International Journal of Pharmacology and Pharmaceutical Sciences

ISSN Print: 2664-7206
ISSN Online: 2664-7214
IJPPS 2025; 7(2): 43-52
Impact Factor (RJIF): 8.15
www.pharmacologyjournals.net
Received: 15-04-2025
Accepted: 21-05-2025

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A review of potential pharmacological and phytochemical effects of aphrodisiac plants used in the treatment of sexual dysfunction in men from Gabon

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DOI: https://www.doi.org/10.33545/26647206.2025.v7.i1a.25

Abstract
The uses of plants for therapeutic purposes, aphrodisiac plants seem attractive for improving sex life. However, their uses are not without danger. The aim of this work is to review the uses in ethno-medicine, the bio-pharmacological properties and the toxicity of plants used as aphrodisiacs and for the management of sexual dysfunction problems in Gabon.
Thus, this review article was conducted based on 248 articles (reviews and original articles) and related books from reputable databases.
The results showed that plants used in the management of dysfunctions and as aphrodisiacs are also used in ethno-medicine and present good pharmacological activities.
Other results of several studies on the toxicity of some of these plants show that several are toxics with significant LD_{50}. These two observations suggest that use of certain plants would be toxic and could be fatal for consumers, especially in people with renal or hepatic insufficiency.

Keywords: Pharmacology, phytochemical, aphrodisiac, sexual dysfunction, Gabon

Introduction
The use of plants in the treatment of pathologies dates back thousands of years and is present in all cultures around the world, particularly in developing countries where 80% of rural populations in developing countries and 85% of populations south of the Sahara use medicinal plants [1].
Most therapies around the world involve the active ingredients of medicinal plants [2]. In addition, plants are invaluable resources for the pharmaceutical industry [3, 4]. Among the pathologies treated are those of the male reproductive system such as sexual dysfunction in the male gender. There are several types of sexual dysfunction, including anorgasmia, sexual aversion, dyspareunia, premature ejaculation, delayed ejaculation, frigidity, and impotence are the most common [5].
Among different types, erectile dysfunction is the most common disorder, affecting the life quality of many men around the world. The prevalence, all ages combined, seems to be between 12.9% in Southern Europe and 20.6% in Anglo-Saxon countries [6].
More recent studies show an incidence that can range from 32 to 80% depending on the age patients groups [6]. The most significant projected increases concern developing countries from continents such as Africa, Asia and South America [7, 8].
A study carried in Burkina Faso on erectile dysfunction shows that 855 subjects working in companies and in the civil service, for a mean age of 37.4±9.1, revealed an overall prevalence of 47% [9].
In another study from Massachusetts shows that approximately 40% of men in their forties had erectile dysfunction of varying severity and the prevalence increases approximately 10% per decade. In the same study, the prevalence of severe erectile dysfunction tripled between the ages of forty and seventy of 5% to 15% [10].
In Gabon, the problem of erectile dysfunction remains poorly understood by the population and scientific data on the etiology of problems related to sexual dysfunction are almost non-existent. The few studies available show that populations use medicinal plants to treat erectile dysfunction and as aphrodisiacs [11]. In view the data from the aforementioned works

and the lack of data encountered show that erectile dysfunction would constitute a real public health problem in Gabon like other countries around the world.

In addition to sexual dysfunction, there is the use of plants as natural aphrodisiacs to increase libido. Considered aphrodisiacs of natural origin, remedies supposed to increase sexual desire or improve sexual performance such as plants, foods, spices and certain medications [12].

Natural aphrodisiacs seem attractive to improve sex life, the fact remains that the products used are not free from all danger. Some can cause serious side effects that can lead to loss of life. Indeed, in the search for sexual performance, aphrodisiac products based on natural plants are increasingly consumed in Central Africa with a lack of awareness of the associated dangers [13].

The objective of this review is to provide a general overview of the traditional uses, phytochemical, pharmacological potential and toxicology of plants used as aphrodisiacs and in the treatment of sexual dysfunction in Gabon. In this bibliographic synthesis work, pharmacological tests, phytochemical and toxicological screenings will be reviewed or visited.

Methodology of the bibliographic research

The plants used in the treatment of sexual dysfunction and as aphrodisiacs of natural origin and their bio-pharmacological activities were documented as proposed by Mcneill and Jurgens (2006) [13]. The plants of the study were selected on the basis of the information obtained from users such as herbalists, scientific data published in original articles, reviews and some books on the Gabonese flora [13, 14, 15, 16].

Thus, this review article was carried out on the basis of 248 articles (reviews and original articles) and related books from reputable databases, such as Medline (www.pubmed.gov), BioInfoBank (http://lib.bioinfo.pl), Elsevier (www.sciencedirect.com) and Google Scholar. Information on ethno-medicine, ethno-pharmacological uses, phytochemical, pharmacological and toxicological properties were collected using keywords such as "pharmacological properties", "phytochemical", "medicinal plants", "toxicology" [12]. The keywords explored during data collection consisted of making combinations of "plant names", "pharmacological properties", "antioxidant activity", "antiplasmodial activity", "toxicity" (Example: combination of *Carpolobia alba* G.Don with phytochemical properties or *Garcinia punctata* Oliv. with pharmacological properties).

Physiology of erection and sexual dysfunction

Erection is the result of smooth muscle relaxation actively controlled by the central nervous system through the non-cholinergic parasympathetic nervous system, whose main neurotransmitter is nitric oxide (NO). A second nerve impulse is also necessary for the purpose of regulation by the sympathetic system with noradrenaline, because erection is an active phenomenon [17].

Noradrenaline is not only a reflection of sexual arousal, but also the driving force of the physical act (apart from erection) because sexual activity is linked to striated muscle activity of the limbs and trunk, as well as the muscles of the perineum, necessary for ejaculation, but noradrenaline also causes muscular retraction of the corpus cavernous, so too much noradrenaline leads to a decrease or even the disappearance of the erection [17].

The erectile response occurs in four stages with firstly, sensory stimulation, perception of desire and sending a parasympathetic nerve impulse to the penis. Secondly, the muscles of the penis which were in a state of tonic contraction at the start are relaxed under the effect of the stimulation, this is an essential term of active relaxation, and the whole problem of the erection of the man is in this double muscular play. In a third phase, the arterial flow increases and fills the corpus cavernous, once the erection is established, the venous compression allows the maintenance of the tumescence even if the arterial influx decreases and almost stops [17].

Erectile dysfunction (ED) is a disorder of sexual dysfunction whose causes are diverse (hormonal disorder, neurological disorders, traumatic injuries, diabetes and psychiatric disorders). Erectile dysfunction is defined as the inability to obtain or maintain an erection sufficient to allow satisfactory sexual activity. It falls within the framework of sexual dysfunctions, because it causes disorders of desire, pleasure, orgasm or ejaculation [18, 19].

Erectile dysfunction appears in the context of the antagonism between the phenomenon of tumescence and the phenomenon of detumescence. When the balance between the two is disturbed, whatever the cause, a difficulty or an inability to maintain a sufficient erection occurs [17].

When the origin of the disorder is hormonal, in particular a hormonal insufficiency, this has the effect of a decrease in relaxation causing insufficient preparation of the corpus cavernous by a decrease in the capacity to receive the erotic stimulus. This decrease in relaxation causes insufficient blood pressure which will lead to a decrease in NO secretion at the level of the vascular endothelium [17]. This phenomenon results in insufficient relaxation of the corpus cavernous, and this imbalance will self-amplify through the resulting performance anxiety which will raise the level of circulating catecholamine, increase the retraction phenomena and aggravate the erectile dysfunction [17, 21].

Presentation of some plants used for the management of sexual dysfunction and as aphrodisiac in Gabon.

The use of these plants in the management of erectile dysfunction has been reported by other authors [22, 24].

In Gabon, published scientific studies show that populations use plants in the management of sexual insufficiency problems [11, 15 22]. Overall, published data show that twenty-three (23) wild plant species distributed in nineteen (19) botanical families are used in the management of sexual dysfunction problems by populations in Gabon and in ethno-medicine around the world.

Tableau 1: Plants list uses against erectile dysfunction and as aphrodisiacs

N°	Botanical family	Vegetal species	Ref
001	Annonaceae	*Annickia chlorantha* (Oliv.) Setten & Maas	*a*
002	Annonaceae	*Greenwayodendron Suaveolens* (Engl. & Diels) Verdc.	*b*
003	*Apocynaceae*	*Picralima nitida* (Stapf) T. Durand & H. Durand	*a*
004	Cluciaceae	*Garcinia punctata* Oliv.	*a*

005	Cyperaceae	*Scleria boivinii* Steud.	*c*
006	Euphobiaceae	*Manniophyton fulvum* Müll. Arg.	*c*
007	Fabaceae	*Arachis hypogaea* L.	*a*
008	Fabaceae	*Tetrapleura tetraptera* (Schum. & Thonn.) Taub.	*a*
009	Longaniaceae	*Strychnos Icaja* Baill.	*b*
010	Marantaceae	*Megaphrynium gabonense* Koechli.	*a*
011	Melastomataceae	*Memecylon klaineanum* Jacq.-Fél.	*b*
012	Myristicaceae	*Scyphocephalium ochocoa* Warb.	*a*
013	Moraceae	*Milicia excelsa* (Welw.) C.C. Berg	*a*
014	Pandaceae	*Microdesmis hausmania* J. Léonard.	*c*
015	Poaceae	*Saccharum officinarum* L.	*a*
016	Polygalaceae	*Carpolobia alba* G.Don	*a*
017	Polygalaceae	*Carpolobia lutea* G.Don	*b*
018	Rubiaceae	*Nauclea diderrichii* (De Wild. & T. Durand) Merr.	*a*
019	Rubiaceae	*Pausinystalia yohimbe* Kschum	*b*
020	Rubiaceae	*Schumanniophyton magnificum* (K.Schum.) Harms	*a*
021	Sapotaceae	*Omphalocarpum elatum* Miers	*a*
022	Selaginellaceae	*Selaginella myosurus* (Sw.) Alston	*c*
023	simaroubaceae	*Quassia africana* (Baill.) Baill.	*b*

Legends: a: Betti *et al*. 2013 [11], **b:** Moussavou-Moussavou, 2024 [22], **c:** Nsi Akoué, 2017 [16].

Among the plants listed in the table 1, six plants (*Q. africana*, *C. lutea*, *S. Icaja*, *G. Suaveolens*, *P. yohimbe* and *M. klaineanum*) are used as aphrodisiac substance only and others as aphrodisiacs and for the treatment of erectile dysfunction problems [14, 16, 22].

Ethno-medicine of plants used for the management of sexual dysfunction

The analysis of uses of the twenty-three plants used in traditional medicine shows that several of them are included in the management in ethno-medicine for sexual dysfunction, aphrodisiac and a diversity other pathologies.

We will analyze in the rest of our work, the uses in ethno-medicine and bio-pharmacological of some plant species selected on the basis of their published data pharmacological properties.

Concerning the uses in ethno-medicine, studies highlight that these species are used for the treatment of several pathologies. This is the case, for example of *Annickia chlorantha* which is used for the treatment of several pathologies such as stomach, malaria, hepatitis, jaundice, anemia, infected wounds, fever, tuberculosis, typhoid fever, urinary tract infections [25, 26, 27].

Other studies also mention the treatment of aches, boils, vomiting, intestinal worms, intestinal spasms, sexual asthenia, gastric and duodenal ulcers and leprosy spots with *Annickia chlorantha* [28]. Two species of *Carpolobia* (*C. alba* and *C. lutea*) treat several pathologies such as rheumatism, cataracts, intestinal parasites, sterility, bone fracture, reproductive disorders, malaria, ulcer, rheumatism, skin infections, tapeworm, venereal diseases, deworming, gonorrhea, gingivitis, headaches and facilitate childbirth [29, 30, 31]. Likewise, several other species such as *Schumanniophyton magnificum*, *Scyphocephalium ochocoa*, *Milicia excelsa*, *Tetrapleura tetraptera*, *Strychnos icaja*, *Quassia africana* and *Selaginella myosurus* are used in the management of a variety of pathologies such as malaria, dysentery, gonorrhea, syphilis, antivenom, anemia, various cancers (breast, stomach, skin and liver), asthma, edema, dysmenorrhea, heart disorders, convulsions, ear infections, hernia, pain, injuries, scabies, gastritis, dental caries, tonsillitis, hypertension, bone fractures, urinary and respiratory infections, gingivitis, female sterility, antidote against poisonous stings and bites [32-46].

Regarding plant parts used in ethno-medicine, results show that all the organs are used. Among which, the stem, roots, barks and leaves are mainly used for the composition of recipes [44, 45]. Other parts such as fruits (*T. tetraptera*) are also rarely used [41, 42].

Regarding the methods of preparation, decoction and maceration constitute methods of preparation used for the preparation of recipes [42, 44, 45].

Phytochemistry of plants used for the management of sexual dysfunction

The results of the various documented studies on phytochemical analyses (phytochemical screening and compound isolation) of different plants show that almost all species used in the management of sexual dysfunction and aphrodisiacs are rich in secondary metabolites such as coumarins, alkaloids, flavonoids, tannins, saponins, phenolic compounds, steroids, cardiotonic glycosides, tepenoids, anthraquinones and anthocyanins [15, 23, 24, 26, 34, 35, 38].

All these chemical compounds are bioactive and responsible for various bio-pharmacological effects. Their presence would justify the multiple uses in ethno-medicine not only in the management of sexual dysfunction and as aphrodisiacs, but also in the treatment of other conditions [47].

Specifically, chemical study of different parts of *A. chlorantha* species shows that they contain compounds such as alkaloids, flavonoids, tannins, saponins, phenols, steroids, cardiotonic glycosides, tepenoids, anthraquinones and carboxylic acids [48]. Saponins being steroidal in nature, are known to play an intermediary role in the synthesis of steroid hormones [22]. Similarly, alkaloids are known to have performance enhancing properties, acting either by inducing vasodilation through the synthesis of nitric oxide and thus promoting erection. On the other hand, alkaloids could stimulate steroid-genesis in rat testes by relaxing the smooth muscles of the corpus cavernous in the male sexual organ [22]. The presence of sterols and alkaloids could justify a probable use as an aphrodisiac. Indeed, the stem bark of some of these vegetal species allowed the isolation of seven alkaloids (1-7), one triterpene (9) and two steroids (8a-8b, 10) including 1,2,3-trimethoxy-4,5-dioxo-6a,-dehydroaporphine A (1), cepharadione B (2), O-methyl-moschatoline (3), palmatine (4), jatrorrhizine (5),

columbamine (6), pseudojatrorrhizine (7), the mixture of β-sistosterol (8a) and stigmasterol (8b), cyclofoetigenin A (9) and β-sitosterol-3-O-β-D-glucopyranoside (10) [49]. The said family of metabolites would cause an increase in the level of neurotransmitters involved in erectile function and would modulate the action of neurotransmitters within their target cells or even raise the level of androgens according to [22].

Chemical screening of other species such as *Carpolobia lutea* which used as aphrodisiac [22] are revealed the presence of alkaloids and others compounds as tannins, saponins, flavonoids, cardiac glycosides, anthraquinone, saponins and cardénolides [15]. Indeed, phytochemical screening of the methanolic extract of the roots of *C. lutea* revealed the presence of saponins, anthraquinones, flavonoids, cardiac glycosides, simple sugars and terpenes; it was found to be free of alkaloids and tannins. Phytochemical analysis of the ethanolic extract of the leaves of the same species revealed the presence of alkaloids, saponins, tannins, anthraquinone, cardiac glycosides and flavonoids [15].

Hydrodistillation of its leaves using a Clevenger-type apparatus allowed to obtain an essential oil yield (0.06-0.10%). The composition of this oil showed that it contains terpenoids, hexahydro farnesyl acetone, (E)-geranyl acetone, (E)-2-decenal, farnesyl acetone, germacrene B and α-calacorene [15].

Chromatographic fractionation of the ethyl acetate fraction allowed to obtain two new cinnamonyl: 1-deoxy-glucopyranosides (1 and 2) and two new p-coumaroyl and 1-deoxy-glucopyranosides (4 and 5), in addition to cinnamic acid (3) [15].

At the same time, phytochemical analysis of bark and leaf extracts from another species (*Scyphocephalium ochocoa*) showed the presence of compounds such as coumarins, alkaloids, flavonoids, tannins, saponosides, reducing sugars and sterols and terpenes [50].

Chromatographic separation of the aqueous alcoholic extract of the stem bark of *S. ochocoa* allowed the isolation of the known biomolecule, isoregomisin $C_{22}H_{30}O_6$ representing 0.0047% of the starting dry matter quantity [50].

Similarly, the phytochemistry of the fruits of *Tetrapleura tetraptera*, another species used in the management of sexual dysfunction and other pathologies such as epilepsy and inflammatory conditions [42] allowed the identification of the presence of alkaloids, saponins and flavonoids. The total phenolic contents of the methanolic, hexane, chloroform and ethyl acetate extract fractions were 38.63±8.11, 52.41±1.92, 8.16±0.36 and 5.16±0.56 mg gallic acid equivalent/g extract, respectively, while the methanolic, hexane, chloroform and ethyl acetate extract fractions had total flavonoid contents of 6.87±0.81, 7.44±0.78, 12.38±0.72 and 9.32±0.37 mg quercetin equivalent/g extract, respectively. Other authors have shown that fruits of the same species contained other compounds such as saponins (4.27±0.03 mg/g of extract), tannins (23.87±0.44 mg/100 g of extract) and alkaloids (5.03±0.15% w/w of extract) (Mensah *et al*., 2024) [52]. Higher contents of secondary metabolites such as flavonoids (32.19±0.23 mg/100g of extract), saponins (23.74±0.20 mg/100g of extract), cardiotonic glycosides (15.28±0.23 mg/100g of extract), steroids (16.53±0.12 mg/100g of extract), tepenoids (26.24±0.12 mg/100g of extract), tannins (18.74±0.17 mg/100g of extract) and phenols (13.10±0.11 mg/100g of extract) were shown in quantitative phytochemical analyses of extracts of *Selaginella myosurus*, a plant species also used in ethno-medicine in the management of various pathologies and sexual dysfunction [46, 53].

Also, phytochemical studies carried out on the roots of *Strychnos icaja*, also used in the management of sexual dysfunction and for the treatment of several other pathologies [43] have allowed the isolation of three derivatives of sungucine and other alkaloids such as vomicine, isostrychnine, isosungucine (8), 18-hydroxy-sungucine (9), 18-hydroxy-isosungucine (10), alkaloids such as strychnine, hydroxystrychnine, methylstrychnine, three monomers (icajine (1), 19,20-α-epoxynovacin (3) and 19,20-α-epoxy,15-hydroxynovamine (4) and two dimers (bisnordihydrotoxiferine (6) and sungucine (7) [54].

These riches in chemical compounds attest to the multiple uses of these different plants for the treatment of sexual dysfunction and as aphrodisiacs in Gabon [11, 22]. Similarly, this would justify at the same time, their uses to treat different pathologies in ethno-medicine throughout the world.

Pharmacology of some plants from the management of sexual dysfunction

The results on the different pharmacological activities of plants used in ethno-medicine for the management of sexual dysfunction, aphrodisiacs and various other pathologies show that the majority of these plants have several pharmacological activities. The different pharmacological properties (16) recorded during our study are listed in Table 1.

Among the sixteen (16) pharmacological activities of the different plants used for the management of sexual dysfunction and aphrodisiacs, four activities (antioxidant, antiplasmodial, antimicrobial, antiparasitic, anticancer and anti-inflammatory) were the most representative in terms of the number of species exhibiting pharmacological properties.

The number of plant species for a pharmacological activity varies between one (1) species (anti-sickle activity) to eleven (11) for antioxidant, antimicrobial and anti-inflammatory activities. The smallest amounts of plants (one and two) were listed with anti-sickle cell (G. punctata), anticonvulsant (*A. chlorantha* and *T. tetraptera*), antiulcer (*C. alba* and *P. nitida*) and gastroprotective (*T. tetraptera* and *A. chlorantha*) activities (Table 2).

Antioxidant activity

Eleven of the twenty-three plants used for the management of sexual dysfunction and aphrodisiacs have antioxidant properties (table 2).

The models for evaluating antioxidant activity by DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging, nitric oxide scavenging property, ferric reduction property (FRAP), the phosphomolybdenum method and hydroxyl radical scavenging property are the most commonly used [28, 37].

The results based on DPPH radical scavenging (a method for defining the Antioxidant Activity Index (AAI) of plants) show that some extracts of these eleven plants have strong antioxidant activity *in vitro*. This is the case of the extracts (methanol, n-hexane, chloroform, ethyl acetate and water) of the stem bark of *Enantia chlorantha* which showed that the inhibition of the DPPH radical up to 96.53% suggesting an excellent antioxidant activity [28].

Similar results were also obtained in *Milicia excelsa* with a range of DPPH inhibition percentages (56.21%, 56.88%, 68.71%, 76.26%, 94.27%) for a concentration of 500 µg/mL for ethyl acetate, methanol, ethanol, n-butanol and water, confirming that plants used in the treatment of sexual dysfunction and aphrodisiacs have excellent antioxidant activities [39].

In parallel, the antioxidant activity of *S. ochocoa* bark extract evaluated by the antioxidant activity index (AAI) method and that of phosphomolybdenum showed a greater antioxidant activity marked by a great inhibition of the DPPH radical (IC_{50} = 4.969±0.263 µg/mL, AAI = 10.080±0.517) And a greater total antioxidant capacity (87.766±0.852 EQ (mg)/g) [37]. Comparing this antioxidant activity to those of known reference molecules, it appears that the water-ethanol extract has an antioxidant activity three times stronger than that of BHT (IC_{50} = 13.759±0.029 µg/mL, AAI = 3.634±0.008), Twice as strong as that of quercetin
(IC_{50} = 11.224±0.611 µg/mL, IAA = 4.463±0.245) And similar to that of vitamin C (IC_{50} = 4.597±0.095 µg/mL, AAI = 10.880±0.228). Other extracts of the same plant also exhibit good antioxidant activity with an IC_{50} ranging from 8.373±0.242 µg/mL to 16.188±0.336 µg/mL And an AAI ranging from 3.090±0.065 to 5.975±0.172 [37].

Which supports the hypothesis that plants used in the treatment of sexual dysfunction and aphrodisiac in Gabon have excellent antioxidant properties.

Antimicrobial or antibacterial activity

As with antioxidant activity, eleven plants have also been identified as having antimicrobial or antibacterial properties among the twenty-three used for the management of sexual dysfunction and aphrodisiacs (table 2).

Among the eleven species we have *E. chlorantha*, *S. magnificum*, *S. ochocoa* and *N. diderrichii* which show better antimicrobial and antibacterial activity against germs such as *Trichophyton tonsurans* and *Candida glabrata*, *Trichophyton interdigitali*, *Candida albicans*, *Staphylococcus aureus*, *Bacillus substilis*, *Escherichia coli*, *Salmonella typhymurium*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Staphylococcus saprophyticus*, *Shigella flexneri*, *Salmonella typhimurium*, *Staphylococcus cohnii*, *Enterococcus faecalis*, *Streptococcus pneumonia*, *Klebsiella aerogenes*, *Proteus mirabilis* and *Aspergillus flavus* [33, 36, 50, 54].

Analyses of inhibition diameters and minimum inhibitory concentrations (MICs) have shown that the different extracts of these plants have a strong antimicrobial activity.

Indeed, the best MIC of some extracts of these plants were obtained in *S. aureus* (0.63 mg/ml), *P. aeruginosa* (1.25 mg/ml) and *A. flavus* (0.63 mg/ml). Others showed the lowest MIC with *S. cohnii* (20.00 mg/ml), *E faecalis* (20.00 mg/ml), *K. aerogenes* (20.00 mg/ml) and *P. aeruginosa* (>20.00 mg/ml) [33, 50, 54].

These different results allow us to say that among the eleven plants identified, some present good antimicrobial activities justifying their uses in ethno-medicine as antimicrobial or antibacterial agents.

Antiparasitic activity

The results concerning the search for antiparasitic plants of these twenty-three species recorded show that nine (table 2) present antiparasitic activities. Analysis results of their different antiparasitic activities shows that the extracts of the stem bark of *Enantia chlorantha* and the root bark of *Quassia africana* have a pronounced inhibitory activity against protozoa such as *Trypanosoma b. brucei*, *Trypanosoma cruzi* and *Leishmania infantum* [44].

Concretely, the stem bark of *Enantia chlorantha* showed a pronounced activity against Trypanosoma cruzi with IC_{50} values of 1.87 and 1.88 g/ml, but with a marginal selectivity (SI > 3.0 and > 3.3). A similar result was obtained with *Quassia africana* root bark (IC_{50} = 6.20 g/ml, SI = 1.4) [44]. The authors suggest that the activity of *Enantia chlorantha* extract against *Trypanosoma b. brucei* (IC_{50} = 8.36 g/ml) could be attributed to non-specific cytotoxicity (CC_{50} = 5.66 g/ml, SI < 1). Aqueous and ethanolic extracts of *Enantia chlorantha* on the other hand have been reported to eliminate parasitemia in a dose-dependent manner in mice infected with the chloroquine-resistant *Plasmodium yoelii nigeriensis* strain after oral administration [44].

Aqueous extracts of *Quassia africana* root bark also showed good activity against *Trypanosoma b. brucei* and *Leishmania infantum*. The root bark extract of *Quassia africana* showed pronounced antiplasmodial activity (IC_{50} = 0.46 g/ml) with acceptable selectivity (SI = 13.7) [44].

Another study evaluating the antiparasitic effect of a decoction of the bark of *P. nitida* against *Trypanosoma brucei* in rats also showed that the extract at a dose of 8 mg/kg had a trypanocidal effect that was statistically comparable to that of diminazene aceturate [35].

Similarly, the chloroform extract of the seed of *P. nitida* was evaluated for possible antileishmanial activity using a radiorespirometric microassay technique and the result of the study confirmed the activity against *Leishmania donovani* at a dose of 50 µg/mL [35].

In parallel, the larvicidal activity of ethanolic and aqueous extracts of *P. nitida* leaf was evaluated in a static bioassay, on fourth-stage larvae of *Anopheles gambiae*. The results obtained showed an increase in larvicidal activity in function of the concentration and time, with LC_{50} values at 72 h of 0.660% and 1.057% w/v for ethanolic and aqueous leaf extracts respectively [21].

According to Dibua *et al.*, (2015) Aqueous and methanolic extracts of the leaf and seeds of *P. nitida* also showed concentration- and time-dependent larvicidal activity in third- and early-fourth-stage larvae of *Anopheles gambiae* with 72-h LC_{50} values of 0.164, 0.333, and 0.150 mg/mL for the aqueous leaf extract, methanolic leaf extract, and methanolic seed extract, respectively [35].

The analysis of all these results shows that the identified species have antiparasitic potential, which would justify their use in ethno-medicine for the management of parasitic diseases.

Anti-inflammatory, analgesic and antipyretic activities

The plants presenting the anti-inflammatory activities are eleven, like those used for antimicrobial and antioxidant activities (table 2).

Regarding said activity, the results show us on the basis of the data obtained that a study of the methanolic extract of the fruit of *P. nitida* showed a potent dose-dependent anti-inflammatory activity [35]. The extract administered intraperitoneally inhibited the induced rat paw edema with an IC_{50} value of 102 mg/kg, and with the highest dose tested (300 mg/kg) producing an inhibition of 72.2% [55].

In another study conducted this time on the ethanol extract of *P. nitida* seeds, the extract at 1.5 and 3.0 g/kg suppressed the maximal edema of the rat paw reached after 6 hours.

Similarly, the total alkaloid extract of the seeds of the same species at doses of 75-300 mg/kg significantly (P<0.05) inhibited in a dose-dependent manner the maximal edema in rats over a period of 6 hours when administered 1 hour before the induction of edema [35]. In cases where inflammation was already established, the same alkaloid extract (300 mg/kg) reduced the time course of paw edema as well as the adjuvant-induced knee arthritis in rats [35].

Several other studies show that compounds present in *T. tetraptera*, such as menthol, methyleugenol, α-copaene and octadecanoic acid, are known to possess anti-inflammatory activities [52].

In the same vein, others researchers are examined the anti-inflammatory effects of *T. tetraptera* fruit extract on egg albumin-induced inflammation of hind paw edema in rats. The results indicated a dose-dependent reduction of 50 to 800 mg/kg in induced inflammation [52].

Other authors in the same framework evaluated the anti-inflammatory properties of *Milicia excelsa* leaf ethanol extract and its fractions. The anti-inflammatory activities of the extract and various organic fractions were studied using a bovine erythrocyte membrane stabilization test [38].

The results obtained showed that the crude extract and the ethyl acetate fraction exhibited minimum inhibition percentages of 0.88±0.30 and 72.05±0.45% and maximum inhibition percentages of 81.66±0.23% and 99.07±0.30% respectively compared to indomethacin, a standard anti-inflammatory drug which showed minimum and maximum inhibition percentages of 52.64±0.83 and 75.51±1.52% respectively [38].

Regarding the study of the analgesic properties of the aqueous extract of *C. lutea* roots in rodents, the results show that the said extract produces significant anti-nociceptive stimuli when evaluated using the tail-wagging test, acetic acid-induced abdominal constrictions, formalin-induced hind paw licking and the hot plate test [15].

The fractions (ethanol, ethyl acetate, chloroform, n-hexane) and the crude ethyl acetate extract of *C. lutea* led to a significant inhibition of both phases of formalin-induced pain in mice, a reduction in acetic acid-induced writhing as well as an elevation of the pain threshold in the hot plate test in mice with effects superior to those produced by indomethacin were observed [15].

The results of anti-inflammatory and antipyretic effects evaluated using the acute anti-inflammatory and antipyretic models showed that all fractions of *C. lutea* extracts tested were found to induce significant inhibitory effects on the acute phase of inflammation with formalin, egg albumin, capsaicin-induced edema and xylene-induced ear edema, as well as in carrageenan-induced paw edema in rats [15].

In the study of antipyretic effects, the result showed significant inhibition of 2, 4-dinitrophenol-induced pyrexia but not in yeast-induced pyrexia or on normal body temperature of rats [15], which attests that *C. lutea* has an antipyretic effect in rats.

All of these different results attest that the plants used in ethno-medicine in Gabon for the management of sexual dysfunction and as aphrodisiacs also have proven therapeutic potential against anti-inflammatory conditions, thereby justifying their different uses against inflammatory, analgesic and antipyretic conditions.

Gastroprotective activity

Regarding the gastroprotective pharmacological properties, two plants (*A. chlorantha* and *T. tetraptera*) have been identified. These gastroprotective properties were demonstrated in *T. tetraptera* by pretreating rats with a fruit extract of the said plant species. The result obtained showed that *T. tetraptera* attenuates the total protein concentration as well as the activities of pepsin and myeloperoxidase in rats suffering from untreated ulcers [42]. According to the authors, the effect of the extract obtained was comparable to that of the group pretreated with omeprazole, particularly at 200 mg/kg body weight [42].

The same study also showed that there was a significant increase (P<0.05) in pepsin activity after extract pretreatment compared to the omeprazole pretreated group [42]. Indeed, ulcer induction led to a significant increase (P<0.05) in malondialdehyde levels in rats.

However, pretreatment with *T. tetraptera* fruit extract significantly reduced (P<0.05) malondialdehyde concentration and the effect was favorably comparable to that of omeprazole.

Regarding glutathione peroxidase activity, pretreatment with the extract resulted in a significant increase (P<0.05) in the activity of this enzyme in a manner comparable to that of omeprazole, especially at 200 mg/kg body weight [42].

Other authors have evaluated the gastroprotective effects of *A. chlorantha* bark extract. The result revealed a protective effect without inhibiting ulceration. The authors concluded that the cytoprotective properties of the extract could be possible due to the inhibition of gastric acid secretion. They attributed the gastroprotective and antiulcer properties of *A. chlorantha* bark extract to 7, 8-dihydro-8-hydroxypalmatine (7) [25]. Thus, it is proven through these results that the plants (two) listed have gastroprotective properties in rats.

Anti-sickle activity

Only one plant species has been identified to have an anti-sickle effect among all the plants used for the management of sexual dysfunction and aphrodisiac.

The results of the study on the evaluation of the anti-sickle cell activities of *Garcinia punctata* and the anti-sickle cell modes of action of organic acids extracted from the same plant revealed that the normalization rates of erythrocytes (RBCs) were > 75% for all *G punctata* plant extracts tested [58].

Also, the inhibition rates of hemolysis of sickle cell RBCs were 64 and 57% for organic acids extracted from *G. punctata*. The organic acid extract also showed an increase in the osmotic fragility of sickle cell RBCs, an inhibition of the polymerization of hemoglobin S [58].

This study thus highlights that plants used by Gabonese populations for the management of sexual and aphrodisiac dysfunction would have an anti-sickle cell effect.

Antiulcer activity

Studies on the evaluation of the existing antiulcer effect in relation to plants used in Gabon for the management of erectile dysfunction show that only one species (*C. lutea*) has antiulcer properties.

Indeed, data collected on *C. lutea* that the ethanolic extract of its leaves has antidiarrheal and antiulcerogenic potential [15]. Specifically, this study demonstrated dose-dependent gastroprotective and antidiarrheal effects in rodents [15].

The gastroprotective effects of the leaf were more pronounced with the ethyl acetate extract than leaf fractions based on n-hexane, chloroform and ethanol. The ethyl acetate fraction also showed dose-dependent effects in all models of antiulcer activity studied in rats with leaf and stem extracts of the same species [15].

Anticonvulsant activity

Among the plants listed in the management of sexual dysfunctions and aphrodisiacs, two (*A. chlorantha* and *T. tetraptera*) have been found to have anticovulsant activities.

Indeed, the work carried out on the subject reveals that decocts of *Enantia chlorantha* inhibit convulsions induced by bicucculin induced by carrageenan in rodents [59]. The results showed that the decoction extract also increased the latency time between two consecutive convulsions in all animal species treated. In the same study, the aqueous extract obtained from the maceration behaved similarly in mice [59].

Other authors found that, like the standard anticonvulsant agents (phenobarbital and diazepam) used, the aqueous extract of *T. tetraptera* fruits administered at doses ranging from 50 to 800 mg/kg significantly delayed ($p<0.05$-0.001) the onset of seizures induced by pentylenetetrazole (PTZ) [41]. The aqueous extract of the fruits administered at the same doses profoundly inhibited seizures induced by fibrotoxin (PCT) and partially inhibited seizures induced by bicucculin (BCL). The authors conclude on the basis of these results that the aqueous extract of *Tetrapleura tetraptera* fruits has anticonvulsant properties [41]. This is consistent with the study of *E. chlorantha* which has shown anticonvulsant effect.

Anticancer activity

Data collected on the anticancer activities of plants used in ethno-medicine for the management of sexual dysfunction show that six (6) plants (*A. chlorantha*, *A. hypogaea*, *P. nitida*, *S. ochocoa*, *S. icaja*, *T. tetraptera*) exhibit anticancer activities [60].

Regarding species as *A. hypogaea*, studies show that the bioactive compounds present in the skin of peanut seeds have demonstrated an anticancer capacity [60]. Indeed, studies carried out have shown a correlation between the inhibition of oxidative DNA damage by reactive oxygen species (ROS) and their cytotoxicity against cancer cell lines and the presence of bioactive compounds present in the skin of peanut seeds [60].

The cancer prevention mechanism involves that polyphenol hinders the progression of tumor growth by sealing receptors in affected cells or by continuously binding to certain carcinogens.

These studies conducted on *A. hypogaea* seed peel confirmed the *in vivo* cytotoxicity of A. hypogaea seed peel extracts and higher antioxidant activity against human cell lines [60].

The same authors reported that acetone extract (80%) of *A. hypogaea* seed peel revealed a significant cytotoxic effect of 71.28%, 40.27% and 38.58%, of colon cancer cells (HCT116), liver cancer cells (HePG2) and breast cancer cells (MCF-7) respectively [60]. Another study reported that ethanol extract of *A. hypogaea* seed peel present hypogaea molecule (80%) which are showed 22.44% for HCT116, 13.24% for HeP-G2 and 34.27% for human cell line MCF7 [60].

However, the latest study revealed that *A. hypogaea* seed skin polyphenols do not exhibit *in vitro* cytotoxicity against normal cells in the concentration ranges with maximal antioxidant effect, and thus exert a bioprotective influence at a concentration range that is nontoxic to normal cells [60].

Similarly, *in vitro* and *in vivo* studies on polyphenols from other widely studied plant sources on a diverse range of cancer cells have also shown promising results. Among them, the antiangiogenic effect of *S. ochocoa* in several types of cancers can be mentioned [37].

Antiviral activity

Three plants (*A. chlorantha, Q. africana* and *T. tetraptera*) belonging to the batches of species used in the management of sexual dysfunction with antiviral activities have been listed (table 2).

The antiviral activity of polyphenols such as those highlighted in these three plant species is described as being related to the basic tannic structure due to their ability to bind to viral surface proteins, which is common in condensed tannins (proanthocyanidins) [45, 51, 52]. Suggested antiviral mechanisms of action include inhibition of viral polymerase and binding of viral nucleic acid or viral capsid proteins.

Studies generally suggest that genistein, quercetin, ellagitannins and several proanthocyanidins have an ability to bind to viral envelope mechanisms [60].

Catechins were also shown in the same study to inhibit HIV-1 DNA polymerases; demethylated jardinin A and robinettin are known to inhibit HIV-1 proteinase. A quercetin is described to enhance the effects of 5-ethyl-2-dioxyuridine and acyclovir against herpes simplex virus (HSV) infection and pseudorabies [60].

Antidiabetic activity

Five plants (*N. diderrichii*, *P. nitida*, *Q. africana*, *S. magnificum*, *T. tetraptera*) have been identified among the twenty-three species used for the management of sexual dysfunction and aphrodisiac (table 2). Indeed, some experimental and clinical studies have shown that these species have antidiabetic activities. This is the case of studies carried out on *A. hypogaea* which showed that the bioactive compounds of the skin of the seeds of *A. hypogaea* play a key role in the management and prevention of obesity and diabetes mellitus. The presence of dietary fiber, proanthocyanidins, and flavonoids, among others in the skin of the seeds of *A. hypogaea* would cause the reduction of the risk of obesity and type 2 diabetes mellitus [60].

Oxidative stress is considered as the main cause of the development of type 2 diabetes, confirming the relationship between antioxidant and antidiabetic effects. The bioactive compounds present in peanut skin act in the prevention of diabetes through different mechanisms, namely: regulation of insulin secretion, insulin signaling, carbohydrate digestion and glucose uptake in insulin-sensitive tissues [60].

For *S. magnificum*, biochemical analysis of blood samples was performed only for the sub-acute toxicity study. Phytochemical analysis revealed that the plant extract contains phenolic compounds, flavonoids, anthocyanins, saponins, gallic tannins, coumarins and anthraquinones. In both studies, the aqueous extract of *S. magnificum* stem bark reduced the area under the blood glucose curve produced by dexamethasone injection [57].

The extract, as well as glibenclamide, significantly reduced the dexamethasone-induced increase in transaminase activities and uric acid concentration as well as superoxide

dismutase activity increased in all extract and glibenclamide groups compared to the dexamethasone group [57].
Organ histology of dexamethasone-treated rats revealed hepatic cytolysis, leukocyte infiltration and islet hypotrophy. The extract and glibenclamide-treated groups had fewer or no abnormalities observed with dexamethasone administration. The aqueous extract of S. magnificum stem bark protects against dexamethasone-induced pancreatic and hepatorenal abnormalities, probably due to the antioxidant properties of the chemical groups present in this extract [57].

Toxic activities

Several plant species used in ethno-medicine for the treatment of pathologies have been shown to be toxic, contrary to what users claim. *E. chlorantha*, for example, is widely used in herbal medicine for the treatment of several human diseases, but its toxicity profiles are not well documented. Indeed, *in vivo* studies on aqueous and ethanolic extracts of *E. chlorantha* leaves and bark have been tested orally and subcutaneously, indicating possible acute and chronic toxicity on reticulocyte and hematocrit values as well as on the number of nucleated cells in the spleen, bone marrow, peritoneum, liver and peripheral blood in rats [28].
Other studies on the toxicity of other plant species such as *P. nitida* and *C. lutea* have been listed.
Regarding *C. lutea*, the analysis of the crude extract of the said plant showed that it produced mortality in rats at a dose of 1500 mg/kg by administering the extract by the intra-peritoneal route. The extract showed a lethal dose (LD_{50}) of 866.025 mg/kg [15, 31].
As *C. lutea*, the acute toxicological profile of the methanolic extract of the fruit of *P. nitida* in rats revealed signs of toxic effect on the liver, kidneys and lungs after prolonged exposure to doses of 1.5 to 6 g/kg with LD_{50} values of 14.5 and 12.5 g/kg for male and female rats respectively [35].
Unlike the three previous plant species where researchers have shown that they are toxic, the study of the extract of the stem of *G. suaveolens* showed that it was not toxic with an LD_{50} greater than 5000 mg/kg tested in rats [22].
The doses of hydro-ethanolic, ethanolic and aqueous extracts of stem barks of *G. suaveolens* of 2000 and 5000 mg/kg of body weight were administered. The results show that the average body weight of the rats increased normally during the 14-day observation period, the authors considered that the LD_{50} was greater than 5000 mg/kg of their body weight [22].
According to the Organization for Economic Co-operation and Development (OECD) guide, a plant substance is considered non-toxic if its LD_{50} is greater than the dose of 5000 mg/kg [22].
These four results reveal that among the plants used for the treatment of sexual dysfunction and as aphrodisiacs, some are toxic and others no toxic.
Contrary to the assertion that medicines derived from plants would be free of toxicity. The argument often put forward by traditional practitioners and ethnologists is that these products are used and transmitted from generation to generation.
Our bibliographic data show that it would be a mistake to systematically consider things in this way, because certain plant species such as *S. icaja* used for their aphrodisiac effect in Gabon [22] present a toxicity and are used as poison in certain traditional rites [13], their systematic use as it is done in ethno-medicine could be fatal for consumers.

Conclusion

This review focused on analyzing the bio-pharmacological potential and toxicity of twenty-three plants used for the treatment of sexual dysfunction and/or as aphrodisiacs by populations in Gabon.
Based on 248 articles and reviews, it appears that the twenty-three listed plants are used in ethno-medicine for the treatment of various pathologies such as stomachache, malaria, hepatitis, jaundice, anemia, infected wounds, fever, tuberculosis, typhoid fever, urinary tract infections, etc. These different plants also exhibit good pharmacological properties such as antioxidant, antiplasmodial, antimicrobial, antiparasitic, anticancer, and anti-inflammatory activities (Table 1), which would justify their uses in ethno-medicine for the management of a variety of pathologies.
Looking at the results of the various studies on the toxicity of these plants, the analysis of the said results shows that certain plants such as *E. chlorantha*, *P. nitida*, *S. icaja* and *C. lutea* present the toxicity effects with significant LD_{50}.
However, another plant species such as *G. suaveolens*, have not shown toxicity in rats confirming the thought that plants used in ethno-medicine are non-toxic. Thus, these two observations suggest that, contrary to this assertion that plant-derived medicines used in ethno-medicine are free of toxicity, some plants are toxic, and their use could be fatal for consumers, especially when factors such as liver and kidney failure are taken into account.

Acknowledgement

Thanks to Mr. Michel MOUDABA, Herbalist, for the information on the uses such as aphrodisiac and for treating erectile dysfunction of certain plants in traditional Gabonese medicine. We also extend our thanks to Mr. Wilfrid MBADINGA-MBADINGA for his assistance in identifying of some botanical plants used in the traditional recipes for treating erectile dysfunction.

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