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REVIEW

Cite this: DOI: 10.1039/x0xx00000x

The uniqueness and therapeutic value of natural products from West African medicinal plants, part III: Least abundant compound classes

Received 05th June 2014,
Accepted xxth July 2014

DOI: 10.1039/x0xx00000x

www.rsc.org/npr

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Covering: 1971 to 2014

In this review, a continuation of our in depth coverage of natural products derived from West African medicinal plants with diverse biological activities has been given. In the previous parts of this review series, the most abundant bioactive compounds classes; terpenoids, flavonoids and alkaloids from West Africa were thoroughly investigated. We now focus on the least abundant compound classes (quinones, steroids, phenolics, glycosides, and other classes) having remarkable biological activities. A correlation between biological activities of the derived compounds and the uses of the plants in African traditional has been established.

1 Introduction

Plants have been used by large number of population for various purposes since the existence of human civilization,[1-4] including healthcare, food, clothing, shelter, agriculture, agrochemicals, pharmaceuticals, narcotics, etc. The traditional uses of plants is generally referred to as ethnobotany.[5,6] According to the World Health Organization (WHO) traditional medicine strategy for 2014-2023, traditional medicine (TM) has a long history and is defined as the sum total of the knowledge, skill and practices based on the theories, beliefs and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness.[7,8] This knowledge became enriched over numerous generations due to experimentation as well as through observations of animal behaviour.[5,9] The knowledge of African traditional medicine (ATM) is facing the danger of being lost in favour of Western medicine (WM), as there is little little communication between the age of traditional healers on the number of species reported and the scientific community. Moeover, the method of transmission of indigenous knowledge is similar (inherited orally).[10,11] In developing or poorest countries in the world (mostly in Africa, Asia and Latin America), access to WM is limited. Consequently, most families have resorted to traditional medicine, based on various plant extracts. This has rendered TM the most affordable and easily accessible source of treatment in the primary healthcare system for poor communities. This local therapy remains the most reliable means of medical treatment for such communities.[10]

It is estimated that about 80 % of the populations in some Asian, Latin American and African countries depend on TM for their primary healthcare,[12-15] and some of these plants have been documented in journal articles, as well as in MSc and PhD theses in university libraries.[12,16] In traditional African societies, phytotherapy is highly valued and widely utilised. Thus, the majority of the populations use plant materials as their sources of primary healthcare.[17] The importance of the useful aspects of traditional medicine and practices being incorporated to healthcare delivery at primary healthcare level has been the subject of many studies.[18,19] In the last two and a half decades, drug discovery utilizing ethnopharmacological and traditional

uses of herbal remedies have particularly received a lot of attention in Africa.[20] It is well known that traditional healers make use of a large variety of herbs in the treatment of several ailments. A wide proportion of herbal remedies dispensed by traditional healers are widely believed by their clients to be effective, thus the practice of TM in Africa is mostly driven by habits, low purchasing power and belief systems.[21,22] Phytochemical investigation of the plant species, based on the ethnobotanical knowledge may provide the chemical lead for the discovery of a new generation drug molecules or as hits/leads for synthetic modifications that should lead to more potent or less toxic analogues with improved drug metabolism and pharmacokinetic (DMPK) profiles.[9,23-25]

African flora has a huge potential and remains an interesting reservoir for new drugs targeting a variety of diseases.[12] This is because the region is highly diverse ethnobotanically and these plants are used in the treatment of several diseases as a common practice in Africa.[25,26] Recent review papers on the potential of natural products (NPs) isolated from African medicinal plants have been focused on particular plant families, genera or species,[27-32] particular diseases[33-35] and particular countries or regions.[34,36-38] It is believed that, the derived NPs holds enormous potential for drug discovery.[12] Due to the diverse use of these plants in TM practices, research groups in Africa have embarked on extraction, bioassay-guided fractionation, isolation and characterisation of bioactive metabolites from the plants commonly used in ATM,[39-44] with the view of identifying the active ingredients, which might have implications in drug discovery program.[45-48]

West Africa is a natural environment which consists of subtropical and tropical regions with semi-arid and humid climates, occupying an area of over 6,140,000 km^2, including sixteen countries.[49] The floral diversity in West Africa and the wide use against many diseases, extending from endemic tropical diseases such as malaria,[50-56] trypanosomiasis[9,55-59] and leishmaniasis,[60-62] to complex illnesses like asthma,[63] psychosis,[64,65] hepatitis,[66,67] diabetes[68,69] and cancer[70,71] is well documented. Unique NPs isolated from West African flora have been reviewed and published in the first part of this series of review.[45] The objective of the present review is to highlight the least abundant molecular compound classes from West African flora, along with a correlation between the biological activities of the derived compounds and the uses of the plants in ATM.

2 Ethnobotany *versus* bioactivity survey

The biological activities of the selected compounds, along with the ethnobotanical uses of the plants from which they were derived have been summarised in Tables 1 to 5. Whenever there is a correlation between bioactivity and ethnobotany, these have been highlighted in bold in the tables. The discussion that follows is arranged according to the various compound classes identified, with a focus on quinones, steroids, phenolics, glycosides and other compound classes from West African flora.

2.1 Quinones

Quinones are widely distributed among plant genera in Africa, including the *Vismia* species (Guttiferae), *Tectona* species (Lamiaceae) and *Psorospermum* species (Guttiferae). The summary of the most important findings on bioactive quinones from West African flora are given in Table 1.

Abrus precatorius (Fabaceace) is a perennial shrub and the seed commonly known as rosary beads is widely used traditionally for several medicinal purposes in Africa, US and Asia for a wide range of pharmacological possibilities.[72,73] Muhammad and Amusa investigated and reported the use of the stem bark of *Abrus precatorius* in the treatment of malaria.[74] Limmatvapirat *et al*. isolated abruquinone B (**1**) from the stem bark of this plant, which showed *in vitro* anti-plasmodial activity, with IC_{50} = 1.5 µg/mL against the K1 strain of *P. falciparum*.[75]

Diosquinone (**2**), isolated from the roots of *Diospyros mespiliformis* (Ebenaceae), has shown very good anticancer activity against all the cell lines tested with ED_{50} values ranging between 0.18 µg/mL against Human Glioblastoma (U373) and 4.5 µg/mL against hormone dependent human prostate cancer (LNCaP).[76] The relationship with the ethnobotanical use of this plant has not however been established as the leaf decoction has been used for the treatment of whooping cough and root extracts used as worm expellants. The use of the leaves and stem bark of *Cassia siamea* have been reported in the treatment of malaria.[77] Investigation of the leaves of this plant by Morita *et al*.[78] and Oshimi *et al*.[79] led to the isolation of emodin or 1,6,8-trihydroxyl-3-methyl-anthraquinone (**3**).

Aframomum danielli (Zingiberaceae), also known as alligator pepper, is most common in tropical and subtropical regions where it is used traditionally as a food spice and also as an anti-inflammatory agent and in crop protection.[80] The long chain polypropenyl benzoquinone derivatives; phytyl plastoquinone (**4**) and heptaplastoquinone(**5**) have been isolated from the active petrol and alcohol extracts.[81] Both compounds inhibited 5-lipoxygenase at 6.25 and 18.5 µM respectively, as compared to Fisetin (the standard drug) which inhibited the enzyme at 0.92 µM.

2.2 Steroids

Among the bioactive steroids derived from West African flora as summarised in Table 2., are those from *Alchornea cordifolia* (Euphorbiaceae). This plant is used locally as traditional remedy for arthritis, muscle pain and other inflammatory disorders.[82] The crushed leaves are usually rubbed on painful joints or made into paste and applied to painful stingray wounds, as they are claimed to possess remarkable anti-inflammatory and pain-relieving properties. Ethyl iso-allocholate (**6**) isolated from the leaves of *A. cordifolia*

possesses anti-inflammatory effect, which have been well documented.[83-86]

Loranthus micranthus (Loranthaceae) is widely used in folkloric medicine as an immunostimulant, antioxidant etc. Recent research report for this practice have provided preliminary scientific evidence.[87,88] The stigmastane steroids; stigmast-7,20 (21)-diene-3β-hydroxy-6-one (**7**) and 3β-hydroxystigmast-23-ene (**8**)) at the highest concentration of 100 mg/mL showed statistically significantly ($p < 0.05$) stimulatory activity on the C57B1/6 splenocytes.[86]

2.3 Phenolics

Bioactive phenolics from West African flora have been isolated from across a broad range of plant species and families (Table 3). Among these phenolic compounds is ellagic acid (**9**),[89] identified from the stem of *Alchornea cordifolia* (Euphorbiaceae); responsible for its antimalarial activity.[34,55]

Loranthus micranthus (Loranthaceae) grows on many host trees,[90,91] and the leaves are traditionally used in folkloric medicine for the treatment of several ailments such as diarrhea, epilepsy, hypertension and rheumatism.[92] Compounds **10** to **19** have been isolated from the leaves of this plant from Nigeria and their antioxidant activities were evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, with IC_{50} values varying from 23.8 to 50.1 µM; all being more active than the reference drug chlorogenic acid (with IC_{50} = 67.9 µM).[93] Vassallo *et al*. also investigated antioxidant flavonoid glycosides from *Chrozophora senegalensis*, also known as *Croton senegalensis* (Euphorbiaceae) harvested in Mali.[94] It is a small tree widely distributed in Mali and is used in folk medicine for the treatment of diarrhoea, rheumatism, teniasis, stomach ache, rachitis, and venereal diseases. The leaf and root decoctions are also drunk for hairloss.[95,96] In order to justify the ethnobotanical use of *C. senegalensis*, the leaf extracts were assayed for *in vitro* antioxidant activity. Bioassay-guided fractionation revealed the methanol extract to be active. Separation of this extract led to the isolation of three new flavonoids, along with known flavonoids, a phenolic derivative, 4-hydroxyphenyl-*O*-α-L-rhamnopyranosyl-(1→6)-β-*D*-glucopyranoside (**20**) and three megastigmane glycosides. All isolated compounds were tested for their antioxidant activity on DPPH stable radical, superoxide anion, metal chelating activity and DNA cleavage induced by the photolysis of H_2O_2.

The antioxidant activity of caffeic acid (**21**), derived from fruits and leaf of *Spathodea campanulata* (Bignoniaceae), popularly known as African tulip tree, has been used to endorse the use of the plant in South Western Nigeria for ulcer treatment by drinking the decoction of its stem bark.[97] *Securinega virosa* (or *Flueggea virosa*) is a small tree widely distributed in Mali[98,99] and is used in traditional medicine for many diseases, including diarrhoea, rheumatism, malaria, liver disease, inflammation and pain. Antioxidant bioassay-guided fractionation of *S. virosa* methanol extract by Sanogo *et al.*, led to the isolation of 11-*O*-caffeoylbergenin (**22**) and other compounds.[100] Among these compounds; 11-*O*-caffeoylbergenin (**22**), kaempferol 3-*O*-(4-galloyl)-β-*D*-glucopyranoside and glucogallin exhibited the highest antioxidant capacity, being also able to modulate hydroxyl radical formation more efficiently than the other compounds, acting as direct hydroxyl radical scavengers and chelating iron.

Idowu *et al*.[101] identified procyanidin A2 (**23**), ixoratannin A-2 (**24**), cinnamtannin B-1 (**25**) and other constituents from *Ixora coccinea* (Rubiaceae) leaves. The antioxidant properties of the identified compounds were also investigated. This revealed that ixoratannin A-2 (**24**), cinnamtannin B-1 (**25**) were the most active compounds in DPPH, inhibition of lipid peroxidation and nitric oxide radical scavenging assays. This could explain why the plant is effective in the treatment of chronic ulcers.[101,102]

2.4 Glycosides

Ximenia americana (Olacaceae) is widely distributed in Africa from Senegal to West Cameroon and in tropical America and Asia as a shrubby tree which can grow up to 5m high.[103] The use of roots and leaves has been reported for the treatment of various ailments such as throat infection, malaria, dysmenorrhea, wound healing, leprotic ulcers and skin diseases.[104-106] Sambunigrin (**26**) was found to be the main compound in the EtOAc extract of this plant and showed strong inhibitory effect of 15-lipoxygenase and xanthine oxidase.[107]

From *Chrozophora senegalensis* (described above) three megastigmane glycosides; roseoside (**27**), icariside B5 (**28**) and ampelopsisionoside (**29**) were isolated and tested for their antioxidant activity on DPPH stable radical, superoxide anion, metal chelating activity and DNA cleavage induced by the photolysis of H_2O_2.[94] The antioxidant activities of compounds **30** to **32** isolated from the flowers, fruits, leaf and stem bark of *Spathodea campanulata* (Bignoniaceae), were also investigated by Elusiyan *et al*.[97] It was shown that the antioxidant principles isolated from the various parts of the plant are verminoside (leaf, stem bark and flowers; EC50 = 2.04 µg/ml), specioside (**30**) from the flowers, with EC_{50} = 17.44 µg/ml, Kampeferol diglucoside from the leaves, with EC_{50} = 8.87 µg/ml) and caffeic acid (**21**) from the leaves and fruits. The non anti-oxidant components isolated in the study include ajugol (from the stem bark and fruits) and phytol (from the leaves).[97]

Russelia equisetiformis (Fabaceae) is a medicinal plant used by traditional healers to treat malaria, cancer, inflammatory diseases, analgesic and to stabilize membranes.[108,109] Awe *et al*.[110] studied and examined the ethylacetate (most active) fraction for its antinociceptive effect, and from it isolated russetinol (**33**) and russelianoside A (**34**). Compounds **33** and **34** both displayed tremendous activity on acetic acid induced writhing with less activity on tail-flick response in mice. This

result confirms the traditional uses of *R. equisetiformis* in the treatment of inflammation and pain.

2.5 Other compound classes

Table 5 is a summary of other bioactive compounds isolated from the West African flora. *Allium sativum* (Alliaceae), commonly known as garlic, is a plant that is traditionally used in Nigeria for the treatment of malaria,[34,111] among diverse uses.[68,112] From this plant, ajoene (**35**) and allicin (**36**) have been isolated. Ajeone was active against *Plasmodium berghei* in mice,[113] thus validating the ethnobotanical use of the plant, while allicin was reported as a *P. falciparum* cysteine protease inhibitor.[114]

Investigation of the leaves of *Cassia siamea* (Leguminosae) led to the isolation of emodin (**37**).[77] This plant is traditionally used in the treatment of malaria. In Asia, stem bark is used as a mild, pleasant, safe purgative; to treat diabetes; the paste is used as a dressing for ringworm and chilblains; the roots are used as an antipyretic; and the leaves are used for the treatment of constipation, hypertension, and insomnia.[115,116] *Guiera senegalensis* (Combretaceae) is commonly used in treatment of malaria**,** fevers, hepatitis, diabetes, malaria, pain, chemoprevention and anti-*Helicobacter pylori* while the external application of dried leaves on wounds and infusion of leaves for the treatment of measles.[117-119] The leaf extract of this plant harvested in Mali led to the isolation of guieranone A (**38**), as one of the active principles.[118,119]

Among the compounds isolated from *Quassia amara* (Simaroubaceae) are simalikalactone D (**39**), samaderine X (**40**), samaderine Z (**41**), samaderine B (**42**) and samaderine E (**43**) with anti-plasmodial activities.[120-122] This could explain the use of leaves and stem of this plant for anti-malarial preparations. *Q. amara* (also called bitterwood tree) displayed the highest anti-malarial reputation for curative and preventive purposes in the Simaroubaceae family.[113,120]

Bryophyllum pinnatum (Crassulaceae) has diverse uses in ATM most especially for the treatment of ulcers, allergic inflammation and epilepsy.[123,124] Gallic acid (**44**) have been identified as the main active principles responsible for the antibacterial activity of this plant, which explains why it is used in many West African traditional medicinal recipes for the treatment of ulcers.[125] From *Ximenia americana* (described above and in the part I of this review series).[47] Gallic acid has also been isolated from this plant, alongside the gallotannins; β-glucogalline (**45**) and 1,6-digalloyl-β-glucopyranose(**46**).[107]

Alchornea floribunda and *Alchornea cordifolia* (Euphorbiaceae) are used locally as traditional remedy for malaria, arthritis, muscle pain and other inflammatory disorders.[82] The crushed leaves are usually rubbed on painful joints or made into paste and applied to painful stingray wounds because of its local as well as the systemic anti-inflammatory properties. Various extracts and fractions of *A. floribunda* and *A. cordifolia* have been validated by the results of some pharmacological studies.[83,126-128] Okoye *et al*.[129] reported the isolation and identification of compounds **47** - **61** from the *n*-hexane fractions of *A. floribunda* and *A. cordifolia* leaves with topical anti-inflammatory properties. This could be used to validate the work of Mavar-Manga *et al*.[130] were it was shown that, the topical anti-inflammatory effect of *A. cordifolia* is due to highly lipophilic constituents of the *n*-hexane fraction of the leaf extract. It also validates the claimed ethnomedicinal use of crushed leaves of *A. cordifolia* and *A. floribunda* in topical management of arthritis and other inflammatory diseases.

The compound, 9-acetoxynerolidol (**62**) have been isolated as the main active ingredient from the seed extract of *Jatropha gossypifolia* (Euphorbiaceae).[88] This plant is used to treat various disease conditions such as cough, tuberculosis, bacterial infections, boils, carbuncles, eczema, itches and cancerous growths.[131,132] *Cajanus cajan* is used in cancer treatment. The two constituent stilbenes, longistylins A (**63**) and C (**64**), isolated from the active dichloromethane (CH_2Cl_2) fraction of the leaves of this plant had IC_{50} values of 0.7-14.7 µM against a range of cancer cell lines.[131]

Mitracarpus scaber (Rubiaceae) is used in Benin and the neighboring countries of West Africa, traditionally as medicine to treat a variety of skin diseases such as eczema or ringworm.[133,134] Gbaguidi *et al*. verified the presence of 2-azaanthraquinone (**65**) in extracts and samples of *M. scaber* grown in Benin; to evaluate its antimicrobial activity against *D. congolensis* and reported it to have MIC value of 7.5 µg/mL.[135] Lagnika *et al*. isolated three compounds (methoxy-4-acetophenon, 3,4,5-trimethoxybenzoic acid and azaanthraquinone) from the alcoholic extract of *M. scaber* and evaluated their antibacterial and the free radical scavenging activities using the *p*-iodonitrotetrazolium method and the DPPH method.[136,137] Azaanthraquinone was the most interesting with MIC values of 7.5 µg/mL, 19 µg/mL, 38 µg/mL and 150 µg/mL on *Dermatophilus congolensis*, *Staphylococcus aureus*, *Enteroccocus feacalis*, *Escherichia coli* and *Pseudomonas aeruginosa*, respectively. All three compounds showed mild scavenging activity in the DPPH test, with IC_{50} values between 12 µg/mL and 45.74 µg/mL.

Kasim *et al*. investigated the leaves of *Struchium sparganophora* (Asteraceae), a plant used traditionally to treat malaria and measles.[138-140] The isolated compounds; luteolin, vernodalin (**66**) and 3-methyl,2,6-hexacosedienol (**67**) demonstrated antimicrobial activities against the bacteria *Staphylococcus aureus*, *Klebsiella aerogenes*, *Escherichia coli* and *Proteus vulgaris*, as well as against the fungal strains *Candida albicans* and *Aspergilus niger*.

Fagara macrophylla (Rutaceae) used traditionally as a remedy for several afflictions, in particular for the cure of toothache, rheumatism and urogenital affections as well as to prepare

poisonous arrows.[141,142] This plant is also known to be rarely attacked by insects.[143] The EtOH extract obtained from the bark of this plant led to the isolation and identification of Sesamin (**68**), magnoflorine (**68'**), a rare aporphine alkaloid, unique to West Africa, along with other secondary metabolites.[144]

Keetia leucantha is a West African tree used in traditional medicine to treat several ailments including parasitic diseases.[145] Twenty seven compounds were identified in the oil and their antitrypanosomal activity on *Trypanosoma brucei brucei* bloodstream forms (*Tbb* BSF) and procyclic forms (*Tbb* PF) were performed to identify their activity on the glycolytic process of trypanosomes. The oil showed an IC_{50} of 20.9 µg/mL on *Tbb* BSF and no activity was observed on *Tbb* PF. Three triterpenic acids and β-ionone (**69**) showed inhibitory activities on GAPDH with oleanolic acid being the most active with an inhibition of 72.63 % at 20 µg/mL.[146]

Dennettia tripetala (Annonaceae) is a medium-size tree and is widely distributed in rain tropical forest of some West-African countries. The leaves are used as spices for special local dishes, while the ethanolic extract has been used traditionally in Nigeria to combat the growth of *Ostrinia nubilaris* that affects significantly corn, cotton as well as other vegetable crops.[147,148] Oyemitan *et al*. investigated the hypnotic, anti-convulsant and anxiolytic effects of 1-nitro-2-phenylethane (**70**) obtained from the oil of this plant and established its mechanism of action.[149]

Sorghum spp (Poaceae) cultivated worldwide are rich in polyphenols belonging to the flavonoids and phenolic acid families and is ranked as the fifth in cereals global production.[150] *Sorghum bicolor* is medicinally use for malaria, fever, blood tonic and sickle-cell in Nigeria and other West Africa countries.[1,151] Extraction of the plant's leaf sheath by Khalil *et al*. using a mixture of 1,3-butanediol and ethanol led to the isolation of 8-hydroxy-2-(4'-hydroxyphenyl)-5-(4''-hydroxyphenyl)-pyrano[4,3,2-*de*]1-benzopyrylium (**71**).[152] The antibacterial activity of 4-butylamine-10-methyl-6-hydroxycannabinoid dronabinol **(72)** isolated from *Cassia alata* (Leguminosae), could explain the use of this plant in the treatment of ulcers, amongst other skin diseases.[153]

3 Conclusions

In this review series, emphasis has been laid on NPs derived from medicinal plants from West Africa, whose experimentally measured bioactivities have been used to validate the ethnobotanical uses of the plant species from which they were derived. The entire study showed that about 700 NPs from 97 plant species grouped into 41 families, exhibiting diverse biological activities. How these plants and/or derived NPs could be employed in drug discovery programs now depends on a number of factors. It becomes important to properly address the most critical issues involved, seeing that most of the research is currently being carried out by mainly academic groups. Research projects funded *via* collaborative programs tailored such that the African researchers play more than just the role of plant sample collectors need to be set up. Synergistic effects, such as those being promoted by the African Network for Drugs and Diagnostic Innovations ANDI[154,155] may be the promising way forward, since the most 'equipped' laboratories in Africa barely host enough instrumentation to be able to perform extractions and purifications. Another approach would be to set up national and regional repositories for readily affordable samples for biological screening, like that of the pan-African natural products library (p-ANAPL).[156]

4 Acknowledgements

Financial support is acknowledged from Lhasa Ltd, Leeds, UK through the Chemical and Bioactivity Information Centre (CBIC), University of Buea, Cameroon.

5 Notes and references

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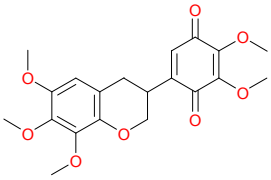

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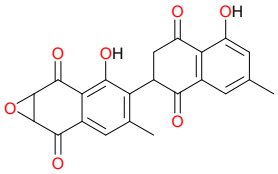

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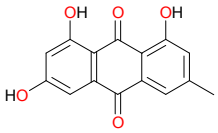
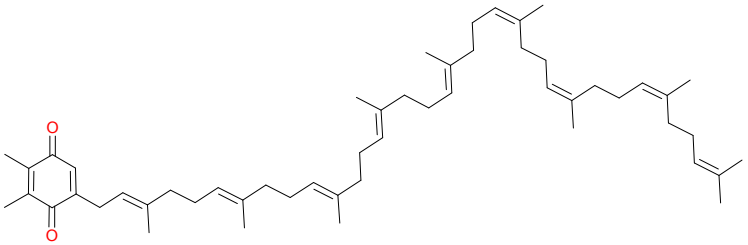
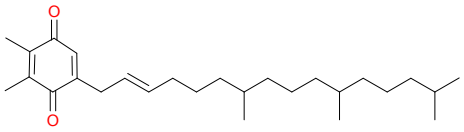


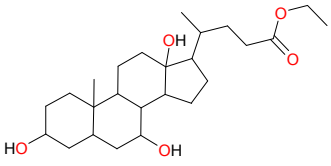
Emodin or 1,6,8-Trihydroxyl-3-methyl-anthraquinone (**3**)



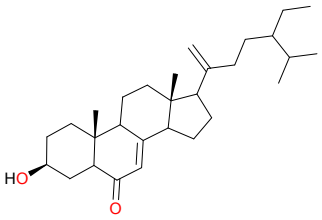
Phytyl plastoquinone(**4**)



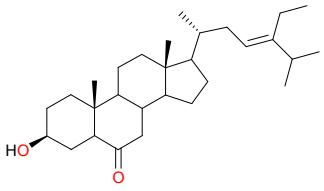
Heptaplastoquinone(**5**)



Ethyl iso-allocholate (**6**)



Stigmast-7,20 (21)-diene-3β-hydroxy-6-one (**7**)



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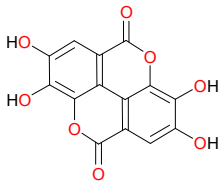

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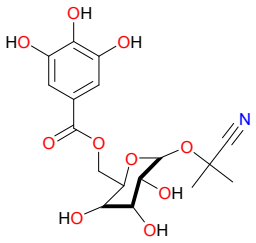
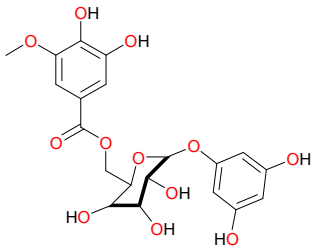
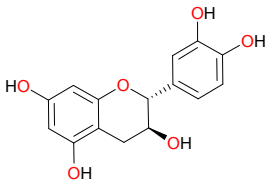


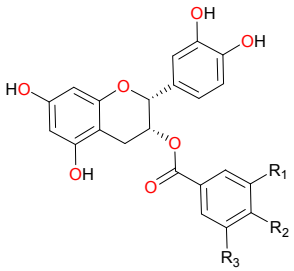
Linamarin gallate (**10**)



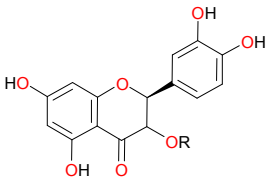
Walsuraside B (**11**)



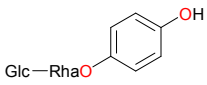
Catechin (**12**)



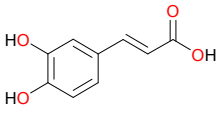
Epicatechin-3-*O*-gallate (**13**): $R_1 = R_2 = R_3 = OH$
Epicatechin-3-*O*-(3-*O*-methyl) gallate (**14**):
$R_1 = R_2 = OH$, $R_3 = OCH_3$
Epicatechin-3-*O*-(3,5-*O*-dimethyl) gallate (**15**):
$R_1 = R_3 = OCH_3$, $R_2 = OH$
Epicatechin 3-*O*-(3,4,5-*O*-trimethyl) gallate (**16**):
$R_1 = R_2 = R_3 = OCH_3$



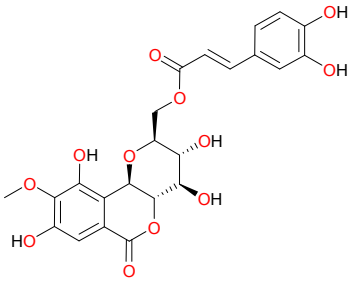
Quercetin 3-O-β-D-glucopyranoside (**17**) R = β-D-Glu
Rutin (**18**) R = α-L-Rha(1→6)-β-D-Glu
Peltatoside (**19**) R = α-L-Ara(1→6)-β-D-Glu



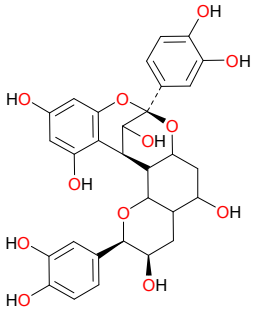
4-Hydroxyphenyl-*O*-α-L-rhamnopyranosyl-
(1→6)-β-D-glucopyranoside (**20**)



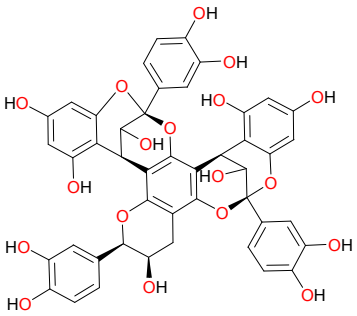
Caffeic acid (**21**)



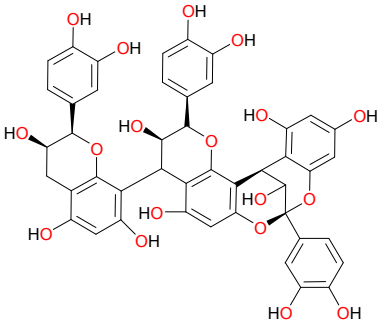
11-*O*-Caffeoylbergenin (**22**)



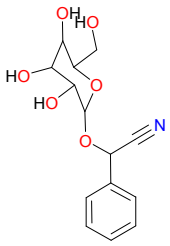
Procyanidin A2 (**23**)



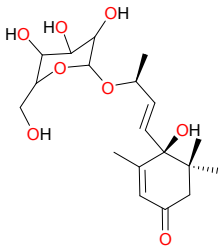
Ixoratannin A-2 (**24**)



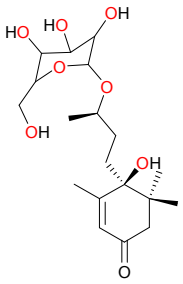
Cinnamtannin B-1 (**25**)



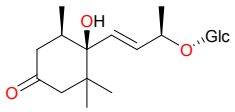
Sambunigrin (**26**)



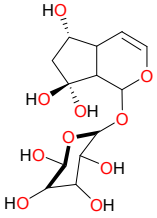
Roseoside (**27**)



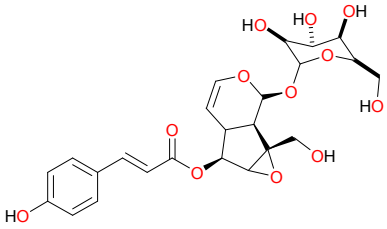
Icariside B5 (**28**)



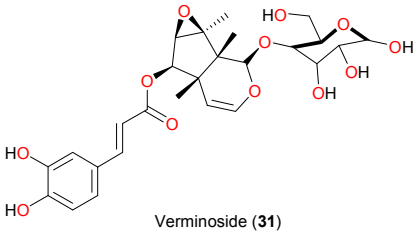
Ampelopsisionoside (**29**)



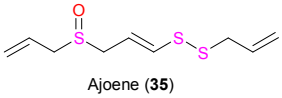
Ajugol (**32**)



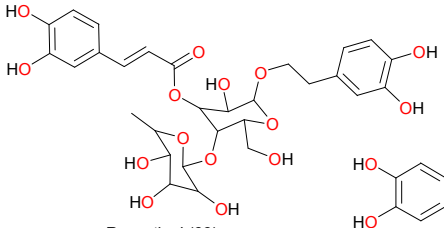
Specioside (**30**)



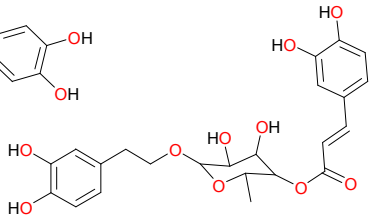
Verminoside (**31**)



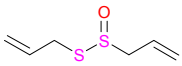
Ajoene (**35**)



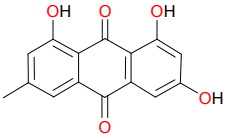
Russetinol (**33**)



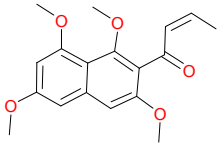
Russelianoside A (**34**)



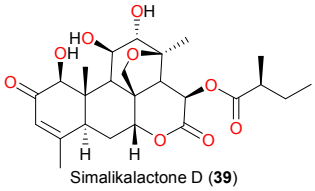
Allicin (**36**)



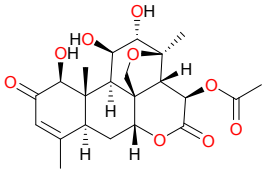
Emodin (**37**)



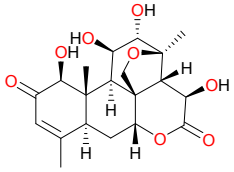
Guieranone A (**38**)



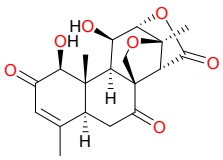
Simalikalactone D (**39**)



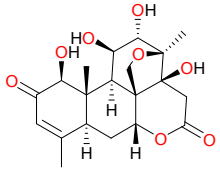
Samaderine X (**40**)



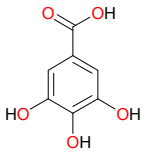
Samaderine Z (**41**)



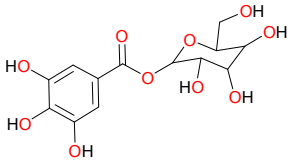
Samaderine B (**42**)



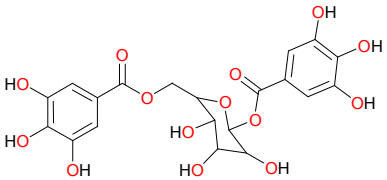
Samaderine E (**43**)



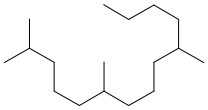
Gallic acid (**44**)



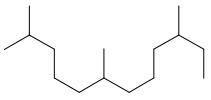
β-Glucogalline (**45**)



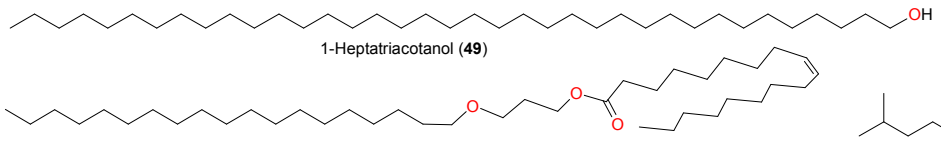
1,6-Digalloyl-β-glucopyranose (**46**)



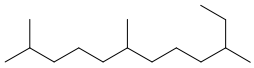
2,6,10-Trimethyltetradecane (**47**)

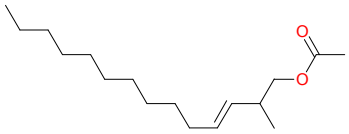


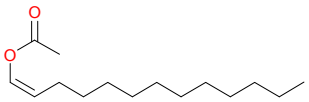
2,6,10-Trimethyldodecane (**48**)

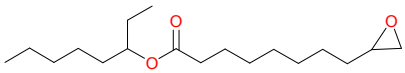

1-Heptatriacotanol (**49**)

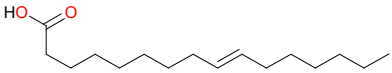
3-(Octadecyloxy)propyl oleate (**50**)

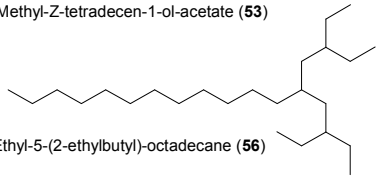

3,7,11,-Trimethyldodecan (**51**)

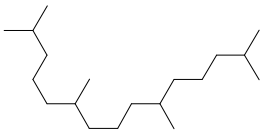

E-2-Methyl-3-tetradecene-1-ol-acetate (**52**)

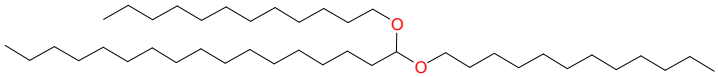

7-Methyl-Z-tetradecen-1-ol-acetate (**53**)

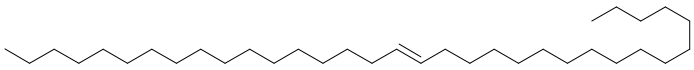

3-Octyl-,cis-oxiraneoctanoic acid (**54**)

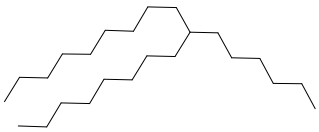

9-Hexadecenoic acid (**55**)

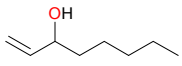

3-Ethyl-5-(2-ethylbutyl)-octadecane (**56**)

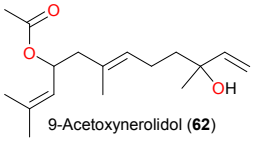

2,6,10,14-Tetramethylpentadecane (**57**)

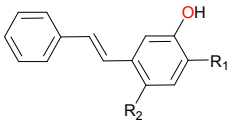

1,1-Bis(dodecyloxy)-hexadecane (**58**)

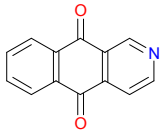

17-Pentatriacotene (**60**)

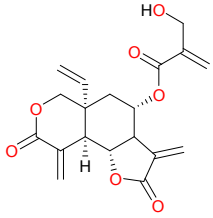

9-Hexylheptadecane (**59**)

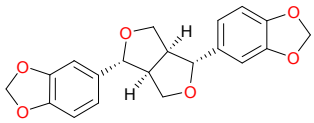

1-Octen-3-ol (**61**)

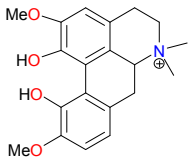

9-Acetoxynerolidol (**62**)

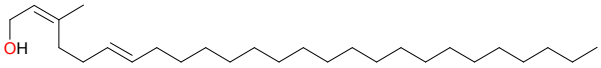

Longistylin A (**63**): R_1 = Prenyl, R_2 = OMe
Longistylin C (**64**): R_1 = OMe, R_2 = Prenyl

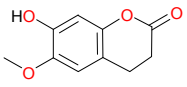

2-Azaanthraquinone (**65**)

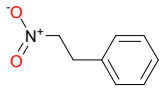

Vernodalin (**66**)

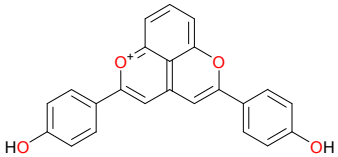

Sesamin (**68**)


Magnoflorine (**68'**)


3-Methy-2,6-hexacosedienol (**67**)


β-Ionone (**69**)


1-Nitro-2-phenylethane (**70**)


8-Hydroxy-2-(4'-hydroxyphenyl)-5-(4''-hydroxyphenyl)-pyrano[4,3,2-*de*]1-benzopyrylium (**71**)

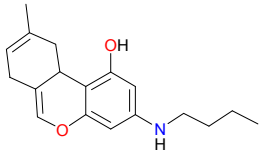

4-Butylamine-10-methyl-6-hydroxy cannabinoid dronabinol (**72**)

Table 1: Bioactivity of derived quinones *versus* ethnobotanical uses of plant species

Compound	Plant species (Country)	Family	Ethnobotanical use	Measured Activity	References
1	*Abrus precatorius* (Nigeria)	Leguminosae	Treatment of **malaria**	**Antimicrobial activity**	Muhammad *et al.*[74] Limmatvapirat *et al.*[75]
2	*Diospyros mespiliformis* (Nigeria)	Ebenaceae	Leaf decoction for whooping cough and root extract as worm expellants	Cytotoxicity	Adeniyi *et al.*[76]
3	*Cassia siamea* (Nigeria)	Leguminosae	Treatment of **malaria**	**Antiplasmodial activity**	Ajaiyeoba *et al.*[77] Morita *et al.*[78] Oshimi *et al.*[79]
4 and **5**	*Aframomum danielli* (Nigeria)	Zingiberaceae	Used as traditional food spice and also as antiinflamatory agent	Lipoxygenase inhibition	Odukoya *et al.*[81]

Table 2: Bioactivity of derived steroids *versus* ethnobotanical uses of plant species

Compound	Plant species (Country)	Family	Ethnobotanical use	Measured Activity	References
6	*Alchornea cordifolia* (Nigeria)	Euphorbiaceae	Remedy for arthritis, muscle pain and other **inflammatory disorders**.	**Anti-inflammatory activity**	Okoye *et al.*[85]
7 and **8**	*Loranthus micranthus* (Nigeria)	Loranthaceae	As an immunostimulant and antioxidant especially in several debilitating diseases including **cancer**, flu and other viral infections but not limited to these	**Proliferative activity**	Ogechukwu *et al.*[86]

Table 3: Bioactivity of derived phenolic compounds *versus* ethnobotanical uses of plant species

Compound	Plant species (Country)	Family	Ethnobotanical use	Measured Activity	References
9	*Alchornea cordifolia* (Nigeria)	Euphorbiaceae	Source of treatments to cure **malaria symptoms** traditional healers	**Antiplasmodial activity** and cytotoxicity	Banzouzi *et al.*[89]
10 - 19	*Loranthus micranthus* (Nigeria)	Loranthaceae	Treatment of diarrhea, epilepsy, hypertension and rheumatism	Antioxidant activity	Agbo *et al.*[93]
20	*Chrozophora senegalensis* (Mali)	Euphorbiaceae	Treatment of diarrhea, rheumatism, teniasis, stomach ache, rachitis, and venereal diseases. The leaf and root decoctions are also drunk for hair loss.	Antioxidant activity	Vassallo *et al.*[94]
21	*Spathodea campanulata* (Nigeria)	Bignoniaceae	Treatment of diseases (**ulcers**, dysentery, oedemas, skin eruptions, scabies, wound healing and urethral discharge) and veterinary application have been attributed to the plant in different cultures	**Antioxidant activity**	Elusiyan *et al.*[97]
22	*Securinega virosa* (Mali)	Euphorbiaceae	It is used in traditional medicine for many diseases including diarrhea, rheumatism, malaria, **liver disease, inflammation** and pain. Extracts of the plant are used for the expulsion of worms and in the treatment of bilharziasis, and for other urinary and genital tract disorders	**Antioxidant Activity**	Sanogo *et al.*[100]
23 - 25	*Ixora coccinea* (Nigeria)	Rubiaceae	Treatment of a variety of infections, hypertension, menstrual irregularities, sprains, **chronic ulcers** and skin diseases	**Antioxidant activities**	Idowu *et al.*[101]

Table 4: Bioactivity of derived glycosides *versus* ethnobotanical uses of plant species

Compound	Plant species (Country)	Family	Ethnobotanical use	Measured Activity	References
26	*Ximenia Americana* (Mali)	Olacaceae	Treatment throat infection, malaria, dysmenorrhea, malaria, leprotic, **ulcers**, skin diseases, for wound healing	**Antioxidant activity**	Le *et al.*[107]
27 - 29	*Chrozophora senegalensis* (Mali)	Euphorbiaceae	Treatment of diarrhea, rheumatism, teniasis, stomachache, rachitis, and venereal diseases. The leaf and root decoctions are also drunk for hairloss.	Antioxidant Activity	Vassallo *et al.*[94]
30 - 32	*Spathodea campanulata* (Nigeria)	Bignoniaceae	Treatment of diseases (**ulcers**, dysentery, oedemas, skin eruptions, scabies, wound healing and urethral discharge) and veterinary application have been attributed to the plant in different cultures	**Antioxidant activity**	Elusiyan *et al.*[97]
33 and **34**	*Russelia equisetiformis* (Nigeria)	Fabaceae	Medicinal plant used by traditional healers to treat malarial, cancer, inflammatory diseases, **analgesic** and to stabilize membranes.	**Antinociceptive activity**	Johnson *et al*[108] Kolawole and Kolawole[109] Awe *et al.*[110]

Table 5: Bioactivity of other derived compounds *versus* ethnobotanical uses of plant species

Compound	Plant species (Country)	Family	Ethnobotanical use	Measured Activity	References
35 and **36**	*Allium sativum* (Nigeria)	Alliaceae	Treatment of **malaria**	**Antiplasmodial activity**	Adebayo *et al.*,[34] Perez *et al.*,[113] Coppi *et al*.[114]
37	*Cassia siamea* (Nigeria)	Leguminosae	Treatment of **malaria**. In Asia, stem bark is used as a mild, pleasant, safe purgative; to treat diabetes; a paste is used as a dressing for ringworm and chilblains; the roots are used as an antipyretic; and the leaves are used for the treatment of constipation, **hypertension**, and insomnia	**Antiplasmodial activity, vasodialator effect**	Ajaiyeoba *et al*.,[77] Morita *et al*.,[115] Oshimi *et al*.[116]
38	*Guiera senegalensis* (Nigeria, Mali)	Combretaceae	Treatment of **malaria,** fevers, hepatitis, diabetes, malaria, pain, chemoprevention, anti-Helicobacter pylori while the external application of dried leaves on wounds and infusion of leaves for the treatment of measles	**Antiplasmodial activity**	Iwalewa *et al*.,[117] Ancolio *et al*.,[118] Combier *et al*.[119]
39 - 43	*Quassia amara* (Nigeria)	Simaroubaceae	Treatment of **malaria**	**Antiplasmodial activity**	Bertani *et al*.,[121] Kitagawa *et al*.[122] Ajaiyeoba et al.[120]
44	*Bryophyllum pinnatum* (Nigeria) *Ximenia Americana* (Mali)	Crassulaceae	Treatment of **ulcers**, allergic inflammation and epilepsy	**Antibacterial activity**	S. Pal and A. K. N. Chaudhuri.[124] Ogungbamila *et al*.[125]
45 and **46**	*Ximenia Americana* (Mali)	Olacaceae	Treatment throat infection, malaria, dysmenorrhea, malaria, leprotic, **ulcers**, skin diseases, for wound healing	**Antioxidant activity**	Le *et al.*[107]
47 – **49**	*Alchornea cordifolia* (Nigeria)	Euphorbiaceae	Remedy for arthritis, muscle pain and other **inflammatory disorders**	**Anti-inflammatory activity**	Okoye *et al*.[129]

50 - 61	*Alchornea floribunda* (Nigeria)	Euphorbiaceae	Leaves are traditionally used as a remedy for arthritis, muscle pain and other **inflammatory disorders**	**Anti-inflammatory activity**	Okoye and Osadebe.[127] Okoye *et al*.,[129]
62	*Jatropha gossypifolia* (Nigeria)	Euphorbiaceae	Treatment of various disease conditions such as cough, tuberculosis, bacterial infections and cancerous growths. Traditionally the leaves of the plant are applied to boils, carbuncles, **eczema**, itches, and veneral diseases and also used as febrifuge, while its bark is used as emmenagogue. The Roots are used to treat leprosy, and stem latex possess coagulant activity	**Antifungal activity**.	Abiodun *et al*.[88]
63 and **64**	*Cajanus cajan* (Nigeria)	Fabaceae	**Cancer** treatment	**Cytotoxicity**	Ashidi *et al*.[131]
65	*Mitracarpus scaber* (Benin)	Rubiaceae	To treat a variety of skin diseases such as eczema or ringworm	Antimicrobial Activity against Dermatophilus congolensis	Gbaguidi *et al*.[135] Lagnika et al.[136]
66 and **67**	*Struchium sparganophora* (Nigeria)	Asteraceae	Treatment of diseases (**ulcers**, dysentery, oedemas, skin eruptions, scabies, wound healing and urethral discharge) and veterinary application have been attributed to the plant in different cultures. It is also used in the treatment of malaria and **measles**, cutaneous, subcutaneous **parasitic infection**, rheumatic pains, **diarrhea, dysentery** as well as venereal diseases,asan abortifacient, and in the treatment of inflammatory and **tumor- related ailments**. Also used in the preparation of soup in the South Western part of Nigeria	**Antioxidant activity Antimicrobial** and **antitumour activities**	Kasim *et al*.[138] Liobikas *et al*.[139] Gnoatto *et al*.[140]
68	*Fagara macrophylla* (Guinea)	Rutaceae	For the cure of **toothache**, rheumatism and urogenital affections as well as to prepare poisonous arrows. This plant is also known to be rarely attacked by insects.	**Antifeedant activity**	Tringali *et al*.[144]

69	*Keetia leucantha* (Benin)	Rubiaceae	To treat **parasitic diseases**.	**Anti-trypanosomal** activity	Bero *et al.*[146]
70	*Dennettia tripetala* (Nigeria)	Annonaceae	The leaves of the plant are used by the local herbalists in combination with other medicinal plants to treat various kinds of ailment including fever, **infantile convulsions**, typhoid, cough, worm infestation, vomiting and stomach upset.	**Anticonvulsant**, Hypnosis and Anxiolytic activities.	Oyemitan *et al.*[149]
71	*Sorghum bicolor* (Burkina Faso)	Poaceae	Globally used for cereals production. In Africa it is used for malaria, fever, blood tonic and sickle-cell	Not specified	Khalil *et al.*[152]
72	*Cassia alata* (Nigeria)	Leguminosae	Treatment of skin diseases such as ringworm, eczema, pruritis, itching, scabies, **ulcers** and other related disease	**Antibacterial activity**	Okwu and Nnamdi.[153]

African flora
121x33mm (96 x 96 DPI)