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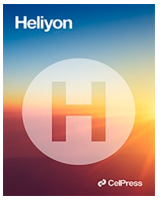

Review article

A review of indigenous knowledge and ethnopharmacological significance of African Copaiba Balsam Tree, *Daniellia oliveri* (Fabaceae)

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A R T I C L E I N F O

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A B S T R A C T

Daniellia oliveri has found its indigenous relevance in the management of diseases including but not limited to diabetes mellitus, tuberculosis, fever, ulcers, pain, worm manifestation, pneumonia, skin ailments, infectious diseases, sickle cell anaemia, hence, a review of its indigenous knowledge, ethnopharmacological and nutritional benefits was undertaken. Information used for the review was sourced from popular scientific databases (Google Scholar, PubMed, Science Direct, Web of Science, BioMed Central, JSTOR, African Plant, Global Biodiversity Information and others), conference proceedings, dissertations or theses, chapters in books, edited books, and journal collections. The materials obtained from 121 scientific documents targeting majorly between 1994 and 2023 established the presence of major secondary metabolites (such as polyphenols, flavonoids, saponins, alkaloids, etc.), minerals (e.g., sodium, potassium, phosphorus, selenium, calcium, magnesium, etc.), vitamins (beta-carotene, thiamine, riboflavin, niacin, ascorbic acid, etc.), and nutrients (crude protein, moisture, dry matter, ether, carbohydrates, and energy). Literature also lent credence to the preliminary safety profiles of the plant and its pharmacological potentials as analgesic, antinociceptive, antioxidant, antidiabetic, antidiarrhoeal, anthelmintic, anti-inflammatory, antimelanogenesis, antimicrobial, antiplasmodial, antisickling, cardiotoxic, cytotoxic, and neuroprotective agents. While the review is majorly limited to Africa particularly western countries (such as Nigeria, Burkina Faso, Mali, Ghana, Togo, and Benin) and the plant is found to be largely underutilized, it is evident that limited information exists on the *in vivo* pharmacological evaluation, bioactive compounds identification, and there is a lack of preclinical and clinical trials for possible drug development. Based on the aforementioned, it is hoped that further research studies geared toward providing insights into the established grey areas (such as traditional use investigation, targeted or assay-guided compounds identification, and preclinical and clinical studies) are necessary in order to fully explore the therapeutic, nutritional, and economic benefits of the plant.

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1. Introduction

Medicinal plants (MP) have continued to play a part in the maintenance of health in several communities across the world. Typically, a number of medicinal plants including *Duabanga grandiflora*, *Lepidagathis hyalina*, *Ophiorrhiza rugosa*, *Andrographis paniculata*, *Aglaonema hookerianum* and many others have been explored for the attainment of health in people's lives [1–5]. With well over 17810 species, 80% of the global population uses MP in various formulations against a number of diseases associated with mental function, physical and non-disease-related care that are not limited only to diabetes mellitus, hypertension, fever, cancer, pain, infections, headaches, migraine, infertility problems [6]. The impact of MP is far-reaching; wide acceptance, easy accessibility, cost-effectiveness, and lesser or no toxic implications are some of the factors that marked its preference in recent times compared with conventional treatments with various side effects. A typical example of these MP is *Daniellia oliveri* (*Rolfe*) Hutch. & Dalz., which is endowed with numerous medicinal uses and has found consistent applications for more than 40 decades [7]. However, despite the numerous recorded nutritional compositions of its parts (leaves, stem bark, and root), the plant is still considered to be underutilized [8].

Daniellia oliveri belongs to an economically important family, Fabaceae. The family contains ca. 19500 species among 770 genera [9]. According to the last taxonomic revision on the genus, Daniellia, ten species (*D. alsteeniana*, *D. glandulosa*, *D. klainei*, *D. oblinga*, *D. ogea*, *D. pilosa*, *D. pynaertii*, *D. soyauxii*, *D. thufera* and *D. oliveri*) are currently recognized [10] with *D. oliveri* being the most economically useful species; widely explored in Africa [10]. In some parts of Africa particularly Sudan and Guinea, the tree is regarded as the largest tree in the wooded savannahs, where it is used and traded for timber, gum, and medicinal uses [11]. Due to the dependence of the teeming African population on MP, the plant has been further explored by different cultures in the treatment of several ailments such as epilepsy, pain (abdominal, menstrual and general body), rheumatism, fever (malaria, jaundice), diabetes, dementia, sexual dysfunction, skin disease, headaches cold, cough, ulcer, dysentery, and to prevent miscarriages in pregnant women [12,14]. The numerous traditional uses and medicinal records of the plant have made several ethnopharmacological studies, as well as phytochemistry of different extracts to lend credence to different folkloric uses. However, the information are still scattered in the literature, as we are not aware of any review paper on this important, and yet underutilized plant species. Therefore, this paper aims to highlight the indigenous knowledge, nutritional and ethnopharmacological significance of *D. oliveri* in Africa by critically appraising its pharmacological properties, phytoconstituents, and safety profiles.

1.1. Nomenclature, botanical description, and distribution

Daniellia oliveri, a member of the subfamily Caesalpinioideae and Fabaceae family was named by Hutchinson and Dalziel with *Paradaniellia oliveri* Rolfe as the basionym [15]. Due to the popularity of *D. oliveri* among several cultures, the species has several vernacular names including Falmey, Za, Iya (Benin); Maje, Agba, Eepo-Iya (Nigeria); Sana, Sana yiri, Aonga (Burkina Faso); Ewe-lifiti, Onyabugu (Togo); Santan, Sambian, Tewi (Senegal); Sanam brou, Mudie, Sourotchiqui (Cote d'Ivoire); Farme, Mage (Niger); Tallo, Dettah (Gambia); Bolengu (Zaire); Sinfa N'dola (Congo); Lonlaviol (Gabon); Sanan, Kedje, Kaha, Kalahi (Mali); Aonga, Osanya, Niale (Ghana); Santan (Guinea-Bissau); Sandan, Tiewi, Ouloungui (Guinea); Boussa (Togo); Tere Bente, Capalier, Africain de Balsam (French); Ogea (United Kingdom); Daniella (Germany); Samein (Arabic); Copaihu africana, West African Copal, Rolfe, African copaiba Balsam, African copiba Balsani tree (English) [13,16,17].

In terms of morphology, the plant is an evergreen tree [18] growing up to a height of 30.48 m and a trunk diameter of 1.22 m. The leaves with 4–9 leaflets (0.06–0.15 m x 0.04–0.08 m) are green and paripinnate [19]. While the leaves also have spines of 0.15–0.30 m long, the leaflets may be oblong-ovate or lanceolate and are oppositely paired (to one another) [13,20]. The base is glabrous, petiolate (0.15–0.46 m long), and swollen [19]. Inflorescence consists of glabrous sepals (0.01–0.02 × 0.01 m diameter) and large petals (0.008–0.015 m long) [18,21], while the flowers are white in colour, panicles flat (terminal) with alternate branches (horizontal). The fruit is flat, obovate with valves (rigid and papery), to which a funicle of 0.015 m long attaches to one of the valves [20].

In terms of distribution, *D. oliveri* is native to tropical Africa and Central Africa and it is distributed in countries such as Burkina

Table 1
Indigenous uses of *Daniellia oliveri* (Rolfe) Hutch & Dalz.across region or countries.

No	Local names	Ailment(s) cured	Region/country	References
1	Aonga, Osanya, Niale	Pain, toothache, headache, dysmenorrhea, gonorrhoea	Ghana	[36,38]
2	Kahi	Menstrual, STD (syphilis, chlamydia), worm infections, stomach troubles	Northern Cameroun	[6,28]
3	Sana, Sana yiri, Aonga	Mental problems, headaches, tuberculosis, fever (jaundice), pneumonia, ulcers, hemiplegia, wounds, hernias, impotence, hiccups, and skin problems as well as pregnancy pain, skin ailments	Burkina Faso	[22,29,31,52]
4	Maje, Agba, Iya	Diabetes mellitus, syphilis, earache, ringworm, fever (typhoid), diaarhoea, tumors (breast), abscesses, genito-urinary tract infections, swellings, bacterial and fungal infections	Nigeria (Northern and Southern)	[8,32,34,35,61, 118,119]
5	Sanam brou, Mudie, Sourotchiqui	Aphrodisiac and diuretic. Other diseases include headache, skin illnesses, cough, painful menstruation, ulcers, venereal illnesses, leprosy, sores, dysentery, wounds (circumcision), fever, tuberculosis, rheumatism, kidney problems	Cote D'Ivoire	[7,39,54]
6	Boussa	Fungi infection such as intertrigo, oral candidiasis, sexual candidiasis	Togo	[20]
7	NS	Headache, wound healing, yellow fever, psychosis and anxiety	Africa	[12]

STD: Sexually transmitted diseases; NS: Not stated.

Table 2
Phytoconstituents from *Daniellia oliveri* (rolfe) Hutch. & Dalz.

No	Part(s)	Fractions/dilution solvent	Phytocompounds	Technique (s)	Region(s)	Reference (s)
1	Trunk bark	Aqueous-ethanol	Glycerol ethanoate, Pyrocatechol, Octadeca-9-enamide, Methyl ethanoate, Oxime benzyloxymethyl, Valproic acid, Syringole, carotenoid, Pyrocatechol 3-Méthyl, Orthovanilline, Cholestane, Phloroglucinol, 4-ethoxymethyl-2-methoxyphenol, α- methyl mannofuranoside, 2-hydroxy-5-methylisophthalaldehyde, 3-deoxyestradiol, Hexadecanamide, 9Z-12-hydroxyoctadecenamide, Cholesta-2.4-diene, Ethylisoallocholate, Hydrocortisone acetate, ursodeoxycholic acid	GC-MS	Benin	[45]
2	Bark (oil)		α-Pinene, α-Cubebene, Cyclosativene, α-Copaene, β-Bourbonene, β-Cubebene, *trans*-β-Elemene, Sesquithujene, *cis*-α-Bergamotene, (*E*)-Caryophyllene, β-Copaene, *trans*-α-Bergamotene, (*Z*)-β Farnesene, α-Himachalene, Geranyl acetone, *trans*-Muurola-3,5-diene, (*E*)-β-Farnesene, α-Humulene, Sesquisabinene, *allo*-Aromadendrene, *trans*-Cadina-1(6),4-diene, γ-Muurolene, (*E*)-β-Ionone, γ Himachalene, *ar*-Curcumene, *trans*-β-Bergamotene, β-Selinene, γ-Amorphene, Bicyclogermacrene, α-Selinene, α-Muurolene, (*Z*)-α-Bisabolene, β-Bisabolene, β-Curcumene, γ-Cadinene, δ-Cadinene, *trans*-Calamenene, Zonarene, β-Sesquiphellandrene, *trans*-Cadina-1,4-diene, α-Calacorene, 1,5 Epoxysalvial-4(14)-ene, Caryophyllene oxide, Salvial-4(14)-en-1-one, Humulene epoxide I, Tetradecanal, (*Z*,*Z*)-Geranyl, Linalool, Cubenol, Cadalene, 10-*nor*-Calamenen-10-one	GC-MS	Nigeria	[46]
3	Exudate	Dichloromethane	β-Cubebene. Copaene, *Cis*-muurola-4(14),5-diene, Aromadendrene, Murolene, δ-Cadinene, Bicyclo[3.3.1]nonane, 1 phenyl-β-Calacorene, Spathulenol, 1-Formyl-2,2-dimethyl-3-trans-(3-methyl-but-2-enyl)-6-methylidene-cyclohexane, 1,3,3-Trimethyl-2-hydroxymethyl-3,3-dimethyl-4-(3-methylbut-2-enyl)-cyclohexene, Mansonone C, Cadala-1 (10),3,8-triene, 2(5H)-Furanone, 5-(2,5-dimethylphenyl)-4-methyl-14-heptadecenal, 1-(4-Hydroxy-7-isopropyl-4-methyloctahydro-1H-inden-1 yl) ethenone, 5,14-Dimethyl-12,17-dioxogonan-3-yl acetate, 2,2,6,6-Tetramethylheptane, 4-Hydroxyimino-but-2-enoic acid, ethyl ester, 1,2-Dimethylcyclopentanol, n-hexadecanoic acid, polyalthic acid	GC-FID/ GC-MS	Nigeria	[67]
4	Exudates	Heptane-ether (80/20 v/v)	Cadelene	HPLC	France	[22]
5	Leaves Stem bark Roots	Aqueous-methanol (1:2 v/v)	Gallic acid, protecatechic acid, catechin, chlorogenic acid, caffeic, *p*-coumaric acid, homo-orietin, quercetrin-glucosyl and coumarin Gallic acid, protecatechic acid, chlorogenic acid, caffeic, *p*-coumaric acid, homo-orietin, rutin, quercetrin-glucosyl, quercetrin-dehydrate, coumarin, delphinidi and quercetrin Gallic acid, protecatechic acid, caffeic, *p*-coumaric acid, homo-orietin, rutin, quercetrin-glucosyl, quercetrin-dehydrate, coumarin and quercetrin	RP-HPLC	Mali	[41]
6	Leaves	n-pentane	α-copaene, β-bourbonene, β-cubebene, β-elemene, cyperene, α-gurjunene, β-caryophyllene, β-copaene, α-guaiene, β-humulene, α-humulene, allo-aromadendrene, γ-amorphene, γ-muurolene, germacrene D, β-selinene, muurola-4(14),5-diene, α-selinene, epi-cubebol, α-muurolene, γ-cadinene, *cis*-calamenene, cubebol, δ-cadinene, cadina-1,4-diene, α-calacorene, 1-norbourbonanone, β-calacorene, elemol, cadinene ether, caryophyllene oxide, germacrene D-4-ol, salvial-4(14)-enone, humulenol, humulene oxide II, 1,10-di-*epi*-cubenol, α-cadinol, neo-intermedeol, *cis*-calamenen-10-ol, *trans*-calamenen-10-ol, cadalene, 10-nor-calamenen-10-one and 14-oxy-α-muurolene α-copaene, β-bourbonene, β-cubebene, β-elemene, cyperene, α-gurjunene, β-caryophyllene, β-copaene, α-guaiene, α-humulene, allo-aromadendrene, γ-amorphene, γ-muurolene, germacrene D, β-selinene, muurola-4(14),5-diene, α-selinene, α-muurolene, germacrene A, *cis*-calamenene, δ-cadinene, cadina-1,4-diene, α-calacorene, β-calacorene, caryophyllene oxide, germacrene D-4-ol, salvial-4(14)-enone, humulene oxide II, fonenol, neo-intermedeol, *cis*-calamenen-10-ol, *trans*-calamenen-10-ol, cadalene and oplopanone	GC, GC-MS	Senegal Ivory Coast	[47]
7	Bark	NS	α -cubebene, α -ylangene, α -copaene, β - e I e m e n e cyperene, β -caryophyllene, β -gurjunene, α -humulene, allo-aromadendrene, germacrene D, valencene, bicyclogermacrene, α-muurolene, γ -cadinene, 6-cadinene, α -calacorene, β-calacorene, γ -muurolene, germacrene D-4-01, cubenol, T-muurolol, α -cadinol and calacorene oxide	GC, GC-MS	Benin and Burkina Faso	[48]

(*continued on next page*)

Table 2 (*continued*)

No	Part(s)	Fractions/dilution solvent	Phytocompounds	Technique (s)	Region(s)	Reference (s)
8	Root Stem bark Leaves	DCM Ethylacetate Petroleum ether DCM Ethylacetate Petroleum ether	Germacrene D, 1-tridecanol, Cedrene, Cadina-1(10),4-diene, Pentadecanoic acid methyl ester, Hexadecanoic acid, Octadecadienoic acid methyl ester, Octadecenoic acid methyl ester, *Cis*, *cis* 7-10 headecadienal, Aromadrene oxide, 1-naphtalencarboxylic ac, delta.-Cadinene, (+)-, Bicyclo[5.2.0]nonane, 4-methylene-2,8,8- trimethyl-2-vinyl and Enantio-Polyalthic acid or Daniellic acid. Germacrene D, Naphtalene, *T-murolol,* Columbin, Hexadecanoic acid, *Cis*, *cis* 7-10 hexadecadienal, *Cis*, *cis* 7-10 hexadecadienal, 10–12 pentacosadienyoic acid, Iso-aromadendren epoxid, 1-naphtalencarboxylic acid, Cadina-1(10),4-diene, *α-Cadinol,* Cadala-1(10),3,8-triene, 2 (3H)-Benzofuranone, 6-ethenylhexahydro-6- methyl-3-methylene-7-(1-methylethenyl), Bicyclo [5.2.0] nonane, 4-methylene-2,8,8-trimethyl-2-vinyl-, 1-Naphthalenecarboxylic acid, 5-[2-(3- furanyl)ethyl]decahydro-1,4a-dimethyl-6- methylene, Benzene-1-isopropyl-4-methyl- and *β*-Stigmast-8(14)-en-3-ol. Hydroxyl amine, Nonanoic acid, *α*-caryophyllen*,* Naphtalene, Isocoumarin, Caryophyllen oxide, 12 oxabicyclic [9,10]dodeca-3, 7-diene, Myristic acid, Pentadecanoic acid, Benzenpropanoic acid, Hexadecanoic acid, 10-dodecyn-1-ol, Octadecadienoic acid, Octadecadienoic acid Cis, cis 7-10- Hexadecadienal, Eicosapentaneoic acid methyl ester, Linolenic acid, Labda-8(20),13(16),14-trien-18-oic acid, Mellein (3,4-Dihydro-8-hydroxy-3-methylisocoumarin), Caryophyllene epoxide, Humulene-1,2-epoxide, Benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, methyl ester, 3-Tetradecy-n-1-ol, Stigmasta-5,22-dien-3-ol, (3.*β*.)-/Stigmasterin and *γ*-sitosterol. Pentadecanoïc acid, Hexadecanoic acid, Chloromethyl chlorododecanoate, Hexadecanoic acid 1,1-dimethyl ester, Docosatetranoic acid methyl ester, Octadecadienal, Octadecanoic acid, 2-Methylbutanoic acid, Succinic acid, Vanillin, Benzoic acid, Benzoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, Tetradecanoic acid/Myristic acid, Hexadecanoic acid methyl ester, *n*-Pentadecanoic acid ester, Linoleic acid, methyl ester, 6-Octadecenoic acid, methyl ester, (Z)-/Methyl *cis*-6-octadecenoate, 9,12-Octadecadienoic acid, *cis*-10-Heptadecenoic acid, Heptadecanoic acid (Margaric acid), Hexadecane-1,2-diol, 12-Octadecadienoic acid (Z, Z)-/Linoleic acid, *trans*-9-Octadecenoic acid/(9E)-9-octadecenoate, arachidic acid, Behenic acid/Docosanoic acid, 9-Octadecenoic acid, Oleic acid, Tetracosanoic acid/tetracosanoate, Pentacosanoic acid, Hexacosanoic acid, Campesterol, Stigmasterol, β-sitosterol and β-Amyrin. Hexadecanoic acid, 3,12-Octadecadienal, 8-methyl 6 nonenamide and 5,9-dimethyl cyclodecanol 6-linalool, Aromadendrene, *α*-caryophyllen, Germacrene D, Naphtalene, Caryophyllene oxide, 1,5,5,5,8-tetramethyl-12-oxabicyclo [9,10] dodeca-3,7-diene, *T*-murolol, Tricyclo [5.2.2.0(1,6)] undecane-3-ol, Hexadecanoic acid, 3,7,11,15- tetramethyl-2-hexadecen-1-ol, Cis, cis, cis, 7-10-13-hexadecatrienal, 6-chamigrene, (7a-isopropenyl-4, 5-dimethyloctahydroinden-4-y) methanol, Aromadendrin oxide, Cadina-1(10),4-diene/*δ*-Cadinene, Humulene-1,2-epoxide/Humulene epoxide 2 and 9,12-Octadecadienoic acid.	GC-MS	Togo	[20]
9	Leaves	Stem bark	n-Hexadecanoic acid, 15-Hydroxypentadecanoic acid, Tetradecanoic acid, Glycidyl palmitate, Octadecanoic acid, 2-hydroxy-1, 3-propanediyl ester, cis-Vaccenic acid, Oleic acid, Cyclopentadecanone, 2-hydroxy, 9-Octadecenal, (Z), *trans*-13-Octadecenoic acid, 15-Hydroxypentadeca-noic acid, Lauric anhydride, Lauric acid, 3, 4-dichlorophenyl ester, Carazolol, Dodecanoic acid, 1-(hydroxymethyl)-1, 2- ethanediyl ester	GC-MS	Nigeria	[120]
10	Stem bark	Ethanol	Caffeic acid, *p*-coumaric acid, ferulic acid, rutin, apigenin-7-glucoside, quercetin and kaempferol	HPLC	Nigeria	[55]

GC: gas chromatography; GC-MS: gas chromatography-mass spectrometry; HPLC: high-pressure liquid chromatography; RP-HPLC: reverse-phase high-pressure liquid chromatography; DCM: dichloromethane; NS: not stated.

Faso, Benin, Cameroon, Gambia, Nigeria, Senegal, Sudan, Uganda, and the Democratic Republic of Congo [7,22], mostly in the savannah and woodland regions [13,23]. The plant has also been reported to be found in the Amazon region and South America [14, 24].

1.2. Indigenous uses

Several ethnobotanical studies have reported the family Fabaceae as one of the most important families of angiosperm in terms of

ethnobotanical uses most especially for food and medicine [25–27]. The plant is explored for various indigenous uses as presented in Table 1, with the majority of the ethnobotanical records from different treatments being peculiar to some regions and or tribes in Africa. In the Garoua, the northern part of Cameroun, its usage includes for treatment against menstrual disorders, sexually transmitted diseases (such as syphilis, chlamydia, gonorrhoea, HIV/AIDS, genital herpes) [6], and worm infections [28]. Neuropsychiatric disorder [29], headaches, tuberculosis, fever (jaundice), pneumonia, ulcers, hemiplegia, wounds, hernias, impotence, and hiccups [30,31], diarrhoea (bark), malaria fever, pregnancy pains (stem bark) and fatigue (leaves), skin conditions (seed oil) [22], are some of the plant's indigenous usefulness in Burkina Faso. In Nigerian traditional medicine, stem bark, leaf, and root are handy for the treatment of syphilis, pain in the ear, ringworm, diarrhoea, backache, and fever, most especially typhoid [8,32,33]. Regionally, there are differences in the part of the plant adopted for diseases therapy; while the northern Nigeria used the leaf for diabetes and other ailments such as gastrointestinal tract (GIT) disturbances, diarrhoea, and as sexual desire stimulant [34], the southerners uses the root for diabetes management [35] as well as its use (leaf and bark) for mouthwash (in cases of toothache or tooth troubles) and wound healing in the unspecified region [24]. While it is used to cure pain in northern Ghana [36], other areas applied the gum resin for skin diseases, bark and leaves (decoction) for toothache, dysmenorrhea (bark), and headaches (infusion of bark and buds) [37] as well as the roots for gonorrhoea [37,38]. The gum is similarly adopted for aphrodisiac, diuretic purposes and against other numerous illnesses including headache, cough, and painful menstruation in Cote D'Ivoire [39]. In Togo, the stem bark and sap of the plant is used for managing various fungi infection including intertrigo, oral candidiasis, and sexual candidiasis [20]. Additionally, the plant is sometimes incorporated with other plants for curing disease conditions such as ulcers, venereal illnesses, leprosy, sores, dysentery, wounds (circumcision), fever, tuberculosis, rheumatism, and kidney problems [7]. Generally, in Africa, the flush of the newly emerging leaves is used in preventing miscarriages in women and diabetes, while the powder from the dried leaves is used for backache, headache, wound healing, and yellow fever [12,14]. The roots of the plant have also found usage in the treatment of psychosis and anxiety [12]. Other uses of the plant are in its consumption as foods and construction (of furniture, boat, and canoe) [10–12].

1.3. Mineral composition and phytochemistry of D. oliveri

A number of mineral elements (both minor and major) required for proper functioning and overall wellbeing of the human body have been detected in the plant most especially, the leaves and the barks. An analysis of the elemental composition of the leaf and bark of *D. oliveri* revealed the presence of sodium (23.47 and 20.33 mg/100 g), potassium (42.46 and 41.24 mg/100 g), calcium (17.47 and 15.53 mg/100 g), magnesium (21.43 and 25.38 mg/100 g), zinc (16.92 and 18.71 mg/100 g), iron (5.20 and 4.38 mg/100 g) and lead (16.00 and 15.34 mg/100 g) [7]. Additionally, the stem bark was found to contain various minerals [such as calcium (71.33 mg/100 g), phosphorus (45.08 mg/100 g), potassium (8.17 mg/100 g), sodium (25.11 mg/100 g), iron (3.57 mg/100 g), zinc (10.22 mg/100 g), magnesium (20.93 mg/100 g), selenium (1.45 mg/100 g) and manganese (1.33 mg/100 g)], vitamins (beta-carotene, thiamine, riboflavin, niacin, pyridoxine, cyanocobalamin, ascorbic acid, calciferol and phytonadione at 1.97, 0.74, 0.42, 0.30, 0.22, 0.18, 6.84, 0.13 and 0.10 mg/100 g, respectively) and nutrients [including moisture (6.25%), dry matter (93.75%), crude protein (6.07%), ether (1.03%), ash (9.11%), carbohydrate (21.09%) and energy (488.73 KJ/100 g)] in a study by Alagbe et al. [40]. The plant was reported to possess various secondary metabolites as established from various submissions from different geographical regions. Typically, polyphenols, flavonoids, anthocyanins, glycosides, tannins, saponins, terpenes, and alkaloids were detected from the plant (leaves, stem bark, and roots) from Mali [41], sterols, polyterpenes, alkaloids, tannins and anthocyanin [6,42] from Togo. Additionally in Ghana, stem bark contains, terpenoids, saponins, steroids, flavonoids, tannins, phlobatannins, emodels, and flavanols [36] while the Nigeria-studied phytochemicals are flavonoids, alkaloids, saponins, tannins, carbohydrates, reducing sugars, glycosides, steroids, and terpenoids from the root [35], tannins, cardiac glycosides, steroids, terpenes, flavonoids and saponins in the stem bark [43] and alkaloids, flavonoids, phenols, tannins, saponins from the leaf [8] as well as sterols, polyterpenes excluding saponins in Ivory Coast [44].

The gas chromatography-mass spectrometry (GC-MS) analysis of the aqueous-ethanolic trunk bark revealed the presence of 22 compounds not limited to glycerol ethanoate, pyrocatechol and octadeca-9-enamide [45]. The oil from the exudates of the plant collected in Ilorin, Nigeria had 22 compounds revealing the presence of diterpenes as the major constituents with δ-cadinene (42.92%) as the most abundant phytocompound followed by copaene (11.36%), *cis*-muurola-4(14),5-diene (9.56%), polyalthic acid (4.6%), β-calacorene (4.37%), 2(5H)-furanone, 5-(2,5-dimethyl phenyl)-4- methyl- (4.35%) and aromadendrene (4.14%) [43]. Similarly, the oil (oleoresin) from the bark collected from three regions in the northern part of Nigeria presented 59 compounds with δ-cadinene (12.8%), α-muurolene (6.7%), α-calacorene (5.9%), and caryophyllene oxide (5.5%) as major components while epoxide II (8.0% and 16.3%), caryophyllene oxide (7.4% and 12.4%), pentadecanal (8.9% and 6.0%), phytone (6.5% and 2.2%), δ-cadinene (5.3% and 3.0%), and α-muurolene (5.3% and 2.6%) are prominent constituents of its leaves [46]. Cadalene was obtained from the exudates (oleoresin) through a high-pressure liquid chromatography technique (HPLC) [22]. A study by Schwob et al. [47] on the comparison of the oils from the leaves part collected from Senegal and the Ivory Coast established that the oil constituents (though in varied proportions) were terpenoids in nature with δ-cadinene and α-copaene being the most prominent having 24.2–31.1% and 7.0–8.3% abundance, respectively (Table 2). An earlier study by Menut et al. [48] comparing the oil constituents of the bark from Benin and Burkina Faso revealed sesquiterpenoids as major compounds with germacrene D in addition to α-copaene and δ-cadinene as the most abundant with 4.5–29.5%, 6.0–12% and 25.5–29.8%, respectively. The δ-cadinene was common in both regions but germacrene D was richer in the species from Burkina Faso while α-copaene was found in abundance from the species from Benin. However, in Togo, the GC-MS evaluation of the leaves, stem bark, and roots in various solvents revealed that most of the phytoconstituents for leaves are terpenes with aromadendrin oxide as the most abundant (37.66%), fatty acids, sterols, phenolics and terpenes for the stem bark with octadecadienal, octadecadienoic acid Cis, cis 7-10- hexadecadienal and, 8-methyl 6 nonenamide as prominent compounds (22.33, 20.02 and 8.46% for petroleum ether, dichloromethane (DCM) and ethylacetate fractions, respectively) while the roots are more of

terpenes, fatty acids and phytosterols depicting 1-naphtalencarboxylic with the highest abundance (78.87, 81.29% for DCM and ethylacetate fractions, respectively) [20]. The studies above have confirmed the influence of geographical distribution on the essential oil composition and phytoconstituents of the plant. There is also a need to test the essential oil extracted from *D. oliveri* from different localities to see whether it will affect its pharmacological activities.

Spectroscopic isolation and identification of four glycosides flavonoids [rutin (Fig. 1A), narcissin (Fig. 1B), quercitrin (Fig. 1C), and quercimeritrin (Fig. 1D)] from the ethanolic fraction of the leaves have also been reported [49]. Similarly, two triterpenoids; a lupane and oleanane −9(11), 12-diene acid identified as Lup-20(29)-en-3-ol [Lupenol (Fig. 1E)] and 3-acetoxy −9(11),12-dien-e-28-carboxylic acid (Fig. 1F) have also been isolated from DCM extract of the leaves of *D. oliveri* [50]. Additionally, polyalthic acid (Fig. 1G) from exudates [51], daniellic acid (Fig. 1H) from oleoresin were also reportedly isolated from the plant [52].

Despite that, the leaf of *D. oliveri* is ethnobotanically useful as the bark, and several compounds have been isolated from it, studies on its essential oil composition remain relatively scanty. Therefore, it is important to explore this knowledge gap perhaps the leaf may contain constituents of significant ethnopharmacological and industrial importance. Also, no study has investigated the presence or absence of heavy metals and antinutrients such as calcium oxalate crystals from both the leaf and the bark. The study is important to unravel these plant parts' safety and toxicity profiles.

2. Methodology

2.1. Strategy adopted for literature search

Based on Moher et al. [53] description of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline, information on the review was generated from prominent databases (Google Scholar, Science Direct, Web of Science, PubMed, BioMed Central, JSTOR, African Plant, New York Botanical Garden, Brazilian Flora Online, Global Biodiversity Information), journals, books, and/or chapters, thesis, dissertations, and conference proceedings, when *Daniellia oliveri* was cross-referenced with terminologies such as medicinal plants, indigenous uses, ethnoveterinary potentials, phytochemistry, bioactive compounds, secondary metabolites, pharmacological effects, biological properties, toxicity or side effects, quality control, and nutritional benefits between 1994 and 2023, resulting in a total number of 121 scientific documents out of 134 downloaded or identified records.

2.2. Selection of study

Parameters considered during the selection of used or studied reports are: (1) studies written in the English Language; (2) presented information relating to *D. oliveri* (a) ethnobotany (nomenclature and/or common names, description and distribution), (b) indigenous uses, (c) phytochemistry (secondary metabolites, phytoconstituents), (d) pharmacological and biological potentials, (e) quality and nutritional effects; (3) reports providing information on the applications of the plant. Articles exempted are (1) those written in other languages aside from the English Language; (2) studies that reflect nothing about the plant; (3) studies that mentioned the name of the plant with no information on the ethnobotany, indigenous uses, phytochemistry, pharmacological/biological effects, nutritional benefits, and other applications. The authors adopted the '2SR' acronym (search, screen, and review) during the consideration of the

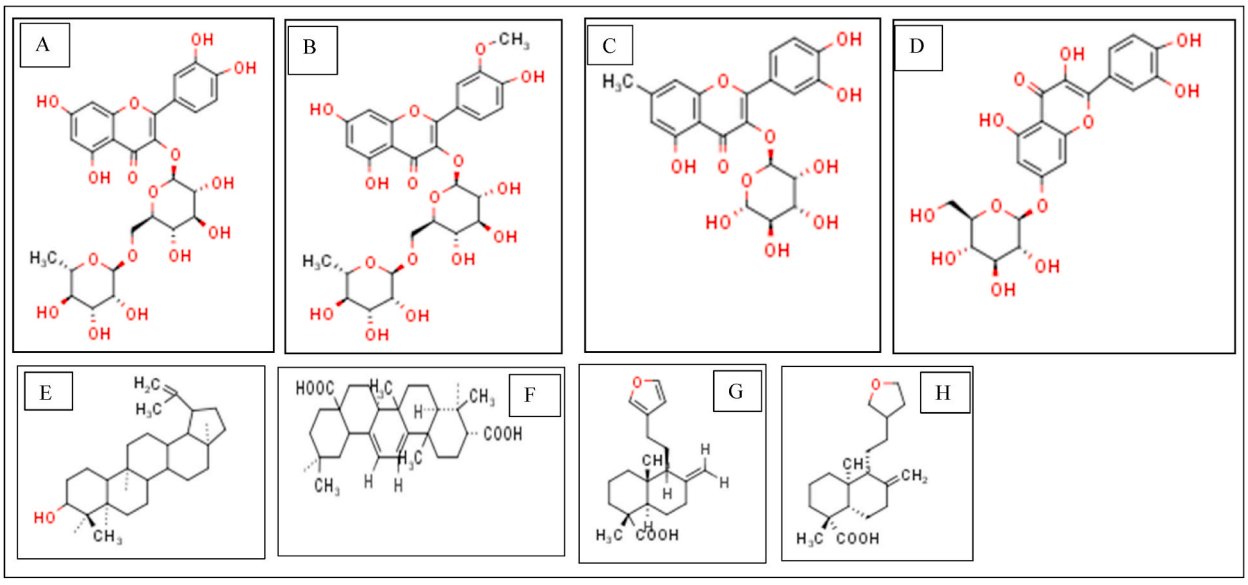

Fig. 1. Structures of isolated compounds from *D. oliveri* [49–52]. [A] Rutin; [B] Narcissin; [C] Quercitrin; [D] Quercimeritrin; [E] Lupenol; [F] 3-acetoxy- 9(11), 12-diene-28-carboxyllic acid; [G] Polyalthic acid; [H] Daniellic acid.

Table 3
Established pharmacological and biological potentials of *Daniellia oliveri* (Rolfe) Hutch. & Dalz.

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
1					Anagelsic		
	Stem bark	Methanol (crude and fraction)	*In vivo* (acetic acid-induced pain mice)	50, 100, 200 and 400 mg/kg b.w.	The extract and fractions dose-dependently alleviated the induced pain. The highest inhibition was reported to be 67.7% (fraction) and 49.5% (crude) when compared with paracetamol (68.5%) used as control signifying the analgesic action of the stem bark	Burkina Faso	[31]
	Stem bark	Aqueous-ethanol (70%) and fractions (n-hexane, ethyl acetate, and methanol)	*In vivo* (acetic acid-induced pain mice)	100, 250 and 500 mg/kg b.w	Hexane fraction demonstrated 42.6% alleviation of pain in acetic acid mice depicting a moderate analgesic effect though the activity of the standard, indomethacin was better at 56%	Nigeria	[54]
2					Antinociceptive		
	Stem bark	Aqueous	*In vivo* (hot plate, paw pressure pain models)	250, 500, 1000, 2000 mg/kg b.w.	Produced a lower pain threshold at concentrations from 500 mg/kg and above better than diclofenac indicating its potential antinociceptive effect.	Ghana	[36]
	Stem bark		*In vivo* acetic acid -induced writhing	50, 100, 200 mg/kg b.w.	Extract inhibited nociception in the animals	Nigeria	[55]
3					Antioxidant and hepatoxic		
	Leaves, stem bark and root bark	Cold aqueous-methanol (50%)	*In vitro* (DPPH, ABTS, phosphomolybdenum (PPM))	100 μM	The leaves extract reported to have best activity inhibiting DPPH radical (93.3%). The root bark showed the highest value of 606.0 mg/100g dw. VCEAC indicating the antioxidant potential of the plant.	Mali	[41]
		Hexane		0.03, 0.06, 0.125, 0.25 and 0.50 mg/ml		Nigeria	[62]
		Ethanol	*In vitro* (DPPH)			Nigeria	[63]
	Seed (oil)	Ethanol	*In vitro* (Hydroxyl radical, metal chelating, reducing power, and lipid peroxidation	20, 40, 60, 80 and 100 μg/mL		Nigeria	[81]
	Leaves and stem bark			156.25–5000 μg/mL			
	Stem bark		*In vitro* (DPPH, FRAP, and PPM)	100, 200 and 300 mg/kg b.w.	Good activity at concentrations 0.03 and 0.25 mg/ml, though weak when compared with standards (BHA, Vit C and quercetin)		
			In vivo (CCl_4 -induced hepatotoxic rats)		Stem bark extract exhibited superior activity over the leaf extract in all the evaluated assays suggestive of the antioxidant effect		
					Increased inhibition of DPPH radical with increasing concentrations of the extract. Depicted an IC_{50} of 0.05 mg/ml lower in effect compared to Vitamin C (0.01 mg/ml).		
					200 mg/kg b.w. and silymarin (100 mg/kg b.w.) reversed the elevated activities of antioxidant enzymes, lipid profiles and other parameters		
	Stem bark	Aqueous	*In vitro* (DPPH)	20, 40 and 80 μg/ml	Showed a good inhibitory (IC_{50} 14.57 μg/ml) potential though inferior to ascorbic acid (7.39 μg/ml) suggesting	Ghana	[36]
	Leaves	Ethanol and fractions (n-hexane, diethyl ether and petroleum	*In vitro* (DPPH)			Nigeria	[8]
	Stem bark		*In vitro* (DPPH)	1, 3, 5, 10, 20, 30, 50, 100 μg/ml		Nigeria	[45]
			In vitro (DPPH)			Nigeria	[67]

(*continued on next page*)

Table 3 (*continued*)

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
	Exudates (Oleiresin)	ether) Crude (aqueous, aqueous-ethanol, ethanol) and fractions (ethylacetate, ethylether, butanol) Methanol		NS 200, 250 μg/ml	a considerable antioxidant activity. Diethyl ether (94.60%) and ethyl acetate (93.06%) fractions showed the highest inhibitions of the DPPH radical indicating good antioxidant effect. Although, the inhibition of BHT (standard) was highest at 98.46%. Dose-dependent inhibition of the radical by the crude and fractions of the plant. The aqueous and aqueous-ethanol extracts depicted the best activity with an IC_{50} value of 6.5 μg/ml Depicted moderate (IC_{50}: 15.49 μg/mL) activity compared to tocopherol (0.25 μg/mL) in the inhibition of DPPH		
4					Antidiabetic		
	Root	Aqueous	*In vivo* (alloxan-induced diabetic rats)	250 mg/kg b.w.	Reduces the fasting blood glucose level (119. 00 mg/dl) from 302.75 mg/dl on day 0. The activities of the hepatic enzymes were also brought down indicating the antihyperglycaemic effect of the combined (*S. latifolus* and *D. oliveri*) extract.	Nigeria	[35]
	Leaves	Ethanol and fractions (n-hexane, diethyl ether and petroleum ether)	*In vitro* (alpha-amylase and alpha-glucosidase)	2, 4, 8, 10, 15 μg/ml	Ethyl acetate showed the best activity [84.32 (α-amylase) and 35.02 (α-glucosidase) IC_{50} values] among the plant extract and fractions indicating the antidiabetic activity of the plant. The inhibition of the acarbose was superior compared to the extract and fractions with an IC_{50} value of 77.84 μg/ml against α-amylase and 25.97 μg/ml (α -glucosidase).	Nigeria	[8]
	Leaves	Aqueous	*In vivo* (streptozotocin -induced) diabetic rats	200, 400 mg/kg b. w.	Reduced the elevated level of FBG following glucose overload and reversed the activities of carbohydrate enzymes towards normal suggesting the glucose-lowering effect of the plant.	Nigeria	[56]
	Stem bark	Aqueous-ethanol (70% v/v)	*In vitro* (alpha-amylase)	50, 250, 500, 1000, 2500, 3300, 5000 μg/ml	The activity was dose-dependent; attained a 78.61% inhibition at 1000 μg/ml and 100% inhibition above this concentration corroborating its antihyperglycaemic effect.	Burkina Faso	[73]
5					Antidiaarhoeal		
	Leaves Stem bark	Aqueous-ethanol (70%) crude and fractions (ethyl acetate, n-butanol) Aqueous-ethanol	*In vivo* (castor oil-induced diarrhoea mice) *In vivo* (castor oil-induced diarrhoea rats)	50, 100, 200 mg/kg b.w. 200, 400, 800 mg/kg b.w.	All the concentrations afforded protection to the diarrhoea-induced mice; the highest protection (200 mg/kg b.w) comparable	Nigeria (Zaria) Nigeria (Adamawa)	[34] [43]

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Table 3 (*continued*)

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
		(70%) extract and fractions (chloroform, ethyl acetate, n-butanol)			loperamide was found at 80% indicating the antidiarrhoeal potentials. The stem bark extracts provided protection (between 60.6 and 74.4%) to the animals though inferior to loperamide (95.74%), thus, reiterating the antidiarrhoeal effect of the plant.		
6					Antifilarial		
	Leaves and stem bark	Hexane, dichloromethane (DCM), methanol	*In vitro* (Worminator worm motility tracking method)	15.6, 31.3, 62.5, 125, 250, 500 μg/mL	The DCM extracts of the studied parts showed the most potent inhibition of adult *B. pahangi* motility, though the activity of the leaf (IC_{50}: 6.1 μg/mL) was superior than the bark (6.3 μg/mL). Similar activity was witnessed against *O. ochengi* microfilaria though the leaf (16.2 μg/mL) exhibited inferior activity compared to the stem bark (9.7 μg/mL) signifying the antifilarial potential.	Cameroon	[28]
7					Antiinflammatory		
	Stem bark	Aqueous-ethanol (70%) and fractions (n-hexane, ethyl acetate, and methanol)	*In vivo* (1% croton oil in acetone)	10% w/w (in petroleum jelly)	Methanol fraction revealed 73% inhibition comparable to the activity of hydrocortisyl cream used as control (standard drug) indicating the anti-inflammatory effect	Nigeria	[54]
	Leaves	Aqueous	*In vivo* (carrageenan-induced oedema rats)	400 mg/kg b.w.	Exhibited a 65% inhibition of oedema following oral administration of the extract as a result of carrageenan-induced inflammation indicating its antiinflammatory effect.	Cote D'Ivoire	[44]
	Stem bark	Methanol (crude and fraction)	*In vivo* (carrageenan-induced oedema mice)	50, 100, 200 and 400 mg/kg b.w.	All the crude and fraction concentrations showed a dose-dependent inhibition of oedema indicating an anti-inflammatory effect. Expectedly, 400 mg/kg b.w. being the highest concentrations was reported to show superior activities (77.81% and 85.97% respectively) comparable to AAS (87.3%)	Burkina Faso	[31]
	Stem bark		xylene-induced paw oedema and carrageenan-induced air-pouch (rats) models	50, 100, 200 mg/kg b.w.	Doses at 100 and 200 mg/kg significantly inhibited (73.68 and 75.79%) oedema and diminishes the volume of the exudate, myeloperoxidase production and protein concentration in carrageenan model	Nigeria	[55]
8					Antimicrobial		
	Leaves, bark, root	Aqueous, ethanol	*In vitro* (broth dilution method)	100 mg/ml	Ethanol extract revealed better activity as depicted by the higher zone of inhibition. Root extracts	Nigeria	[60]

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Table 3 (*continued*)

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
					depicted better inhibition of the tested strains indicative of antibacterial effect.		
	Stem bark	Crude (aqueous, aqueous-ethanol, ethanol) and fractions (ethylacetate, ethylether, butanol)	*In vitro* (microplate dilution method)	NS	The crude extracts [aqueous and ethanol (0.39 mg/ml), aqueous-ethanol (3.13 mg/ml)] and ethylacetate and butanol fractions (12.5 mg/ml) showed good antibacterial activity against *E. coli* while ethyl ether and ethylacetate revealed considerable activity (12.5 mg/ml) against *K. pneumonia.*	Benin	[45]
	Leaves Stem bark	Aqueous Methanol	*In vitro* (Agar well diffusion and broth dilution methods)	3.125, 6.25, 12.5, 25, 50, 100 mg/ml	Good inhibition by methanolic leaf and stem bark extracts was established particularly on moulds (*A. niger and R. stolonifera*) and yeast (*Candida albicans, Candida krusei*) with a zone of inhibition ranges between 10 and 26 mm for the former. The MIC of the leaf extracts against *C. albicans* and *T. rubrum* (3.125 mg/ml) was lower compared to the stem bark suggestive of better activity	Nigeria	[24]
	Stem bark	Aqueous (cold and hot), methanol, Ethanol, and acetone	*In vitro* (broth dilution method and colony count)	6.25, 12.5, 25, 50 and 100 mg/ml	The organic extracts are highly active at the lowest concentrations. The MIC of the aqueous (cold and hot) extracts was similar to the organic extracts, though cold aqueous extract was insensitive to *E. faecalis*, *K. pneumonia*	Nigeria	[61]
	Leaves	Aqueous, ethanol, and n-butanol crude and fractions (A-D)	*In vitro*	NS	All fractions showed good activity against *S. aureus* while the n-butanol and the four fractions revealed considerable activity against fungus	Nigeria	[49,59]
	Leaves and bark	Ethanol	*In vitro* (agar diffusion method)	0.84, 1.88, 3.75, 7.5, 15, 30 and 60 mg/ml	The highest ZID was reported at 15 mm (*S. dysentariae*). Extracts are all active against tested microorganisms above 7.5 mg/ml indicating the antimicrobial potential.	Nigeria	[7]
	Leaves and bark	Oleoresin	*In vitro* (agar diffusion method)	NS	The oil showed marginal activity against all the tested organisms though the antifungal effect against *A. niger* and *T. rubrum* was good (MIC: 78.1 μg/ml) Bacterial growth was inhibited at the highest concentration of 256 μg/mL. The root extracts were the least active while methanol extracts showed a maximal inhibition of the gram-positive bacterial at 64 μg/	Nigeria	[46]
		Methanol, methanol-DCM (50/50 v/v)		1, 2, 4, 8, 16, 32, 64, 128 and 256 μg/mL		Togo	[20]
	Leaves, stem bark and roots	Aqueous, ethanol and ethylacetate	*In vitro* (micro broth dilution method)			Nigeria	[121]
	Whole plant		*In vitro* (agar well diffusion method)	25, 50, 60, 70, 80, 90, 100 mg/ml			

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Table 3 (*continued*)

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
					mL revealing the antibacterial potential. None of the crude extract showed activity against the fungi strains tested 100 mg/ml (ethanol extract) reported with highest ZID (23 ± 1.46 mm) against *Streptococcus pyogenes*. Similarly, the plant was active against *Fusarium oxysporum* at concentrations 80 and 100 mg/ml. Thus, indicating the antimicrobial activity of the plant		
9					Antiplasmodial		
	Leaves	Methanol	*In vivo* (NK-65 *Plasmodium berghei* -induced parasitemic mice)	200, 400 and 800 mg/kg b.w	No significant difference in the biochemical and haematological parameters of both plasmodium infected and extract-treated animals	Nigeria	[64]
10					Antiwrinkle		
	Exudates	DMSO	*In vitro*	25 μg/mL	Revealed a percentage inhibitory activity above 100 in the stimulation of glycerol-3-phosphate dehydrogenase indicating the antiwrinkle effect	France	[22]
11					Cardioprotective		
	leaves	Ethanol	*In vivo*	50, 100, 200 mg/kg b.w.	Reduced activity of ACP at higher concentrations (100, 200 mg/kg b.w.) indicating possible exposure to cardiovascular problems	Nigeria	[91]
12					Cytotoxic		
	Exudates (oleoresin)	Methanol	*In vitro* (MTT colorimetry assay)	200, 250 and 500 μg/mL	Exhibited low activity compared to doxorubicin (standard drug) against cancer (PC3) cell line	Nigeria	[67]
	Leaves, stem bark and roots	Methanol, methanol-DCM (50/50 v/v)	Cell lines (MTT method) such as Hs 683, U 373, SKMEL 28, A549, MDA-MB 231	0.78–100 μg/mL	Only the methanolic extract of the stem bark revealed toxicity against the Hs683 cell line with an IC_{50} of 91 μg/mL	Togo	[20]
13					Neuroprotective		
	Roots	Aqueous	*In vivo* (diazepam induced amnesia mice	100, 200, 300 mg/kg b.w	Extracts (200 mg/kg b.w.) showed neuroprotective potential	Cameroun	[14]
14					Antisickling		
	Bark	Aqueous	*In vitro* (haemoglobin electrophoretic assay, Emmel's test *In vivo* (rats)	10, 20 40 mg/ml 200 mg/kg b.w	Depicted reduced mean sickle cell count for 40 mg/ml comparable to control. Also reversed sickled red cells to normal biconcave cells No change in the level of MHC between the control and the extract group	Benin	[65]
15					Larvicidal		
	Stem bark	Aqueous	*In vitro* (Egg hatch and embryonated egg assays	75, 150, 300, 600, 1200 and 2400 μg/ml	Total death of the egg larvae (L1) was witnessed in the highest two concentrations for the EHA. The effective concentration (EC_{50}) was reported to be 245.9 μg/ml indicating the ovicidal and larvicidal activities of the	Burkina Faso	[57]

(*continued on next page*)

Table 3 (*continued*)

No	Part used	Solvent/extract	Assay types	Tested concentrations or doses	Pharmacological effects	Country	References
					plant. For the EEA, the eclodibility of the embryonated egg depicted an EC_{50} of 362.3 μg/ml. Following 24 h *Haemonchus conturtus* exposure to extract, 100% mortality of the adult Larvae for levamisole however, this can't be said for the extract with an inconsistent concentration-activity relationship		
16					Toxicity/safety profiles		
	Leaves	Aqueous-ethanol (70%) crude and fractions (ethyl acetate, n-butanol)	Acute	[Phase 1 (10, 100, 1000 mg/kg b.w.); Phase II (200, 400, 800, 1600 mg/kg b.w.)]	No behavioural changes or death was witnessed following the intraperitoneal administration of the extract after 2 days indicating the safety net of the extract at the doses tested	Nigeria	[34]
	Leaves		Acute			Nigeria	[56]
	Leaves		Acute Acute (*in vivo*; intraperitoneal)			Nigeria	[35]
	Root	Aqueous	Acute	5000 mg/kg b.w.		Cote D′ Ivoire	[44]
	Stem bark	Aqueous	Acute (OECD 423)	250, 400, 450, 600 and 700 mg/kg b. w.		Burkina Faso	[31]
	Stem bark	Aquoues	Acute toxicity	10000, 5000, 2900, 1500, 1000 mg/kg b.w.	Revealed no behavioural symptoms and recorded no mortality of the animals, thus signifying the safety of the extract at the studied dose.	Nigeria	[55]
		Methanol (crude and fraction)		2000 mg/kg b.w.	Reported no behavioural changes though the study recorded mortality of study animals at all concentrations except 250 mg/kg b.w., the LD_{50} was reported to be at 436.51 mg/kg b.w.		
				2000 mg/kg b.w.	The lethal dose of the extract was found to be in excess of 5 g/kg b.w. indicating the safety potential of the extract.		
					No signs of toxicity and death were reported following 2 weeks of observing the animals, hence, maintained that the LD_{50} is greater than 5000 mg/kg b.w., thus, not toxic		
					No sign of toxicity or mortality, hence safe for oral consumption at concentration below 2000 mg/kg		

NS: not stated; DPPH: 1,1-diphenyl-2-picryl hydrazyl radical; ABTS: 2,2_-azino-*bis*(3-ethylbenzothiazoline-6-sulfonic; BHT: butylated hydroxyl toluene; BHA: butylated hydroxyl anisole; FBG: fasting blood glucose; EHA: egg hatch assay; EEA: embryonated egg assay; ASA: acetylsalicyclic acid; OECD: organization for economic co-operation and development; MIC: minimum inhibitory concentration; ZID: zone of inhibition diameter; DW: dry weight; VCEAC: vitamin C equivalent antioxidant capacity; FRAP: ferric reducing antioxidant power; PCV: packed cell volume; MTT: 3-[4,5-dimethylthiazole-2-yl]-2,5-diphenyltetrazolium bromide; DMSO: dimethyl sulfoxide; DCM: dichloromethane; IC_{50}: Half-maximal inhibitory concentration; ED_{50}: (Median) Effective dose; EC_{50}: Half-maximal Effective concentration; LD_{50}: Median Lethal dose; MHC: mean haemoglobin concentration.

documents and remove (where necessary) duplicated information and those that do not align with the scope of the review.

3. Results (Pharmacological and safety properties)

Daniellia oliveri has been established to possess numerous pharmacological, biological and toxicity effects not limited to analgesic [31,54] antinociceptive, antioxidant [36,55], antidiabetic [8,35,51,56], antidiarrhoeal [30,43], anthelminthic [57], anti-inflammatory [31,44,54,55], antimelanogenesis [52], antimicrobial [7,24,45,46,58–61], antioxidant [41,62,63], antiplasmodial

[64], antisickling [65], antispasmodic [66], cytotoxic [28,67], cardiotoxic [68], neuroprotective [14] and safety profiles [31,34,35,55,56] as discussed below. Table 3 summarises the *in vitro* and *in vivo* pharmacological activities of *D. oliveri*.

3.1. Analgesic/antinociceptive

Moderate to severe pain are witnessed in 1 out of every 5 individuals globally and only 1 in every 3 of such cases or sufferers have the capability to live a life independent of pain [36]. The use of plants are conventionally explored to manage pain aside the pharmacological use of opioids (anagelsics) or non-steroidal anti-inflammatory drugs. A number of MP not limited to *D. oliveri* are in recent times used in the management of pains.

The antinociceptive effect of the aqueous stem bark extract [at concentrations 250, 500, 1000, and 2000 mg/kg body weight (b.w.)] of the plant was evaluated using the hot plate and paw pressure pain models on mice. The modes of analgesic effect of the extract, diclofenac, and morphine (standard drugs) were also studied in the presence of three antagonistic drugs (theophylline, naloxone, and glibenclamide). It was observed that the extract and standard (diclofenac) reduced the pain threshold of the animals dose-dependently, though, the effect was more prominent at the higher concentrations of the extract. The mechanism of antinociceptive action of the plant depicted no analgesic response for the three antagonistic drugs when administered alone, however, it resulted in the activation of the opioid receptor (concerned with pain modulation in mammals) for naloxone (which is a non-selective opioid receptor antagonist) to elicit an antinociceptive effect. The study also demonstrated its antinociceptive action by activating the blocked ATP-sensitive K^+ channel opening inhibited by glibenclamide (an ATP-sensitive K^+ channel blocker) in the hot plate test [36]. Recently in a related study, lower concentrations (50, 100 and 200 mg/kg b.w) of ethanolic stem bark extract was assessed following acetic acid induced (interperitoneal) nociception of experimental mice. The study found out that the extracts dose-dependently showed moderate antinociceptive effect with 35.61%, 48.07% and 61.40% inhibition respectively, though the activity of the extracts were inferior to the standard (acetylsalicylic acid) having inhibition score of 91.93% [55].

The analgesic property of the stem bark was also replicated in Burkina Faso where methanolic crude extract and fraction at varying doses (50, 100, 200, and 400 mg/kg b.w.) orally administered were evaluated on acetic acid (10 mg/kg b.w.; intraperitoneal) pain -induced mice. The analgesic effect was evaluated by measuring the percentage inhibition of the pain by the extracts. While the inhibition of the various concentrations was reported to be dose-dependent, the 400 mg/kg b.w. dose (crude and fraction) exhibited the best effect. However, the methanol fraction depicted a good inhibition (67.7%) insignificantly different from paracetamol (200 mg/kg b.w), the standard drug (68.5%) while the crude methanolic extract revealed a moderate inhibition (49.8%) of pain induced in the mice [31]. The review identified that stem bark was the only part of the plant explored for this bioactivity conducted in only two west African countries. It will therefore be germane or appropriate to determine this activity in other (including unexamined aerial) parts like the leaves in other regional African countries and continents of the world; doing this is assumed would provide information on the geographical differences (if there is) which is vital when considering the holistic antinociceptive effect of the plant. Besides, the study of phytoconstituents responsible for the effect is also an additional research gap that needs to be identified.

3.2. Antidiabetic

The prevalence of diabetes mellitus (DM) is high (about 463 million in 2019), mostly among adult population (17–79 years) [69] and the figure is likely to reach 764 million by 2030 [70] according to International Diabetic Federation. While the management revolves around regular exercise, dietary regimen and the use of oral hypoglycaemic agents (OHAs), however, the side effects from these synthetic drugs necessitated the use of MPs [71,72] including *D. oliveri*.

The antidiabetic potential of *D. oliveri* was established by numerous authors from Nigeria [8,35,51,56] and Burkina Faso [73]. A combined decoction root extract of *Sarcocephalus latifolius* and *Daniellia oliveri* at 250 mg/kg b.w. was administered twice daily to alloxan (65 mg/kg b.w.) -induced diabetic rats following a 21-day experimental period in a Nigeria study. The increased fasting blood glucose level of the diabetic rats declined upon administration of the extract after 7 days toward lower-level and up to the last day of the study. The same scenario was witnessed with glibenclamide (5 mg/kg b.w.) used as standard. Additionally, the extract was reported to reverse the levels of the studied diabetes enzymes (such as hexokinase, glucokinase, and phosphofructokinase) and glycogen content towards normality indicating the antihyperglycaemic activity of the extract [35].

The antidiabetic effect of the leaf crude ethanolic extract and fractions (n-hexane, diethyl ether, and petroleum ether) of the plant was evaluated *in vitro* against carbohydrate-hydrolysing enzymes (alpha-amylase and alpha-glucosidase) using 5 concentrations (2, 4, 8, 10 and 15 μg/ml). The study [8] established the antidiabetic of the plant in an ethylacetate fraction to be better at inhibiting the activities of the enzymes; alpha-amylase (84.32 μg/ml) and alpha-glucosidase (35.02 μg/ml) going by half-maximal inhibitory concentration (IC_{50} values). The activity of acarbose was the best (77.84 and 25.97 μg/ml respectively) while the least activity was reported with the crude extract (147.56 and 64.98 μg/ml respectively). To further buttress the antihyperglycaemic effect of the leaf, Shuaibu et al. [56] revealed the glucose-lowering effect of 200 and 400 mg/kg b.w. concentrations of aqueous leaf extract orally administered to streptozotocin-induced rats for 28 days, and found a reduction in the glucose level following overload and the reversal of diabetic enzyme activities toward normal.

In addition to reports from the leaves and root parts, the activity of the stem bark collected from Burkina Faso was also evaluated by Sempore et al. [73] on alpha-amylase in an effort to determine the antidiabetic effect. The hydroethanolic (70%) stem bark extract activity was studied in 7 concentrations (50, 250, 500, 1000, 2500, 3300, and 5000 μg/ml) and the evaluation was followed by the kinetics of inhibition study. The study revealed a dose-dependent inhibition of alpha-amylase achieving 100% inhibition above 1000 μg/ml (i.e., at 2500, 3300, and 5000 μg/ml). The IC_{50} value corroborated the percentage inhibition determination at 0.75 mg/ml. The

mode of inhibition of the enzyme by *D. oliveri* hydroethanolic stem bark extract depicted a constant Vmax of 4.52 mol/L/min (between the extract and the control) with a reduction in Km values 9.86 mol/L (extract) to 2.64 mol/L (control) signifying a competitive inhibition (Table 3). Interestingly, polyalthic acid (1 mg/ml), an isolated compound from the plant evaluated for antidiabetic activity in antiglycation procedure *in vitro* (Table 3) and pharmacokinetics study was similarly found to exhibit a negative antiglycation effect relative to rutin (standard drug), hence, suggesting the activation of glycation leading to the emergence of complications for potential patients. However, the pharmacokinetic parameters and bioactivity reports reflected the potential of the compound as a possible lead candidate as it violated none of the Lipinski's rules of 5 (though rutin violated 3) and revealed positive values (0.38 and 0.60) as ligand and enzyme inhibitors, respectively [51].

With these extensive works (*in vitro* and *in vivo* alike) on the various parts (leaves, roots, and stem) of the plant (particularly from Nigeria) across varying solvent ranges, it is still believed that the established activity, limited to western Africa can be exemplified in other regions of the world in an effort towards confirming the effectiveness of the plant across diverse geographical locations. Based on this, it is necessary that bioactive compounds responsible for the effect are also identified as a further step to possible drug development since the polyalthic acid already isolated revealed no clear-cut finding on this. Therefore, following this, the need for clinical studies to be carried out is critical.

3.3. Antidiarrhoeal

One of the major global health concerns affecting mostly (infants and toddlers) in tropical and sub-tropical nations is diarrhoea [34,74]. Facts from WHO established between 3 and 5 billion cases annually are reported worldwide [34]. The available management therapy involves the use of oral rehydration therapy (a mixture of salt and sugar), pharmacological agents, and phytotherapy including *D. oliveri*.

The study by Ahmadu et al. [34] investigated the antidiarrhoeal effect of n-butanolic leaf extract of *D. oliveri* in Swiss albino mice. Various doses (50, 100, 200 mg/kg b.w.) were intraperitoneally administered to the mice followed by intragastrical administration of castor oil to induce diarrhoea after 30 min. While the animals were observed for the presence of peculiar symptoms of diarrhoea in faeces, the study reported that the various concentrations of the extract conferred protection of 40, 60, and 80% respectively (based on the degree of doses) to the animals. The protection of the highest dose was comparable to that of loperamide, (5 mg/kg b.w.; standard drug) at 80% indicating the antidiarrhoeal effect of the plant.

In addition to earlier report, the antidiarrhoeal action of the plant was replicated on Wistar albino rats using the stem bark in a study by Hassan et al. [43] where higher concentrations (200, 400, and 800 mg/kg b.w.) were considered. The ethanolic extracts (orally administered) and the standard (loperamide, 5 mk/kg b.w.) intraperitoneally given to the rats were followed by oral administration of castor oil (1 ml) after an hour to induce diarrhoea; the study lasted 6 h for likely presence of watery droppings. The findings revealed good protection for the animals with 400 mg/kg b.w. affording the best (76.6%) followed by 800 mg/kg b.w. (74.4%) and lastly, 200 mg/kg b.w. with 60.6%. The antidiarrhoeal activity was attributed to the presence of flavonoids in the plant. So far and as at the time of compiling the review, Nigeria was the only country where reports of the antidiarrhoeal effect of the aerial parts (leaves and stems) were submitted, hence, replicating these activities in the root part and in other areas or regions of the globe would come handy towards the development of a suitable antidiarrhoeal candidate.

3.4. Anthelminthic/antifilarial

The continued survival of livestock (small ruminant) are partly dependent on the possible eradication of worm nematodes. The importance of these animals in farming operation necessitate keeping them healthy to prevent economic losses [57,75]. While anthelmintics such as levamisole are used to keep these parasites at bay, however, their high cost and side effects have warranted plant-based formulations in recent times as probable alternatives.

Kabore et al. [57] studied the larvicidal potential of aqueous stem bark extract of *D. oliveri* on *Haemonchus conturtus* at three developmental stages (eggs, first larvae, and adults) of life in an *in vitro* experiments (egg hatch and embryonated egg assays) at varying concentrations (75, 150, 300, 600, 1200, 2400 μg/ml). The study established dose-dependent activities for eggs and first larvae (L1) stages depicting a 100% inhibition or mortality at the highest two concentrations (1200 and 2400 μg/ml). The effective dose (ED_{50}) of the extract for the egg hatching assay (EHA) and embryonated egg (EEA) was reported to be 245.9 and 362.3 μg/ml respectively indicating the anthelminthic activity of the plant. However, the mortality of adult worms after 24 h exposure to the extract was not only thorough and inconsistent in terms of concentration-activity relationship but was in contrast with findings from levamisole (standard drug) depicting a dose-dependent activity with 100% mortality of the worms.

Furthermore, the antifilarial potential of leaves and stem bark of the plant was evaluated on the inhibition of motility of adult *Brugia pahangi* and microfilariae and adults *Onchocerca ochengi* worms using worminator system. The extracts (hexane, dichloromethane, and methanol) at concentration ranges between 15.6 and 500 μg/mL showed a dose-dependent action against *B. pahangi* and *O. ochengi* worms. The dichloromethane (DCM) extracts of the studied parts showed the most potent inhibition of adult *B. pahangi* motility, though the activity of the leaf (IC_{50}: 6.1 μg/mL) was superior to the bark (6.3 μg/mL). Similar activity was witnessed against *O. ochengi* microfilaria though the leaf (16.2 μg/mL) exhibited inferior activity compared to the bark (9.7 μg/mL). However, against adult *O. ochengi*, the hexane extract of the bark depicted the most effective inhibition with an IC_{50} of 13.9 μg/mL followed by the DCM of the bark and leaf (22.5, 43.3 μg/mL respectively). Additionally, the lowest IC_{100} was found with hexane extract of the bark (31.3 μg/mL). In terms of selectivity of the extracts for the infections, hexane stem bark extract was more selective for the adult *O. ochengi* than microfilariae with a half-maximal and 100% inhibitory concentrations (IC_{50} and IC_{100}, respectively) against adult *O. ochengi* to be 13.9

and 31.3 μg/ml, respectively [28].

The review identifies the plus in the established activity of the plant across solvent ranges, however, the review saw the lack of studies on the isolation and identification of compounds responsible for these effects and lack of clinical studies as grey areas fundamental to the development of a suitable anthelmintic drug candidate. There may also be a need to replicate these findings in other regions of Africa (south, east, north) and across different parts of the globe to ensure the holistic effectiveness of the plant despite geographical differences.

3.5. Anti-inflammatory

Inflammation manifest various signs like redness, heat, swelling, or pain [31] as a result of the body's response to an attack [76]. The pharmacological treatment of these symptoms are with the use of either steroid or non-steroidal drugs (NSAIDs) which are however prone to side effects [31], hence, the exploration of MP like *D. oliveri* as an alternative option.

The anti-inflammatory potential of the stem bark extract (hexane, ethyl acetate, and methanol) of the plant was evaluated using an animal model (Wistar albino rats) in a Nigerian study. The hair of the back of the animals was scrapped and exposed to 10% w/w extract (in petroleum jelly) followed by the introduction of croton oil (1% w/v in acetone) after 30 min to induce inflammation. The findings reported the best inhibitory activity (73%) of methanol extract, which was comparable to hydrocortisyl used as the standard [54]. In an effort to corroborate the activity from another country, Traore et al. [31] in a study conducted in Burkina Faso similarly assessed the anti-oedema effect of oral administration of methanolic extract and fraction at 50, 100, 200, and 400 mg/kg b.w. doses on carrageenan (1% in normal saline) -induced inflamed mice following 5 h experimental period. The crude and fraction dose-dependently reduced or inhibited the development of oedema from the first hour to the termination of the study (5 h) signifying the anti-inflammatory action attributed to the antagonistic effect on inflammatory mediators' biosynthesis. The 400 mg/kg b.w. concentration was not only able to show the best effect in preventing the development of oedema, but also revealed superior (77.81% and 85.97% respectively) inhibition (among other doses) comparable to acetylsalicylic acid (200 mg/kg b.w.) (87.3%) used as reference drug. Additionally, the testing of 50, 100, 200 mg/kg b.w. of the ethanolic stem bark extract on xylene -induced paw oodema mice in a study by Sofidiya et al. [55] from Nigeria revealed the two higher concentrations (100 and 200 mg/kg) were comparable in

Table 4
Pharmacological effects of isolated compounds from *Daniellia oliveri* (Rolfe) Hutch. & Dalz.

No	Compound name	Plant (part) material	Compound class	Assay	Pharmacological effect	References
1	Polyalthic acid	Exudates	Diterpenoid	*In vitro* (antiglycation procedure	Glycation. Good bioactive and pharmacokinetics profile as potential lead drug	[51]
2	Daniellic acid	Oleoresins	Diterpenes	*In vitro* (DPPH, FRAP) *In vitro* (Cell-free mushroom tyrosinase) Cell lines (A549 lung carcinoma, MCF-7 breast adenocarcinoma, and U373 brain glioblastoma) *In vitro* (melanin content determination; B16F10 and Malme-3M melanocyte)	Showed moderate inhibition of DPPH radical and FRAP though exhibited inferior effect compared to quercetin used as standard signifying the antioxidant effect While the inhibition of tyrosinase was dose-dependent, the IC_{50} value of 1.2 mM was depicted, though less active compared to kojic acid (0.2 mM) used as standard, thus, signifying the antityrosinase effect. The kinetics of inhibition of tyrosinase by daniellic acid was non-competitive Revealed moderate cytotoxic effects on the tumour cell lines with IC_{50} range between 0.03 and 0.14 mM Daniellic acid and kojic acid (standard drug) on exposure to B16F10 and Malme-3M melanocytes resulted in 50% reduction of its production indicating its anti-melanogenesis effect	[52]
3	Lupenol	Leaves	Triterpenoids	ND	NS	[50]
4	3-acetoxy −9 (11),12-diene-28-carboxyllic acid	Leaves	Triterpenoids	ND	NS	[50]
5	Rutin	Leaves	Flavonoid glycosides	*In vitro* (agar well diffusion assay)	Antibacterial (*S. aureus*)	[49,58]
6	Narcissin	Leaves	Flavonoid glycosides	*In vitro* (agar well diffusion assay)	Antibacterial (*S. aureus*)	[49,58]
7	Quercitrin	Leaves	Flavonoid glycosides	*In vitro* (agar well diffusion assay)	Antibacterial (*S. aureus*)	[49,58]
8	Quercemeritrin	Leaves	Flavonoid glycosides	*In vitro* (agar well diffusion assay)	Antibacterial (*S. aureus*)	[49,58]

DPPH: 1,1-diphenyl-2-picryl hydrazyl radical; FRAP: ferric reducing antioxidant power; MTT: 3-[4,5-dimethylthiazole-2-yl]-2,5-diphenyltetrazolium bromide; ND: not determined; NS: not stated.

their anti-inflammatory action with dexamethasone (1 mg/kg) used as reference drug inhibiting the induced paw oodema of the animals by 73.36 and 75.79% respectively.

Additionally, a study [44] on the anti-inflammatory effect on the leaves from Ivory Coast corroborated the findings on the stem bark. The *Rattus norvegicus* Wistar strain was also exposed to carrageenan-induced inflammation in the footpad of the right hind paw to determine the development of oedema following 1, 2, 3, 4, 5, and 6 h post-induction. The 400 mg/kg b.w. of the aqueous extract of *D. oliveri* was reported to exhibit a significant effect on oedema. While the activity of the extract at inhibiting the inflammation is not only dose-dependent but comparable with indomethacin (10 mg/kg b.w.), it was though low after 3 h (20%) post carrageenan induction, however, it increased afterward attaining a somewhat 65% inhibition by 6 h expiration of the study. The need to compare these reports with findings from other parts of the globe may be necessary to confirm the effectiveness across board while taking into account the 400 mg/kg b.w most active in most of the studies. Additionally, it is vital to identify the bioactive compound(s) responsible for the activity.

3.6. Antimelanogenesis

Inflammation, hyperpigmentation, hypopigmentation, cell proliferation have been attributed to reasons for various skin deformities [77] such as skin darkening, keloids, and scars. While therapy involves surgery, intralesional injection, 5 fluorouracil, radiotherapy, among others, the use of natural products such as *D. oliveri* are considered as effective therapy due to various side effects from these pharmacological treatments [78,79].

The antimelanogenesis effect of daniellic acid (compound) isolated from the oleoresin of the plant was evaluated on B16F10 and Malme-3M melanocytes in a cell line study conducted in Burkina Faso by Nacoulma et al. [52]. The chloroform (diluted) oleoresin extract following various chromatographic and spectroscopic techniques produced daniellic acid which was investigated to inhibit B16F10 and Malme-3M melanocytes production since melanin plays an essential role in the prevention of the skin from ultraviolet exposure. It was reported that daniellic acid halted the production of the B16F10 cell line by half. Similar activity was witnessed with Malme-3M melanocyte where it depicted superior inhibition compared to kojic acid (standard). Other activities (antioxidant, cytotoxic, and anti-tyrosinase) of the compound as reported in this study were summarized in Table 4. The present review identified that none of the major parts (leaves, stem bark, and roots) of the plant were evaluated to check the antimelanogenesis activity of the plant. Besides, the established activities were only based on cell line and *in vitro* evaluations and since it is a known fact that sometimes activity related to *in vitro* assessments do not in most cases necessarily translate into *in vivo* results, hence, the need to replicate these findings (crude extract and identified compound) in an animal model.

3.7. Antimicrobial

Infectious diseases are responsible for almost half of all deaths particularly in tropical nations [60]. Antibiotics and/or other multi-drug resistant agents are potentially used to curb microbial infections, however, due to organisms resistant or side effects has necessitated the new search (MP) for alternative therapeutic solution.

A number of studies on the antimicrobial effectiveness of different parts of the plant have been submitted from Nigeria. Typically, a comparative study [60] on the leaves, bark, and root aqueous and ethanol extracts of *D. oliveri* were tested against various strains of bacteria (such as *Klebsiella pneumonia*, *Pseudomonas aeruginosa*, *Escherichia coli*, *and Staphylococcus aureus*) in a broth dilution method using 100 mg/ml concentration. The study revealed that ethanolic root extract showed a wide inhibition zone (5–7 mm) on the tested bacteria strains indicating enhanced activity compared to other extracts (in terms of the solvent of extraction and plant part). The minimum inhibitory concentration (MIC) of strains differs among the bacteria organisms [*K. pneumonia* (6.25–25 mg/ml), *S. aureus* (6.25–100 mg/ml), *P. aeruginosa* (50–100 mg/ml) and *E. coli* (50–100 mg/ml) and higher than gentamycin (12.5–25.0 μg/ml) indicating the inferior antibacterial effects of the extracts.

The antifungal effectiveness of aqueous and methanolic leaves and stem bark extracts of the plant at varying concentration ranges (3.125, 6.25, 12.5, 25, 50, and 100 mg/ml) on eight fungal strains (*Trichophyton floccosum*, *Aspergillus niger*, *Candida krusei*, *Rhizopus stolonifer, Candida albicans, Trichophyton rubrum, Epidermophyton floccosum and Trichophyton interdigitale*) through agar diffusion and broth dilution methods to determine the zone of inhibitions (ZID) and MIC. The study established moderate and good inhibitions of the organisms especially mould fungi species (*A. niger*, *R. stolonifera*) and yeast (*C. albicans*, *C. krusei*) with a zone of inhibition values ranging between 10 – 14 mm and 10–26 mm respectively by the methanolic leaves extract; the activity of the extract was better than ketoconazole and tioconazole (10 mg/ml). Additionally, the methanolic stem bark showed good activities on the tested strains, though less effective to the leaf. The ZID result was corroborated by the MIC findings. The MIC of the leaf methanolic extract was found at 3.125 mg/ml for *C. albicans* and *T. rubrum*. Hence, indicates the antifungal effect of the plant, particularly the methanolic leaf extract.

In an effort to assess the antimicrobial properties of *D. oliveri* across wide solvent ranges, Nwuche and Eze [61] investigated the impact of aqueous (cold and hot), methanol, ethanol, and acetone stem extracts on a range of broad-spectrum organisms such as *S. aureus*, *Bacillus subtilis*, *K pneumonia*, *P. aeruginosa*, *Enterococcus faecalis*, *E. coli* and *C. albicans* using broth dilution method across diverse concentration ranges. The study established organic solvents showing good antimicrobial activity even at the lowest concentration (6.25 mg/ml) against all the tested microorganism strains. The aqueous extracts showed similar activity, however the cold extract shower weaker inhibitions of the tested strains except with *S. aureus* and *C. albicans* where a comparable effect (at 25 mg/ml) was observed. While the outcome from the study showed the better effectiveness of ethanol among the organic solvents for the organisms, the sensitivity to inhibitions of the tested gram-positive organisms was reported to be more pronounced above gram-negative bacteria species. The findings from the investigation corroborated earlier findings on the superior activity of the organic extracts over

the aqueous extract, especially for the stem plant part.

Recent revelations on the evaluation of the antimicrobial effectiveness of the plant were further tested on 10 strains of microorganisms including *E. coli, P. aeruginosa*, *S. aureus*, *K. pneumonia, Bacillus cereus, Proteus vulgaris, Streptococcus viridians, Shigella dysenteriae, B. subtilis* and *Salmonella typhi* by leaf and bark ethanolic extracts at 0.94, 1.88, 3.75, 7.5, 15, 30, 60 mg/ml concentrations using agar well diffusion method in a study by Osuntokun et al. [7]. The highest concentration at 60 mg/ml, revealed higher ZID; 15 mm (*S. dysentariae*), 14 mm (*P. vulgaris*) and 13 mm (*P. aeruginosa*) and comparable to ciprofloxacin, though, less effective compared to the latter, thus, indicating higher or good activity of the plant. While at lower concentrations (0.94–7.5 mg/ml), organisms' growth indicating the ineffectiveness at these concentrations, revealed minimum bactericidal concentration (MBC) at 15 mg/ml. The presence of secondary metabolites such as alkaloid, saponin, steroid, and phenol was attributed as probable compounds responsible for the elicited antimicrobial activity. The antimicrobial activity of oleoresin and volatile oils (from the bark and leaves) of the plant was investigated by Owolabi et al. [46]. The stem and leaves reportedly collected from two states [Katsina (Batsari) and Zamfara (Zurmi)] from the northern part of Nigeria were subjected to hydrodistillation to obtain the oil tested on 7 bacteria (*B. cereus*, *Cutibacterium*, *S. aureus*, *Staphylococcus epidermidis*, *Streptococcus pyogenes, P. aeruginosa* and *Serratia marcescens*) and 8 fungi (moulds and yeast) strains (*Aspergillus fumigatus*, *A. niger*, *Cryptococcus neoformans*, *Microsporum canis*, *Microsporum gypseum*, *Trichophyton mentagrophytes*, *Trichophyton rubrum, C. albicans)* of microorganisms using the micro broth dilution technique. The study maintained that the oil from the leaf showed moderate activity against the tested organisms depicting a MIC of 156 μg/ml, though a noticeable antifungal effect against *A. niger* and *T. rubrum* (MIC: 78.1 μg/ml) was recorded. The activities depicted by extracts were less effective compared to gentamycin and amphotericin B (for bacteria and fungi respectively).

The antimicrobial potential of *D. oliveri* aqueous-ethanolic leaf extract was experimented in an *in vivo* (broiler chicken; Ross 308) study by Olufadehan et al. [80] where the animals were administered 10, 20, 30, 40 ml/l concentrations of the extract and neomycin (control drug) for 28 days in order to verify the growth performance of the animals. While the chemical composition of the extract was found to contain dry matter (89.11%), crude protein (18.95%), crude fibre (13.11%), ether (4.78%), ash (6.10%), organic matter (93.9%), neutral detergent fibre (47.5%), acid detergent fibre (28.1%) and nitrogen-free extract (46.17%), the average dietary feed intake of the animals reduced with increasing doses of the extract. Thus, the overall performance of the animals was however enhanced (at 40 ml/l) without causing any deleterious effect based on the outcomes from the biochemical parameters. In fact, a review on the excellent effect of the plant (leaves) on growth performance, caeca microbial population, carcass characteristics and blood profiles of the broiler chicken had been submitted by Alagbe [18]. The review established the antimicrobial activity of various parts of the plant which is laudable, an indication of the potential of the plant against a wide range of pathogenic infections. However, isolating and characterizing the bioactive compounds eliciting these effects will be appropriate if the development of a suitable antibiotic candidate from the plant is desired.

3.8. Antioxidant and hepatoprotective

The emergence of pathological conditions or diseases such as diabetes mellitus, high blood pressure, cardiovascular diseases have been linked to compromised antioxidant defense mechanism [81,82]. Hence, an elevated or boosted defense status through the use of (synthetic) antixodants (such as vitamin C) protect the body from the onset of these illnesses [83]. Numerous epidemiological findings have indicated MPs including *D. oliveri* with antioxidant potential to exhibit (better) protection in the maintenance of health and prevention of diseases [41,62,81].

The antioxidant and hepaprotective effects of different parts of *D. oliveri* have been investigated in different areas of the African continent. The aqueous-methanolic leaf, stem bark, and root bark of Malian collection reported by Maunda et al. [41] were determined using phosphomolybdenum 1,1-diphenyl-2-picryl hydrazyl radical (DPPH) and 2,2-azino-*bis*(3-ethylbenzothiazoline-6-sulfonic (ABTS) radicals assays as well as evaluation of possible detection of constituents in a reversed-phase high-pressure liquid chromatography (RP–HPLC) equipment. The highest TPC (7600 mg GAE/100 g dry mass) and TFC (12080 mg CE/100 g dry mass) were depicted by the stem bark extract followed by the leaves and root bark. However, the highest total anthocyanidins content was reflected by leaves extract (12257 CE g/L). Additionally, the leaves extract showed the best activity at inhibiting DPPH radical (93.3%) followed by root bark (87.6%) and stem bark (86.1%) while the root bark showed the highest value of 606.0 mg/100g dry weight of vitamin C equivalent antioxidant capacity (VCEAC) indicating the antioxidant potential of the plant. Caffeic acid (stem bark) was detected as the most vital compound presenting a concentration of 2410.4 μg/ml from a list of 13 detected compounds from the RP-HPLC analysis as represented in all the plant parts.

The leaf and stem bark antioxidative activities were replicated in a Nigeria study by Olaleye et al. [63] exploring a number of radicals such as hydroxyl radical, metal chelating effect, reducing power and lipid peroxidation undetermined in the previous investigation and in the addition to determining other antioxidant parameters including TPC, TFC and total proanthocyanins (TPAC). Like the Malian study, the stem bark depicted the highest TPC (396.71 mg/GAE), however, the findings from Nigeria contradicted the study from Mali, where the highest TFC was found in the leaves (70.82 mg/quercetin) and TPAC (419.11 mg/CE) in the stem bark. The stem bark revealed the best activities in the inhibition of the radicals and metal chelating effects indicating the antioxidant potential of the plant. Typically, the stem bark reached an inhibition of 40.84% at the lowest concentration of 10 μg/mL for hydroxyl radical, higher reducing power (0.81) better than tocopherol (0.40), inhibited lipid peroxidation (71.30%) at 100 μg/mL, and similarly showed comparable metal-chelating effect, though, lower compared to ethylenediamine tetraacetic acid (EDTA) in terms of activity. While the moderate antioxidative potential of the oleoresin ($IC_{50} = 15.49 \pm 0.39$ μg/mL) compared to alpha-tocopherol (0.25 ± 0.40 μg/mL) against DPPH has been established [67] in the Nigerian study, the oil from the seed was also investigated by Danlami and David [62]. The activities of the oil (prepared in ethanol) at various concentrations (0.03, 0.06, 0.125, 0.25, and 0.50 mg/ml) and standards

(butylated hydroxyl anisole, quercetin, and vitamin C) were also evaluated by their abilities to inhibit DPPH radical. The oil only showed good activity at concentrations of 0.03 and 0.25 mg/ml though exhibited a weak potential when compared with the standards.

The antioxidant and hepaprotective effect of the ethanolic stem bark extract in an animal model was examined [83] at 100, 200, and 300 mg/kg b.w. concentrations. The effect of the orally administered extract on carbon tetrachloride-induced (1 mg/kg in olive oil; intraperitoneal) hepatotoxic Wistar rats were monitored for 12 days. The hepatoprotective potential was evaluated on liver enzymes [alanine transaminase (ALT), aspartate aminotransferase (ASP), alkaline phosphatase (ALP)], antioxidant enzymes [glutathione peroxidase (GP), catalase (CAT) and superoxide dismutase (SOD)], lipid profile parameters [triglyceride (TG), high-density lipoprotein-cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), total cholesterol (TC)], lipid peroxidation (measurement of malonaldehyde formation) and others. The effect of the extract on markers of liver damage showed that the extract (particularly 200 mg/kg b.w.) lowered the elevated activities of ALT, ASP, ALP, total bilirubin, and so on following CCl_4 induction towards control. The doses of the extract reduce the levels of the lipid parameters; increase (with silymarin) the HDL level compared to the negative control (CCl_4 group with no treatment). The reduced level of the antioxidant (defense) enzymes and increased MDA level as a result of hepatoxicity were reversed by various doses of the ethanolic stem bark extract, although, 200 mg/kg b.w. best enhanced the activity of the enzymes, thus, liver tissues were improved following damage due to toxicity. The arrays of antioxidant and hepatoprotective studies whose findings were established in this review are only limited or restricted to two western Africa countries (Mali and Nigeria) which may not reflect the reality in terms of effectiveness across the globe. Additionally, with these results, it would have been appropriate to test the isolated and identified daniellic acid *in vivo* to confirm or buttress the *in vitro* investigation.

3.9. Antiplasmodial

Malaria is an acute febrile disease whose prevalence has continued to increase over the years; from over 227 million cases in 2019 to 241 million in 2020 and with accompanying deaths of 627, 000 [84]. Managing the infection was originally with the use of synthetic drugs (single and combinations), however, due to the resistance of the parasite, alternative therapeutic approach in medicinal plants such as *Artemisia annua* (Artemisinin), *D. oliveri,* and others [64,85] became a vital necessity.

The antimalarial action of the methanolic leaf extract at 200, 400, and 800 mg/kg b.w. concentrations were studied in Swiss albino mice induced with NK-65 *Plasmodium berghei* during a 7-day experimental period. Various indicators such as weight changes, biochemical parameters (including liver and lipid profiles), and haematological indices were used to assess the antiplasmodial activity of the plant. The study revealed a drastic reduction in weight of *P. berghei*-infected animals administered with lowest dose as compared with the highest two extract doses and chloroquine-treated mice compared to the uninfected and treated groups (control) having increased weight. Reduction in the activities of AST, ALT, and a total bilirubin level of 800 mg/kg b.w. mice following elevated levels of these parameters arising from plasmodium induction were also reported. A significant increase in the levels of packed cell volume (PCV), haemoglobin, red blood cells (RBC), white blood cells (WBC), and platelet was also depicted by the various doses of the extract; decline in the level of these parameters was submitted for parasitic (without treatment) group. The overall findings of the antimalarial evaluation of the plant were attributed to the hepatoprotective potential of the plant [64]. The reported investigation did not outrightly confirm the antiplasmodial action of the plant, hence, it will be suggested that more investigations be conducted on the different parts of the plant across regions of the world. Furthermore, the necessity to determine the bioactive compounds responsible for the antimalarial activity is germane.

3.10. Antiwrinkle

The antiwrinkle effect of the plant was evaluated on the exudates (oleoresin) in a study reported by Lamy et al. [22]. The action was determined spectrophotometrically by the ability of the extract to stimulate the activity of glycerol-3- phosphate dehydrogenase concerned with the neo-synthetic formation of intracellular lipids (triglycerides). The activity of the extract (dissolved in dimethylsulfoxide) at 25 μg/ml was compared with Pulpactyl® at 0.5% concentration and the study revealed a percentage activity (between 119 and 240%) of the enzyme by the extract (comparable to the control drug) indicating the antiwrinkle action of the plant [22]. Identification of the compound(s) responsible for this effect is vital for further drug development.

3.11. Antisickling

Sickle cell disorder (sicked red blood cells) is a haematological (genetic) disease [86] whose prevalence affects 5% of the entire population [87], particularly children below 5 years of age [88]. Declared as a major health concern [89], the management options involve the use of drugs (penicillin, particularly for new-borns, hydroxyurea therapy) [86] and medicinal plants such as *D. oliveri* [65].

The antisickling effect of the aqueous bark extract of *D. oliveri* was studied *in vitro* (at concentrations of 10, 20, and 40 mg/ml) and in rats (200 mg/kg b.w.) during a 28-day study. It was reported that the extract prevented the formation of sickle cells dose-dependently with the mean sickle cell count of 40 mg (0.64 ± 0.13) showing a superior decline in the count compared to the control cases (0.85 ± 0.09 mg). Similarly, the extract reversed sickled cells to the normal (biconcave) form of red cells exhibiting an average sickle cell count of 0.55 ± 0.1048 (40 mg) and 0.76 ± 0.1092 (control), thus, indicating its potential in reversing sickle cells. The mean haemoglobin level was found not to change between the control and the extract-treated group suggesting that the extract did not stimulate the production of haemoglobin [65].

3.12. Neurological

The neurological effect of the root part of the plant was investigated by Beppe et al. [14] in *in vivo* technique. The aqueous root extract at 100, 200, and 300 mg/kg b.w. was evaluated on diazepam-induced amnesia in Swiss albino mice during the 14-day experimental period. The learning and memory of the animals evaluated using the radial arm maze and T-maze established 200 mg/kg b.w. to most efficiently increase the preferred arm compared with the dementia group; the positive effect was also shared by piracetam (150 mg/kg b.w.). Additionally, the increased number of returns of the arm as a result of the diazepam induction was brought down by the doses of the extract. Increased MDA content was reversed significantly ($p < 0.001$) with 100 mg/kg b.w. while the reduced glutathione concentration was enhanced significantly ($p < 0.001$) by the doses of the extract especially the 200 mg/kg b.w. The histopathological observation of the hippocampus revealed the presence of abnormal architecture (granular cell at the dentate gyrus) with evidence of cell degeneration in the diazepam without treatment group; however, these aberrations were reversed with 300 mg/kg b.w. indicating the neuroprotective action of the plant. For the purpose of conservation, it will be appropriate that the aerial parts (leaves and stem bark) be evaluated for neurological potential and the likely compounds responsible for the activity be determined for possible drug development.

3.13. Cytotoxic

The cytotoxic activity of the oil exudates at 200, 250 and 500 μg/ml concentrations was evaluated in prostate cancer (PC3) cell line using 3-[4,5-dimethylthiazole-2-yl]-2,5-diphenyltetrazolium bromide (MTT) colorimetry assay. The investigation reported a weak cytotoxic effect (IC_{50}: >30 μg/ml) at tested concentrations compared to doxorubicin (2.8 μg/ml) [67]. The cytotoxicity of the leaf and bark extracts (hexane, DCM, and methanol) at concentration ranges of 15.6–500 μg/mL were also studied on neuronal (immortalized rat mesencephalic) N27 cell line using the same MTT assay. The potential activity elicited by the extract was compared to the parasite so as to determine the selectivity. All the tested extracts except hexane (bark) showed the ability to reduce the cell viability at the relatively highest concentration (250 μg/mL). Further findings revealed that all the extracts were greatly selective for the parasite than the N27 cells as evidenced by their selective index (SI) greater than 1. Hexane extract of the bark revealed an SI value of 18 indicating its profound toxicity level since SI greater than 1 is a measure of toxicity to the cells [28]. The review established a wide evaluation of different parts of the plant across varying solvent polarities, however, it will be appropriate for more research work centred on the identification and characterization of bioactive compounds.

3.14. Cardiotoxic

Cardiovascular ailments (CVD) as one of the leading causes of death globally [90] are groups of diseases associated with the heart and blood vessels [68]. While the management can either or both be non-pharmacological (exercise, diets etc.) and use of synthetic drugs. However due to accompanying side effects from the latter, numerous MP including *Daniellia oliveri* have been found to be effective in its therapy [91].

The cardioprotective effect of the oral administration of the ethanolic leaf extract using various concentrations (50, 100, 200 mg/kg b.w.) on Wistar strain rats was studied and various biochemical (alkaline phosphatase, acid phosphatase, ALT, AST) and lipid profile [total cholesterol (TC), HDL-c, triacylglycerol (TG), atherogenic index (AI)] parameters were checked. The study [92] submitted that the extract had no effect ($p > 0.05$) on the AI but showed increased ($p < 0.05$) level of TC (at doses of 100 and 200 mg/kg b.w.) and the heart's AST activity (50 and 100 mg/kg b.w.). Similarly, the activity of ACP was reported to be significantly increased at 50 mg/kg dose while it diminished with the two higher concentrations. Following these findings, the study concluded that intake of ethanolic extract may subject individuals to a possible risk of CVD.

3.15. Safety profile/Toxicology

One major shortcoming of traditional medicine is the lack of therapeutic dosage [92], indicating the likelihood of abuse by the users due to excessive consumption. Therefore, understanding the safety profile of herbal medicine or formulation is very paramount [93] especially through clinical trials to unravel the possible adverse effects of different extracts [94].

The toxicity profile of *D. oliveri* combined with *Sarcocephalus latifolius* was evaluated by Iwueke and Nwodo [35]. The acute and subchronic toxicities of the aqueous root extract were carried-out upon oral administration of 10,000 mg/kg and 1000 mg/kg doses to rats as well as 1500, 2900, and 5000 mg/kg b.w. to mice for 3 days. The study submitted no behavioural changes was witnessed nor death recorded following the introduction of higher doses of the extract to the animals indicating that the lethal dose (LD_{50}) was above 5 g/kg b.w. and thus, concluded it to be safe. Shuaibu et al. [56] studied the safety potentials of the leaf when 5000 mg/kg b.w. of the aqueous extract was orally administered singly to rats and then observed for behavioural changes for possible toxicity and mortality. The study revealed no changes in the behaviour of the rats and no recorded death, thus corroborating the submission of Iwueke and Nwodo [35] on the LD_{50} to be above 5000 mg/kg, therefore not toxic. Additionally, the safety parameter of the leaf was experimented in a two-phase study on mice following intraperitoneal administration of 10, 100, 1000 mg/kg b.w. (first phase) and 200, 400, 1000, 1600 mg/kg b.w. (phase 2) of n-butanolic extract. At the expiration of the studies after 48 h, it was reported that no behavioural changes were seen in the animals and no mortality was observed. The LD_{50} was reported to be in excess of 4000 kg/kg b.w [34].

As against to earlier submissions, intraperitoneal injection of 250, 400, 450, 600 and 700 mg/kg b.w. aqueous leaf extract to Swiss strain mice resulted in 0, 2, 6, 8, and 10 respectively number of deaths suggesting the toxicity of the extracts, particularly at 700 mg/kg

b.w. where all the mice were reported to be dead. While agitation, jerky breathing, sluggishness in movement, loss of appetite were reported as possible behavioural changes observed, the LD_{50} was said to be 436.51 mg/kg b.w. for this Ivory Coast study [44]. Acute toxicity investigation using Organization for Economic Co-operation and Development (OECD) 423 guideline on the stem bark was established in the report of Traore et al. [31]. A single oral dose of 2000 mg/kg b.w. of the methanol extract was given to Naval Medical Research Institute (NMRI) bred mice and were observed after 2, 24, 48, and 72 h as well as after 7 and 14 days for toxicity signs such as coat modification, noise sensitivity, breathing, tremor, weight changes, mobility, shock, and death. The study reported no changes in behaviour and no mortality recorded in the animals, thus, concluded that the LD_{50} of oral administration of the methanolic stem bark extract was in excess of 5000 mg/kg b.w. based on Global Classification and Harmonization System (GHS), that it was safe.

Additionally, a report from Burkina Faso by Kabore et al. [95] on the decoction stem bark extract administered orally using 6 concentrations (500, 1000, 2000, 2500, 3000, 3500 mg/kg b.w) into NMRI mice for 3 days were monitored for any signs of toxicity and deaths. The study established no observed behavioural changes (mobility, feeding, breathing) in the activities of the animals, and no death recorded and thus, concluded the LD_{50} to be above 3500 mg/kg b.w. orally. Similarly, 2000 mg/kg ethanolic stem bark extract was administered (p.o.) to experimental mice in a Nigerian study and monitored for 4 and 24 h for signs of toxicity and occurrence of mortality, respectively. The animals were found to be restless within 4 h of behavioural monitoring and recorded no death after 1 day of high dosage administration [55]. Summarily, the toxicity findings established the plant to be safe orally, however, this may not be said of intraperitoneal administration as differences of reports existed though the finding from Ivory Coast was the only study that presented the toxic nature of the plant through this route which we feel might be related to a number of factors not limited to proper handling of the animals, expertise in intraperitoneal administration; hence, may not be taking as an indication of toxicity of the plant as this is only report out of many from different regions.

3.16. Other uses and applications

The odour and or aromatic resin produced from the burning of bark or wood of *D. oliveri* are used as a mosquito repellent in homes of most African countries not limited to the Gambia and Guinea Bissau, this is as reported by Atolani and Olatunji [51] in works of Snow [96], Lindslay and Janney [97] and Paalson and Jaenson [98]. Ethnoveterinary use of this plant in some African nations including Burkina Faso, Cameroon for the control of gastro-intestinal parasites has also been submitted [99,100]. Interestingly some of the nutritional uses have also been verified scientifically. Typically, a study by Okunade et al. [101] reported the improvement in nutritional benefit (increased feed intake and weight gain), rumen fermentation, and microbial ecology of Yankassa male lambs whose diets were fortified with different concentrations (50, 100, 150 g/kg) of *D. oliveri* seed meal with the highest concentration exhibiting the best performance or outcome.

A related study by Olufadehan et al. [102] determined the importance of fortifying the meal with leaf extract of *D. oliveri* on carcass quality, nutritional retention, and caeca microbial population of day-old chicken during a 56-day experimental study. They found out that administration of 40 ml/l extract of the plant enhances the proliferation of Lactobacillus and similarly does not cause any dangerous or deleterious effect on the caeca quality and performance or activity of the chicks. Further nutritional benefit was also found in a study by Osakwe et al. [103] where ammonia level in the rumen and nutrient digestibility were evaluated in small ruminant animals (such as sheep) upon consumption and found it to be a good fodder plant despite its high condensed tannin content. Additionally, the benefit of the plant nutritionally was also established in broiler chickens fed (fortification) with leaf extract of the plant and used as an antibiotic alternative to the regular diets fed to day-old chickens in a study that lasted 56 days. The outcome revealed that AI increased with increasing concentrations of the extract and thus concluded the enhancement of general performance of the animals by promoting the fatty acids composition and meat quality [104].

The application of *D. oliveri* has been found in water management using its sawdust as an adsorbent base for the removal of trimethoprim (in water) constituting (perhaps) health and ecological problems (particularly to the aquatic habitats) if exposed to them involuntarily [105]. Additionally, a great diversity of microorganisms (bacteria) from the genera, Bacillus (*B. cereus*, *B. subtilus*, *B. megaterium*) and Micrococcus isolated and or identified from the plant in a study [106] resulted in the production of some enzymes (such as amylase, cellulase, esterase, lipase, and protease) that aids the rapid decomposition of leaf litter appropriate for organic fertilizer production [106]. The bark of the plant has also been explored in briquettes production thus, providing a cheaper means of fuel utilization, particularly for rural dwellers [107]. The influence of temperature (400, 500, 600 °C) and catalytic pyrolysis (at different 10, 20, 30, and 40 wt %) on biofuel yields production from the plant's sawdust have been studied and established that though sodium carbonate might not be the best or ideal catalyst to be considered during future catalytic pyrolysis on the plant, however, adoption of pyrolysis process (at 500–600 °C) definitely influenced biofuel production [108]. Another study also maintained that the addition of salt (to seed flour) influences the functional properties of the plant's seed in terms of water absorption, gelation, foaming stability or capability, protein solubility and stability as well as emulsion capability. That the extent of the effect is a function of salt concentration and type [16].

The enhanced coppice growth of the *D. oliveri* tree by weed removal was studied in Benin following the report from Houehounha et al. [109]. The study revealed a three-time shoot density height (7250 ± 454 shoots ha^{-1}) and rapid growth following clearance after 34 months compared to ones on weedy plots (2425 ± 215 shoots ha^{-1}) suggesting regular cutting of the plant's branches (for use by local people for firewood purposes) could hasten the growth of the plant. Other available physiological findings on the plant are on determination of physicomechanical properties of the plant (wood) when heated at varying degrees of temperature [110], examination of anatomy and morphology of the root (a measure of proper identification) [111] and assessment of the plants' biomass [112].

4. Discussion

Medicinal plant usage in the treatment and or management of diseases is an age-long tradition. Indigenous medicine is now in recent times recognized within the national healthcare system or policy of most countries [113]. The effectiveness of herbal medicine on these illnesses is attributed to the richness in the arrays of embedded secondary metabolites and or compounds. Interestingly, *D. oliveri* is not an exception as various parts (leaves, stem, and roots) of the plants possessed several secondary metabolites such as flavonoids, polyphenols, tannins, alkaloids, saponins peculiar to most West African countries (Mali, Nigeria, Ghana, Burkina Faso, Cote D'Ivoire and Togo) where studies on the plant have been attributed to numerous established pharmacological potentials including antimicrobial, antioxidant, antidiabetic, anti-inflammatory, antiwrinkle, antimalarial, antimelanogenesis, antidiarrhoea, antisickling, hepatoprotective, cytotoxic and safety potentials. In fact, typical of some of these compounds isolated from this plant are rutin and quercetin reported or known from the literature to exhibit peculiar pharmacological potentials not limited to anti-inflammatory, antioxidant, and anticancer (quercetin) [114] as well as antioxidant, antiviral, anticancer, neuroprotective, cardioprotective (rutin) [115]. Although, it suffices to mention that variation existed in the presence or detection of some other compounds such as terpenes, sterols, glycosides, carbohydrates, and reducing sugars in the same part of the plants going by findings submitted by authors from these countries. The differences in compound classes as observed and summarized in this review are not surprising as such variations are attributed to differences in geographical locations whether in the soil type, weather condition, state of maturity, harvest time, and so on. While the review establishes and applauds the huge number of phytoconstituents obtained from various extracts/fractions of the plant (and its parts) as determined through a few analytical methods from different regions, however, the lack of further purification of the fractions to be able to identify bioactive compounds is a gap that requires to be investigated from the established biological and pharmacological potentials and/or applications.

Notwithstanding the fact that the review found the predominant use of water and polar solvents such as ethanol and methanol (alcohol) as the most suitable medium for extraction in indigenous medicine [116] while the stem bark was the majorly explored part of the plant for extract formulation accounting for 47% followed by the leaves with 35%. The leaf part would have been expected to reveal the highest usage percentage from an ethnobotanical point of view based on the clamour for its use to encourage biodiversity, however, this report identifies and buttressed the wide choice of the stem (bark) part for many ailments by the indigenous people and/or medicinal plant users of West Africa. The reason for this could be partly because the part is greatly explored for other purposes such as firewood and as repellent for mosquitoes.

In an effort towards drug development, preliminary assays such as *in vitro* and *in vivo* evaluations, as well as toxicity studies, are important to be carried out as a way of partly confirming the indigenous usage and to guide decision-making on further studies such as preclinical and clinical trials. Literature reports established that to a larger extent, the plant was well studied *in vitro* and *in vivo* (to a smaller extent) against a number of diseases accounting for 52% and 37% respectively of the overall reported experimental models. The below-average percentage in animal-model reports may signify that a number of these established pharmacological effects needed to be confirmed *in vivo*. Toxicity evaluation accounted for 11% of the total reported investigations and no clinical study report on the plant at the time of compiling this review was established, hence, above all, it would be encouraged that more focus and or efforts on *in vivo*, preclinical *in vivo,* and translational experimental designs or studies centering on 'omics' (metabolomics, proteomics, genomics, and transcriptomics) applications and concept are required to be put forward on the plant which would serve as a template or preliminary basis for further studies such as clinical trials towards developing novel drugs since it is a known fact that findings from *in vitro* evaluation may not necessarily translate into *in vivo* outcomes. Although, while no clinical trial studies were found in the literature with respect to this plant, clinical relevance of medicinal plants generally has continued to increase based on their acceptance and usage by (conventional) physicians and/or pharmacists in the management of different diseases, thus, playing a pivotal role in the elongation of human life [117] Interestingly, *D. oliveri* is not an exception to this concept. Besides, the various pharmacological and safety attributes established on this plant in both *in vitro* and *in vivo* testing are indications of likely positive feedback or sign of successful outcomes by the time the plant is eventually subjected to clinical trials.

Deductions from the review also indicated that more than 95% of the studies took place in West Africa with Nigeria recording the highest percentage. While the reason for this could be due to the wide distribution of the plant across this region of the globe, it may also points to the fact that the plant had not been adequately explored or is still underutilized which is concerning, and until this is achieved globally, the full therapeutic potentials may not be realized or attained. Hence, though considerable pharmacological potentials of the plant particularly in *in vitro* evaluations have been established and laudable, the review identified the need for the reported activities to be replicated in other continents of the world so as to give a thorough insight into the effectiveness of the plant on many disease conditions across wider populations and cultures. Similarly, across the board, validation of *in vitro* investigation in animal models as well as in clinical trials are necessary. Above all, it can be concluded that despite the fact that the review was able to establish numerous nutritional and pharmacological benefits of the plant attributed to various chemical and bioactive components; thus providing insights into likely development of probable natural moieties against a number of diseases, it is still evident that much research undertakings are needed on the identified grey areas (for the afore-mentioned to be achieved) in order for the multi-therapeutic effect of the plant to be maximally explored.

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Data availability statement

No data was used for the research described in the article.

Fig. 1 [49–52] [A] Rutin; [B] Narcissin; [C] Quercitrin; [D] Quercimeritrin; [E] Lupenol; [F] 3-acetoxy- 9(11), 12-diene-28-carboxyllic acid; [G] Polyalthic acid; [H] Daniellic acid.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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