td>0.95</td>
</tr>
<tr>
<td>Benzene : Ethyl acetate (19:1)</td>
<td>0.86</td>
</tr>
<tr>
<td>Chloroform: Ethyl acetate (4:1)</td>
<td>0.91</td>
</tr>
<tr>
<td>Ethyl acetate: Acetone (9:1)</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 3: TLC analysis of the compound on silica gel G.

Figure 2: IR Spectrum of Compound AJ-1.
δ : 6.51 (1H, dd, J=2.2 and 9.6 Hz, =CH)
δ : 6.43 (1H, dd, J=6.4 and 9.6 Hz =CH)
δ : 5.99 (1H, dd, J=5.1 and 15.3 Hz, =CH): Two olefinic terminal
δ : 5.92 (1H, dd, J=5.1 and 15.3 Hz, =CH)=CH2
δ : 5.45 (1H, bd, J=5.1 Hz, =CH): Five olefinic=CH
δ : 5.26 (2H, S, terminal olefinic CH2)
δ : 2.94–2.87 (3H, m, CH2)
δ : 2.60 (2H, bd, J=Hz,=CH2)
δ : 2.51 (2H, tdt, J=Hz,=CH2)
δ : 2.34 (2H, S, CH2)
δ : 1.98–2.14 (10H, m, CH2)
δ : 1.75–1.85 (4H, m, CH2)
δ : 1.52 (4H, S, either NH or OH, or both protons)
δ : 1.33 (6H, S, 2XCH3)
δ : 1.32 (3H, S, CH3)
δ : 1.31 (3H, S, CH3)

13C-NMR (Pyr d5, 500 MHz)

13C-NMR spectrum of the compound was also recorded (Figure 3) on NMR-spectrophotometer (500MHz) with 100 MHz frequency and pyrd5 was sued as solvent and the data are given below.

<\text{C}=\text{O} at 176.02, 174.41, 174.36 and 173.08 ppm.
Ar\text{CH} at 144.63, 140.86, 138.08 and 130.55 ppm.
Ar\text{C} at 126.59 and 126.49 ppm.

=CH at 109.75 and 109.72 (Down field signals may be due to the presence of neighbouring electronegative group, such as OH)
=CH at 74.47, 71.56 and 71.47 (olefinic CH)
–CH at 52.65, 50.53, 47.53, 47.59, 46.88, 45.09 and 44.60 (aliphatic)
=CH2 at 81.97 and 81.90 ppm (olefinic=CH2)
–CH2 at 42.26, 42.15, 41.79, 38.33, 36.93, 35.52, 27.19, 27.04, 18.27 and 17.60, CH2 aliphatic)
–CH3 at 28.93, 28.41, 24.98 and 23.87 ppm

Result and Discussion

Preliminary extraction

The paste materials were taken in a clean flat bottomed glass container (2.5 litre) and macerated with sufficient amount of rectified spirit and with occasional shaking. After 15 days the solvents was decanted and filtered by tincture press. Then the extract was evaporated under normal pressure and normal temperature to obtain a gummy mass.

Examination of the rectified spirit extract

The rectified spirit extract showed at least three components (Rf=0.4, 0.54 and 0.73) on thin layer chromatographic plates with Petroleum ether: Ethyl acetate (1:2). The rectified spirit extract was then subjected to column chromatography on alumina. The column was eluted successively with n-hexane, n-hexane-petroleum ether mixtures and finally with methanol (Table 1). The fractions were combined on the basis of their preliminary TLC examination to give combined fractions A, B, C, D, E and F (Table 2). The combined fractions were evaporated to dryness under reduced pressure. Fraction A did not give any residue.

Fraction D: Fraction D showed two spots (Rf=0.53 and 0.73) on the TLC plate with Petroleum ether: Ethyl acetate (1:2). The combined fraction was examined by 1D and 2D NMR spectroscopy. The 1H-NMR spectrum showed three doublets, two triplets and two singlets. The 13C-NMR spectrum showed three singlets, two doublets and one triplet. The results were consistent with those of the crude extract.

Figure 3: 13C-NMR Spectrum (500 MHz, pyr-d5) of Compound AJ-1.
TLC plates using solvent system Petroleum ether: Ethyl acetate (1:2).
The fraction D was further subjected on mini column chromatography
using Petroleum ether: Ethyl acetate (1:1). The two eluants were
collected and evaporated to get two components designated as AJ-1
(40 gm) and AJ-2 (5 mg). The component AJ-1 was crystalline but the
component AJ-2 was not crystalline and was insufficient quantities.

Isolation and purification of pure compound

The compound AJ-1 showed single spot on TLC analysis with
some impurities. The compound AJ-2 was recrystallized dissolving in
Petroleum ether: Ethyl acetate (1:1) and the crystals were washed with
different solvents of varying polarity. The isolated compound AJ-1 was
tested in different solvent systems (Table 1) for its purity. The compound
showed a single spot on TLC examination. So, this compound was pure.
Finally its Rf values (Table 3) were determined using the various solvent
systems.

Characteristics of the compound AJ-1

(A) Physical characteristics

Physical form: Fine crystals (needles shaped) having single Rf value
was obtained.

Color: The compound was all most colorless.

Solubility: The solubility data of the compound have been
summarized below.

The compound is highly soluble in ethyl acetate and chloroform.
The compound is insoluble in n hexane, petroleum ether.
The compound is sparingly soluble in ethanol, diethyl ether.

Melting point: Melting point of the compound was observed in

REICHERT AUSTRIA, Nr. 341910 melting point apparatus; melting
point of the compound is 178°C.

(B) Chemical characteristics:

The compound gave positive test for ketone group, tertiary amine
group, alcohol, ester, unsaturation, alkaloid and negative test for
carbohydrate, phenol and hydrocarbon.

1H and 13C-NMR (Nuclear Magnetic Resonance) Spectra:

1H and 13C-NMR spectra were recorded on a JEOL AX-500 (500
MHz) and JEOL JNM AX 400 (400MHz), FT NMR spectrometers,
Faculty of Pharmaceutical Sciences, Nagoya City University, Tanabe-
dori, Mizuho-ku, Nagoya 467, Japan. CDC13 was used solvent with
Tetramethylsilane (TMS) as an internal standard and the chemical shifts
are given in δ-values. All organic extracts were dried over anhydrous
Na2SO4 and solvent was evaporated off under reduced pressure in a
rotary evaporator.

Study of spectral data: The Infrared (IR) spectrum (Figure 2) of
the compound in KBr disc showed the absorption bands at 3509; 2993,
2971, 2938; 1762; 1744; 1705; 1502 and 1150 cm⁻¹, respectively. The
absorption bands observed could be assigned to the following:

The band at 3509 cm⁻¹ showed O−H stretching vibration in
hydrogen bonded alcohols and phenols.

Bands at 2993, 2971 and 2938 cm⁻¹ showed alkane type C−H
stretching (C−H stretching vibration in CH₃).

The bands at 1705 cm⁻¹, 1502 cm⁻¹ and 1150 cm⁻¹ indicated the
presence of >C=O, NH and CH− stretching, respectively.

From the complete decoupling 13C-NMR spectrum of the
compound, a total of 37 carbon signals were detected (Figure 3).
In J resolved DEPT 45° spectrum four down field signals appeared at 173.08, 174.36, 174.41 and 176.02 ppm and are assumed to be carbonyl carbon. Chemical examination showed the positive test for carbonyl group and absence of aldehyde which is also supported by the appearance of three peaks in its IR spectrum at 1762, 1743 and 1705 cm⁻¹ for carboxyl functions. Signal for aldehyde group proton did not appear in ¹H-NMR spectrum. From the above findings, four ketone functions are present in the molecule. Six aromatic carbons appeared at 126.49, 126.5, 130.55, 138.03, 140.85 and 144.63 among which two are quaternary and the other four are methane carbon atoms, identified by DEPT 135° spectrum, which indicates the presence of a benzene ring in the molecule.

Four benzene ring protons are present in the ¹H-NMR spectrum and their splitting pattern is 1:3 i.e. a singlet equivalent to one proton and a multiplet equivalent to three protons. From the above ¹C-NMR and ¹H-NMR spectra, the benzene ring, substituted in two portions which are presumed to be ortho and para and are evident form the asymmetrical splitting pattern of the benzene ring protons (1:3) (Figure 4).

Eleven methane carbon signals appeared in the ¹C-NMR and are identical from the DEPT 135° spectrum—out of which 5 carbons are double bonded carbon and the rest are saturated CH carbons. Of the five doubly bonded methane carbons, two carbons showed down field shift probably due to the presence of electro negative groups or atoms present adjacent to these two carbons which appeared at 109.72 and 109.75 ppm and the rest three carbons appeared at 71.47, 71.56 and 74.47 ppm. Six saturated methane carbons appeared in higher field at 44.60, 45.09, 46.88, 47.53, 50.53 and 52.65 ppm.

Two low field methylene carbon signals appeared at 81.97 and 81.90 ppm indicated the presence of two terminal CH₂ groups with double bond in the side chain of the molecule. The other 10 saturated CH₂ carbon signals appeared between 17.60 and 42.26 ppm.

From the methyl carbon signals at 23.87, 24.98, 28.41 and 28.93 ppm, it has been confirmed that four methyl groups are present in the molecule. This is also supported by its ¹H-NMR (Figure 5) spectrum. Four methyl group protons appeared at δ: 1.33 (6H, 2XCH₃), 1.32 (3H, 1XCH₃) and 1.31 (as 3H, 1XCH₃) singlets.

From the ¹H-NMR spectrum of the compound four benzene ring protons appeared in an unsymmetrical pattern, one as singlet at δ: 7.73 and other three as multiplet between δ: 7.65~7.67. One doublet, equivalent to two protons, appeared at δ: 6.70 with J values of 1.3 and 12.2 Hz and other singlet of two protons appeared at δ: 5.26. These two sets of protons seems to be a doubly bonded terminal methylene group present in the molecule. The above discussion field proton signals satisfy all the carbon signals appeared in the down field region in ¹C-NMR spectrum.

Rest of the saturated CH₂ protons appeared between δ: 1.75 and 2.94 ppm (please, vide experimental). A peak of four protons appeared as singlet at δ: 1.52 which seems to be NH or OH protons or mixture of these two. Positive test with alkaloidal reagents indicated the presence of nitrogen and the presence of OH group can also be predicted from the IR spectrum since a broad peak for OH stretching centered at 3509 cm⁻¹ appeared in the IR spectrum. Four methyl protons signals also appeared which have been discussed above.

Figure 5: ¹H-NMR Spectrum (500 MHz, pyr-d₅) of Compound AJ-1.
Form the above spectral evidences; the compound is an alkaloid containing 37 carbon atoms with 52 hydrogen along with secondary or tertiary nitrogen and several OH groups in the molecule.

Conclusion

From the research work only one compound is isolated and the above spectral evidence, the compound is an alkaloid containing 37 carbon atoms with 52 hydrogen along with secondary or tertiary nitrogen and several OH groups in the molecule. For complete structure elucidation, Mass spectrum, HSCOSY, HSQC and HMBC spectra will be required. From the above discussion, it is clear that this plant may contain other medicinal compounds. Further research may be extended to isolate active compounds specially from fractions B, C, E and F.

References


Figure 6: Expanded 'H-NMR Spectrum (500 MHz, pyr-d₅) of Compound AJ-1.