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EXPLORING SOME ANTIMALARIAL PLANTS SOLD IN THE MARKET IN LIBREVILLE GABON

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ABSTRACT: The increasing microorganism resistance to common antimicrobial drugs constitutes a major public health issue worldwide and particularly in Gabon. The objective of this study was to conduct an ethnobotanical survey among merchants of Peyrie market in Libreville (Gabon) to identify plants or a combination of plants used to treat malaria in traditional medicine. Information was collected by interviewing merchants of the market using a structured questionnaire. Plant samples were identified and authenticated at National Herbarium at the Institute of Pharmacopeia and Traditional Medicine in Libreville, Gabon. A literature review of the collected species was done. Twenty-nine (29) plants were identified, and some of them are often used in combination. Decoction, maceration, and herbal teas were the different methods of preparation. Barks, leaves, and fruits were the most plant parts used. Overall, some of these plants have already been investigated for their antimalarial properties, such as *Momordica foetida* (Cucurbitaceae) and *Enantia chlorantha* (Annonaceae). The data also highlighted several chemical compounds in the plants which can be responsible for the antiplasmodial activity described, such as kaempferol, berberine, eugenol, and ascarisin. No study assessing the antimalarial effects of 13 plants like *A. klaineana*, *D. benthamianus* or *M. monandra* was found so far. Also, no data regarding the potential antiplasmodial activity of *Amphimas ferrugineus*, *Amphimas klaineanus*, *Poga oleosa*, and *Desmodium salicifolium* were available, as well as any information about the chemical compounds present in these species. This study has validated the use of some plants in the treatment of malaria in Gabon.

INTRODUCTION: The increasing micro-organism resistance to common antimicrobial drugs constitutes a major public health problem worldwide as it impacts negatively both socio-economic and healthcare systems [1, 2].

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Globalization, massive use, and malpractices seem to play a role in the occurrence and the spread of drug-resistant microbial strains [3]. The concern raises a critical point in areas where healthcare systems are basics and where governments are unarmed against this threat. Besides, in these regions, highly pathogenic microorganisms such as HIV, *Mycobacterium tuberculosis*, enteropathogens viruses, and *Plasmodium falciparum* [4] are responsible for high morbidity and mortality rates and contribute to the massive economic burden due to their associated disabilities.

In this review, the potential of Gabonese medicinal plants to be a reliable and sustainable source of antiplasmodial molecules is particularly addressed. Why *P. falciparum* causing malaria? Malaria is, according to the World Health Organization (WHO), one of the deadliest diseases that accounted in 2017 for about 435 000 deaths, with an estimated 219 million cases mainly in Sub-Saharan and Southeast Asian regions [5]. Pregnant women, infants, children under five years of age, patients with HIV/AIDS, but also non-immune migrants, mobile population, and travelers are at considerably higher risk of contracting malaria, and developing severe disease, than others [5]. Children are at the highest risk for severe disease and death between six months and five years of age: During this period, children are more vulnerable as they have lost maternal immunity and they haven't yet developed specific immunity to infection.

In the past 15 years, the number of malaria cases has tremendously declined [6]. This relative success is the consequence of: the conjugated efforts of governments and populations, the wide use of artemisinin-based combination therapy (ACT) and insecticide-treated bed nets. Unfortunately, reports of ACT-drug-resistant strains are increasing worldwide. Hence, a malaria vaccine would have been an important contribution to effective malaria control [7, 8, 9]. Yet, for this concern, several candidate malaria vaccines are being set up and are progressing through clinical trials while many more are in pre-clinical development [10]. As an example, the malaria vaccine candidate RTS,S/AS01 has shown moderate efficacy [11,] but the further investigation needs to be undertaken to allow his utilization. Therefore, in the absence of a formally marketed vaccine, special efforts must be done to better control the deleterious effects of malaria in an integrated approach including (i) vector control, (ii) vaccine development, and (iii) search for new molecules active against the parasite.

In Gabon, a holoendemic country with a perineal *P. falciparum* transmission, *P. falciparum* malaria is the leading cause of hospitalization, especially in children [12]. As in most African countries, the Gabonese population uses both conventional and plant-based traditional medicine against malaria. In many countries, a large number of medicinal plants are used to treat malaria and showed great antimalarial potential [13, 14, 15]. Thus, many studies related to Gabonese antimalarial plants have been led by Gabonese researchers [16, 17, 18]. These investigations must be extended to the systematic evaluation of the antiplasmodial activity of the plants widely used to treat malaria and the identification of the active compounds. At the end of the day, these investigations might validate their utilization by the population and help to manufacture improved traditional treatment.

This study aimed to carry out an ethnobotanical survey with merchants of Peyrie market in Libreville on plants used by Gabonese people to treat malaria.

MATERIALS AND METHODS:

Study Area: Among the several sites where medicinal plants are sold in Libreville (capital), Peyrie Market is one of the biggest markets where a large variety of medicinal plants can be found **Fig. 1**.

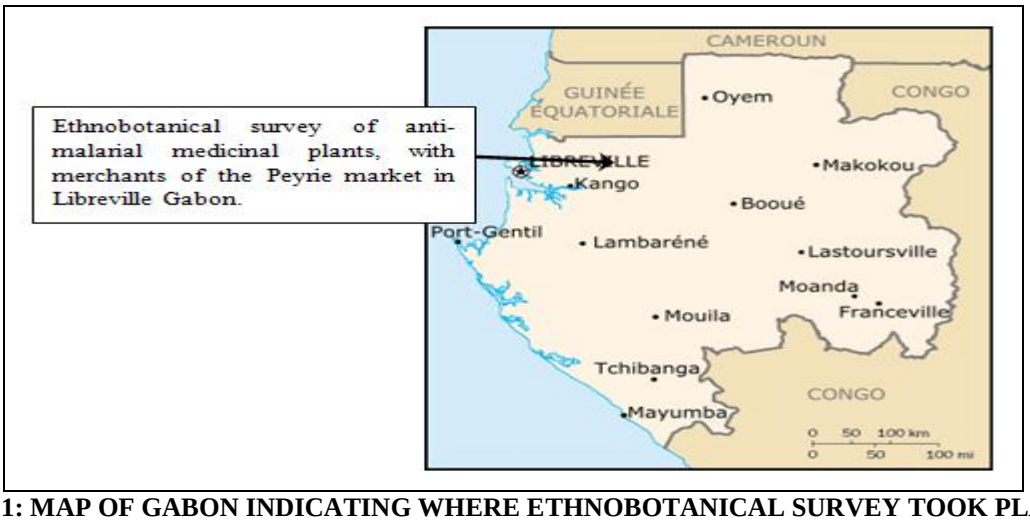

FIG. 1: MAP OF GABON INDICATING WHERE ETHNOBOTANICAL SURVEY TOOK PLACE

This study was conducted with twenty-three (23) merchants who provided information about the plants used to treat malaria such as the part(s) of the plant (leaves, bark, roots, *etc*.), mode of preparation (maceration, infusion, decoction, *etc*.) as well as the dosage then, the samples were collected.

Questionnaire Administration: Ethnobotanical data were collected following semi-structured interviews and field observation. The questionnaire was used to interview the traders about their knowledge of the plants used in the treatment of malaria. The questionnaire recorded the date of the interview, name, surname of the merchants, age, sex, and ethnic group. Indications on the vernacular plant name, part(s) used, dosage, duration of the treatment, preparation, administration modes, and other therapeutic uses were also asked.

After the above-mentioned data were collected, plant materials were purchased, identified, and authenticated at the National Herbarium at the Institute of Pharmacopeia and Traditional Medicine in Libreville Gabon. After authentication, a literature review was undertaken to gather knowledge about the selected plants.

Literature Review: Data regarding the plant species cited by the vendors were then gathered using Google Scholar and Scopus. The information needed was the antimalarial activity, antiplasmodial activity, chemical compounds, geographical location, and the traditional uses in other countries. Recent manuscripts describing the *in-vitro* or *in-vivo* study design for antimalarial assessment as well as those reporting on the phytochemical assessment of the studied plants were retained for the study. Abstracts, old manuscripts and manuscripts with a study design not well detailed were excluded from the study.

RESULTS AND DISCUSSION: The twenty-third traders were divided into 22 females and one (1) male aged between 30 and 55 years old. The Ipunu was the most represented language, followed by the Fang. The interviewed had globally a basic primary or secondary level education. Religion was not determined. In Gabon, medicinal plant merchants are mostly women who have the knowledge of plant usage inherited from their parents.

The mode of preparation and the administration route of traditional antimalarial treatment were recorded. The reported preparation modes were mostly maceration and decoction, while the administration modes were oral, bathing, and enema **Table 1**. The major symptoms reported were fever, cold, dizziness, headaches, and to lesser extent, diarrhea. The ethnobotanical survey of medicinal plants used to treat malaria and sold in the market yielded a total of 29 species distributed into 20 families **Table 1**. The Fabaceae family was the most represented with 8 species, followed by the Apocynaceae with 4 species.

TABLE 1: ETHNOBOTANICAL INVESTIGATION OF ANTIMALARIAL MEDICINAL PLANTS

Name	Family	Local Language	Composition of the recipe	Posology and Duration of the treatment
Momordica foetida Schumach.	Cucurbitaceae	Mambubulu (Punu)	The crushed fresh leaves of *Momordica foetida* are macerated in water	Drink and bathing morning, noon and evening for seven days
Ocimum gratissimum L.	Lamiaceae	Mesep (Fang) Makadumba (Punu)	The crushed fresh leaves of *Ocimum gratissimum* are macerated in water	Drink morning, noon and evening. Enema (evening) for seven days
Chenopodium ambrosioides L.	Amaranthaceae	Diable	The crushed fresh leaves of *Chenopodium ambrosioides* are macerated in water	Drink (morning, noon and evening), Bathing (morning and evening), Enema (evening) for seven day
-*Distemonanthus benthamianus* Baill. + *Alstonia congensis*	Fabaceae Apocynaceae	Mouvengue (Punu); Eyene (Fang) Ekouk (Fang)	The barks of *Distemonanthus benthamianus* and *Alstonia congensis* are boiled or macerated in water for 30 minutes	Drink and bathing one glass morning and evening during one week
Distemonanthus benthamianus Baill. + *Enantia chlorantha*	Fabaceae Annonaceae	Mouvengue (Punu); Eyene (Fang) Mfôl (Fang); Ogowa (Mpongwè)	The barks of *Distemonanthus benthamianus* and *Enantia chlorantha* are boiled ormacerated in water for 30 minutes	Drink one glass morning, noon and evening during one week

Aucoumea klaineana Pierre.	Burseraceae	Angouma (Fang) ; Mukumi (Punu)	Maceration of the fresh barks overnight	Drink and enema morning and evening for third days
Enantia chlorantha Oliver.	Annonaceae	Mfôl (Fang); Ogowa (Mpongwè)	Decoction of the fresh barks for 30 min	Drink one glass morning, noon and evening during one week
Cymbopogon citratus (DC) Stapf.	Gramineae	Ocimetang (Fang)	Maceration of fresh leaves of *Cymbopogon citrates* and *Ocimum basilicum* and add the fruit of *Citrus limon*	Drink one glass morning and evening for four to seven days
Macaranga monandra Müll. Arg.	Euphorbiaceae	Odzic-sol (Fang)	Decoction of the fresh leaves	Drink one glass morning and evening for seven days
Scyphocephalium ochocoa Warb.	Myristicaceae	Soghe (Fang) ; Musuku (Punu)	Decoction of the fresh barks	Drink one glass morning and evening during seven days
Amphimas ferruginas Pierre	Fabaceae	Ngone (Fang) Ikokodi (Bapunu)	Decoction of the fresh barks	Drink one glass morning and evening
Amphimas klaineanus Pierre ex Pellegrin	Fabaceae	Ngone (Fang) Ikokodi (Bapunu)	Decoction of the fresh barks	Drink
Cylicodiscus gabunensis Harms	Fabaceae	**E**dum (Fang) Muduma (Bapunu, Nzebi)	Maceration of fresh leaves treats the migraine and the decoction of barks treats the fever and is febrifuge	Drink
Harungana madagascariensis Choisy.	Hypericaceae	Atsu (Fang) Mosasa (Nzebi)	Decoction of the fresh barks from *Harungana madagascariensis* and fresh leaves of *Cajanus indicus* treat the fever and the febrifuge condition	Drink one glass morning and evening
Picralima nitida (staff) Th & Hel. Dur	Apocynaceae	Ebam (Fang) Dugundu (Eshira)	Decoction of barks is febrifuge	Drink
Ocimum basilicum L.	Lamiaceae	Osim (Fang)	Maceration of fresh leaves treats the headaches and the migraine	Drink one glass morning and evening
Tetrapleura tetraptera (Schumach. & Thonn.) Taub.	Fabaceae	Kwagsa (Fang) Muyaga (Banzani)	Decoction of barks is febrifuge	Drink one glass morning and evening
Pogaoleosa Pierre	Anisophylleaceae	Afo + Ekuk + Ebam + Alloure me bare (Fang)	Decoction of the fresh barks of *Poga oleosa* + *Alstonia congensis* + *Picralima Nitida* with the fruits of *Citrus limon* during 3 h	Drink one glass morning and evening
Leucanthemum vulgare (Vaill.) Lam.	Asteraceae	Female Marguerite	Maceration of the leaves crushed	Drink one glass morning and evening
Picralima Nitida (staff) Th & Hel. Dur.	Apocynaceae	Ebame + Alloure me bare + Ayinibe (Fang)	Decoction of the fresh barks of *Picralima Nitida* + *Anthocleista nobilis* with the fruits of *Citrus limon* during 1 h	Drink one glass in the morning.
Anthocleistavogellii Planch.	Gentianaceae	Ayinibe (Fang)	Decoction of the fresh barks	Drink one glass in the morning.
Carica papaya L.	Caricaceae	Alola (Fang) Ololo (Mpongwè)	Decoction of the fresh leaves of *Carica papaya* + *Citrus aurantifolia* + *Cassia occidentalis*	2 spoons morning and evening for 4 to 7 days
Alstonia congensis Engl.	Apocynaceae	Ekouk (Fang)	Decoction of the fresh barks	Drink one glass morning, noon and evening during one week.
Aframomumgiganteum (Oliv. & D. Hanb.) K. Schum.	Zingiberaceae	Ndong (Fang) Ndungu-a-tsisi (Nzebi)	Maceration of the raptures of the heart	Drink twice a day for 2 days
Desmodium salicifolium (Poir.) DC.	Fabaceae	Obogbe-nzèn (Fang) Mpépénda (Nzebi)	Decoction of the leaves	3 times per day for one week
Scorodo phloeuszenkeri Harms	Fabaceae	Esun (fang) Mufira (Bapunu) Lévyola (Nzebi)	Decoction of barks from *Scorodo phloeuszenkeri* + the rapures of the barks from *Pentaclethra macrophylla* and crushed seeds of *Aframomum*	Drinking twice per day

			melegueta.	
Naucleadi derrichii De Wild. & Dur.	Rubiaceae	Otoma (Fang); Mbilinga (Mpongwè); Murundi (Bapunu, Nzebi)	Infusion of the fresh young leaves or barks	Drink
Sarcocephalus esculentus Afzel. ex Sabine	Rubiaceae	Otoma (Fang); Mbilinga (Mpongwè); Murundi (Bapunu, Nzebi)	Infusion or decoction of the fresh young leaves or the barks	Drink
Drypetes gossweileri S. Moore	Putranjivaceae	Asogmo (fang); Muyungu (Nzebi); Mudjungu (Bapunu)	Maceration or decoction of fresh barks with chilli pepper for the fever and also as anthelmintic	Drink twice a day

Plants cited by different vendors were not recorded twice. Further, the origin of plant specimen and their national geographic distribution was determined. Several species are also found in other regions of Gabon, namely: Mouila (1°52′ 00″S, 11°03′18″ E), Tchibanga (2°55′ 59″S, 10° 58′59″ E) in the southern region; Lambarené (0°42′ 05″S, 10°14′04″ E) in the center, Oyem (1°37′00″N,11° 35′00″ E) in the North and Makokou (0°34′ 00″N,12° 52′00″ E) in the northeastern region.

In this study, some plants such as *Momordica foetida*, *Ocimum gratissimum*, *Chenopodium ambrosioides*, *Aucoum eaklaineana*, *Macaranga monandra*, and *Scyphocephalium ochocoa* were told to be used alone; while othersareoften used in combination such as *Distemonanthus benthamianu*/*Alstonia congensis; Distemonanthus benthamianus*/*Enantia chlorantha*; *Cymbopogon citratus*/ *Ocimum basilicum/Citrus limon*. Also, the survey revealed that fresh material, mainly leaves and barks is used. However, other parts of the plants (oil, roots, inflorescence) can be used for the treatment of other ailments.

Simultaneously, a literature review aiming at identifying published research on the recorded plants was done. The literature investigation revealed that out of 29 plants, 16 (*Momordica foetida, Ocimum gratissimum, Chenopodium ambrosioides, Alstonia congensis, Enantia chlorantha, Cymbopogon citratus, Ocimum basilicum*, and *Citrus limon*) have been previously assessed for antiplasmodial effect (*in-vivo* or *in-vitro*) and have displayed interesting antimalarial activities **Table 2**. For the remaining plants (*A. klaineana*, *D. benthamianus*, *M. monandra*, *S. ochocoa*, *A. ferrugineus*, *A. klaineanus*, *H. madagascariensis*, *P. oleosa*, *L. vulgare*, *A. giganteum*, *D. salicifolium*, *S. zenkeri* and *D. gossweileri*), the antimalarial activity is still to be determined. Additionally, many of the compounds present in some of the cited plants have been elucidated except for *Amphimas ferrugineus, Amphimas klaineanus, Poga oleosa* and *Desmodium salicifolium* where no data regarding any phytochemical screening was found so far.

TABLE 2: ANTIMALARIAL ACTIVITIES AND ISOLATED COMPOUNDS OF THESE MEDICINAL PLANTS

Plants name, voucher and location in Gabon	Other diseases treated	Antimalarial studies	Phytochemical compounds
Momordica foetida Schumach. *Simons 334* Estuaire; Moyen Ogooué	Antidiabetic, antioxidant, antibacterial and antilipogenic	Anti-malarial activity on the multi-resistant clone Dd2 of *P. falciparum*[19]	Phenolic glycosides: eriodictyol-,5,7,4'-trihydroxyflavanone-, kaempferol- and 5,7-dihydroxychromone-7-*O*-ß-D-glucopyranoside [19]
Ocimum gratissimum L. *Wilks1282* Estuaire; Moyen Ogooué; Ogooué Ivindo ; Ngounié	Headaches, cough, ophthalmias, otitises, diarrhea, anthelmintic and antitussive	Anti-malarial activity against *P. falciparum*[20]	Terpenoids[20]
*Chenopodium ambrosioides*L. *Duparquets.n.* (P) det.: Cavaco, 1963 Estuaire; Ngounié	Vermifuge, antispasmodic, stomachic, and carminatives properties	The crude hydroalcoholic extract (HCE) from the leaves of *Chenopodium ambrosioides* could inhibit the parasite growth *in vitro* (IC_{50} = 25.4 g/mL) and *in vivo*	Kaempferol-7-O-alpha-L-rhamnopyranoside, patuletin, quercetin-7-O-alpha-L-rhamnopyranoside, grasshopper ketone, 4-hydroxy-4-methyl-2-cyclohexen-1-one, and 4-

		[21].	hydroxy-N-[2-(4-hydroxyphenyl) ethyl] benzamide[22]
Alstonia congensis Engl. *BernardSRFG 315*; *Bradley1093* Estuaire; Moyen Ogooué ; HautOgooué ; Ngounié ; Ogooué Maritime	Purgative, galactogen, diarrhea, ulcers, scabies, rheumatism, venereal diseases, cough, yaws and headache	The aqueous extract, the 80% methanol extract and the alkaloid-enriched extract exhibited strong antiplasmodial activity against *P. falciparum* K1 with IC50 values < 10 µg/ml and against *P. falciparum* NF54 A19A with IC_{50} values < 0.02 µg/ml[23]	Alkaloids and phenols, flavonoids, tannins, saponins and terpenoids [24, 25]
Enantia chlorantha Oliver. *Bourobou591* Whole Gabon	Jaundice, fevers, tuberculosis, emetic, urinary tract infections, hypoglycemia, typhoid fever, leprosy, hemostatic agent and uterus stimulant	The stem bark of *E. chlorantha* has resulted in the isolation of berberine and protoberberine alkaloids possessing antimalarial effects[26]	Berberine and protoberberine alkaloids [26]
Cymbopogon citrates (DC) Stapf. *Alers100* Whole Gabon	Repellent, insecticidal, anti-amoebic, antibacterial, antidiarrheal, antifilarial, antifungal and anti-inflammatory	*C. citratus* possessed a good antimalarial property and can be used for prophylactic and chemotherapeutic purposes [27]	Phytosterols, anthocyanin, amino acids, phenolic compounds, volatile components, fatty acids, fumesol, flavonoids, methylheptenone, L-linanool, furfurol, isopulegol, p-coumaric acid[28]
Ocimum sanctum L. *Leeuwenberg12534* Estuaire; Moyen Ogooué ; WoleuNtem	Vermifuge, anti-stress, anti-hypolipidemic, antioxidant, antifungal, skin diseases, anti-fertility, anti-cancer and antiviral	Antimalarial activities against *Plasmodium vivax* and *Plasmodium berghei* [14, 29]	Eugenol, eugenal, urosolic acid, carvacol, linalool, caryophyllene, limatrol, caryophyllene, methyl carvicol, anthocyans[14]
Citrus limon (L.) Osbeck. *Ngok Banak1863*; *van Valkenburg2784* Whole Gabon	Antioxidant and antibacterial.	Lemon decoction demonstrated antimalarial activity in mice infected with *P. berghei* ANKA through parasites suppression by 39%[30]	Caffeoyl N-Tryptophan, Hydroxycinnamoyl-Oglucoside acid, Vicenin 2, Eriocitrin, Kaempferol-3-O- rutinoside, and Quercetin-3-rutinoside[31]
Aucoumea klaineana Pierre. *Bourobou599* Whole Gabon	Antioxidant, antifungal and antibacterial	(no studies)	Monoterpenoids, δ-3-carene, p-cymene, limonene, terpinolene and α-terpineol [32]
Distemonanthusbenthamianus Baill. *BernardSRFG 320*; *SRFG 409* Whole Gabon	Anti-tuberculosis and antibacterial	(no studies)	Sitosterol 3-*O*-β-D-glucopyranoside, 4-methoxygallic acid, syringic acid, quercetin, 6″-*O*-acetylvitexin, quercetin 3-*O*-β-D-glucopyranoside and apigenin 7-methyl ether 6-*C*-[β-xylopyranosyl-(1→3)-β glucopyranoside][33]
Macaranga monandra Müll. Arg. *Bourobou1020* Whole Gabon	Antifungal	(no studies)	Two active clerodane-typediterpenes as kolavenic acid and 2-oxo-kolavenic acid[34]
*Scyphocephalium ochocoa*Warb. *Simons329* Whole Gabon	Antibacterial, seizure, gonorrhea, sterility and antioxidant properties.	(no studies)	Cyclolignans [35]
Amphimas ferrugineus Pierre *Breteler 15369* Estuaire; Ngounié ; Nyanga; Ogooué Ivindo; Ogooué Lolo; Moyen Ogooué ; WoleuNtem	Dysmenorrhea, cough, pulmonary infection, gonorrhea and poison antidote	(no studies)	(no studies)
Amphimas klaineanus Pierre ex Pellegrin *NguemaMiyono 1785* Estuaire; Ngounié ; Nyanga; Ogooué Ivindo; Ogooué Lolo; Moyen Ogooué ; WoleuNtem		(no studies)	(no studies)
Cylicodiscusgabunensis Harms Moungazi 1628 Estuaire; Ngounié ; Nyanga; Ogooué Ivindo; Ogooué Lolo;	Stomach-ache, migraine, venereal diseases, psoriasis and rheumatism	The antimalarial activity of ethanolic extracts of *C. gabunensis* bark was confirmed *in vitro*, with	Epicatechin--(4β → 8)-epicatechin--(4β → 8)-catechin trimer, Procyanidin C-1, Epiafzelechin-(4β → 8)-

Ogooué Maritime; WoleuNtem		evidence for phenolic acids, primarily gallic acid and close analogues such as ethyl gallate, likely providing this effect. Further fractionation produced the most potent fraction with a 50% inhibitory concentration of 4.7 µg/ml [36]	epicatechin-3-O-gallate, Epicatechin-(4β → 8)-catechin-3-O-(4-hydroxy)benzoate, 3-(4Hydroxybenzoyl)epicatechin, 3,4,5-Trimethoxyphenyl 6-O-(3,4,5-trihydroxybenzoyl)-β-D-glucopyranoside, Trans-3,5,3′,4′-tetrahydroxystilbene-3-O-β-D-glucopyranoside, Ethyl gallate, Gallic acid[36]
Harunganamada gascariensis Choisy. *Niangadouma 141* Estuaire; Ngounié ; Nyanga; OgoouéIvindo; Moyen Ogooué ; WoleuNtem,; Haut Ogooué ; Ogooué Maritime	Diarrhea, venereal diseases, sore throat, headache, antipyretic, jaundice, asthma, diuretic, antiemetic and ulcers	(no studies)	Anthranoids, anthraquinones, xanthones and triterpenoids, flavonoid, steroid, alkaloid and benzophenone[37]
Picralima nitida (staff) Th & Hel. Dur *AzizetIssembet 319* Estuaire; Ngounié; Nyanga; OgoouéIvindo; MoyenOgooué; Woleu Ntem; Ogooué Lolo; Ogooué Maritime	Otitis, sterility, hernia, cough, typhoid fever, analgesic, diarrhea, abscesses, jaundice, and vermifuge	*Picralima nitida* seeds, fruit rind, and stem bark have showed remarkable inhibitory activity against drug resistant clones of *Plasmodium falciparum* at doses of 1.23-32 micrograms/ml[38]	3-hydroxy-9-methoxy-2-[2'(*E*)-4'-hydroxy-3'-methylbutenyl]-8-isoprenylcoumestan, 3- hydroxy-9-methoxy-2-[2'(*E*)-4'-hydroxy-3'-methylbutenyl]-8-[2"(*E*)-3"-methyl-4"-oxobutenyl]coumestan, and 3-hydroxy-9-methoxy-4-[2'(*E*)-4'-hydroxy-3'-methylbutenyl]-8-[2"(*E*)-3"- methyl-4"-oxobutenyl]coumestan[39].
Ocimum basilicum L. *Leeuwenberg 12534* WoleuNtem	Vermifuge, headache, rheumatism, aphrodisiac, cough, dysentery, diarrhea, nephritis, nausea, abdominal cramps, gastro-enteritis, migraine, skin infections, insomnia, depression and exhaustion	The extracts showed IC50 of 68.14 µg/ml (CQ-s) and 67.27 µg/ml (CQ-r) chloroquine (CQ)-resistant (CQ-r) and CQ-sensitive (CQ-s) strains of *Plasmodium falciparum*[40]	Stragole, 1,6-Octadien-3-ol, 3,7-dimeth, trans-.alpha.-Bergamotene, Eucalyptol, Citral, N-Cyano-3-methylbut-2-enamine, cis-.alpha.-Bisabolene, Levomenthol, alpha.-Pinene, cis-Linaloloxide, Eugenol, Copaene, Humulene, Nerolidol and beta.-Myrcene [41]
Tetrapleura tetraptera (Schumach. & Thonn.) Taub. *Wilks 900* Estuaire; Ngounié ; Nyanga; Ogooué Ivindo; Moyen Ogooué ; WoleuNtem,; Ogooué Lolo; Ogooué Maritime	Cough, cold, antipyretic, vermifuge and emetic	Dichloromethane extracts of *Tetrapleura tetraptera* used to treat malaria in Gabon, had interesting antiplasmodial activity *in vitro* against *P. falciparum* strains FCB (chloroquine-resistant) and 3D7 (chloroquine-sensitive) on fresh clinical isolates [17]	Cardiac glycoside, tannins, phenol, flavonoids, alkaloids, Terpenoids, steroids, phlebotanin, D-fructose, 2-hydroxy-gamma-butyrolacetone, acetic acid, glyceraldehydes, piperazine, octodrine, glycidol and *n*-decanoic [42]
*Pogaoleosa*Pierre *Wieringa 1287* Estuaire; Nyanga; MoyenOgooué; WoleuNtem	Emetic, wounds, dermatitis, toothache and venereal diseases	(no studies)	(no studies)
Leucanthemum vulgare (Vaill.) Lam.	Not found	(no studies)	1,8-cineole, verbenly acetate, lavandulyl acetate, M-isopropoxyaniliene, α-terpineol, α-amorphene, neryl acetate, caryophyllene oxide, α-cadinol, torreyol, β-guaiene, β-eudesmol, caryophyllenol-II and β-spathuleno[43]
Anthocleis tavogelii Planch. *Dibata 1051* Estuaire; Haut Ogooué ; OgoouéIvindo; MoyenOgooué ; WoleuNtem,; Ogooué Lolo; Ogooué Maritime	Purgative, diuretic, constipation, abortifacient, leprosy, hepatitis, jaundice, venereal diseases, bronchitis, oedema, abscesses, cicatrisation, antipyretic, stomach-ache and otitis	The extracts exhibited significant dose-dependent chemo suppression of *P. berghei*[44](47)	Tarennoside, 3-Hydroxydodecanedioic acid, 4R-hydroxy-octanoic acid, 8- oxo-nonanoic acid, Pyrazols (endo-1-methyl-N-(9-methyl-9-azabicyclo[3.3.1]non-3-yl)-N-oxide), and dithiole (3H-1,2-

			Dithiole-3-thione) [45]
Carica papaya L. *N. Halle 4213* Whole Gabon	Vermifuge, rheumatism, coughs, bronchitis, asthma, wounds and abortifacient	Administration of aqueous leaf extract of *C. papaya* significantly ($P < 0.05$) decreased parasite load in mice and enhanced their survival[46]	Flavonoids, tannins, saponins, alkaloids, steroids, terpenes, anthraquinones, glycosides and carbohydrate[47]
Aframomum giganteum (Oliv. & D.Hanb.) K.Schum. *Bourobou 225* Estuaire; Ngounié; Nyanga; Ogooué Ivindo; Ogooué Lolo.	Vermifuge and laxative	(no studies)	Kaempferol-3,7,4-trimethylether, Quercetin-3,7,30, 4-tetramethylether, Quercetin-3,7,4-trimethylether [48].
Desmodium salicifolium (Poir.) DC.	Epilepsy, kidney pain, diarrhea, rheumatism	(no studies)	(no studies)
Scorodo phloeuszenkeri Harms *12844* Whole Gabon	Constipation, vermifuge, rheumatism, cough, headache, bronchitis, urinary tract infection, hernia and aphrodisiac	(no studies)	2,3,5-trithiahexane 5-oxide, 2,4,5,7-tetrathiaoctane 2-oxide, bis-methyl-sulphonylmethane, and bis-(methylthiomethyl) sulfone, 2,3,5-trithiahexane, 2,3,4,6-tetrathiaheptane, 2,4,5,7-tetrathiaoctane, two pentathianonanes, 2,4,5,7,9-pentathiadecane and two hexathiaundecanes[49].
Naucleadi derrichii De Wild. & Dur. *Klaine 1600* Estuaire; Ngounié ; Nyanga; Ogooué Ivindo; MoyenOgooué ; WoleuNtem,; Ogooué Lolo; Ogooué Maritime	Fever, diarrhea, diuretic, stomach-ache, anaemia, vermifuge, hepatitis and jaundice	A promising antiplasmodial activity of the crude-extract and those of crude-extract-fractions was demonstrated against *Plasmodium falciparum*[50]	Alkaloids, glycosides, saponins, phenolic compounds, tannins, phytosterols, carbohydrates, 3-oxo, Naucledine desoxycordifolinic acid, 3 α, 5 α-tetrahydrodesoxycordifoline, nauclexine, antiarol[51,52]
Sarcocephalus latifolius Afzel. ex Sabine *Dibata 1091* Ngounié; Nyanga; Ogooué Ivindo; Moyen Ogooué	Fever, diarrhea, dysentery, pain, hypertension, mouth odor, tooth decay, epilepsy and leprosy	The extract exhibited significant dose-dependent antiplasmodial activity in the suppressive and repository tests on *Plasmodium bergheiberghei* infected mice [53] The methanol and aqueous extracts of different parts of *Sarcocephalus latifolius.* The aqueous extract of the stem bark of *Sarcocephalus latifolius* showed the highest antiplasmodial activity ($p<0.05$) when compared with the untreated, chloroquine standard control and other treatment groups [54]	Triterpenoid glycosides, ethyl glucoside, monoterpene indole alkaloids, sterol, decanoic acid and its derivatives, 1,2,3-propanetriol, derivatives of benzoic acid (α-Hydroxytoluene, Benzene carboxylic acid, 1-Ethyl-2-nitrobenzene), 3,5-Dihydroxy-6-methyl-2,3-dihydro 4H-pyran-4- one, N-(5-Hydroxy-7-oxacyclohept-2-Cyl) acetamide, methylene, squalene, phytol, transsqualene, farnesyl acetate and two sugars (β-D-glucopyranose and α-Methyl mannopyranoside) [55]
Drypetes gossweileri S. Moore *Florence 544* Estuaire; Ogooué Ivindo; WoleuNtem	Diarrhea, dermatitis, headache, toothache, pain, rheumatism, aphrodisiac, venereal diseases, fever, ulcers, asthma, swellings, bronchitis, ocular and respiratory problems	(no studies)	6,12-Dihydroxy-13-methylpodocarpa-5,8,11,13-tetraene-3,7-dione ; Friedelin; Friedelane-3.7-dione; glucosinolates; N -β- d -glucopyranosyl- p -hydroxyphenylacetamide, p -dolichandroside A, and β-amyrone[56]

Nowadays, malaria is still a major global health concern that kills primarily pregnant women and children, especially in developing countries. Although several medications are available for prevention and treatment, many reports on death from malaria are done every year, mainly due to drug resistance. Medicinal plants remain the key source to fight malaria as some antimalarial drugs are plant derivatives such as quinine, chloroquine (*Cinchona* spp), and Artemisinin (*Artemisia annua)* [57]. In this regard, the plants mentioned in the ethnobotanical survey were subjected to a literature review, and it was found that many of them have shown antimalarial and antiplasmodial activity against several strains of parasites responsible for causing malaria. Indeed, *in-vitro* and *in-vivo* studies

demonstrated that several plants such as *Sarcocephalus latifolius, Picralima nitida, Carica papaya,* and *Tetrapleura tetraptera* cited in this study can be used as potential treatment for malaria caused by *Plasmodium falciparum* and *P. Vivax* [15, 17, 53]. Besides, Froelich [19] demonstrated that*M. foetida*has an antimalarial activity on the multi-resistant clone Dd2 of *P. falciparum.* And according to Shekins*et al.* (2014) [27], *C. citratus* possesses a good antimalarial property and can be used for prophylactic and chemotherapeutic purposes, while the essential oil displays an antimalarial potential [58].

Amongst the species that were cited to treat malaria in Gabon folk medicine, 17 plant species have displayed *in-vitro* antiplasmodial and/or *in-vivo* antimalarial effects **Table 2**. Additionally, active compounds were isolated from some of these plants, such as kaempferol, berberine, eugenol, or linalool. Moreover, studies indicated that plant extracts from *Momordica foetida*, *Drypetes gossweileri*, *Sarcocephalus latifolius*, *Carica papaya*, *Tetrapleura tetraptera*, *Cylicodiscus gabunensis*, and *Distemonanthus benthamianus* contained sugar and derivatives such as D-fructose, β-D-glucopyranose, and α-methyl mannopyranoside [19, 47, 55] which might contribute to the antimalarial activity displayed. Flavonoids were also detected in the studied plants, and compounds such as quercetin and derivatives were successfully isolated from *Momordica foetida*, *Aframomum giganteum*, *Distemonanthus benthamianus* and *Citrus limon*. Monoterpenes were identified in *Chenopodium ambrosioides*, *Sarcocephalus latifolius*, and *Aucoumeak laineana* extracts. Juma and collaborators [59] demonstrated that sesquiterpene lactones present in the ethanol extract of *O. basilicum* have antimalarial activities against chloroquine-resistant (CQ-r) and CQ-sensitive (CQ-s) strains of *Plasmodium falciparum*. *C. ambrosioides* phytochemical composition shows the presence of a monoterpene named ascaridole (also known as ascarisin; 1,4-epidioxy-p-menth-2-ene) which is a potent inhibitor of *P. falciparum* development

Overall, the present study highlighted the plants previously studied for anti-malaria properties, thus, validating their use in traditional medicine to treat malaria as claimed by the Gabonese vendors. However, no study related to the potential antimalarial activity has been done yet regarding *Distemonanthus benthamianus*, *Aucoumeak laineana*, *Scorodophloeus zenkeri*, *Aframomum giganteum*, *Leucanthemum vulgare*, *Harunganama dagascariensis*, *Macaranga monandra*, *Drypetes gossweileri*, and *Scyphocephalium ochocoa*, which arealso used in traditional medicine to treat malaria. As such, these plants should be the subject of scientific studies to confirm their antimalarial activities. On the other hand, no information was available in the literature regarding the phytochemical composition and the potential activity against malaria of *Desmodium salicifolium*, *Poga oleosa*, *Amphimas ferrugineus,* and *Amphimas klaineanus which* were also mentioned as good for treating malaria in Gabon. Thus, investigation of the potential antimalarial activity along with the identification of compounds responsible for the activity must be done to validate the use of these plants.

The investigation of the geographical distribution of the plants revealed that these species can be found in the sub-regions (Cameroon, Congo, and Equatorial Guinea) and also in other countries such as Ivory Coast and Nigeria. Besides, many of these plants are distributed through the whole country such as *Carica papaya*, *Naucleadi derrichii*, *Picralima nitida* or *Scyphocephalium ochocoa* except for *Drypetes gossweileri*, *Chenopodium ambrosioides*, *Momordica foetida* and *Ocimum basilicum* which are found only in 3, 2 and 1 regions (Estuaire, Woleu Ntem, OgoouéIvindo or Moyen Ogooué) respectively. The preparation and the administration modes used for malaria treatment were found to be the same in West and Central Africa and different other countries like Ivory Coast, Uganda, Nigeria, and Mexico [60, 61, 62]. These findings support the fact that, regardless of the region, numerous plants are commonly used to treat the same ailments. The increasing number of studies reporting antimalarial resistance on the one hand, and the low number of available efficacious drugs, on the other hand, call for an urgent search for new antimalarial molecules. But, the fact that at least 15 years are needed for a molecule to complete the 3 phases of clinical research appears to be a major concern to the modern use of medicinal plants. However, it is possible to overcome this situation. Firstly, the development of

improved traditional medicine derived from traditional healers' remedies (which are already consumed by the population and which show efficacy and safety) should be preferred to the conventional approach of drug development; secondly, studies must be conducted to evaluate potential synergistic or antagonistic relation between pharmaceutical drugs and medicinal preparations; thirdly, training must be given to traditional healers to improve their comprehension of posology and toxicity. These together may help to better use of plant-based antimalarial preparations by both Traditional African Medicine and modern medicine.

CONCLUSION: Malaria remains a major public health problem in endemic countries, particularly in sub-Saharan countries with tropical and subtropical climates. Some of the plants in this study are also found in other countries (Cameroon, Mexico, Congo, and Equatorial Guinea) and are used for approximately the same diseases and ailments. This shows that the use of medicinal plants in traditional medicine worldwide is frequently the same.

Plants such as *M. foetida, O. gratissimum, C. ambrosioides, A. congensis, E. chlorantha, C. citratus, O. basilicum,* and *C. limon* have been previously investigated as having anti-malarial potential, hence confirming their use in traditional medicine. Further investigations are needed to allow the development of improved traditional medicines (ITM) as described by the traditional healers in order to mimic as much as possible the way the herbal remedy is indigenously used.

The advantages of ITM are that they are not time and resources consuming; moreover they will allow low-income populations to afford cheap and efficient treatments.

It is true that many studies have been done in this direction, but the results obtained with medicinal plants worldwide and the data presented in this study show that the use of medicinal plants is of great importance in managing diseases such as malaria.

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