ABSTRACT: Tuberculosis is a global burden with one–third of the world’s population infected with the pathogen Mycobacterium tuberculosis and an annual 2 million deaths from the disease. This high incidence of infection and the increased rate of resistant strains of the organism (MDR- and XDR- TB) have called for an urgent need to develop new anti-tuberculosis drugs from plants. The crude extract of Uvaria afzelli Scott Elliot (Annonaceae) root bark, and leaves and root bark of Tetracera alnifolia Willd. (Dilleniaceae) were investigated for anti-Mycobacterium tuberculosis activity using the MABA assay method. Anti-Mtb activity was determined against Mtb H37RvATCC 27294 at concentrations of 100-0.390µg/mL. The hexane and chloroform extracts of the root bark of Tetracera alnifolia and the chloroform extract of Uvaria afzelli had anti-Mtb activity with MIC <100 µg/mL. Phytochemical screening for secondary metabolites revealed the presence of tannins, triterpenoid saponins, cardiac glycosides and alkaloids. The anti-Mtb activity demonstrated by the crude extracts is attributed to the presence of tannins and other secondary metabolites which are known to have strong antimicrobial activity. The results therefore support the local use of Uvaria afzelli and Tetracera alnifolia in the treatment of cough associated with tuberculosis and other microbial infections of the respiratory tract and suggest that these plants may be of therapeutic importance in the treatment of tuberculosis.

Keywords: Uvaria afzelli, Tetracera alnifolia, crude extracts, Mycobacterium tuberculosis

INTRODUCTION

Infection with Mycobacterium tuberculosis (Mtb) results in tuberculosis (TB), a contagious disease with high mortality worldwide. About 2 billion people (or one-third of the world’s population), are infected with Mycobacterium tuberculosis. Globally, there were an estimated 13.7 million chronic active cases, 9.3 million new cases and 1.8 million deaths mostly in developing countries in 2007 (WHO, 2009). It is estimated that there are currently 2 million deaths from tuberculosis annually (Deng et al., 2008). Moreover, up to 50 million people are infected with drug-resistant forms of TB with about 500,000 cases of MDR tuberculosis a year worldwide (WHO, 2007). The recent increase in the widespread existence of extensively drug-resistant tuberculosis (XDR-TB) especially in the developing nations emphasized the need for the development of new drugs to treat this infection. Such new anti-tubercular agents should have novel modes of action and full activity on the pathogen- Mycobacterium tuberculosis.

The use of herbs and other alternative therapies for the treatment of tuberculosis is on the increase. Natural products continue to play a most significant role in the drug discovery and development process (Newman and...
Cragg, 2007), and plants are recognized as a useful source of highly active antimycobacterial metabolites (Gibbons, 2005; Pauli et al., 2005).

The plant *Uvaria afzelii* belong to the family Annonaceae which contains 130 genera and about 2300 species, found mainly in the tropical regions of the old world (Trease and Evans, 1989). They are known to have compounds with pharmacological, insecticidal, antiprotozoal and antimicrobial activities (Kihampa et al., 2009). The genus *Uvaria* includes approximately 150 species widely distributed in tropical areas particularly in Africa (Akendengue et al., 2003). All parts of the plant are fragrant and are used to make pomade in Ghana (Irvine, 1961). *Uvaria* species are used locally in the treatment of various infections and diseases. The decoction of the leaves is used in the treatment of swollen face, hands and feet. A paste made from the ground leaves is rubbed over ulcers and wounds. A decoction of the fruits is used in the treatment of vaginal tumor and breast aches. The whole plant is used in the treatment of leucorrhoea and gonorrhoea (Verger, 1995). The pulped leaves are eaten with oil palm seed for cough treatment (Kerharo and Bouquet, 1950). A decoction of the plant is used to wash a person with small-pox (Bouquet, 1974). *Uvaria afzelii* has been reported to have anti-parasitic activity (Okpekon et al., 2004). It is used locally in the treatment of fever and cough (Kayode et al., 2009). The root bark of *U. afzelii* is used in Nigeria for infections of the kidneys, bladders and liver and also a purge, a febrifuge and for coughs (Oliver, 1960).

The family Dillenaceae is almost pantropical with about 18 genera and 530 species. *Tetracera alnifolia* and other species of *Tetracera* have been reported to contain chemical constituents used in the treatment of various diseases and infections. A leaf decoction is taken for dysentery (Walker and Sillans, 1961). The roots of some *Tetracera* are used for yaws. A root macerate is used for urethral discharge (Kerharo and Bouquet, 1950). The plants lianous stems are macerated in its sap and taken for leprosy (Kerharo and Adam, 1962). The sap of *T. potararia* is used for toothache and cough (Oliver, 1960).

Flavonoids and coumarin derivatives are the main chemical constituents isolated from these plants genera (Akendengue et al., 2003; Hufford et al., 1981; Gurni et al., 1981). There are very few reports on the phytochemical and antimicrobial investigations on these plants in the literature. It is therefore the aim of this study to investigate the local use of these plants for the treatment of cough associated with tuberculosis and other respiratory tract infections.

**MATERIALS AND METHODS**

**Plant collection and authentication**

The root of *Uvaria afzelii* and the leaves and root of *Tetracera alnifolia* were collected. The samples were authenticated at the Herbarium, Forestry Research Institute of Nigeria (FRIN) and were assigned voucher specimen numbers FHI 107510 and 107511 respectively. The samples were air-dried, ground to coarse powder and weighed.

**Plant extraction and preparation of extracts**

Four hundred grams (400g) of *Uvaria afzelii* root bark, 300g leaf and 420g root bark of *Tetracera alnifolia* were subjected to exhaustive Soxhlet extraction with n-hexane and chloroform. The different fractions were concentrated in-vacuo, weighed and stored at room temperature until needed for assay. Stock solutions of each of the crude extracts were reconstituted with DMSO (1%) to final concentrations of 100µg/mL-0.390µg/mL for anti-Mtb assay.

**Bacterial strain for anti-Mtb biological assays**

*Mycobacterium tuberculosis* H37Rv ATCC 27294 was grown in 100 mL of Middlebrook 7H9 broth (Difco, Detroit, Mich.) supplemented with 0.2% (v/v) glycerol (Sigma Chemical Co., Saint Louis, Mo.), 10% (v/v) OADC (oleic acid, albumin, dextrose, catalase; Difco), and 0.05% (v/v) Tween 80 (Sigma), also referred to as 7H9GC-T80.

**Susceptibility Testing of Mtb H37Rv ATCC 27294 and determination of minimum inhibitory concentration (MIC)**

Anti-Mtb susceptibility testing of extracts was determined by the fluorometric Microplate Alamar Blue Assay (MABA) assay as described by (Collins et al., 1997) in black, clear-bottomed, 96-well microplates, (black view plates; Packard Instrument Company, Meriden, Conn.) in order to minimize background fluorescence. Extracts were prepared to100µg/mL in DMSO (200µL) and subsequent twofold dilutions were performed in 100µL of 7H12 medium (i.e. 7H9 broth containing 0.1% W/v casitone, 5.6µg/mL palmitic acid, 5mg/mL bovine serum albumin, 4mg/mL catalase, filter-sterilized) in the microplates. The test concentrations ranged between 100µg/mL – 0.390µg/mL. Rifampin (RMP, Sigma; concentrations at 4-0.0156µg/mL) was used as a positive control. *Mycobacterium tuberculosis* H37Rv ATCC 27294 strain was diluted in 7H12 media to reach approximately 2 × 10⁵ CFU/mL, and 100µL was added to individual wells containing the extracts yielding a final volume of 200µL and final inoculum of...
In vitro anti-mycobacterial effects of plants extracts.

1x10^5 CFU/mL in each well. Wells containing extracts only were used to detect auto-fluorescence of extracts. Additional control wells consisted of bacteria only and medium only. Plates were incubated aerobically at 37 °C. At day 7 of the incubation, 20 μL of Alamar Blue solution (Trek Diagnostic Systems, Cleveland, Ohio) and 12.5 μL of 20% Tween 80 were added to all of the wells, and the plates were re-incubated at 37 °C for 24 hours. Fluorescence was measured in a Victor III multilabel fluorometer (Perkin Elmer Life Sciences Inc., Boston, MA) in bottom-reading mode with excitation at 530 nm and emission at 590 nm. Anti- Mtb activity was recorded as percentage inhibition of >90% relative to the mean of replicate bacteria-only controls after incubation for 7 days. The minimum inhibitory concentrations (MICs) were determined after incubation for 7 days at 37 °C, defining percent inhibition as 1-(test well fluorescence units/mean FU fluorescence units of triplicate wells containing only bacteria) × 100. The MIC values refer to the lowest concentration at which samples exhibited an inhibition of ≥90% relative to the mean of replicate bacteria-only controls.

**RESULTS**

The yield, percentage yield and macroscopic characteristic of extracts of *Uvaria afzelii* root bark and *Tetracera alnifolia* are presented in Table 1. Phytochemical screening of these plants revealed the presence of tannins, triterpenoid saponins, cardiac glycoside and alkaloids. The percentage inhibition of Mtb *H37Rv ATCC 27294* by the extracts is shown in Table 2.

<table>
<thead>
<tr>
<th>Sample/solvent</th>
<th>Yield (g)</th>
<th>% Yield</th>
<th>Macroscopic characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Uvaria afzelii</em> root bark Chloroform</td>
<td>20.90</td>
<td>5.23</td>
<td>Dark brown shiny congealed mass</td>
</tr>
<tr>
<td>Tetracera alnifolia leaf n-Hexane</td>
<td>3.58</td>
<td>1.19</td>
<td>Dark green shiny congealed extract</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.53</td>
<td>0.18</td>
<td>Dark green shiny congealed extract</td>
</tr>
<tr>
<td><em>Tetracera alnifolia</em> root bark n-Hexane</td>
<td>0.52</td>
<td>0.12</td>
<td>Dark green shiny congealed mass</td>
</tr>
<tr>
<td>Chloroform</td>
<td>7.56</td>
<td>1.80</td>
<td>Greenish-brown flakes</td>
</tr>
</tbody>
</table>

The chloroform extract of *Uvaria afzelii*; the hexane and chloroform extracts of *Tetracera alnifolia* root bark had good anti-TB activity with MIC values < 100 μg/mL. The leaf extracts of *Tetracera alnifolia* had weak anti-TB activity (MIC >100 μg/mL) (Table 3). The Cytotoxicity assay gave IC_{50} values lower than the MIC thus selectivity index (SI= IC_{50}/MIC) was lower than 1 (Table 3). Thus the extracts are toxic to the VERO cells and have moderate selectivity for anti-TB activity.
Table 2:
Percentage inhibition of MTB H37Rv by the crude extracts of Uvaria afzelli and Tetracera alnifolia

<table>
<thead>
<tr>
<th>Conc. (µg/ml)</th>
<th>100</th>
<th>50</th>
<th>25</th>
<th>12.5</th>
<th>6.25</th>
<th>3.125</th>
<th>1.5625</th>
<th>0.78125</th>
<th>0.390625</th>
</tr>
</thead>
<tbody>
<tr>
<td>cUa</td>
<td>98</td>
<td>65</td>
<td>15</td>
<td>13</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>hTaL</td>
<td>26</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>cTaL</td>
<td>70</td>
<td>37</td>
<td>34</td>
<td>16</td>
<td>15</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>hTaR</td>
<td>96</td>
<td>55</td>
<td>52</td>
<td>18</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>cTaR</td>
<td>93</td>
<td>54</td>
<td>53</td>
<td>24</td>
<td>14</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Controls(µg/ml)</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.25</td>
<td>0.125</td>
<td>0.0625</td>
<td>0.03125</td>
</tr>
<tr>
<td>RMP</td>
<td>NT</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>98</td>
<td>87</td>
<td>73</td>
<td>48</td>
</tr>
<tr>
<td>INH</td>
<td>99</td>
<td>99</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>97</td>
<td>23</td>
<td>3</td>
<td>NT</td>
</tr>
</tbody>
</table>

NOTE: h- hexane, c- chloroform, Ua- Uvaria afzelli, TaL-Tetracera alnifolia leaf, TaR-Tetracera alnifolia root bark, RMP- rifampicin, INH-isoniazid, NT- Not Tested

Table 3:
Anti-TB activity of extracts of Uvaria afzelli and Tetracera alnifolia on MTB H37Rv

<table>
<thead>
<tr>
<th>Plant</th>
<th>Part</th>
<th>Extract</th>
<th>MIC (µg/mL)</th>
<th>IC50 (µg/mL)</th>
<th>SI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uvaria afzelli</td>
<td>root bark</td>
<td>chloroform</td>
<td>87.5</td>
<td>51.69</td>
<td>0.59</td>
</tr>
<tr>
<td>Tetracera alnifolia</td>
<td>Leaf</td>
<td>Hexane</td>
<td>&gt;100</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chloroform</td>
<td>&gt;100</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td></td>
<td>root bark</td>
<td>Hexane</td>
<td>93.3</td>
<td>14.92</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chloroform</td>
<td>96.5</td>
<td>9.19</td>
<td>0.09</td>
</tr>
<tr>
<td>*RMP</td>
<td></td>
<td></td>
<td>0.07</td>
<td>147.58</td>
<td>2108.29</td>
</tr>
<tr>
<td>*INH</td>
<td></td>
<td></td>
<td>0.12</td>
<td>n/d</td>
<td>n/d</td>
</tr>
</tbody>
</table>

*Controls: RMP - Rifampicin, INH - Isoniazid, * Selectivity index (SI = IC50/MIC), n/d- not determined

DISCUSSION

The primary treatment for M. tuberculosis disease is specific chemotherapy. When antituberculosis drugs are used singly, resistant tubercle bacilli emerge rapidly and multiply. Therefore, drugs are used in combination to yield cure rates of > 95%. However, these regimens are complicated lasting for several months and associated with various adverse effects thus patients compliance to therapy is poor (Fair et al., 2007). This result in the organisms rapidly developing resistance to the chemotherapeutic agents (drugs) used for the treatment of the disease.

The use of herbs for the treatment of tuberculosis is on the increase due to increased incidence of resistance to the available antibiotics. Natural products continue to play a most significant role in the drug discovery and development of highly active antimycobacterial metabolites (Newman and Cragg, 2007; Gibbons, 2005; Pauli et al., 2005).

In Nigeria, many medicinal plants have found use in the treatment of microbial infections including tuberculosis. However, there are very few reports on the phytochemical and antimicrobial investigations on these plants. It is our interest to report the anti-tuberculosis activity of these plants since some species in the genera had been reported to possess antimicrobial activity (Mbatchi et al., 2006; Okpekon et al., 2004). Species in the Uvaria genus are used in the treatment of wounds, ulcer, inflammation of the face, hands and feet, small pox, leucorrhoea, gonorrhoea, infection of the kidney, bladders and liver, malaria, fever and cough (Kerharo and Borquet, 1950; Oliver, 1960; Walker and Sillans, 1960; Kerharo and Adam, 1962). Extracts of Tetracera species are used in the treatment of dysentery, urethral discharge, leprosy, toothache and cough (Kerharo and Borquet, 1950; Oliver, 1960; Walker and Sillans, 1960; Kerharo and Adam, 1962).

The activity demonstrated by the extracts is attributable to the presence of tannins, alkaloids and triterpenoid saponins which are secondary metabolites known for their broad-spectrum antimicrobial activity. Asres et al., (2003) reported the potent activity of...
tannins isolated from *Combretum molle* against *Mycobacterium tuberculosis*. Alkaloids isolated from *Alstonia scholaris* had activity against *Mycobacterium tuberculosis* as reported by Macabeo *et al.* (2005) while Wordemichael and colleagues in 2004 reported the activity of triterpenes isolated from *Sapium haematospermum* against *Mycobacterium tuberculosis*.

The present work in accordance with the local uses of these plants demonstrates that *Uvaria afzelli* and *Tetracera alnifolia* may be of therapeutic importance in the treatment of tuberculosis. Further investigations will focus on isolating and identifying the compounds eliciting the activity observed.

**Acknowledgements**

*This work was sponsored by the MacArthur Foundation Grant to TOL.*

**REFERENCES**


