PHYTOCHEMICAL ANALYSIS OF THE LEAF, STEM BARK AND ROOT OF SOME ANTIMALARIAL PLANTS USED IN SOUTH-WESTERN NIGERIA

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ABSTRACT
Quantitative phytochemical analysis of the leaf, stem bark and root of some antimalarial plants common in South-Western Nigeria was carried out. Results obtained showed the presence of tannins, alkaloids, flavonoids, terpenoids, saponins and phenolic acids in various concentrations in the different plant parts analysed. A high composition of phytochemicals was observed in the leaves, which confirms their frequency of usage in traditional medicine for the treatment of malaria. Of the various plants analysed, Mangifera indica leaves and stem bark had the highest tannin (176.3±1.5 mg/kg Garlic acid equivalents) and alkaloid (7350.3±2.5 mg/kg GAE) contents, respectively. Flavonoids were significantly highest (p<0.05) in the roots of Vernonia amygdalina (5055.0±3.0 mg/kg GAE). Terpenoid content was highest in the leaves of Khaya senegalensis and Psidium guajava (164.0±1.0 mg/kg GAE). Saponin content was generally low but was significantly highest (p<0.05) in the stem bark of Tithonia diversifolia (98,260.0±5.0 mg/kg GAE) while phenolic acid content was highest in the roots of Citrus paradisi (110.0±5.0 mg/kg GAE). All the plant parts analysed contained phytochemicals in various proportions, thus, justifying their use in traditional therapy and management of malaria disease.

Key words: Phytochemicals; antimalarial; South-Western; plasmodium; malaria

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INTRODUCTION
Traditional medicines have been used to treat malaria for thousands of years and are the source of the two main groups (artemisinin and quinine derivatives) of modern antimalarial drugs (Willcox and Bodeker, 2004). Malaria is caused by Plasmodium parasites and it is spread to people through the bites of infected female Anopheles mosquitoes. According to WHO, malaria is endemic in 91 countries predominantly in Africa, Asia and Latin America with an estimated 216 million cases of malaria and malaria deaths reaching 445, 000 in 2016 (WHO, 2017). The WHO African Region carries a high share of the global malarial burden as the region was home to 90% of malarial cases and 91% of malarial deaths.

Despite the efforts to provide and distribute anti-malarial drugs, people in rural communities are not able to access these drugs due to their high cost which has made them unaffordable and has led to widespread use of herbs for the treatment of malaria. In 2007, the traditional medicine policy (TMP) reported that plants/herbs remain the mainstay of healthcare systems in rural communities. Plants are a valuable source of various pharmacological active substances capable of dealing with health problems of humans. The attempt by mankind to use plants and plant products to cure diseases like malaria and relieve physical suffering is as old as creation (Mirutse et al., 2003). WHO estimates that at least 80% of the populations in most developing countries of the world rely on traditional treatments for their primary healthcare needs (WHO, 1993; Ene et al., 2009).

The medicinal value of plants has assumed a more important dimension in the past few decades owing largely to the discovery that extracts from plant samples contain not only minerals and primary metabolites but also a diverse array of secondary metabolites with antioxidant potential (Akinmoladun et al., 2007).
Plants have limitless ability to synthesise aromatic substances, mainly secondary metabolites, used as defensive mechanisms against microorganisms, insects and herbivores. Close and McArthur (2002), Okwu, (2004), Okwu and Omodamiro (2005) and Okwu et al. (2007) have reported that woody plants and herbs synthesise and accumulate in their cells a great variety of phytochemicals including low molecular phenolics (hydroxybenzoic and hydroxycinnamic acids) as well as oligo or polymeric forms (hydrolysable and condensed tannins and lignins). These secondary metabolites have been shown to have a number of medicinal properties to improve human health (Lal et al., 2023).

Nigeria is gifted with an immense floral diversity which is exploited as a source of food, medicine, raw materials for businesses and industry, and for other ecological services. Such a rich biodiversity implies that the country is blessed with plants with diverse secondary metabolites and unique phytochemicals which can serve as a source of medicine for the treatment of ailment in rural communities.

Ethnobotanical survey is an important step in the identification, selection and development of therapeutic agents from medicinal plants (Idowu et al., 2010). In ethnobotany and natural products chemistry, the mode of preparation and administration of herbal preparations are often crucial variables in determining efficacy in pharmacological evaluations (Idowu et al., 2010).

A review of the medicinal plants used in south-western Nigeria for the treatment of malaria indicates that a rich floral diversity exists in Nigeria (Odagbemi et al., 2007). Ethnobotanical surveys carried out by several researchers have shown the use of a variety of plant species used, singly or in combination, for the treatment of malaria. Some of the mostly used plants in the Western part of Nigeria includes Azadirachta indica (Dogonyaro), Khaya senegalensis (Oganwo), Alstonia boonei (Ahun), Mangifera indica (Mangonro), Morinda lucida (Oruwo), Carica papaya (Ibepe), Citrus species (Osan wewe, Osan gerepu), Anacardium occidentalis (kashu), Enantia chlorantha (Awopa), Chromolaena odorata (Ewe Akintola), Psidium guajava (Gova), Tithonia diversifolia (Sepeleba) (Odagbemi et al., 2007; Idowu et al., 2010; Ene et al., 2010). A research into the phytochemical contents of these plants may lead to the discovery of novel metabolites with great medicinal potentials against malaria.

**MATERIALS AND METHODS**

**Plant Selection and Preparation**

Plants were selected based on their high frequency of usage, as indicated in various ethnobotanical surveys carried out in the South-western part of Nigeria, on plants used in the treatment of malaria. All plant materials shown in Table 1 were collected around Ibadan, Oyo State in the South-western part of Nigeria and identified at the Department of Botany Herbarium, University of Ibadan, Oyo state, Nigeria. The different parts of the plant materials (leaves, bark, roots) were shade-dried. The dried samples were chopped into smaller pieces and pulverised using an electronic mill (commercial / generic disc attrition mill). The powdered samples were then stored in small plastic air-tight containers.

**Phytochemical Screening**

**Determination of Tannin/Tannic acid using Harborne (1973) method**

One gram (1g) of each sample was weighed and soaked in 25 ml solvent mixture (80 ml of acetone and 20 ml of 10% glacial acetic acid) for 5 hours to extract tannins. The samples were filtered through a double layer filter paper to obtain the filtrate. A standard solution of tannic acid was prepared ranging from 10 to 30. The absorbance of the standard solution as well as that of the filtrate were read at 500 nm on a spectrophotometer (Spectrum lab 23A).

**Determination of Terpenoids using Harborne (1973) method**

Extraction was done by weighing one gram (1g) each of the sample into 250 ml conical flask and soaked with 10 ml of petroleum ether. These were allowed to stay for 15 min and then filtered through double-layer filter paper. A standard solution 10, 20, 30, 40 and 50 ppm, standard solution was prepared and read in the spectrophotometer. The absorbance of the samples was measured on a spectrophotometer (Spectrum lab 23A) at 420 nm.
Determination of Alkaloids using Harborne (1973) method
One gram (1g) of each sample was weighed into 50 ml of 10% Acetic acid (HOAC) with Ethanol. It was mixed by shaking it and was allowed to stand for 4 hours, after which it was then filtered. The filtrate was evaporated to 1/4 of its volume, after which concentrated ammonia was added in drops to precipitate the alkaloids. The precipitate was then filtered into a weighed filter paper and washed with 1% NH₄OH. The precipitate on the filter paper was dried in an oven at 60°C for 30 min. The % alkaloid was calculated using the formula:

\[
\% \text{ alkaloid} = \frac{W_2 - W_1}{W} \times 100
\]

Where,
- \(W\) = Weight of sample
- \(W_1\) = Weight of filter paper alone
- \(W_2\) = Weight of filter paper with precipitate

Determination of Flavonoids using the method of Boham and Kocipal-Abyaza (1974)
Two grams (2 g) of the plant samples was extracted with 20 ml of 80 % methanol at room temperature for 2 hr. The solution was filtered through Whatman filter paper No. 1 (110 mm). The filtrate was later transferred into a crucible, evaporated to dryness over a water-bath and weighed to constant weight. The total flavonoid content was computed using the formula:

\[
\% \text{ Flavonoid} = \frac{W_2 - W_1}{W} \times 100
\]

Where,
- \(W\) = Weight of sample
- \(W_1\) = Weight of crucible alone
- \(W_2\) = Weight of crucible + flavonoids

Determination of Saponin using the method of Obadoni and Ochuko (2001)
One gram (1g) of each sample was weighed into bottles and 15 ml of 20% ethanol was added. These were heated in a water-bath at 55 °C for 4 hours and filtered. The residue was washed with 20 % ethanol twice and the extract was reduced to about 5 ml over the water-bath. Five (5) ml of petroleum ether was added in a separating funnel. The ether layer was discarded to the aqueous layer at the bottom, after which 3 ml butanol was added and washed with 5 ml of 5% NaCl in a separating funnel. The butanol layer was then poured into a weighed Petri dish and the saponin content was calculated using the formula:

\[
\% \text{ Saponin} = \frac{W_2 - W_1}{W} \times 100
\]

Where,
- \(W\) = Weight of sample
- \(W_1\) = Weight of Petri dish alone
- \(W_2\) = Weight of Petri dish + Saponin

Determination of Phenolic Content using the method of Singleton and Rossi (1965)
Two grams (2 g) of each sample was extracted with 20 ml of acetone (80%) and 0.2 % formic acid (20%) for 2 min. The extract was then filtered through Whatman filter paper 1. The supernatant was used for total phenolics analysis. Two (2) mls of the sample extract was measured into a test tube and 0.5 ml folhin ciocalteau reagent was added. The mixture was allowed to stand for 30 mins and read in a spectrophotometer (Spectrum lab 23A) at a wavelength of 765 nm. Total phenolic content was expressed as tannic acid equivalents in mg/kg.

Statistical Analysis
The data were analysed using the two-way analysis of variance (ANOVA), using GLM procedure (Proc GLM) of SAS (Statistical Analysis System). The data were expressed as mean ± standard deviation (mean of 3 determinations) and differences between groups were considered significant at p < 0.05.
RESULTS

Medicinal plants used for the study
Medicinal plants with anti-malarial activity used in this study include *Morinda lucida* Benth., *Psidium guajava* L., *Mangifera indica* L., *Vernonia amygdalina* Delile., *Citrus paradisi* L., *Tithonia diversifolia* A. Grey. *Rauwolfia vomitoria* Afzel., *Khaya senegalensis*. Scientific, family, local and common names of the plant and parts used are presented in Table 1.

Plant parts used as anti-malarial
The number of parts for each plant used as anti-malarial in this study is presented in Table 2. Three (3) plant parts, namely leaf, bark and root, were recorded to be used as anti-malarial for *Citrus paradisi* L. and four (4) for *Rauwolfia vomitoria* Afzel., *Psidium guajava* L., *Mangifera indica* L. while leaf and twig of *Tithonia diversifolia* were used and one (1) plant part was recorded for *Vernonia amygdalina* A. Grey. and *Khaya senegalensis* Desr (bark). Quantitative phytochemical analysis of the leaf, bark and root of anti-malarial plants in this study revealed the presence of medicinally active constituents in various quantities in the different plant parts analysed.

Quantitative phytochemical analysis of the leaf
The quantitative estimation of the crude phytochemical constituents in the leaf showed that the highest and the least amounts of tannins were recorded in *Mangifera indica* and *Citrus paradisi*; alkaloids-*Psidium guajava* and *Mangifera indica*; flavonoids - *Mangifera indica* and *Citrus paradisi*; terpenoids-*Psidium guajava*, *Khaya senegalensis* and *Citrus paradisi*; saponins- *Tithonia diversifolia* and *Vernonia amygdalina*; phenolic acids - *Vernonia amygdalina* and *Khaya senegalensis* (Table 3).

Quantitative phytochemical analysis of the bark
Quantitative crude phytochemical constituents in the stem bark of plants used in this study revealed that the highest and the least amounts of tannins were recorded in *Tithonia diversifolia* and *Citrus paradisi /Vernonia amygdalina*; alkaloids - *Mangifera indica* and *Vernonia amygdalina*; flavonoids - *Mangifera indica* and *Rauwolfia vomitoria*; terpenoids - *Psidium guajava* and *Tithonia diversifolia*; saponins- *Tithonia diversifolia* and *Psidium guajava*; phenolic acids; *Morinda lucida* and none was present in *Vernonia amygdalina* and *Citrus paradisi* (Table 4).

Quantitative phytochemical analysis of the root
In the roots of the plants used for this study, the highest and least amounts of quantitative phytochemical constituents recorded were as follows: tannins-*Psidium guajava* and *Tithonia diversifolia*; alkaloids - *Psidium guajava* and *Vernonia amygdalina*; flavonoids - *Vernonia amygdalina* and *Morinda lucida*; terpenoids – *Khaya senegalensis* and *Rauwolfia vomitoria /Tithonia diversifolia*; saponins- *Mangifera indica* and *Tithonia diversifolia*; phenolic acids-*Citrus paradisi* and *Morinda lucida* (Table 5).
Table 1: Medicinal plants with anti-malarial activity employed in this study

<table>
<thead>
<tr>
<th>S/No</th>
<th>SCIENTIFIC NAME</th>
<th>FAMILY NAME</th>
<th>LOCAL NAME</th>
<th>COMMON NAME</th>
<th>PARTS USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Morinda lucida Benth</td>
<td>Rubiaceae</td>
<td>Oruwo</td>
<td>Brimstone tree</td>
<td>Stem, Bark, leaves</td>
</tr>
<tr>
<td>2</td>
<td>Psidium guajava L.</td>
<td>Myrtaceae</td>
<td>Gilofa</td>
<td>Guava</td>
<td>Stem, Bark, leaves</td>
</tr>
<tr>
<td>3</td>
<td>Mangifera indica L</td>
<td>Anacardiaceae</td>
<td>Mangoro</td>
<td>Mango</td>
<td>Stem, Bark, leaves</td>
</tr>
<tr>
<td>4</td>
<td>Vernonia amygdalina Del.cent</td>
<td>Asteraceae</td>
<td>Ewuro</td>
<td>Bitterleaf</td>
<td>Leaves</td>
</tr>
<tr>
<td>5</td>
<td>Citrus paradise</td>
<td>Rutaceae</td>
<td>Osan-gerepu</td>
<td>Grape</td>
<td>Leaves, stem, roots</td>
</tr>
<tr>
<td>6</td>
<td>Tithonia diversifolia A.Grey</td>
<td>Asteraceae</td>
<td>Jogbo, Agbale</td>
<td>Tree marigold</td>
<td>Leaves, twigs</td>
</tr>
<tr>
<td>7</td>
<td>Rauwolfia vomitoria Afzel</td>
<td>Apocynaceae</td>
<td>Asofeyeye</td>
<td>Swizzle stick</td>
<td>Root, bark, leaves, seeds</td>
</tr>
<tr>
<td>8</td>
<td>Khaya senegalensis Desr</td>
<td>Meliaceae</td>
<td>Oganwo</td>
<td>Mahogany</td>
<td>Bark</td>
</tr>
</tbody>
</table>

Table 2: Frequency of the parts used as anti-malarial

<table>
<thead>
<tr>
<th>Family name</th>
<th>Frequency of part used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morinda lucida Benth</td>
<td>3</td>
</tr>
<tr>
<td>Psidium guajava L.</td>
<td>3</td>
</tr>
<tr>
<td>Mangifera indica L</td>
<td>3</td>
</tr>
<tr>
<td>Vernonia amygdalina Del.cent</td>
<td>1</td>
</tr>
<tr>
<td>Citrus paradise</td>
<td>3</td>
</tr>
<tr>
<td>Tithonia diversifolia A.Grey</td>
<td>2</td>
</tr>
<tr>
<td>Rauwolfia vomitoria Afzel</td>
<td>4</td>
</tr>
<tr>
<td>Khaya senegalensis Desr</td>
<td>1</td>
</tr>
</tbody>
</table>

The frequency of plant part used, represented in percentage, showed that leaf recorded the highest frequency of use (54%), followed by bark (31%) while root had the least (15%) (Figure 1).
Table 3: Phytochemical composition of leaves of some plant species

<table>
<thead>
<tr>
<th>Plant</th>
<th>Part</th>
<th>Tannins (mg/kg GAE)</th>
<th>Alkaloids (mg/kg GAE)</th>
<th>Flavonoids (mg/kg GAE)</th>
<th>Terpenoids (mg/kg GAE)</th>
<th>Saponins (mg/kg GAE)</th>
<th>Phenolic acids (mg/kg GAE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus paradisi</td>
<td>Leaf</td>
<td>83.7±0.6d</td>
<td>1350.0±2.0e</td>
<td>120.0±0.0f</td>
<td>7.7±2.5e</td>
<td>480.0±2.0e</td>
<td>11.3±0.6d</td>
</tr>
<tr>
<td>Khaya senegalensis</td>
<td>Leaf</td>
<td>168.3±1.5ab</td>
<td>4440.0±5.0b</td>
<td>1234.7±0.6b</td>
<td>164.0±1.0a</td>
<td>2060.0±5.0b</td>
<td>3.0±0.0e</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>Leaf</td>
<td>176.3±1.5a</td>
<td>790.0±2.0f</td>
<td>4520.0±10.0a</td>
<td>162.7±2.5a</td>
<td>397.0±5.2f</td>
<td>65.0±1.0a</td>
</tr>
<tr>
<td>Morinda lucida</td>
<td>Leaf</td>
<td>159.0±2.0c</td>
<td>3060.3±2.5cd</td>
<td>1060.3±2.5c</td>
<td>148.7±1.5b</td>
<td>1190.0±10.0c</td>
<td>64.0±1.0ab</td>
</tr>
<tr>
<td>Psidium guajava</td>
<td>Leaf</td>
<td>152.0±1.0c</td>
<td>7140.0±2.0a</td>
<td>320.0±2.0e</td>
<td>164.0±1.0a</td>
<td>300.0±5.0g</td>
<td>46.0±2.0c</td>
</tr>
<tr>
<td>Rauwolfia vomitoria</td>
<td>Leaf</td>
<td>174.7±1.5a</td>
<td>3290.3±2.5c</td>
<td>150.0±0.0f</td>
<td>157.3±2.5a</td>
<td>560.0±10.0d</td>
<td>63.0±3.0ab</td>
</tr>
<tr>
<td>Tithonia diversifolia</td>
<td>Leaf</td>
<td>159.0±1.5c</td>
<td>2860.0±3.0d</td>
<td>700.0±2.0d</td>
<td>40.0±2.0d</td>
<td>8220.0±5.0a</td>
<td>61.0±1.0b</td>
</tr>
<tr>
<td>Vernonia amygdalina</td>
<td>Leaf</td>
<td>174.0±1.0a</td>
<td>2710.0±0.0d</td>
<td>1215.0±3.0b</td>
<td>97.7±2.5Ac</td>
<td>300.0±5.0C</td>
<td>71.0±1.0a</td>
</tr>
</tbody>
</table>

Figures are expressed as mean ±SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability.

Table 4: Phytochemical composition of stem bark of some plant species

<table>
<thead>
<tr>
<th>Plant</th>
<th>Part</th>
<th>Tannins (mg/kg GAE)</th>
<th>Alkaloids (mg/kg GAE)</th>
<th>Flavonoids (mg/kg GAE)</th>
<th>Terpenoids (mg/kg GAE)</th>
<th>Saponins (mg/kg GAE)</th>
<th>Phenolic acids (mg/kg GAE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus paradisi</td>
<td>Bark</td>
<td>12.0±2.0d</td>
<td>3020.3±2.5c</td>
<td>974.7±2.5e</td>
<td>85.0±5.0d</td>
<td>570.3±2.5e</td>
<td>0.0±0.0d*</td>
</tr>
<tr>
<td>Khaya senegalensis</td>
<td>Bark</td>
<td>125.7±3.5b</td>
<td>2589.7±0.6d</td>
<td>3035.0±5.0b</td>
<td>90.0±0.0d</td>
<td>28840.0±10.0a</td>
<td>51.0±1.0b</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>Bark</td>
<td>24.0±2.0c</td>
<td>7350.3±2.5a</td>
<td>4290.3±2.5a</td>
<td>116.3±1.5c</td>
<td>4529.7±4.5c</td>
<td>61.0±1.0a</td>
</tr>
<tr>
<td>Morinda lucida</td>
<td>Bark</td>
<td>159.0±2.0a</td>
<td>3060.3±2.5c</td>
<td>1060.3±2.5d</td>
<td>148.7±1.5b</td>
<td>1190.0±10.0d</td>
<td>64.0±1.0a</td>
</tr>
<tr>
<td>Psidium guajava</td>
<td>bark</td>
<td>152.0±1.0a</td>
<td>7140.0±2.0b</td>
<td>320.0±2.0C</td>
<td>164.0±1.0a</td>
<td>300.0±5.0f</td>
<td>46.0±2.0c</td>
</tr>
<tr>
<td>Rauwolfia vomitoria</td>
<td>Bark</td>
<td>13.0±2.0d</td>
<td>1300.0±5.0e</td>
<td>150.0±0.0C</td>
<td>157.3±2.5ab</td>
<td>560.0±10.0e</td>
<td>63.0±3.0a.</td>
</tr>
<tr>
<td>Tithonia diversifolia</td>
<td>Bark</td>
<td>159.0±1.5a</td>
<td>2860.0±3.0cd</td>
<td>700.0±2.0f</td>
<td>40.0±2.0e</td>
<td>8220.0±5.0b</td>
<td>61.0±1.0a</td>
</tr>
<tr>
<td>Vernonia amygdalina</td>
<td>bark</td>
<td>12.0±2.0d</td>
<td>729.7±4.5f</td>
<td>1515.3±4.5c</td>
<td>80.0±2.0df</td>
<td>1100.0±5.0d</td>
<td>0.0±0.0c*</td>
</tr>
</tbody>
</table>

Figures are expressed as mean ±SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability.
Flavonoids also act against oxidative stress, platelet aggregation, microbes, ulcers, hepatitis, viruses, and tumours (Okwu and Omodamiro, 2005; Okwu and Emenike, 2006). Flavonoids also act against oxidative stress-related diseases such as diabetes, cancer and allergies, inflammation, etc. Medicinal plants with anti-malarial activity used in this study include Morinda lucida Benth., Psidium guajava L., Mangifera indica L., Vernonia amygdalina Delile., Citrus paradisi, Mangifera indica L.; Tithonia diversifolia A. Grey., Rauwolfia vomitoria Afzel. and Khaya senegalensis Desr. Similar studies by Okello and Kang (2019) reported Mangifera indica, Psidium guajava, Tithonia diversifolia and Vernonia amygdalina. Silva et al. (2011) reported Vernonia amygdalina, Tithonia diversifolia and Morinda lucida while do Céu de Madureira et al. (2002) reported Vernonia amygdalina, Tithonia diversifolia and Morinda lucida as having anti-malarial properties.

The use of leaves, stem and roots of plants as a potential source of malarial treatment has also been reported by Ungogo et al. (2020), Adebayo and Kretti (2011) and Bankole et al. (2016). The leaf is the most common plant part used as anti-malarial. The use of leaves of plants for medicinal purposes ensures that the plant is conserved. The phytochemical analysis of the leaf in this study revealed the presence of tannins, alkaloids, flavonoids, and terpenoids. The presence of tannins which are polyphenolic compounds could also mean that it is an astringent with wound-healing and anti-parasitic properties (Okhale et al., 2010). Tannins have also been reported to have anti-diarrhoeal activity (Enzo, 2007). The presence of tannins is likely to be responsible for the free radical scavenging effects (Ayyola et al., 2008). Tannins have also been reported to demonstrate significant activity against chloroquine-sensitive strain of Plasmodium berghei in mice (Jigam et al., 2010).

Alkaloids are the most efficient therapeutically significant plant substances (Ayoola and Adeyeye, 2010). Alkaloids are amino acid derivatives and their pharmacological effects could be associated with the inhibition of nucleic acid, protein and membrane phospholipid biosynthesis (Shelton, 1991). Pure isolated alkaloids and their synthetic derivatives are used as basic medicinal agents because of their analgesic, anti-spasmodic and anti-bacterial properties (Stray, 1998). Many alkaloids have pharmacological effects and have been used to treat diseases like malaria and in managing heart diseases (Oomah, 2003). It has been reported that isolated alkaloid, 9 – methoxycanthin – 6 – one had higher anti-malarial activity against Plasmodium falciparum Gombak A isolate, when compared with chloroquine (Chan et al., 2004). The anti-oxidant effect of plant alkaloids may represent another mechanism that contributes to its anti-malarial activity. Flavonoids belong to a group of polyphenolic compounds found in fruits and vegetables (Walad-Kahni and Clemens, 2001). The group includes flavonols, flavanones, rutin, etc. The biological functions of flavonoids include protection against allergies, inflammation, platelets aggregation, microbes, ulcers, hepatitis, viruses and tumours (Okwu and Omodamiro, 2005; Okwu and Emenike, 2006). Flavonoids also act against oxidative stress-related diseases such as diabetes, cancer and allergies, inflammation, etc.
coronary heart disease (Burits and Bucar, 2002; Ayoola et al., 2008). In addition to their free-radical scavenging activity, flavonoids have anti-bacterial, anti-fungal and anti-viral effects.

Certain common dietary flavonoids have been reported to inhibit the intra-erythrocytic growth of the chloroquine-sensitive and chloroquine-resistant strain of Plasmodium falciparum (Lehane and Saliba, 2008). The antimalarial activity of flavonoid derivatives has also been reported (Ferreira et al., 2010). Terpenoids have been reported to possess anti-bacterial, anti-fungal and anti-parasitic activities (Cowan, 1999) as well as anti-tumour activities (Guang-Zhong et al., 2007). Terpenes have also been reported to arrest the parasite development and inhibit biosynthesis of Isoprenoids in Plasmodium falciparum (Goulart et al., 2004). The inhibitory effects of terpenes on the intra-erythrocytic stages of Plasmodium species have been shown to appear specific (Goulart et al., 2004; Su et al., 2008); for example, monoterpenes like limonene arrests development at the ring stage while Nerolidol prevents parasites from developing past the trophozoite stage. Also, the monoterpenes 1, 8 cineole present in Eucalyptus oil has been reported to inhibit the growth and development of chloroquine-sensitive and chloroquine-resistant Plasmodium falciparum at their trophozoite stage and the minute concentrations required for these effects make it suitable for drug development (Su et al., 2008).

Saponins are naturally occurring surface-active glycosides, with a distinctive foaming characteristic. The use of saponins as dietary supplements, expectorants and anti-inflammatory agents has been reported (Xu et al., 1996; Marjan et al., 2008). Saponins are also used to control human cardiovascular diseases and to reduce blood cholesterol (Aletor, 1993). The hypoglycaemic, anti-fungal, anti-microbial, anti-cancer, anti-bacterial, analgesic, immunomodulatory, anti-oxidant and anti-malarial activities of saponins have been reported by Desai et al., (2009). Phenolic acids are widely distributed in plants and their quantities vary among the different plant parts and with temperature during the development stage (Singh et al., 2010). It has been reported that the antioxidant activity of phenolic acids is mainly due to their redox properties, hydrogen donors and singlet oxygen quenchers (Nagulendran et al., 2007). The presence of phenolic acids has been reported to confer anti-bacterial and anti-viral effects (Okhale et al., 2010). They are also considered to be bacteriostatic and fungstatic (Okwu and Iroabuchi, 2001; Okwu and Morah, 2007). In addition, phenolics, which are also known to possess anti-parasitic, anti-carcinogenic, anti-inflammatory and immunomodulatory effects, may also play a significant role in the antimalarial activity of plant extracts (Abdulelah and Zainal-Abidin, 2007)

CONCLUSION AND RECOMMENDATION

Results from this study have shown that these plants are rich in phytochemicals which occur in various quantities in the different parts analysed. The high concentration of phytochemicals observed in the leaves confirms their frequent use in traditional medicine for the treatment of malaria. It is, therefore, concluded that phytochemical composition is fundamental to understanding modes and mechanisms of action of medicinal plants in general. Since different parts of some plants have different clinical indications or therapeutic applications, it is important to establish quantitatively the plant raw materials for its constituent plant part composition. This study, therefore, serves as an important step towards intensifying research in the areas of development of new antimalarial drugs especially from medicinal plants in Nigeria.

REFERENCES


