Chapter

Antioxidants from Nigerian Medicinal Plants: What Are the Evidence?

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Abstract

The search for natural antioxidants from plants would continue to be a dominant research interest for many years. This is because of the increasing understanding on the role of oxidative stress in damaging cell structures such as DNA, due to over production of free radicals and reactive oxygen species (ROS) in human systems, which are linked to inflammation, cancer and diabetes. However, phenolic compounds especially from phytochemicals or vegetable foods play important roles in reducing the risk of these diseases and reinforces the importance of natural antioxidants in human health. These antioxidant molecules neutralize or quench the ROS by either hydrogen atom transfer or single electron transfer mechanisms. Thus, the capacity to scavenge ROS and free radicals or inhibits lipid peroxidation is measured quantitatively as the strength of antioxidant activity. Several chemical and biochemical protocols have been used in the evaluation of plant extracts as antioxidants. Overwhelming literature reports have indicated varying degrees of antioxidant efficacies of extracts from Nigerian medicinal plants in comparison to synthetic antioxidants. These efficacies were analyzed to provide insight into the strength of antioxidant activity. This chapter reviewed 250 Nigerian medicinal plants in search of evidence for effective antioxidants.

Keywords: Nigerian medicinal plants, antioxidants, DPPH, ROS, free radicals

1. Introduction

Since the discovery of enzyme superoxide dismutase (SOD) and the evidence that emerged in support of the role of free radicals in biological systems, human understanding of free radical biochemistry in health and disease continue to advance [1]. This provided the basis for continuous search on natural antioxidants from foods and phytomedicines. Overwhelming reports on Google search engine has indicated 92,800 hits for “antioxidant activity” of medicinal plants in the last 10 years (2008–2018). This is due to growing interest on the antioxidant properties of medicinal plants. Several chemical and biochemical protocols have been used in the
evaluation of antioxidant activity including the oxygen radical absorbance capacity (ORAC), total radical-trapping antioxidant potential (TRAP), total oxidant scavenging capacity (TOSC), chemiluminescence (CL), croton bleaching, low density lipoprotein (LDL) oxidation, ferric reducing antioxidant power (FRAP), copper reduction assay (CUPRAC), 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assay, 2,2-diphenyl-1-picrylhydrazyl (DPPH), nitric oxide (NO), hydroxyl radical (OH) hydrogen peroxide (H₂O₂) and total phenolic assay among others [2]. Biochemical protocols are based on animal models for in vivo evaluations of oxidative stress biomarkers. However, this study is focused on in vitro evaluations of antioxidants from plants based on hydrogen atom transfer or single electron transfer mechanisms [2]. The strength of antioxidant activity measured from a combination of different methodologies was used to evaluating antioxidant effectiveness [3]. This review provides fundamental background on free radical and ROS in human health and disease with a view to understand the roles of natural antioxidants. We reviewed 250 Nigerian medicinal plants evaluated for antioxidant activity in search of evidence for effective antioxidants.

2. Reactive oxygen species (ROS) in human health and disease

Human system uses oxidation for normal metabolic activities in the transformation of nutrients into energy. During oxidation, reactive oxygen species (ROS) are also produced at low levels in normal physiological conditions, which are necessary for maintaining normal cell functions such as signaling immunity and homeostasis [4]. These activities are maintained by endogenous antioxidant (enzymatic) defense systems produced by the body for protection against harmful effects. These include superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), glutathione reductase (GSH-Rx) and catalase [5]. Excessive production of ROS beyond the body defense mechanisms can be extremely harmful to cellular functions by damaging nucleic acids, oxidizing proteins, and causing lipid peroxidation [6]. The resultant cell damage by free radicals and ROS appeared as major contributor to aging and degenerative diseases of aging such as cancer, cardiovascular disease, immune system decline, liver diseases, diabetes mellitus, inflammation and brain dysfunction among others [7, 8]. These ROS and reactive nitrogen species (RNS) including superoxide anion O₂−, hydroxide ion OH−, hydroxyl radical OH·, peroxyl radical ROO· and nitric oxide NO· as well as H₂O₂, lipid peroxides ROOH, and singlet O₂ are very reactive and can initiates free radical reactions or lipid peroxidation in living cells.

![Diagram of lipid radical formation](image)

ROS can be produced either by external sources (e.g., tobacco smoke, stress, etc.), as by-products during the mitochondrial electron transport of aerobic respiration or by oxidoreductase enzymes and metal catalyzed oxidation [9]. But the biological effects of ROS depend on the types of cell or tissue in relation to enzyme production, signal transduction and DNA repair [10]. ROS are harmful when excessive productions are not balanced by body antioxidant mechanism. This imbalance between ROS production and enzymatic antioxidant defense systems is called oxidative stress [11]. Antioxidants counteract oxidative stress by neutralizing free radicals because they are reducing agents that react with and buffer ROS as a form of defense against oxidative stress [12].
3. Phytochemicals as sources of natural antioxidants

Antioxidants are molecules that prevent oxidation or inactivates the reactive oxygen species and thus prevent oxidative damage to the cells and body tissues [13]. Antioxidants can also inhibit, quench or scavenge free radicals converting them into new and stable chemical compounds [14]. Broadly, antioxidants are classified as enzymatic and non-enzymatic with each class providing complementary role of protection against free radicals in human systems. Previous work has concisely discussed on antioxidants classification [3] as summarily reproduced in Figure 1.

But our focus is the non-enzymatic antioxidant involving flavonoids, phenolic acids, vitamins, carotenoids, minerals and cofactors. They are exogenous sources of protection through diet. Plants foods contain a variety of nutrients and non-nutrients chemicals which are good antioxidant agents. These sources of natural antioxidants including Vitamin A (retinol) obtained from β-carotene, vitamin C (ascorbic acid), Vitamin E (α-tocopherol), lycopene and carotenoids occur naturally in fruits, vegetables, legumes and grains which are commonly consumed and play important role in the defense against free radicals [3, 15]. Medicinal plants are rich source of phenolic compounds such as flavonoids, phenolic acids and coumarins [16, 17]. Flavonoids are antioxidants compounds composed of anthocyanins, flavanones, flavonols, flavones, isoflavonoids and flavanones, while hydroxycinnamic and hydroxybenzoic acids such as gallic acid are components of phenolic acids widely distributed secondary metabolites in plants with antioxidant and antiradical properties [18]. They are important as chelators and free radical scavengers of hydroxyl and peroxyl radicals, superoxide anions and peroxynitrates [19]. Carotenoids natural pigments are important phytochemical antioxidants obtained from plants. They are structurally grouped into carotenes and xanthophyll based on the degree of oxygenation of carotenoid hydrocarbons and exert antioxidant effect by singlet oxygen quenching ability [3]. Several studies on the antioxidant activities of various herbal plants have indicated their enormous medicinal values as inhibitors of free radical and ROS [20].

![Figure 1](image-url)

**Figure 1.**
*Board classification of antioxidants adapted from Carocho and Ferreira [3].*
4. Antioxidants from Nigerian medicinal plants

Nigeria is a west African country with an area of 923,769 km$^2$ having a population of 198 million with 250 ethnic groups [21]. The country shares border with the republic of Cameroun to the east, Niger and Chad republics to the north, Benin republic to the west and Gulf of Guinea to the south. Nigeria has favorable climate conditions with enormous diversity of plant species, which are distributed across geographical contrast of the mangrove swamps in South-South (SS), to the tropical rain forests covering South-West (SW) and South-East (SE) and to the grassland vegetation of North-Central (NC) up to the Sahel savannah of semi-arid North-East (NE) (Figure 2). Many of these plants are used as medicines for treatment of illness or management of human and animal health among rural and urban dwellers.

The application of herbal recipes especially in the management of human metabolic diseases such as diabetes and cancer is common knowledge among Nigerians. This prompted research interest in academia on the potentials of phytomedicines as complimentary or alternative treatment agents, and consequent research efforts to validate their pharmacological properties. The number of Nigerian medicinal plants reported for antioxidants is enormous. However, 250 medicinal plants evaluated for antioxidant activity were studied in addition to the 28 compounds isolated from 44 plants. But antioxidant evaluations on crude extracts rather than on pure compounds largely dominated the literature. Thus, effective activity based on concentrations required to inhibit 50% free radicals (IC$_{50}$) for selected extracts are presented (Table 1) together with concentrations of various standard antioxidants used.

![Figure 2. Map of Nigeria showing the six geopolitical zones.](image)

| S. No | Plant name              | Family         | Part used | IC$_{50}$ sample | IC$_{50}$ standard | Ref. |
|-------|-------------------------|----------------|-----------|------------------|--------------------|------|
| 1     | *Abrus precatorius*     | Leguminosae    | Seed      | 1.92$^{*}$       | AA = 1.83          | [37] |
|       |                         |                |           | 2.10$^*$         | AA = 1.20          |      |
| 2     | *Acalypha ornata*       | Euphorbiaceae  | Leaf      | 20.50$^{*}$      | TC = 15.4          | [68] |
| 3     | *Acalypha wilkesiana*   | Euphorbiaceae  | Leaf      | 15.25$^{*}$      | AA = 7.26          | [26] |
| 4     | *Acanthospermum hispidum* | Asteraceae     | Aerial    | 28.9$^{*}$       | AA = 1.41          | [39] |
| 5     | *Aframomum melegueta*   | Zingiberaceae  | Fruit     | 0.04$^{**}$      | AA = 0.03          | [69] |
|       |                         |                | Leaf      | 0.07$^{**}$      |                    |      |
S. No | Plant name | Family | Part used | IC$_{50}$ sample | IC$_{50}$ standard | Ref. |
--- | --- | --- | --- | --- | --- | --- |
6 | Ageratum conyzoides | Asteraceae | Leaf | 31.25$^1$ | AA = 7.26 | [26] |
7 | Allassandra cathartica | Apocynaceae | Leaf | 0.46$^-$ | VE = 0.25 | [70] |
8 | Allamblackia floribunda | Guttiferae | Leaf | 0.02$^-$ | VE = 0.01 | [71] |
9 | Alstonia boonei | Apocynaceae | Stem | 0.12$^-$ | AA = 0.06 | [72] |
10 | Alstonia congensis | Apocynaceae | Root | 19.7$^-$ | AA = 4.9 | [73] |
11 | Alternanthera dentata | Amaranthaceae | Leaf | 0.02$^-$ | AA = 0.01 | [74] |
12 | Amaranth caudatus | Amaranthaceae | Leaf | 5.81$^-$ | TC = 13.2 | [27] |
13 | Anacardium occidentale | Anacardiaceae | Bark | 5.66$^+$ | AA = 4.57 | [74] |
14 | Annona senegalensis | Annonaceae | Leaf | 45.72$^+$ | GA = 48.77 | [35] |
15 | Aspilia africana | Asteraceae | Leaf | 160$^+$ | AA = 120 | [75] |
16 | Aveytasia gengetica | Acanthaceae | Leaf | 100$^+$ | AA = 150 | [75] |
17 | Bauhinia galpinii | Caesalpinia | Leaf | 20.52$^+$ | AA = 19.8 | [76] |
18 | Bauhinia monandra | Caesalpinia | Leaf | 5.56$^+$ | AA = 30.0 | [45] |
19 | Bixa orellana | Bixa | Leaf | 45.72$^+$ | AA = 4.87 | [74] |
20 | Borreria ocyoides | Rubiaceae | Aerial | 1.85$^+$ | AA = 0.05 | [77] |
21 | Borreria verticillata | Rubiaceae | Leaf | 2.98$^+$ | AA = 1.05 | [78] |
22 | Bridelia ferruginea | Euphorbiaceae | Leaf | 12.5$^+$ | AA = 7.26 | [26] |
23 | Bridelia micrantha | Euphorbiaceae | Leaf | 0.1 μM | AA = 2.0 μM | [38] |
24 | Bryophyllum pinnatum | Crassulaceae | Leaf | 0.41$^+$ | VC = 0.067 | [79] |
25 | Calliandra surinamensis | Mimosaceae | Flower | 28$^+$ | VE = 38 | [80] |
26 | Calypotrechilum christyanum | Orchidaceae | Whole | 50.6$^+$ | AA = 1.41 | [39] |
27 | Canthium subcordatum | Rubiaceae | Leaf | 23.9$^+$ | AA = 4.9 | [74] |
28 | Capsicum annuum | Solanaceae | Fruit | 1.35$^+$ | BHA = 0.96 | [25] |
29 | Capsicum frutescens | Solanaceae | Fruit | 0.67$^+$ | BHA = 0.96 | [25] |
30 | Carica papaya | Caricaceae | Seed | 0.227$^+$ | AA = 0.109 | [67] |
31 | Cassyia sieberiana | Leguminosae | Leaf | 24.1$^+$ | AA = 4.9 | [73] |
32 | Cassia suguana | Leguminosae | Leaf | 1.20$^+$ | AA = 2.56 | [48] |
33 | Celosia trigyna | Amaranthaceae | Leaf | 120$^+$ | AA = 120 | [75] |
34 | Cissampelos owariensis | Menispermaceae | Leaf | 2.77$^+$ | AA = 0.067 | [25] |
35 | Citrus aurantifolia | Rutaceae | Peel | 12.1$^+$ | VC = 0.067 | [25] |
36 | Commiphora kerstingii | Burseraceae | Leaf | 0.33$^+$ | AA = 0.49 | [23] |
37 | Corchorus olitorius | Malvaceae | Leaf | 11.8 $^{27.52}$ | TC = 13.2 | [27] |
38 | Crassocephalum rubens | Asteraceae | Leaf | 2.91$^+$ | VC = 1.18 | [62] |
39 | Cucumis sativus | Cucurbitaceae | Leaf | 1.68 $^{71.1}$ | BHA = 0.96 | [27] |
| S. No | Plant name                | Family              | Part used | IC<sub>50</sub> sample | IC<sub>50</sub> standard | Ref. |
|-------|---------------------------|---------------------|-----------|-------------------------|--------------------------|------|
| 40    | Cucurbita moschata        | Cucurbitaceae       | Leaf      | 150<sup>1</sup>         | AA = 120, TC = 50        | [75] |
| 41    | Cymbopogon citratus       | Poaceae             | Leaf      | 1.35<sup>1</sup>        | VE = 0.25                | [70] |
| 42    | Danellia oliveri          | Leguminosae         | Leaf      | 15.5<sup>1</sup>        | TC = 0.25                | [50] |
| 43    | Daucus carota             | Apiaceae            | Aerial    | 4.61<sup>1</sup>        | BHA = 0.96               | [25] |
| 44    | Elretia cymosa            | Boraginaceae        | Leaf      | 0.47<sup>1</sup>        | GA = 2.09                | [53] |
| 45    | Emilia coccinea           | Asteraceae          | Leaf      | 120<sup>1</sup>         | AA = 120                 | [75] |
| 46    | Eugenia caryophyllata     | Myrtaceae           | Leaf      | 0.03<sup>1</sup>, 0.02<sup>1</sup> | AA = 0.03                | [47] |
| 47    | Eupatorium adenophorum     | Asteraceae          | Root      | 22.4<sup>1, 2</sup>     | AA = 4.9, RT = 3.3       | [73] |
| 48    | Eupatorium odoratum       | Asteraceae          | Leaf      | 0.07<sup>1</sup>        | AA = 0.06                | [72] |
| 49    | Euphorbia hirta           | Euphorbiaceae       | Leaf      | 2.5<sup>1</sup>         | VC = 4.5                 | [81] |
| 50    | Feretia apodanthera       | Rubiaceae           | Root      | 0.053<sup>1</sup>       | VC = 0.048               | [43] |
| 51    | Ficus exasperata          | Moraceae            | Leaf      | 0.86                    | VE = 0.25                | [70] |
| 52    | Ficus gnaphalocarpa       | Moraceae            | Leaf      | 45.3<sup>1</sup>, 44.6<sup>1</sup> | GA = 48.8, TX = 72.9    | [34] |
| 53    | Ficus sycomorus           | Moraceae            | Stem      | 42.0<sup>1</sup>        | VC = 25.0                | [82] |
| 54    | Globinetula oreophila     | Loranthaceae        | Leaf      | 0.38<sup>1</sup>        | VC = 0.06                | [79] |
| 55    | Gongronema latifolia      | Asclepiadaceae      | Leaf      | 70.0<sup>1</sup>        | VC = 50                  | [83] |
| 56    | Grewia carpinifolia       | Tiliaceae           | Leaf      | 0.32<sup>1</sup>, 0.39<sup>1</sup> | AA = 0.31, AA = 0.18    | [32] |
| 57    | Harungana madagascariensis| Hypericaceae        | Stem      | 37.5<sup>1</sup>        | BHT = 16.2               | [36] |
| 58    | Heliotropium indicum      | Boraginaceae        | Aerial    | 48.4<sup>1</sup>        | AA = 1.41                | [39] |
| 59    | Hibiscus sabdariffa       | Malvaceae           | Leaf      | 0.14<sup>1</sup>        | AA = 0.02                | [84] |
| 60    | Holarrhena floribunda     | Apocynaceae         | Leaf      | 7.2<sup>1</sup>         | QT = 2.95                | [85] |
| 61    | Ipomoea asarifolia        | Convolvulaceae      | Leaf      | 24.3<sup>1</sup>        | AA = 1.41                | [39] |
| 62    | Irvingia gabonensis       | Irvingiaceae        | Root      | 12.4<sup>1</sup>, 25.5<sup>1</sup> | AA = 4.9, TC = 38.9      | [73] |
| 63    | Justicia secunda          | Acanthaceae         | Leaf      | 1.58 μM                | AA = 2.52                | [86] |
| 64    | Kalanchoe pinnata         | Crassulaceae        | Leaf      | 180<sup>1</sup>         | AA = 120                 | [75] |
| 65    | Lactuca sativa            | Asteraceae          | Whole     | 0.26<sup>1</sup>        | QT = 0.83                | [25] |
| 66    | Landolphia oxerienis      | Apocynaceae         | Root      | 8.8<sup>1</sup>, 49.1<sup>1</sup> | AA = 4.9, TC = 38.9      | [73] |
| 67    | Laportea ovalifolia       | Urticaceae          | Leaf      | 100<sup>1</sup>         | AA = 150                 | [75] |
| 68    | Lasianthera africana      | Icacinaceae         | Leaf      | 0.30<sup>1</sup>, 0.27<sup>1</sup> | RT = 0.26               | [28] |
| 69    | Launaea taraxacifolia     | Asteraceae          | Shoot     | 1.94<sup>1</sup>, 1.59<sup>1</sup> | VC = 1.18, VC = 0.56     | [62] |
| 70    | Lawsonia inermis          | Lythraceae          | Leaf      | 3.80<sup>1</sup>        | AA = 7.26                | [26] |
| 71    | Leptadenia hastata        | Asclepiadaceae      | Leaf      | 42.3<sup>1</sup>        | GA = 48.8                | [35] |
| 72    | Lycopersicon esculentum   | Solanaceae          | Fruit     | 1.16<sup>1</sup>, 1.47<sup>1</sup> | QT = 0.83               | [25] |
## Table 1.
Antioxidant activities of selected Nigerian plants.

| S. No | Plant name           | Family         | Part used | IC<sub>50</sub> sample | IC<sub>50</sub> standard | Ref. |
|-------|----------------------|----------------|-----------|-------------------------|--------------------------|------|
| 73    | Massularia acuminata | Rubiaceae      | Leaf      | 70.0<sup>1</sup>         | VC = 7.59                | [87] |
| 74    | Mordia whitei        | Apocynaceae    | Leaf      | 6.1<sup>1</sup>          | AA = 3.4                 | [66] |
| 75    | Moringa oleifera     | Moringaceae    | Leaf      | 0.16<sup>1</sup>         | AA = 0.02                | [84] |
| 76    | Murraya koenigii      | Rutaceae       | Leaf      | 7.35<sup>1</sup>         | TC = 13.2                | [27] |
| 77    | Nauclea diderrichii   | Rubiaceae      | Stem      | 18.12<sup>2</sup>        | AA = 1.41                | [39] |
| 78    | Nauclea latifolia     | Rubiaceae      | Leaf      | 1.0<sup>1</sup>          | AA = 9.0                 | [55] |
| 79    | Ocimum basilicum      | Lamiaceae      | Leaf      | 0.14<sup>2</sup>         | AA = 0.02                | [33] |
| 80    | Ocimum gratissimum    | Lamiaceae      | Stem      | 8.67<sup>2</sup>         | BHA = 3.36               | [27] |
| 81    | Parinari curatellifolia | Chrysobalanaceae | Leaf      | 13.5<sup>1</sup>        | VC = 1.98                | [88] |
| 82    | Parkia biglobosa      | Leguminosae    | Stem      | 15.65<sup>1</sup>        | AA = 7.26                | [26] |
| 83    | Phragmanthera captitata | Loranthaceae  | Leaf      | 1.9<sup>2</sup>           | BHT = 4.6                | [41] |
| 84    | Piliostigma reticulatum | Fabaceae      | Leaf      | 10.3<sup>1</sup>        | AA = 3.9                 | [22] |
| 85    | Piliostigma thomningii | Fabaceae      | Leaf      | 14.7<sup>1</sup>        | AA = 3.9                 | [22] |
| 86    | Piper guineense       | Piperaceae     | Seed      | 7.4<sup>1</sup>          | AA = 31.7                | [89] |
| 87    | Psidium guajava       | Myrtaceae      | Leaf      | 0.04<sup>1</sup>         | BHA = 0.05               | [24] |
| 88    | Sapium ellipticum     | Euphorbiaceae  | Stem      | 0.19<sup>1</sup>         | BHT = 0.11               | [90] |
| 89    | Senna alata           | Fabaceae       | Leaf      | 0.59<sup>1</sup>         | VC = 0.067               | [79] |
| 90    | Simarouba glauca      | Simaroubaceae  | Stem      | 4.7<sup>1</sup>          | BHT = 5.0                | [42] |
| 91    | Solanum macrocarpon   | Solanaceae     | Leaf      | 6.21<sup>1</sup>         | TC = 13.2                | [27] |
| 92    | Spinacia oleracea     | Amaranthaceae  | Leaf      | 12.6<sup>1</sup>         | TC = 13.2                | [27] |
| 93    | Spondias purpurea     | Anacardiaceae  | Stem      | 8.3<sup>1</sup>          | AA = 11.5                | [52] |
| 94    | Stachytaerpha jamaicensis | Verbenaceae  | Leaf      | 5.0<sup>1</sup>          | AA = 9.0                 | [51] |
| 95    | Strophanthus hispidus | Apocynaceae    | Root      | 1.18<sup>1</sup>         | VC = 0.067               | [79] |
| 96    | Telfariia occidentalis | Cucurbitaceae  | Leaf      | 0.16<sup>1</sup>         | AA = 0.02                | [84] |
| 97    | Trichilia catigua     | Meliaceae      | Stem      | 30.28<sup>1</sup>        | AA = 20.72               | [64] |
| 98    | Vernonia amygdalina   | Asteraceae     | Leaf      | 31.25<sup>1</sup>        | AA = 7.26                | [26] |
| 99    | Vernonia calvoana     | Asteraceae     | Leaf      | 1.90 µM                  | AA = 2.0 µM              | [49] |
| 100   | Vernonia cinerea      | Asteraceae     | Leaf      | 6.50<sup>1</sup>         | GA = 0.62                | [30] |
| 101   | Vernonia migoeidii    | Asteraceae     | Leaf      | 20.0<sup>1</sup>         | AA = 18.0                | [91] |
| 102   | Vitex doniana         | Verbenaceae    | Leaf      | 53.23<sup>1</sup>        | GA = 48.8                | [34] |
| 103   | Xylopia aethiopica    | Annonaceae     | Fruit     | 1.04<sup>1</sup>         | VC = 0.067               | [79] |
| 104   | Zingiber officinale   | Zingiberaceae  | Rhizome   | 47.0<sup>1</sup>         | AA = 36.4                | [92] |

AA, ascorbic acid; QT, quercetin; RT, ratio; GA, gallic acid; VC, vitamin C; VE, vitamin E; TX, trolox; BHT, butylated hydroxy toluene; BHA, butylated hydroxy anisole; TC, tocopherol.

IC<sub>50</sub> = mgmL<sup>-1</sup>.

IC<sub>50</sub> = μgmL<sup>-1</sup>.  

AA, ascorbic acid; QT, quercetin; RT, ratio; GA, gallic acid; VC, vitamin C; VE, vitamin E; TX, trolox; BHT, butylated hydroxy toluene; BHA, butylated hydroxy anisole; TC, tocopherol.

IC<sub>50</sub> = mgmL<sup>-1</sup>.

IC<sub>50</sub> = μgmL<sup>-1</sup>.
5. Antioxidant activities of crude extracts

The antioxidant efficacies of Nigerian plants were largely evaluated using protocols involving DPPH, ABTS, FRAP, TAC, NO, OH and or H₂O₂ targets. The DPPH radical scavenging assay is one of the commonly used techniques for quick evaluation of antioxidant capacity. Plant extracts tested for DPPH inhibition have demonstrated interesting efficacies for instance, crude extracts of *P. reticulatum* (40.10 μg mL⁻¹) and *P.thonningii* (50.94 μg mL⁻¹) showed comparable activity with *Ginkgo biloba* (EC₅₀ 40.72 μg mL⁻¹) [22]. Nigerian plants evaluated for antioxidants activity between 2008 and 2012 were reported in 40 publications representing over 166 extracts from 119 plants. These studies showed 29 extracts with effective activity on various free radical targets. However, 15 extracts have comparable antioxidant efficacies to standard antioxidants, while 14 have higher percent (%) inhibition or lower IC₅₀ values than the standards used. These include stem methanol extract of *C. kerstingii* (IC₅₀ 26.27 μg mL⁻¹, ascorbic acid 33.59 μg mL⁻¹) [23] and leaf methanol extract of *P. guajava* (IC₅₀ 0.037 mg mL⁻¹, BHA 0.049 mg mL⁻¹) [24]. But DPPH inhibition studies on selected vegetable plants showed better effective activity for *L. sativa* (IC₅₀ 0.26 mg mL⁻¹), *Z. officinale* (IC₅₀ 0.29 mg mL⁻¹) and *C. frutescens* (IC₅₀ 0.67 mg mL⁻¹) respectively compared to BHA (IC₅₀ 0.96 mg mL⁻¹) and quercetin (IC₅₀ 0.83 mg mL⁻¹) [25]. The activity of *L. inermis* was most profound of the 36 medicinal plants surveyed in Southwestern Nigeria, with lower IC₅₀ of 3.80 μg mL⁻¹ than ascorbic acid (7.26 μg mL⁻¹) [26]. Similar evaluations of DPPH inhibition on 15 medicinal plants showed *S. oleracea* extract with lower IC₅₀ of 12.6 mg mL⁻¹. But *S. macrocarpon* extract was most effective with IC₅₀ 6.21 mg mL⁻¹ lower than α-tocopherol (13.20 mg mL⁻¹) [27].

The analysis of antioxidant efficacies on medicinal plants reported from 2013 to 2017 in 55 publications, involving 211 extracts from 144 plants was carried out. We observed that 70 extracts from 50 plants have exhibited good antioxidant efficacies on various free radical targets with 51 extracts from 53 plants having comparable efficacies to standard antioxidants. However, lower IC₅₀ or higher percent (%) inhibitions compared to standards were observed with 20 extracts from 17 medicinal plants. The NO* inhibition on root extract of *L. africana* (IC₅₀ 0.27 mg mL⁻¹) compared very well with rutin (IC₅₀ 0.28 mg mL⁻¹) [28]. The DPPH inhibition on *P. guajava* (IC₅₀ 1.564 μg mL⁻¹) extract also indicated effective activity compared to ascorbic acid (IC₅₀ 5.950 μg mL⁻¹) [29]. Other plant extracts including *V. cinerea* (IC₅₀ 6.50 μg mL⁻¹) compared to gallic acid (IC₅₀ 0.62 μg mL⁻¹) [30] and *K. senegalensis* stem bark (IC₅₀ 95.76 μg mL⁻¹) with ascorbic acid (223.35 μg mL⁻¹) indicated effective activity [31]. The inhibition of lipid peroxidation using thiobarbituric acid reactive substances (TBARS) assay on leaf extract of *G. carpinifolia* was very effective with IC₅₀ of 0.24 mg mL⁻¹ compared to ascorbic acid (IC₅₀ 0.38 mg mL⁻¹). Moreover, the ABTS assay indicated 100% inhibitions for both extracts and ascorbic acid [32]. The antioxidant evaluations on two of the most locally utilized vegetable plants such as *V. amygdalina* and *O. gratissimum* showed effective inhibitions compared to the standard ascorbic acid [33].

Furthermore, DPPH inhibitions on *S. occidentalis* (IC₅₀ 42.80 μg mL⁻¹) compared to gallic acid (48.77 μg mL⁻¹) was effective, but ABTS assay on *F. gnaphalocarpa* (44.63 μg mL⁻¹) was more effective than Trolox (72.92 μg mL⁻¹) [34]. Similarly, *L. hastata* (IC₅₀ 42.32 μg mL⁻¹) when compared to gallic acid (48.77 μg mL⁻¹) and ABTS on *A. senegalensis* (IC₅₀ 48.98 μg mL⁻¹) with Trolox (72.92 μg mL⁻¹) have interesting lower IC₅₀ values [35]. But *H. madagascariensis* exhibited moderate activity [36] while *A. precatorius* [37] and *B. micrantha* [38] have demonstrated effective inhibitions (Table 1). The analyses of Nigerian plants in 2018 showed interesting activities with 15 plant extracts from 32 published reports. Plants with moderate DPPH inhibition include *A. hispidum*, *A. laxiflora*, *C. christyanum*, *H. indicum* and
I. asarifolia [39]. However, effective inhibitions were observed on root extracts of D. tripetala (IC\textsubscript{50} 0.631 μg/mL\textsuperscript{−1}) and M. excelsa (IC\textsubscript{50} 0.194 μg/mL\textsuperscript{−1}) compared to 4.60 μg/mL\textsuperscript{−1} ascorbic acid [40]. Similarly, P. capitata (27.4 μg/mL\textsuperscript{−1}) was effective than BHT (56.0 μg/mL\textsuperscript{−1}) [41], and the evaluation of S. glauca stem bark on FRAP (4.70 μg/mL\textsuperscript{−1}) and NO\textsuperscript{*} (11.90 μg/mL\textsuperscript{−1}) were effective than 5.0 μg/mL\textsuperscript{−1} and 18.0 μg/mL\textsuperscript{−1} of BHT respectively [42]. Lastly, plant crude extracts have demonstrated varying but strong efficacies on different free radical targets which in many cases surpassed standard antioxidants. The report on DPPH inhibition of F. apodanthera root bark ethanol extract represents effective activity with IC\textsubscript{50} of 0.053 μg/mL\textsuperscript{−1} in comparison to vitamin C (0.048 μg/mL\textsuperscript{−1}) standard [43].

6. Chemical composition and antioxidant activity

6.1 GC-MS analysis of extracts and evaluation of antioxidant activity

The antioxidant evaluations of Nigerian medicinal plants with determination of chemical composition using gas chromatography-mass spectrometry (GC-MS) have become routine studies. The GC-MS is intended to give insight on the probable chemical entities of volatile components present in the sample extract. Several plants constituents have been analyzed using GC–MS by comparison of compounds’ retention times with library of standard chemical entities provided by the National Institute of Standards and Technology (NIST) database imbedded in the instrument. The chemical constituents with low molecular weights such as terpenoids, long chain alkanes, phenolics and fatty acid methyl esters (FAME) are separated and detected by GC-MS. This is perhaps one reason that FAME are prevalent from among plant extracts, but sharp contrast between lipophilic and hydrophilic components are determined by solvent polarity or method of extraction [44].

The GC-MS analyses and evaluation of antioxidants on B. monandra hexane extract showed 4-hydroxy-5-methyl-3-propyl-2-hexanone (42.7%) and oleic acid (20%) as major compounds. The DPPH inhibition (IC\textsubscript{50} 5.56 μg/mL\textsuperscript{−1}) with ascorbic acid (IC\textsubscript{50} 30.0 μg/mL\textsuperscript{−1}) showed interesting efficacy, but ethyl acetate extract containing largely oleic acid (40.76%) and hexadecanoic acid (21.75%) was more effective (IC\textsubscript{50} 0.01 μg/mL\textsuperscript{−1}) [45]. The evaluation on A. dentata methanol extract containing hexadecanoic acid (31.6%), phytol (24.6%) and octadecanoic acid (10.56%) was found to be poor. However, the FRAP inhibition showed optimum activity (0.65 μmol/L\textsuperscript{−1}) compared to ascorbic acid (2.00 μmol/L\textsuperscript{−1}) [46]. The DPPH screening on buds, leaf, root and stem of commonly used spice, E. caryophyllata was reported. The various ethanol extracts showed effective activities IC\textsubscript{50} of 0.02, 0.03, 3.66 and 0.99 μg/mL\textsuperscript{−1} respectively, compared to ascorbic acid (IC\textsubscript{50} 0.03 μg/mL\textsuperscript{−1}) and gallic acid (IC\textsubscript{50} 0.05 μg/mL\textsuperscript{−1}) standards. This indicated an important response to the DPPH scavenging capacity which have been largely attributed to aromatic phenols, caryophyllene, aromatic esters and ethers [47]. Similar comprehensive study on the leaf, stem bark and root of C. singueana was reported. The DPPH, OH and NO\textsuperscript{*} showed IC\textsubscript{50} of 1.20, 2.58 and 35.99 μg/mL\textsuperscript{−1} for DPPH inhibition of stem bark ethanol, root aqueous and leaf ethanol extracts respectively. But the response on OH showed IC\textsubscript{50} of 1.58, 2.05 and 6.47 μg/mL\textsuperscript{−1} respectively, for stem bark ethyl acetate, root aqueous and leaf ethanol extracts. The NO\textsuperscript{*} results however, was interesting on leaf aqueous extract (IC\textsubscript{50} 2.81 μg/mL\textsuperscript{−1}) better than the ascorbic acid (IC\textsubscript{50} 26.28 μg/mL\textsuperscript{−1}) and Trolox (IC\textsubscript{50} 599.21 μg/mL\textsuperscript{−1}) standards used. The chemical components such as resorcinol (54%) and phytol (23.7%) were largely detected from ethanol extracts of stem bark and leaf respectively [48].
The leaf ethyl acetate extract of *V. calvoana* harvested from the South–South Nigeria contains largely aromatic compounds such as ethyl benzene (22%) and 1,2,3-trimethyl benzene (12.5%). FRAP inhibitions on extract (1.98 μM) and ascorbic acid (2.0 μM) were more effective than on DPPH [49]. Although the inhibition on DPPH by plant extracts have been promising but chloroform extract of *D. oliveri* exudate showed rather poor (IC$_{50}$ of 15.5 μg/mL) when compared to α-Tocopherol (0.25 μg/mL) [50]. But *S. jamaicensis* methanol extract (IC$_{50}$ 5.0 μg/mL) was more effective than ascorbic acid (IC$_{50}$ 9.0 μg/mL$^{-1}$). Compounds such as 3,5-dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one (13.7%) and D-arabinitol (13.5%) have been largely identified [51]. It was interesting to note that *S. purpurea* hexane extract showed effective DPPH inhibition (IC$_{50}$ 8.3 mg/mL) than ascorbic acid (IC$_{50}$ 11.5 mg/mL$^{-1}$) [52]. The evaluation of *E. cymosa* leaf extracts on ethyl acetate (IC$_{50}$ 0.56 mg/mL$^{-1}$) and methanol (IC$_{50}$ 0.60 mg/mL$^{-1}$) extracts justifies effective activity compared to gallic acid (IC$_{50}$ 0.47 mg/mL$^{-1}$). The 2-hexadecycloxi-rane (34.2%) and methyl linoleate (28.9%) were detected as major components of methanol extract [53]. Lastly, the GC-MS analyses of various plant extracts and antioxidant evaluation have revealed similar pattern of contents and composition in addition to contrasting influences of solvent polarity to radical inhibition efficacies. Nevertheless, interesting antioxidant efficacies were observed.

6.2 GC-MS analysis of essential oils and evaluation of antioxidant activity

The essential oils (EO) from Nigerian medicinal plants have been analyzed using the GC–MS and evaluated for antioxidants activity. Because they are mixtures of several constituents containing largely low molecular weights compounds, EO are rapidly analyzed using GC–MS to ascertain their chemical composition. The essential oils (EO) from *P. guajava* showed that 3, 6-dioxa-2,4,5,7-tetraoctane-2,2,4,4,5,5,7,7-octamethyl (11.7%) and cyclononane (10.7%) are largely identified. DPPH inhibition showed 71.83% comparable to 68.7% of ascorbic acid [54]. The antioxidant efficacy of *O. basilicum* EO was also interesting (IC$_{50}$ of 1.0 μg/mL) probably due to phenolic constituents such as methyl eugenol (15.5%), o-nitrocumene (14.0%) and 2-phenyl-1-hexanol (14.0%) [55]. The EO of common spices such as *A. melegueta* leaf, *C. crepidioides* stem bark, *O. gratissimum* leaf and *M. myristica* stem bark showed various chemical constituents with interesting antioxidant activity. The EO components largely identified from the four plants are myrtenyl acetate (29.1%), thymol (44%), γ-terpinene (53%) and γ-cardiine (31.1%) respectively. The highest antioxidant activity was found from EO of *O. gratissimum* (96.4%) which compared to BHA (96.7%). However, other EOs have demonstrated radical scavenging of >50% inhibition [56]. The leaf EO of *C. portoricensis* was found to contain thymol (9.64%) and β-caryophyllene (9.15%) as main compounds which might have resulted to 75% DPPH inhibition compared to BHT (95%) [57]. Similarly, analysis on *M. alternifolius* EO that yielded largely tricosane (19.45%) and z-14-nonanone (13.4%) with interesting efficacy (97.95%) compared to ascorbic acid (97.88%) [58]. This trend of activity demonstrated by the EO was observed in *E. maculata* which contained α-pinene (8.0%), β-trans-cimene (8.0%), 1S-α-pinene (7.0%) and cyclofenchene (7.0%) as main components, with the DPPH (IC$_{50}$ 8.0 μg/mL$^{-1}$) and FRAP (10.0 μg/mL$^{-1}$) inhibition efficacies in comparison to 9.0 and 20.0 μg/mL$^{-1}$ ascorbic acid respectively [59]. Lastly, GC-MS analyses of EO from Nigerian plants have revealed interesting but similar chemical compounds with some degree of antioxidant efficacies. EO composition containing phenolics moieties and terpenoids have indicated evidence of effective radical inhibitions.
6.3 HPLC analysis of extracts and evaluation of antioxidant activity

The high-performance liquid chromatography (HPLC) has been reported in the analysis of major chemical constituents of plant extracts alongside with the antioxidant activity. The HPLC technique uses reverse phase chromatography because of simplicity, versatility and sensitivity towards separation, purification, quantification and identification of diverse natural products such as plant phenolics, steroids, alkaloids and flavonoids [60]. Hence, the combination of HPLC methods with antioxidants evaluations may provide the needed understanding of antioxidant efficacies of plant extracts. Previous HPLC profiling of ethanol extract of Z. zanthoxyloide showed quercetin, kaempferol and caffeic acid largely quantified. DPPH inhibition (IC\textsubscript{50} 38.58 \(\mu\text{g mL}^{-1}\)) in comparison to ascorbic acid (6.63 \(\mu\text{g mL}^{-1}\)) was poor [61]. Similarly, aqueous extracts of L. taraxacifolia (IC\textsubscript{50} 6.59 \(\mu\text{g mL}^{-1}\)) and C. rubens (IC\textsubscript{50} 6.21 \(\mu\text{g mL}^{-1}\)) were less effective than Trolox (IC\textsubscript{50} 0.51 \(\mu\text{g mL}^{-1}\)). Although methanol extracts of both plants contain gallic acid, caffeic acid, quercetin, rutin, isoquercetin and kaempferol as the main compounds identified, yet the activity was not interesting. But the OH inhibition on aqueous extracts showed rather interesting results with IC\textsubscript{50} 1.94 and 1.09 \(\mu\text{g mL}^{-1}\) in comparison to IC\textsubscript{50} 1.18 \(\mu\text{g mL}^{-1}\) of vitamin C [62].

Although antioxidant activities of plant extracts using DPPH have been established to correlate with phenolics and flavonoids contents [63]. However, many of the plants evaluated for antioxidants activity have no correlation with the number and amounts of phenolics and flavonoids quantified by HPLC. The report on T. catigua ethanol, ethyl acetate, dichloromethane and butanol extracts showed DPPH inhibition with IC\textsubscript{50} of 9.17, 30.28, 42.42 and 76.35 \(\mu\text{g mL}^{-1}\) respectively. These, in comparison to ascorbic acid (20.72 \(\mu\text{g mL}^{-1}\)) indicated poor activity except the ethanol extract with lower IC\textsubscript{50} than the standard. The extract was quantified to be rich in gallic acid, chlorogenic acid rutin and quercetin [64]. Similarly, S. dulcificum contains phenolic acids and flavonoids but demonstrated poor efficacies on DPPH (IC\textsubscript{50} 139.45 \(\mu\text{g mL}^{-1}\), ABTS (IC\textsubscript{50} 135.83 \(\mu\text{g mL}^{-1}\), NO\textsuperscript{*} (IC\textsubscript{50} 119.17 \(\mu\text{g mL}^{-1}\)) and OH (IC\textsubscript{50} 147.65 \(\mu\text{g mL}^{-1}\)) [65]. However, M. whitei contains largely caffeic acid with interesting efficacies on NO\textsuperscript{*} (IC\textsubscript{50} 6.1 \(\mu\text{g mL}^{-1}\)) and FRAP (IC\textsubscript{50} 5.7 \(\mu\text{g mL}^{-1}\)) compared to ascorbic acid (3.4 and 7.0 \(\mu\text{g mL}^{-1}\)) respectively [66]. Similarly, C. papaya seeds protein analyzed using the LC-ESI-DAD-MS with largely ferulic acid in addition to flavonoid sugars, justifies the antioxidant efficacies on DPPH (IC\textsubscript{50} 0.227 \text{mg mL}^{-1}) and Fe\textsuperscript{2+} chelating (IC\textsubscript{50} 0.157 \text{mg mL}^{-1}) in comparison to ascorbic acid (IC\textsubscript{50} 0.109 \text{mg mL}^{-1}) and EDTA (IC\textsubscript{50} 0.091 \text{mg mL}^{-1}) respectively [67]. The HPLC quantification of plant extracts have shown similar classes of compounds such as chlorogenic acid, ellagic acid, caffeic acid, gallic acid, p-coumaric acid, apigenin, quercetin, rutin and kaempferol which have been repeatedly found in Nigerian plants. But the antioxidant efficacies observed were not reflective of HPLC quantification. This may indicate that phenolic compounds are quantified at miniature level which can only serve as evidence of qualitative presence in plant extracts.

7. Antioxidant activities of isolated compounds

The antioxidant evaluations on isolated compounds from Nigerian medicinal plants are rarely reported. This is probably due to funding problems associated to plant chemistry research in Nigeria, coupled with dysfunctional analytical instruments such as the NMR spectrometer. Most of the published research on isolation and characterization of compounds were carried out abroad. Of the 250 plants
analyzed for antioxidant evaluations, only 28 compounds were isolated from 44 plants together with full spectral characterization. The antioxidant activities of quercetin and quercetin-3-O-rutinoside from *B. monandra* were probably the first report on pure compounds [93]. Since then several isolated compounds were evaluated for antioxidant efficacies and in most cases compared with standard antioxidants. Thus, compounds’ efficacy only with IC\(_{50}\) values of standards are presented in Table 2. The analysis of isolated compounds showed that flavonoids and

| S. No | Chemical name | Plant | Model | Compd. (IC\(_{50}\)) | Stand. (IC\(_{50}\)) | Ref. |
|-------|----------------|-------|-------|----------------------|----------------------|------|
| 1     | Quercetin      | *Bauhinia monandra* | DPPH | 10.64 \(^*\) AA = 12.52 | [93] |
| 2     | Quercetin-3-O-rutinoside | *Bauhinia monandra* | DPPH | 16.11 \(^*\) AA = 12.52 | [93] |
| 3     | Isovitexin     | *Croton zambesicus* | DPPH | 189.1 \(^*\) QT = 5.31 | [98] |
| 4     | Trans-ethyl-3-(3, 4-dihydroxyphenyl acrylate) | *Aspilia africana* | DPPH | 14.49 \(^*\) AA = 13.18 | [99] |
| 5     | p-hydroxy benzaldehyde | *Aspilia africana* | DPPH | 73.50 \(^*\) VC = 37.5 | [102] |
| 6     | Tiliroside     | *Croton gratissimus* | DPPH | 360.1 \(^*\) AA = 70.12 | [100] |
| 7     | Isovitexin     | *Croton gratissimus* | DPPH | 211.6 \(^*\) AA = 70.12 | [100] |
| 8     | Helichryside-3-methyl ether | *Croton zambesicus* | DPPH | 183.4 \(^*\) AA = 70.12 | [100] |
| 9     | Betulin        | *Parinari curatellifolia* | DPPH | >100 \(^*\) VC = 1.98 | [88] |
| 10    | β-sitosterol   | *Parinari curatellifolia* | DPPH | >50 \(^*\) VC = 1.98 | [88] |
| 11    | Betulinic acid | *Parinari curatellifolia* | DPPH | >100 \(^*\) VC = 1.98 | [88] |
| 12    | 4-(3', 3-dihydroxy-1-mercaptopropyl) phenyl-glucosylpyranoside | *Massularia acuminata* | DPPH | 75 \(^*\) VC = 7.9 | [87] |
| 13    | Agathis flavone | *Anacardium occidentale* | DPPH | 366.4 \(^*\) AA = 4.57 | [74] |
| 14    | Quercetin-3-O-rutinoside/ rhamnoside | *Anacardium occidentale* | DPPH | 0.96 \(^*\) AA = 4.57 | [74] |
| 15    | Rosmarinic acid | *Solenostemon monostachyus* | DPPH | 4.99 \(^*\) QT = 2.32 | [97] |
| 16    | Methyl rosmarinate | *Solenostemon monostachyus* | DPPH | 5.97 \(^*\) QT = 2.32 | [97] |
| 17    | Caffeic acid   | *Solenostemon monostachyus* | DPPH | 3.03 \(^*\) QT = 2.32 | [97] |
| 18    | Methyl caffeate | *Solenostemon monostachyus* | DPPH | 13.41 \(^*\) QT = 2.32 | [97] |
| 19    | Apigenin       | *Solenostemon monostachyus* | DPPH | 26.67 \(^*\) QT = 2.32 | [97] |
| 20    | Luteolin       | *Solenostemon monostachyus* | DPPH | 5.35 \(^*\) QT = 2.32 | [97] |
| 21    | Apigenin glucuronide | *Solenostemon monostachyus* | DPPH | 185.89 \(^*\) QT = 2.32 | [97] |
| 22    | Epicatechin    | *Chrysothlym albishon* | DPPH | 19.02 \(^*\) GA = 12.82 | [101] |
flavonoids glycosides constitute major classes of antioxidants reported. Catechin isolated from *A. senegalensis* had effective DPPH inhibition (IC$_{50}$ 0.03 mgmL$^{-1}$) and Fe$^{2+}$ chelating activity (1.29 mgmL$^{-1}$) when compared to ascorbic acid (0.01 mgmL$^{-1}$) and EDTA (IC$_{50}$ 0.05 mgmL$^{-1}$) respectively [94]. The evaluation on H$_2$O$_2$ inhibition by (−)-epicatechin isolated from *A. floribunda* showed effective activity with equal strength as standard ascorbic acid (IC$_{50}$ 8.0 μgmL$^{-1}$) [95]. Similarly, the ABTS inhibition by quercetin isolated from *C. sieberiana* has resulted to effective activity of equal strength to Tocopherol (0.81 mM) [96]. The DPPH inhibition by caffeic acid (IC$_{50}$ 3.03 μgmL$^{-1}$) from *S. monostachys* is another effective activity comparable to quercetin standard (IC$_{50}$ 2.32 μgmL$^{-1}$) [97]. However, the most outstanding DPPH inhibition was recorded on quercetin-3-O-rutinoside/rhamnoside isolated from *A. occidentalis*. The 1:1 mixture of flavonoid glycoside exhibited

**Table 2.**

Antioxidant activity of isolated compounds of Nigerian plants.

| S. No | Chemical name | Plant             | Model       | Compd. (IC$_{50}$) | Stand. (IC$_{50}$) | Ref. |
|-------|---------------|-------------------|-------------|--------------------|-------------------|------|
| 23    | Epigallocatechin | *Chrysophyllum albidum* | DPPH       | 15.88$^*$          | GA = 12.82        | [101]|
| 24    | Procyanidin B5 | *Chrysophyllum albidum* | DPPH       | 8.80$^*$           | GA = 12.82        | [101]|
| 25    | Kaempferol-3-O-rutinoside | *Holarrhena floribunda* | FRAP       | 394.8$^*$           | QT = 2.95         | [88] |
| 26    | Quercetin-3-O-glucoside | *Holarrhena floribunda* | LPI        | 10.4               | QT = 2.95         | [85] |
| 27    | Kaempferol-3-O-glucoside | *Holarrhena floribunda* | FRAP       | 337.5$^*$           | QT = 2.95         | [85] |
| 28    | Quercetin-3-O-glucoside/ galactoside mixture (1: 1) | *Holarrhena floribunda* | LPI        | 9.8$^*$             | 1589.9$^*$ | [85] |
| 29    | Quercetin | *Cassia sieberiana* | DPPH       | 1.58$^a$            | AA = 2.44         | [96] |
| 30    | Kaempferol | *Cassia sieberiana* | DPPH       | 7.75$^a$            | AA = 2.44         | [96] |
| 31    | Dihydrokaempferol | *Cassia sieberiana* | DPPH       | 82.93$^a$          | AA = 2.44         | [96] |
| 32    | Piceatannol | *Cassia sieberiana* | DPPH       | 3.96$^a$            | AA = 2.44         | [96] |
| 33    | (−)-Catechin | *Alchornea floribunda* | DPPH       | 88$^b$             | AA = 6            | [95] |
| 34    | (−)-epicatechin | *Alchornea floribunda* | DPPH | 40$^b$             | AA = 6            | [95] |
| 35    | (−)-epicatechin | *Alchornea floribunda* | DPPH       | 10$^b$             | AA = 6            | [95] |
| 36    | (2R,3R)-dihydroquercetin | *Alchornea floribunda* | DPPH       | 46$^b$             | AA = 6            | [95] |
| 37    | Catechin | *Annona senegalensis* | DPPH       | 0.03$^c$             | AA = 0.01        | [15] |

DPPH, 2,2'-diphenyl-1-picrylhydrazyl radical; ABTS, 2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid; FRAP, ferric reducing antioxidant power; TAC, total antioxidant capacity; LPI, lipid peroxidation inhibition; NO, nitric oxide assay; H$_2$O$_2$, hydrogen peroxide assay; AA, ascorbic acid; QT, quercetin; RT, rutin; GA, gallic acid; VC, vitamin C; VE, vitamin E; TX, trolox; EDTA: ethylenediaminetetraacetic acid.

$^a$IC$_{50}$ = μM.

$^b$IC$_{50}$ = mM.

$^c$IC$_{50}$ = mgmL$^{-1}$. 

$^{**}$IC$_{50}$ = mgmL$^{-1}$. 

$^{**}$IC$_{50}$ = μgmL$^{-1}$. 

$^{**}$IC$_{50}$ = μgmL$^{-1}$. 

Table 2.

Antioxidant activity of isolated compounds of Nigerian plants.
IC\textsubscript{50} 0.96 \textmu g\text{mL}^{-1} less than ascorbic acid (IC\textsubscript{50} 4.57 \textmu g\text{mL}^{-1}). [74]. But generally, the antioxidant efficacies of isolated compounds from Nigerian plants are not interesting. Out of the 28 compounds isolated from 44 plants only 7 compounds from 6 plants exhibited the efficacies with strength of standard antioxidants.

8. Conclusion

Analysis of antioxidant efficacies of Nigerian medicinal plants reported from 1998 to 2018 was carried out. The aim was to provide evidence for effective antioxidants. Our findings have shown the enormous potentials of Nigerian plants as sources of natural antioxidants. We have observed various crude extracts obtained mainly from polar solvents with antioxidant efficacies better than standard compounds. Such preponderance of evidence indicated by broad spectrum of free radical and non-free radical inhibitions has defined the comparable strength of plant extracts to standard antioxidants. Nigerian plants have the capacity to protect or inhibit damage induced by free radical species. This study attempts to provide insights on the strength of antioxidant efficacies of plant extracts comparable to standard antioxidants. However, it is recommended that comprehensive approach to plant bioactive research must be adopted in search of antioxidants to avoid replication of studies especially on certain species. There is need for collaboration among Nigerian scientist working in related areas to enhance on the scope of research questions and improve on the quality of research output.

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References

[1] McCord JM, Fridovich I. Superoxide dismutase an enzymic function for erythrocuprein Hemocuprein. Journal of Biological Chemistry. 1969;244:6049-6055

[2] Prior RL, Wu X, Schaich K. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. Journal of Agriculture and Food Chemistry. 2005;53:4290-4302

[3] Carocho M, Ferreira ICFR. A review on antioxidants, prooxidants and related controversy: Natural and synthetic compounds, screening and analysis methodologies and future perspectives. Food and Chemical Toxicology. 2013;51:15-25

[4] West AP, Shadel GS, Ghosh S. Mitochondria in innate immune responses. Nature Reviews Immunology. 2011;11:389-402

[5] Kurutas EB. The importance of antioxidants which play the role in cellular response against oxidative/nitrosative stress: Current state. Nutrition Journal. 2016;15:71

[6] Sanchez C. Reactive oxygen species and antioxidant properties from mushrooms. Synthetic and Systems Biotechnology. 2016;2:13e22

[7] Halliwell B. Free radicals, antioxidants, and human disease: Curiosity, cause, or consequence? Lancet. 1994;344:721e4

[8] Kozarski M, Klaus A, Jakovljevic D, Todorovic N, Vunduk J, Petrovic P. Antioxidants of edible mushrooms. Molecules. 2015;20:19489e525

[9] Cederbaum AI, Lu Y, Wu D. Role of oxidative stress in alcohol-induced liver injury. Archives of Toxicology. 2009;83(6):519e48

[10] George S, Hamblin MR, Abrahamse H. Effect of red light and near infrared laser on the generation of reactive oxygen species in primary dermal fibroblasts. Journal of Photochemistry & Photobiology, B: Biology. 2018;188:60-68

[11] Qian X, Nie X, Yao W, Klinghammer K, Sudhoff H, Kaufmann AM, et al. Reactive oxygen species in cancer stem cells of head and neck squamous Cancer. Seminars in Cancer Biology. 2018. DOI: 10.1016/j.semcancer.2018.06.001

[12] Sies H. Strategies of antioxidant defense. FEBS Journal. 1993;215:213-219

[13] Halliwell B. Biochemistry of oxidative stress. Biochemical Society Transaction. 2007;35:1147-1150

[14] Halliwell B. How to characterize a biological antioxidant. Free Radical Research Communication. 1990;9:1-32

[15] Govindarajan R, Vijayakumar M, Pushpangadan P. Antioxidant approach to disease management and the role of ‘Rasayana’ herbs of Ayurveda. Journal of Ethnopharmacology. 2005;99:165-178

[16] Larson RA. The antioxidants of higher plants. Phytochemistry. 1988;27(4):969-978

[17] Kahkonen MP, Hopia AI, Vuorela HJ, Rauha JP, Pihlaja K, Kujala TS, et al. Antioxidant activity of plant extracts containing phenolic compounds. Journal of Agriculture and Food Chemistry. 1999;47(10):3954-3962

[18] Nakayoma J, Yamada M. Suppression of active oxygen-indeed cytotoxicity by flavonoids. Biochemical Pharmacology. 1995;45:265-267
[19] Bhadoriya U, Sharma P, Solanki SS. *In vitro* free radical scavenging activity of gallic acid isolated from *Caesalpinia decapetala* wood. Asian Pacific Journal of Tropical Disease. 2012;S833-S836

[20] Xu DP, Li Y, Meng X, Zhou T, Zhou Y, Zheng J, et al. Natural antioxidants in foods and medicinal plants: Extraction, assessment and resources. International Journal of Molecular Science. 2017;18:96

[21] National Bureau of Statistics. Annual Abstract of Statistics. Abuja, Nigeria: Federal Republic of Nigeria; 2011. p. 3

[22] Aderogba MA, Okoh EK, Adelawa TA, Obuotor EM. Antioxidant properties of the Nigerian *Piliostigma* species. Journal of Biological Sciences. 2004;4(4):501-503

[23] Ibrahim T, Muluh GK, Alexander A. Phytochemical screening, antioxidant and antibacterial activities of *Commiphora kerstingii*. International Biological and Biomedical Journal. 2015;2(3):126-133

[24] Ogunlana OE, Ogunlana OO. *In vitro* assessment of the free radical scavenging activity of *Psidium guajava*. Research Journal of Agriculture and Biological Sciences. 2008;4(6):666-671

[25] Azeez L, Adeoye MD, Majolagbe TA, Lawal AT, Badiru R. Antioxidant activity and phytochemical contents of some selected Nigerian fruits and vegetables. American Journal of Chemistry. 2012;2(4):209-213

[26] Adetutu A, Morgana WA, Corcoran O. Ethnopharmacological survey and in vitro evaluation of wound-healing plants used in South-Western Nigeria. Journal of Ethnopharmacology. 2011;137:50-56

[27] Olajire AA, Azeez L. Total antioxidant activity, phenolic, flavonoid and ascorbic acid contents of Nigerian vegetables. African Journal of Food Science and Technology. 2011;2(2):22-29

[28] Atiko R, Onocha PA, Oyedemi SO. Phytochemical analysis and antioxidant properties of leaves, stems and roots extracts of *Lasianthera africana*. Research Journal of Chemical Sciences. 2016;6(9):19-26

[29] Ekaluo UB, Ikpeme EV, Ekerette EE, Chukwu CI. *In vitro* antioxidant and free radical activity of some Nigerian medicinal plants: Bitter leaf (*Vernonia amygdalina* L.) and guava (*Psidium guajava* Del.). Research Journal of Medicinal Plant. 2015;9(5):215-226

[30] Sonibare MA, Aremu OT, Okorie PN. Antioxidant and antimicrobial activities of solvent fractions of *Vernonia cinerea* (L.) leaf extract. African Health Sciences. 2016;16(2):629-639

[31] Abalaka ME, Daniyan SY, Akpor OB, Inyinbor AA. Antimicrobial, *in vitro* free radical scavenging, antioxidant properties of leaf, bark and root extracts from *Khaya senegalensis*. UMYU Journal of Microbiology Research. 2016;1(1):46-54

[32] Adebiyi OE, Olayemi FO, Ning-Hua T, Guang-Zhi Z. *In vitro* antioxidant activity, total phenolic and flavonoid contents of ethanol extract of stem and leaf of *Grewia carpinifolia*. Beni-Suef University Journal of Basic and Applied Sciences. 2017;6:10-14

[33] Adeosun AM, Ighodaro OM, Aminu AO, Ogunlana AI. The antioxidant and phenolic profiles of five green vegetables grown in southern Nigeria. Acta Scientiarum Polonorum Technologia Alimentaria. 2016;15(4):391-397

[34] Dluya T, Daniel D, Umar Y. *In vitro* antioxidant activity and phytochemical evaluation of five medicinal plant...
extracts. The Pharmaceutical and Chemical Journal. 2017;4(5):73-82

[35] Dluya T, Daniel D, Samuel AB. Studies on in vitro antioxidant activities of methanol extract of five African traditional plants. International Journal of Research in Pharmacy and Biosciences. 2017;4(11):28-36

[36] Antia BS, Ita BN, Udo UE. Nutrient composition and in vitro antioxidant properties of Harungana madagascariensis stembark extracts. Journal of Medicinal Food. 2015;18(5):609-614

[37] Okoh SO, Asekun OT, Familoni OB, Afolayan AJ. Antioxidant and free radical scavenging capacity of seed and shell essential oils extracted from Abrus precatorius (L). Antioxidants. 2014;3:278-287

[38] Nwaehwujor OC, Ode JM, Akande OG. In vitro antioxidant activity of some herbal plants from Southern Nigeria. Journal of Medical Science. 2013;1(13):56-61

[39] Sidiq LO, Segun PA, Ogbole OO. Total phenolic contents and antioxidant activity of nine medicinal plants used in nigerian traditional medicine. Tropical Journal of Natural Product Research. 2018;2(9):438-441

[40] Ekere N, Okparanozie T, Agbo M. Effects of solvents on the in-vitro antioxidant activity of Dennettia tripetala G. Baker and Milicia excelsa (Welw.) C. Berg root extracts. Iranian Journal of Health Sciences. 2018;6(3):1-7

[41] Ohikhena FU, Wintola OA, Afolayan AJ. Quantitative phytochemical constituents and antioxidant activities of the mistletoe, Phragmanthera capitata (Sprengel) Balle extracted with different solvents. Pharmacognosy Research. 2018;10:16-23

[42] Osagie-Eweka SDE. Phytochemical analyses and comparative in vitro antioxidant studies of aqueous, methanol and ethanol stem bark extracts of Simarouba glauca DC. (Paradise tree). African Journal of Plant Science. 2018;12(1):7-16

[43] Owolabi OO, James DB, Sani I, Andongma BT, Fasanya OO, Kure B. Phytochemical analysis, antioxidant and anti-inflammatory potential of Feretia apodanthera root bark extracts. BMC Complementary and Alternative Medicine. 2018;18:12. DOI: 10.1186/s12906-017-2070-z

[44] Muhamad II, Hassan ND, Mamat SNH, Nawi NM, Rashid WA, Tan NA. Chapter 14: Extraction technologies and solvents of phytocompounds from plant materials: Physicochemical characterization and identification of ingredients and bioactive compounds from plant extract using various instrumentations. In: Ingredients Extraction by Physicochemical Methods in Food. Elsevier Inc.; 2017. pp. 523-560. DOI: 10.1016/B978-0-12-811521-3.00014-4

[45] Ajiboye AT, Musa MD, Otun KO, Jimoh AA, Bale AT, Lawal SO, et al. The studies of antioxidant and antimicrobial potentials of the leaf extract of Bauhinia monandra plant. Natural Products Chemistry and Research. 2015;3:180. DOI: 10.4172/2329-6836.1000180

[46] Akachukwu D, Uchehgu R. GC-MS antimicrobial and in vitro antioxidant assay of the leaf extract of Eugenia caryophyllata thunb. Acta Poloniae Pharmaceutica-Drug Research. 2015;72(6):1201-1215
[48] Ibrahim MA, Koorbanally NA, Shahidul Islam MD. *In vitro* antioxidative activities and GC-MS analysis of various solvent extracts of *Cassia sinueana* parts. Acta Poloniae Pharmaceutica-Drug Research. 2013;70(4):709-719

[49] Iwara IA, Igile GO, Mboso OE, Mgbeje BIA, Ebong PE. Evaluation of phytochemical components from ethyl acetate fraction of *Vernonia calvoana* using gas chromatography-mass spectrometry analysis and its antioxidants activities. African Journal of Pharmacy and Pharmacology. 2017;11(42):534-539

[50] Atolani O, Olatunji GA. Chemical composition, antioxidant and cytotoxicity potential of *Daniellia oliveri* (Rolfe) Hutch. & Dalz. Turkish Journal of Pharmaceutical Sciences. 2016;13(1):41-46

[51] Ololade ZS, Ogunmola OO, Kuyoro SE, Abiona OO. *Stachytarpheta jamaicensis* leaf extract: Chemical composition, antioxidant, anti-arthritis, anti-inflammatory and bactericidal potentials. Journal of Scientific and Innovative Research. 2017;6(4):119-125

[52] Elufioye TO, Berida TI. GC-MS analysis and antioxidant activity of *Spondias purpurea* L (Anacardiaceae). Pharmacognosy Journal. 2018;10(5):941-945

[53] Ogundajo A, Ashafa AT. Phytochemical compositions and *In vitro* assessments of antioxidant and antidiabetic potentials of fractions from *Ehretia cymosa* Thonn. Pharmacognosy Magazine. 2017;13(S3):470-480

[54] Fasola TR, Oloyede GK, Aponjolosun SB. Chemical composition, toxicity and antioxidant activities of essential oils of stem bark of Nigerian species of guava (*Psidium guajava* Linn.). EXCLI Journal. 2011;10:34-43

[55] Ololade ZS, Fakankun OA, Alao FO, Udi OU. *Ocimum basilicum* var. *purpureum* floral essential oil: phytochemicals, phenolic content, antioxidant, free radical scavenging and antimicrobial potentials. Global Journal of Science Frontier Research: B Chemistry. 2014;14(7):31-38

[56] Owokotomo IA, Jabar JM, Abata EO. Radical scavenging activity of essential oils from some Nigerian medicinal plants and spices. Applied Tropical Agriculture. 2016;21(1):196-200

[57] Okhale SE, Okoro IJ, Ezissi CC, Oladosu PO. GC-MS characterization, antimicrobial and antioxidant effects of the leaf essential oil of *Calliandra portoricensis* (Jacq.) Benth. International Journal of Pharmaceutical Science and Research. 2018;3(1):38-43

[58] Onocha A, Oloyede GK, Akintola JA. Chemical composition, free radical scavenging and antimicrobial activities of essential oil of *Mariscus alternifolius* Vahl Patricia. The Open Conference Proceedings Journal. 2016;7:160-167

[59] Ololade ZS, Olawore NO, Oladosu IA. Phytochemistry and therapeutic potentials of the seed essential oil of *Eucalyptus maculata* Hook from Nigeria. Organic Chemistry Current Research. 2013;2:1

[60] Boligon AA, Athayde ML. Importance of HPLC in analysis of plants extracts. Austin Chromatography. 2014;1(3):1-2

[61] Adekunle AS, Kamdem JP, Rocha JBT. Antioxidant activity and HPLC analysis of *Zanthozylum zanthoxyloide*. Report and Opinion. 2012;4(3):6-13

[62] Borokini FB, Labunmi L. *In vitro* investigation of antioxidant activities of *Launea taraxacifolia* and *Crascocephalum rubens*. International Journal of Food Studies. 2017;6:82-94
Antioxidants from Nigerian Medicinal Plants: What Are the Evidence?
DOI: http://dx.doi.org/10.5772/intechopen.84454

[63] Piluzza G, Bullitta S. Correlations between phenolic content and antioxidant properties in twenty-four plant species of traditional ethnoveterinary use in the Mediterranean area. Pharmaceutical Biology. 2011;49(3):240-247

[64] Kamdem JP, Stefanello ST, Boligon AA, Wagner C, Kade IJ, Pereira RP, et al. In vitro antioxidant activity of stem bark of *Trichilia catigua* Adr. Juss. Acta Pharmacetica. 2012;62:371-382

[65] Obafemi TO, Akinmoladun AC, Olaleye MT, Onasanya A, Komolafe KC, Falode JA, et al. High performance liquid chromatography (HPLC) fingerprinting, mineral composition and *in vitro* antioxidant activity of methanol leaf extract of *Synsepalum dulcificum* (sapotaceae). Journal of Applied Pharmaceutical Science. 2017;7(11):110-118

[66] Esievo KB, Fatokun OT, Adamu A, Egharevba HO. HPLC analysis, antioxidant and antiproliferative evaluation of methanol extracts of leaves and roots of *Mondia whitei* (Hook. f) Skeels. Journal of Chemical and Pharmaceutical Research. 2018;10(4):81-87

[67] Kadiiri O, Akanbi CT, Olawoye BT, Saka O, Gbadamosi SO. Characterization and antioxidant evaluation of phenolic compounds extracted from the protein concentrate and protein isolate produced from pawpaw (*Carica papaya* Linn.) seeds. International Journal of Food Properties. 2017;20(11):2423-2436

[68] Onocha PA, Oloye GK, Olasunkanmi GS. Chemical composition, brine shrimp toxicity and free-radical scavenging activity of leaf essential oil of *Acalypha Ornata* (Hochst.). Advances in Environmental Biology. 2011;5(1):188-193

[69] Mohammed A. Antioxidative and antidiabetic effects of some African medicinal plants [PhD Biochemistry]. School of Life Sciences, College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Durban, South Africa. 2016. pp. 1-250

[70] Omonhinmin AC, Dike IP, Rotimi E. Phytochemical, cytotoxicity and antioxidant activities of five anti-malaria plants. Research Journal of Medicinal Plant. 2015. DOI: 10.3923/rjmp.2015.81.89

[71] Ayoola GA, Coker HAB, Adesegun SA, Adepoju-Bello AA, Obaweya K, Ezennia EC, et al. Phytochemical screening and antioxidant activities of some selected medicinal plants used for malaria therapy in Southwestern Nigeria. Tropical Journal of Pharmaceutical Research. 2008;7(3):1019-1024

[72] Omoregie ES, Oriakhi K, Oikeh EI, Okugbo OT, Akpobire A. Comparative study of phenolic content and antioxidant activity of leaf extracts of *Alstonia boonei* and *Eupatorium odoratum*. Nigerian Journal of Basic and Applied Science. 2014;22(3&4):91-97

[73] Awah FM, Uzoegwu PN, Ifeonu P, Oyugi JO, Rutherford J, Yao XJ, et al. Free radical scavenging activity, phenolic contents and cytotoxicity of selected Nigerian medicinal plants. Food Chemistry. 2012;131:1279-1286

[74] Ajileye OO, Obuotor EM, Akinkunmi EO, Aderogba MA. Isolation and characterization of antioxidant and antimicrobial compounds from *Anacardium occidentale* L. (Anacardiaceae) leaf extract. Journal of King Saud University-Science. 2015;27:244-252

[75] Uche FI. Evaluation of antioxidant activities of some Nigerian medicinal plants by the use of 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical. MSc Pharmaceutical Sciences Degree in Pharmacoognosy. Department
of Pharmacognosy Faculty of Pharmaceutical Sciences, University of Nigeria, Nsukka. 2010. p. 80

[76] Aderogba MA, McGraw LJ, Ogundaini AO, Eloff JN. Antioxidant activity and cytotoxicity study of the flavonol glycosides from Bauhinia galpinii. Natural Product Research. 2007;21(7):591-599

[77] Adesegun SA, Orabueze CI, Coker HAB. Antimalarial and antioxidant potentials of extract and fractions of aerial part of Borreria ocymoides DC (Rubiaceae). Pharmacognosy Journal. 2017;9(4):534-540

[78] Gero A, Ahmad HS, Zezi AU, Hussaini IM. Evaluation of antioxidant activity of leaf extract of Borreria verticillata Linn (Rubiaceae). Journal of Natural Sciences Research. 2014;4(9):31-38

[79] Faboro EO, Witchitnihad W, Fadere OA, Akinpelu DA, Obefemi CA. Antibacterial and antioxidant and phytochemical screening of aqueous methanol extract of eight Nigerian medicinal and aromatic plants. Journal of Pharmacy Research. 2016;10(7):523-532

[80] Falodun A, Irabor EEI. Phytochemical, proximate, antioxidant and free radical scavenging evaluations of Calliandra surinamensis. Acta Poloniae Pharmaceutica-Drug Research. 2008;65(5):571-575

[81] Famobuwa OE, Adekunbi EA, Akinnifesi TA, Hassan GF. In vitro antioxidant and anti-bacterial properties of a contraceptive herbal mixture of Zanthoxylum zanthoxyloides Lam (Rutaceae), Euphorbia hirta Linn (Euphorbiaceae) and Abrus precatorius L. (Leguminosae). Journal of Advances in Medical and Pharmaceutical Sciences. 2016;7(1):1-7

[82] Atiku I, Patheh UU, Musa AM, Sule MI, Sani YM, Abdullahi SM, et al. Phytochemical and antioxidant activity studies of the ethanol leaf extract of Ficus sycomorus (Family: Moraceae). Nigerian Journal of Pharmaceutical Sciences. 2016;15(2):8-14

[83] Essien GE, Effiong GS. Evaluation of antioxidant potentials in methanol extract of Gongronema latifolium and Lasiathera africana leaf. European Journal of Pharmaceutical and Medical Research. 2017;4(9):841-846

[84] Kambizi L, Bakare-Odunola MT, Oladiji AT, Kola-Mustapha AT, Amusa TO, Afolabi O, et al. Proteinase inhibition, membrane stabilization, antioxidant and phytochemical evaluations of leaves, seeds and calyces of four selected edible medicinal plants. Cogent Chemistry. 2017;3:1314064

[85] Badmus JA, Ekpo OE, Rautenbach F, Marnawick JL, Hussein AA, Hiss DC. Isolation and antioxidant activity of flavonoids from Holarrhena floribunda (G.don) leaves. Acta Biochimica Polonica. 2016;63(2):353-358

[86] Onoja OS, Ezeja MI, Omeh YN, Onwukwe BC. Antioxidant, anti-inflammatory and antinociceptive activities of methanolic extract of Justicia secunda Vahl leaf. Alexandria Journal of Medicine. 2017;53:207-213

[87] Oriola AO, Aladesanmi AJ, Idowu TO, Akinkunmi EI, Obuotor EM, Ogunsina MO. A new bioactive thiophenolic glycoside from the leaf of Massularia acuminata (g. don bullock) ex hoyle (Rubiaceae). African Journal of Traditional, Complementary and Alternative Medicine. 2014;11(2):319-323

[88] Halili ME, October N, Balogun M, Namrita L, Abubakar MS. Studies of in vitro antioxidant and cytotoxic activities of extracts and isolated
Antioxidants from Nigerian Medicinal Plants: What Are the Evidence?
DOI: http://dx.doi.org/10.5772/intechopen.84454

compounds from *Parinari curatellifolia* (Chrysobalanaceae). Journal of Natural Sciences Research. 2013;3(13):149-154

[89] Adesegun SA, Elechi NA, Coker HAB. Antioxidant activities of methanol extract of *Sapium ellipticum*. Pakistan Journal Biological Sciences. 2008;11(3):453-457

[90] Ojo OA, Ojo AB, Ajiboye BO, Olaiya O, Okesola MA, Boligon AA, et al. HPLC-DAD fingerprinting analysis, antioxidant activities of *Tithonia diversifolia* (Hemsl.) A. Gray leaves and its inhibition of key enzymes linked to Alzheimer’s disease. Toxicology Reports. 2018;5:585-592

[91] Halilu ME, Usman AO, Sani NA, Hassan LG, Ugwu-Ugojefor CJ, Bello SS. Evaluation of free radical scavenging activity of *Vernonia migodii* (S. Moore) leave extracts. Nigerian Journal of Pharmaceutical and Biomedical Research. 2016;1(1):8-13

[92] Yusuf AA, Lawal B, Abubakar AN, Berinyuy EB, Omonije YO, Umar SI, et al. *In vitro* antioxidants, antimicrobial and toxicological evaluation of Nigerian *Zingiber officinale*. Clinical Phytoscience. 2018;4:12

[93] Aderogba MA, Ogundaini AO, Eloff JN. Isolation of two flavonoids from *Bauhinia monandra* (kurz) leaves and their antioxidative effects. African Journal of Traditional, Complementary and Alternative Medicine. 2006;3(4):59-65

[94] Aladejare TT, Obuotor EM, Aderogba MA. Isolation and characterization of antioxidant compounds from *Amonna senegalensis* leaf extracts. Nigerian Journal of Natural Products and Medicine. 2018;22:124-128

[95] Ajaghaku DL, Obasi O, Umeokoli BO, Ogbruatu P, Nworu CS, Ilodigwe EE, et al. *In vitro and in vivo* antioxidant potentials of *Alchornea floribunda* leaf extract, fractions and isolated bioactive compounds. Avicenna Journal of Phytomedicine. 2017;7(1):80-92

[96] Jibril S, Sirat HM, Basar N. Bioassay-guided isolation of antioxidants and α-glucosidase inhibitors from the root of *Cassia sieberiana* D.C. (Fabaceae). Records of Natural Product. 2017;11(4):406-410

[97] Taiwo BJ, Obuotor EM, Onawunmi GO, Oguntuga AO. Radical scavenging compounds from the aerial parts of *Solenostemon monostachys* BRIQ (LAMIACEAE). African Journal of Traditional Complementary and Alternative Medicine. 2015;12(6):140-144

[98] Aderogba MA, McGawc LJ, Bezabih M, Abegaz B. Isolation and characterization of novel antioxidant constituent of *Croton zambesicus* leaf extract. Natural Product Research. 2011;25(13):1224-1233

[99] Jide FF, Abiodun OO. Evaluation of antioxidant and antimicrobial properties of two isolates from *Aspilia africana*. International Research Journal of Pharmacy. 2012;3(7):135-138

[100] Ndhlala AR, Aderogba MA, Ncube B, van Staden J. Antioxidative and cholinesterase inhibitory effects of leaf extracts and their isolated compounds from two closely related *Croton* species. Molecules. 2013;18:1916-1932

[101] Idowu TO, Ogundaini AO, Adesanya SA, Onawunmi GO, Osungunna MO, Obuotor EM, et al. Isolation and characterization of chemical constituents from *Chrysophyllum albidum* stem-bark extracts and their antioxidant and antibacterial properties. African Journal of Traditional Complementary and
Alternative Medicine. 2016;13(5): 182-189

[102] Johnson EC, Etim EI, Archibong EO. Isolation and anti-oxidant potentials of para-hydroxybenzaldehyde from the methanol leaf extract of *Aspilia africana* (Pers.) C.D. Adams (Asteraceae). Nigerian Journal of Pharmaceutical and Applied Science Research. 2017;6(1):26-32