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Plants Used for Antimalaria Treatment by the Baka in Eastern and Southern Cameroon

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Abstract Malaria is nowadays recognized as one of the most deadly diseases in the world. Due to the increasing resistance of malaria protozoans to conventional drugs, traditional herbal medicine appears to be a possible solution. The present work aims at describing the knowledge of antimalarial treatment by the Baka people. Ethnobotanical surveys were conducted from January 24, 2019, to January 25, 2021, among 207 Baka informants in the East and South Regions of Cameroon. A total of 925 citations and 204 recipes were recorded, involving 119 plant species, distributed in 108 genera and 45 families. The most cited families were Apocynaceae, Annonaceae, and Solanaceae. Remedies were predominantly made from stem bark of plants (68.1% of the total citations) and prepared by boiling (46.6% of the total citations). Based on the use agreement value (UAV) and spatial use convergence (SUC), uses of *Alstonia boonei*, *Capsicum frutescens*, *Picralima nitida*, *Annickia affinis*, *Drypetes gossweileri*, *Diospyros crassiflora*, and *Cylicodiscus gabunensis*, for antimalarial treatment were prevalent in the study sites. However, 98 species out of 119 were cited only by five informants or less out of 207, and 51 species were cited only by one informant. These results suggest that the Baka share major medicinal plants for antimalarial treatment on the one hand, and individuals are always attempting new plants for the treatment on the other hand.

Keywords: Baka people; Ethnobotanical surveys; Local phytomedicines; Malaria; Traditional medicine.

Introduction

Malaria is a devastating infectious disease known to take the lives of millions of people worldwide, particularly in Africa (Miller et al. 2013). It is responsible for significant morbidity and mortality especially among children and pregnant women (Sudhanshu et al.

2003). Globally, an estimated 229 million malaria cases and 409,000 deaths occurred in 2019 (WHO 2020). The African region has the highest malaria burden, with 215 million, representing 94% of cases (WHO 2020). Cameroon is among the fifteen countries most affected by malaria, accounting for 3% of all malaria cases worldwide and 3% of malaria deaths in 2019, making it the third most affected country in Central Africa with 12.7% of cases (WHO 2020). Multi-drug resistance of *Plasmodium* spp. resulting from changes in parasite genetic composition have necessitated the need to search for new compounds that are therapeutically potent against the parasite (Alecrim et al. 1999; Krettli 2009).

Due to the increasing resistance of malaria protozoans to conventional drugs, traditional medicine may be a possible solution, as it is a potential source of new derivatives (phytomedicines). This medicine, made essentially from plants, is attracting more and more attention in the context of health care provision and health sector reform (Okigbo & Mmeka 2006; Moretti & Aubertin 2008; Jiofack et al. 2010; Kasilo et al. 2010; Dibong et al. 2011b). It offers multiple benefits. Not only does it offer natural (gentle) remedies that are well accepted by the body, but it is also currently highly valued especially for the treatment of chronic diseases (asthma, arthritis, etc.) (Ngbolua et al. 2013; Posadzki et al. 2013) reported that, factors such as inability to assess health facilities, and socio-cultural attitudes have prompted the increased use of herbal medicines for healthcare in Africa as practiced in other malaria endemic regions. In addition, for centuries and even millennia, our ancestors have used plants to relieve their pains, heal their ailments and dress their wounds (Kouchade et al. 2017). So the application of ethnobotanical survey to collect and document indigenous knowledge on medicinal plants is envisaged as an important tool for identifying potential active principles with antimalarial activities from the abundant plant species (Dike et al. 2012).

The present study aims to enhance the knowledge on the traditional use of plants in the treatment of malaria. The specific objectives are: (1) to list the different plants used for antimalarial treatment among the Baka people; (2) to characterize their traditional uses; and (3) to note the relative importance of the plants listed.

Methods

I. Study site

The study was conducted in 14 Baka villages distributed in 4 subdivisions in the East (9 villages) and South (5) regions of Cameroon. These villages are in the dense rainforest zone. They belong to the semi-deciduous dense rainforest domain (Letouzey 1985). The vegetation belonging to the category of semi-deciduous and evergreen forests dominated by Sterculiaceae and Ulmaceae (Letouzey 1968, 1985; Nkongmeneck 1999). These areas are characterized by four alternating seasons, namely two dry seasons and two rainy seasons. The overall rainfall between the different zones varies between 1,500 and 1,800 mm/year, with an average monthly temperature between 23°C and 25°C. Table 1 presents a summary description of the sites investigated.

II. Data collection

Data were collected from January 24, 2019, to January 25, 2021. Free, Prior and Informed Consent was obtained from Baka people before the data collection. Meetings were held in each village, to inform of the objectives of study and to set up appointments.

Information was collected from anyone who voluntarily agreed to receive us, regardless of gender. A total of 207 informants, including both male and female, in 14 villages belonging to four subdivisions were interviewed. The repartition of these people by subdivision is such that: Dimako (33 informants), Lomié (37), Mintom (68) and Yokadouma (69). The age of the respondents varies between 17 and 80 years old.

The characteristics of the informants are presented in Table 2. Yokadouma (34% of informants) and Mintom (33%) were the subdivisions where more Baka people were interviewed. Men are more represented at 61% of informants. People with ages ranging between 20–40 years are more represented (66%).

We asked each person about all the plants often used for the treatment of malaria. Because we focused on the physical effects of the treatments, we did not record medicinal-magical effects. We presented the informants with the name of the disease and then interviewed them about the plants used for it, because by showing the informants plant

Table 1 Characteristics of the study sites

Region	Site (subdivisions)	Villages	Forest type	Rainfall (mm)	Average temperture (°C)
East	Yokadouma	- Zoulabot Ancien - Ngatto Ancien - Elanjo	Dense moist semi-deciduous forest	1500–1800	23
	Lomié	- Payo - Norzoh - Sissoh - Ngoulmekong	Dense moist evergreen forest	1500–2000	24
	Dimako	- Lossou - Mayos	Dense moist semi-deciduous forest	1500	24
South	Mintom	- Doum - Assok - Nkolemboula - Bemba I and II	Dense moist semi-deciduous forest	1600	25

Table 2 Socio-demographic characteristics of informants

Variables		Number of informants	Percentage (%)
Administration subdivision	Dimako	33	15.9
	Lomié	37	17.9
	Mintom	68	32.8
	Yokadouma	69	33.3
Sex	Male	126	60.9
	Female	81	39.1
Age classes	≤20	13	6.3
	20–30	69	33.3
	30–40	68	32.9
	40–50	39	18.8
	50–60	8	3.9
	>60	10	4.8

samples and asking about its uses could encourage them to invent recipes (Betti 2001a). Different recipes of a single species indicated by an informant were recorded as different citations.

Malaria is a well-known disease among Baka people manifested by the articulation pain and coldness called "jio" by Baka living in the East Region. The data concerning the details of the recipes were collected according to a standardized framework inspired by the forms proposed in the Traditional Medicine and Pharmacopoeia data bank (Pharmel) (Adjanohoun et al. 1994). This form has 5 headings: characterization of the informant, therapeutic indications, characteristics of the plant material used, methods of preparation and administration of the remedy, and remarks.

Some known plant species were identified in the field with the help of experienced botanists (Ngangsop Eric, Djendj Miassé). Botanical samples were collected in at least two exemplaries and the final identification was made in the National Herbarium of Cameroon, based at Yaounde with the help of Onana Jean Michel and Ngangsop Eric. At the herbarium, all specimens were first sterilized with alcohol at 90°C, dried with hot air, and then kept at 20°C for 3–4 days and sprayed with insecticides. All specimens were identified to the species level by comparing them with specimens in the herbarium, which contains about 70,000 plant samples. The major floristic works of Central Africa were also used to ensure the correct determination of the plants, notably the Flores of Cameroon, Gabon, Belgian Congo and Rwanda-Urundi, and also other ethnobotanical works (Betti 2001a, for example). The correct spelling of plants was done using the online plants databases (https://africanplantdatabase.ch/; https://wfoplantlist.org/plant-list/; https://plantnet.org/).

III. Data analysis

Two indices were used to highlight the most significant uses or plants including the spatial use convergence index or SUC (Betti 2001a) and the value of use agreements index or UAV (Philips & Gentry 1993; Ilumbe 2010; Ilumbe et al. 2014).

The spatial use convergence index (SUC) proposed by Betti (2001a) is used to assess similarities in the use of plants for the same health problem (Malaria in this case). This index is based on the following hypothesis: A plant is confirmed for its use in traditional medicine when it is cited by at least two people in the treatment of the same condition. This confirmation is even more important when these people are based in different regions (Betti 2001a). SUC is therefore determined by an discrete scale between 0 and 1 as follows: SUC = 0 when the plant species is not cited in any site, the importance of that plant is null; SUC = 0.25 when the plant is cited in the one site, the importance is low; SUC = 0.5 when the plant is cited in two different sites, the importance is medium; SUC = 0.75 when the plant is cited in three different sites, the importance is high and SUC = 1 when the plant is mentioned in all four sites, the importance of that plant is very high.

The use agreement value index (UAV) provides a better interpretation of the medicinal cultural value of plants (Ilumbe 2010). It combines the use value index (UV) (Philips & Gentry 1993) and the confirmation index (CIs) which assesses or expresses informants' agreement on the plants used (Ilumbe et al. 2014). The formula is:

$$\mathrm{UAV} = \mathrm{UV} \times \mathrm{CIs}.$$

UV is an average number of uses of the species for informants who cited any of use for the species. The formula is:

$$\mathrm{UV} = \sum_{i=1}^{n} \frac{\mathrm{Uis}}{\mathrm{Ns}}$$

where Uis indicates the number of uses of the species mentioned by informant i and Ns is the number of people who mentioned this species.

The CIs is the ratio of the number of informants who cited the species to the total number of informants. It ranges from 0 to 1, a value close to 0 indicates that informants do not agree on the plants used, while a value close to 1 indicates a strong consensus around the use of the indicated plant. The formula is:

$$CIs = \frac{Na}{Nt}$$

where Na: the number of informants who mentioned species 'a' and Nt: the total number of informants.

The Pearson correlation test from R studio version 4.2.1 software was used to assess whether there is a correlation between the indices of use agreement value (UAV) and spatial use convergence (SUC).

Results

I. Plants used for antimalarial treatment

Table 3 lists each plant species, its family, and the number of citation in each site. A total of 119 plant species were listed and distributed in 108 genera and 45 families. Samples of one hundred species in at least two exemplars were collected and stored at the National herbarium of Cameroon. The twelve most important plant species in terms of citations are *Alstonia boonei* (23.6% of the total citations), *Capsicum frutescens* (10.4%), *Picralima nitida* (10.3%), *Annickia affinis* (9.9%), *Drypetes gossweileri* (3.4%), *Diospyros crassiflora* (3.0%), *Cylicodiscus gabunensis* (2.6%), *Elaeis guineensis* (1.8%), *Lepidobotrys staudtii* (1.7%), *Aframomum daniellii* (1.7%), *Panda oleosa* (1.4%) and *Myrianthus arboreus* (1.2%). The most indicated botanical families are: Apocynaceae (36% of the total citations), Annonaceae (11.6%) and Solanaceae (11.6%), Euphorbiaceae (5.3%), Fabaceae (4.7%), Ebenaceae (3.3%), Moraceae (2.1%), Arecaceae (2.0%), Zingiberaceae (2.0%), Pandaceae (1.8%), Lepidobotryaceae (1.7%) and Malvaceae (1.6%). The high numbers of citation were recorded in Yokadouma (319) and Mintom (306).

The plants cited included five morphological types. The majority of plants recorded were trees (60.5% of species), followed by herbaceous (19.3%), shrubs (11.8%), Liana (7.6%), and Epiphyte (0.8%).

II. Recipes of antimalarial treatment

As shown in Table 3, 925 citations were recorded. From these citations, 204 different recipes were identified (Table 4). Each recipe is represented by the species cited, the part of the plant used for the treatment, and the pharmaceutical form. For each recipe, we recorded the mode of administration.

Nine plant parts were identified among the recipes. Among them, the stem bark was widely solicited (68.1% of the total citations) followed by fruit/seed (15.4%), leaves (12.4%), roots (1.8%), sap (1.1%), stem (0.8%), tuber (0.2%), wood (0.1%), and whole plant (0.1%).

A total of seven pharmaceutical forms modes were registered. Of these, the decoctate was the most prevalent form (46.6% of the total citations), followed by the macerate (34.9%),

Table 3 Citation of plants in different subdivisions

Species plant	Vernacular name	Family	Dimako	Lomié	Mintom	Yokadouma	Grand total
Aframomum daniellii (Hook. f.) K. Schum.	njii (tondo a seko)	Zingiberaceae	12	1		3	16
Afrostyrax lepidophyllus Mildbr.	gimba	Huaceae				1	1
Afzelia bipindensis Harms	bimba	Fabaceae				1	1
Ageratum conyzoides L.	lamoe	Asteraceae		1			1
Albizia ferruginea (Guill. & Perr.) Benth.	londa*	Fabaceae			1		1
Alchornea cordifolia (Schuman. & Thonn.) Müll. Arg.	musasa na kpo	Euphorbiaceae	1				1
Alstonia boonei De Wild.	guga*	Apocynaceae	37	41	73	67	218
Amphimas pterocarpoides Harms	kanga*	Fabaceae				1	1
Annickia affinis (Exell) Versteegh & Sosef	ep'hué*	Annonaceae	22	15	33	21	91
Anonidium mannii (Oliv.) Engl. & Diels	mbe	Annonaceae	3	1	1		5
Antrocaryon klaineanum Pierre	gongô*	Anacardiaceae		1			1
Baillonella toxisperma Pierre	mabé*	Sapotaceae				4	4
Barteria fistulosa Mast.	pambo*	Flacourtiaceae		1			1
Beilschmiedia gaboonensis (Meisn.) Benth. & Hook. f.	mobakoso 1	Lauraceae	1				1
Bidens pilosa L.	no name	Asteraceae				1	1
Bridelia atroviridis Müll. Arg.	taku 1	Euphorbiaceae	1				1
Bridelia micrantha (Hochst.) Baill.	taku 2	Euphorbiaceae				2	2
Capsicum annuum L.	alamba na ngbengbe	Solanaceae				1	1
Capsicum frutescens L.	alamba	Solanaceae	7	1	37	51	96
Carica papaya L.	fofo	Caricaceae	1	6	1	2	10
Ceiba pentandra (L.) Gaertn.	kulo*	Malvaceae				2	2
Celtis adolfi-friderici Engl.	kakala*	Cannabaceae				1	1
Celtis tessmannii Rendle	kèkèlè*	Cannabaceae			2		2
Chromolaena odorata (L.) R. M. King & H. Rob.	yekele	Asteraceae	4	3	1		8
Chrysophyllum lacourtianum De Wild.	bambu	Sapotaceae			1	1	2
Citrus medica L.	no name	Rutaceae	1		2		3
Clerodendrum sp. 4	no name	Lamiaceae	3			1	4
Clerodendrum splendens G. Don	niesoso	Lamiaceae				1	1
Clerodendrum umbellatum Poir	no name	Lamiaceae				1	1
Cnetis sp.	no name	Connaraceae		2			2
Cola acuminata (P. Beauv.) Schott & Endl.	ligoh*	Malvaceae		1	1		2
Combretum Platypterum (Welw.) Hutch. & Daziel	no name	Combretaceae		1			1
Combretum sp. 3	no name	Combretaceae				1	1
Copaifera mildbraedii Harms	modumba*	Fabaceae				4	4
Corynanthe pachyceras K. Schum.	moka*	Rubiaceae	2		1		3
Croton oligandrus Pierre ex Hutch.	ndéngo	Euphorbiaceae	4				4
Cylicodiscus gabunensis Harms	boluma*	Fabaceae	11	5	1	7	24
Cymbopogon citratus (DC.) Stapf	no name	Zingiberaceae				1	1
Desbordesia glaucescens (Engl.) Tiegh.	melea	Irvingiaceae	1	1			2
Diospyros crassiflora Hiern	lembè*	Ebenaceae	2			27	29
Diospyros Gracilescens Gürke	no name	Ebenaceae		2			2
Drypetes gossweileri S. Moore	bologa*	Euphorbiaceae				31	31
Duboscia macrocarpa Bocq.	guluma 1*	Malvaceae		1			1
Duboscia viridiflora (K. Schum.) Mildbr.	guluma 2*	Malvaceae			1		1
Duguetia barteri (Benth.) Chatrou	molombo 1	Annonaceae				3	3
Duguetia confinis (Engl. & Diels) Chatrou	molombo 2	Annonaceae	1				1
Elaeis guineensis Jacq.	mbila	Arecaceae	1	1	15		17
Eleusine indica (L.) Gaertn.	mepapa	Poaceae		1			1
Entandrophragma cylindricum (Sprague) Sprague	boyo	Meliaceae	1			4	5
Erythrophleum ivorense A. Chev.	gwanda*	Fabaceae				1	1
Gouania longipetala Hemsl.		Rhamnaceae	2		1	1	4
Greenwayodendron suaveolens (Engl. & Diels) Verdc.	botunga	Annonaceae	3			1	4
Harungana madagascariensis Lam. ex Poir.	djenè	Hypericaceae			1		1
Haumania danckelmaniana (J. Braun & K. Schum.) Milne-Redh.	kpasele	Marantaceae		1	2		3
Hexalobus crispiflorus A. Rich.	hota	Annonaceae				1	1
Holoptelea grandis (Hutch.) Mildbr.	bèlè*	Ulmaceae				7	7
Hunteria umbellata (K. Schum.) Hallier f.	no name	Apocynaceae	1				1
Hypselodelphys poggeana (K. Schum.) Milne-Redh.	poso	Marantaceae			1		1
Irvingia gabonensis (Aub.-Lec. ex O'R) Bail.	pekie	Irvingiaceae	2	3	1		6
Klainedoxa gabonensis Pierre ex Engl.	bokoko	Irvingiaceae				1	1
Lepidobotrys staudtii Engl.	moussako asséko*	Lepidobotryaceae			16		16
Macaranga sp. 1	Musasa	Euphorbiaceae				1	1

Table 3 Continued.

Species plant	Vernacular name	Family	Dimako	Lomié	Mintom	Yokadouma	Grand total
Maesopsis eminii Engl.	londô*	Rhamnaceae			1		1
Mangifera indica L.		Anacardiaceae	1		1		2
Manihot esculenta Crantz	boma	Euphorbiaceae	1				1
Manniophyton fulvum Mull. Arg.	kusa	Euphorbiaceae	1	1			2
Marantochloa purpurea (Ridley) Milne-Redh.	fondo na njene 1	Marantaceae	3			1	4
Marantochloa cordifolia (K. Schum.) Koechlin	fondo na njene 2	Marantaceae			2		2
Margaritaria discoidea (Baill.) Webster	kango*	Euphorbiaceae	1	1			2
Megaphrynium macrostachyum (Benth.) Milne-Redh.	ngongo	Marantaceae		2			2
Meiocarpidium lepidotum (Oliv.) Engl. & Diels	mabèlenguè*	Annonaceae				1	1
Microdesmis puberula Hook. f. ex. Planch.	fifi	Pandaceae	1		2	1	4
Milicia excelsa (Welw.) Berg	bangui*	Moraceae				4	4
Mondia whitei (Hook. f.) Skeels	no name	Apocynaceae	3				3
Musa paradisiaca L.	ndoo	Musaceae	1		1		2
Musanga cecropioides R. Br. ex Tedlie	kombo	Moraceae		2		1	3
Myrianthus arboreus P. Beauv.	ngata	Moraceae		2	9		11
Neoboutonia mannii Benth.	tubu	Euphorbiaceae		1			1
Nicotiana tabacum L.	dako	Solanaceae	1				1
Ocimum gratissimum L. var. gratissimum		Lamiaceae		2	1	3	6
Palisota bracteosa CB Clarke	njaya	Commelinaceae	1				1
Panda oleosa Pierre	kana	Pandaceae		1		12	13
Pentaclethra macrophylla Benth.	mbalaka	Fabaceae		4		1	5
Persea americana Mill.	fio	Lauraceae		1			1
Petersianthus macrocarpus (P. Beauv.) Liben	boso	Lecythidaceae	1		1	1	3
Picralima nitida (Stapf) T. Durand & H. Durand	motokotoko	Apocynaceae	8	1	65	21	95
Piper umbellatum L.	dembelembe	Piperaceae	3	1			4
Pterocarpus soyauxii Taub.	ngele	Fabaceae	1				1
Pycnanthus angolensis (Welw.) Warb.	malanga	Myristicaceae	1	2	1		4
Raphia sp. 3	peke	Arecaceae	1				1
Rauvolfia macrophylla Stapf	mbonga 1	Apocynaceae	2		3		5
Rauvolfia vomitoria Wennberg	mbonga 2	Apocynaceae	2				2
Ricinodendron heudelotii (Baill.) Heckel	gobo	Euphorbiaceae				1	1
Ricinus communis L.	no name	Euphorbiaceae			2		2
Rinorea keayi Brenan	guindi	Violaceae			1		1
Rourea obliquifoliolata Gilg.	tukussa	Connaraceae			2		2
Santiria trimera (Oliv.) Aubrév.	libaba	Burseraceae				1	1
Schumanniophyton magnificum (K. Schum.) Harms	gogologo	Rubiaceae		1	9		10
Scleria secans (L.) Urb.	kiyéyé	Cyperaceae		3			3
Scorodophloeus zenkeri Harms	minyenge	Fabaceae				2	2
Senna hirsuta (L.) HS Irwin & Bameby	no name	Fabaceae	3				3
Sida rhombifolia L.	tandanda	Malvaceae	4	3	1		8
Solanum anguivi Lam	daka	Solanaceae	2	5		2	9
Spathodea campanulata P. Beauv.	mbelemé	Bignoniaceae	1				1
Spermacoce intricans (Hepper) H.M.Burkill	no name	Rubiaceae			1		1
Spondias dulcis Parkinson	no name	Anacardiaceae	1				1
Staudtia kamerunensis Warb.	malanga	Myristicaceae		1			1
Strombosia pustulata Oliv.	bombongo	Olacaceae				1	1
Tabernaemontana crassa Benth.	fando 1	Apocynaceae			2	1	3
Tabernaemontana pachysiphon Stapf	fando 2	Apocynaceae			5		5
Terminalia superba Engl. & Diels	ngolu	Combretaceae	2		3	4	9
Thomandersia hensii De Wild. & T. Durand	ngoka	Acanthaceae				3	3
Thonningia sanguinea Vahl	no name	Balanophoraceae				1	1
Tithonia diversifolia (Hemsl.) A. Gray	no name	Asteraceae	2			1	3
Trichoscypha oddonii De Wild.	ngoyo	Anacardiaceae		2		1	3
Trilepisium madagascariense DC.	pongui*	Moraceae	1				1
Triplochiton scleroxylon K. Schum.	gbado	Malvaceae				1	1
Xanthosoma sagittifolium (L.) Schott	langa	Araceae	1				1
Zingiber officinale	no name	Zingiberaceae				1	1
Grand total			**174**	**126**	**306**	**319**	**925**

* refers to Tajeukem et al. (2014), some names refers to others authors (Letouzey 1976; Brisson 1988; Hattori, 2020).

Table 4 Recipes for antimalarial treatment

Scientific name	Parts plant	Pharmaceutical forms	Mode of administration	Number of informants (Ni)	Number of citations (NC)
Afzelia bipindensis	Sap	Exsudated	Oral	1	1
Aframomum daniellii	Leaf	Decocted	Cutaneous	10	16
	Leaf	Macerated	Oral		
	Root	Decocted	Oral		
	Root	Expressed	Cutaneous, Nasal, Ocular, Oral		
	Stem	Raw material	Oral		
Afrostyrax lepidophyllus	Stem bark	Decocted	Oral	1	1
Ageratum conyzoides	Leaf	Decocted	Oral	1	1
Alstonia boonei	Sap	Exsudated	Oral	160	218
	Leaf	Macerated	Oral		
	Stem bark	Decocted	Cutaneous, Oral, Rectal		
	Stem bark	Infused	Oral, Rectal		
	Stem bark	Macerated	Cutaneous, Nasal, Oral, Rectal		
Alchornea cordifolia	Leaf	Decocted	Cutaneous	1	1
Albizia ferruginea	Leaf	Macerated	Rectal	1	1
Amphimas pterocarpoides	Stem bark	Decocted	Oral	1	1
Annickia affinis	Stem bark	Infused	Oral, Rectal	79	91
	Stem bark	Decocted	Oral		
	Stem bark	Macerated	Oral, Rectal		
	Stem bark	Raw material	Cutaneous, Oral		
Antrocaryon klaineanum	Stem	Raw material	Cutaneous	1	1
Anonidium mannii	Root	Ash	Cutaneous	5	5
	Stem bark	Decocted	Oral		
	Stem bark	Macerated	Oral		
Barteria fistulosa	Stem bark	Macerated	Cutaneous	1	1
Baillonella toxisperma	Stem bark	Decocted	Oral, Rectal	3	4
Beilschmiedia gaboonensis	Stem bark	Decocted	Oral	1	1
Bidens pilosa	Leaf	Macerated	Rectal	1	1
Bridelia atroviridis	Leaf	Infused	Cutaneous	1	1
Bridelia micrantha	Stem bark	Decocted	Cutaneous, Oral	1	2
Capsicum annuum	Fruit/Seed	Expressed	Cutaneous	1	1
Capsicum frutescens	Fruit/Seed	Decocted	Oral, Rectal	54	96
	Fruit/Seed	Expressed	Cutaneous, Rectal		
	Fruit/Seed	Infused	Oral		
	Fruit/Seed	Macerated	Nasal, Oral, Rectal		
	Fruit/Seed	Raw material	Oral		
	Leaf	Expressed	Ocular		
	Root	Macerated	Rectal		
Carica papaya	Leaf	Decocted	Vapor bath, Cutaneous, Oral	7	10
	Leaf	Macerated	Oral		
Celtis adolfi-friderici	Stem bark	Raw material	Oral	1	1
Ceiba pentandra	Stem bark	Decocted	Oral	2	2
Celtis tessmannii	Stem bark	Ash	Cutaneous	1	2
Chrysophyllum lacourtianum	Stem bark	Decocted	Oral	2	2
	Stem bark	Macerated	Oral		
Chromolaena odorata	Leaf	Decocted	Vapor bath, Cutaneous, Oral	7	8
	Leaf	Macerated	Oral		
Citrus medica	Fruit/Seed	Decocted	Oral	2	3
	Fruit/Seed	Macerated	Oral		
	Leaf	Decocted	Cutaneous		
Clerodendrum sp. 4	Leaf	Decocted	Oral, Cutaneous	3	4
	Leaf	Macerated	Oral		
Clerodendrum splendens	Leaf	Macerated	Oral	1	1
Clerodendrum umbellatum	Leaf	Expressed	Rectal	1	1
Cnetis sp.	Leaf	Macerated	Cutaneous	2	2
Cola acuminata	Leaf	Decocted	Vapor bath	2	2
	Stem bark	Decocted	Cutaneous, Oral		

Table 4 Continued.

Scientific name	Parts plant	Pharmaceutical forms	Mode of administration	Number of informants (Ni)	Number of citations (NC)
Copaifera mildbraedii Harms	Stem bark	Decocted	Oral	4	4
Corynanthe pachyceras	Stem bark Stem bark	Decocted Macerated	Oral Cutaneous	3	3
Combretum Platypterum	Stem	Raw material	Cutaneous	1	1
Combretum sp. 3	Leaf	Expressed	Rectal	1	1
Croton oligandrus	Stem bark	Decocted	Oral	2	4
Cymbopogon citratus	Leaf	Decocted	Oral	1	1
Cylicodiscus gabunensis	Leaf Stem bark Stem bark	Macerated Decocted Macerated	Cutaneous, Oral, Rectal Cutaneous, Oral Oral	17	24
Desbordesia glaucescens	Stem bark	Macerated	Oral	2	2
Diospyros crassiflora	Stem bark Stem bark Stem bark Stem bark	Decocted Decocted Infused Macerated	Oral, Rectal Oral Oral Oral	17	29
Diospyros gracilescens	Stem bark	Decocted	Oral	2	2
Stem bark	Macerated	Oral			
Drypetes gossweileri	Stem bark Stem bark	Decocted Raw material	Cutaneous Oral	18	31
Duguetia barteri	Stem bark	Decocted	Oral	3	3
Duguetia confinis	Stem bark	Decocted	Oral	1	1
Duboscia macrocarpa	Leaf	Decocted	Oral	1	1
Duboscia viridiflora	Stem bark	Decocted	Cutaneous	1	1
Elaeis guineensis	Fruit/Seed Leaf Leaf	Ash Decocted Macerated	Cutaneous Oral Nasal	12	17
Eleusine indica	Leaf	Expressed	Nasal	1	1
Entandrophragma cylindricum	Stem bark Stem bark	Decocted Decocted	Oral Oral	4	5
Erythrophleum ivorense	Stem bark	Decocted	Cutaneous	1	1
Gouania longipetala	Leaf	Infused	Oral	4	4
Greenwayodendron suaveolens	Stem bark Stem bark Stem bark	Decocted Macerated Raw material	Oral Oral Cutaneous	4	4
Haumania danckelmaniana	Leaf Leaf	Expressed Macerated	Nasal Oral	3	3
Harungana madagascariensis	Sap	Exsudated	Cutaneous	1	1
Hexalobus crispiflorus	Stem bark	Raw material	Cutaneous	1	1
Holoptelea grandis	Stem bark Stem bark	Decocted Raw material	Cutaneous, Oral Oral	7	7
Hunteria umbellata	Stem bark	Infused	Cutaneous	1	1
Hypselodelphys poggeana	Root	Ash	Cutaneous	1	1
Irvingia gabonensis	Stem bark Stem bark Stem bark	Decocted Macerated Raw material	Oral Cutaneous Oral	5	6
Klainedoxa gabonensis	Stem bark	Macerated	Oral	1	1
Lepidobotrys staudtii	Leaf Stem bark Stem bark	Macerated Decocted Macerated	Oral, Rectal Oral, Rectal Cutaneous, Oral	8	16
Marantochloa cordifolia	Leaf	Decocted	Oral	2	2
Margaritaria discoidea	Stem bark Stem bark	Decocted Raw material	Oral Cutaneous	2	2
Maesopsis eminii	Stem bark	Decocted	Oral	1	1
Manihot esculenta	Tuber	Decocted	Oral	1	1
Manniophyton fulvum	Leaf Stem	Macerated Raw material	Oral Cutaneous	2	2
Mangifera indica	Leaf	Decocted	Nasal, Ocular, Oral	2	2

Table 4 Continued.

Scientific name	Parts plant	Pharmaceutical forms	Mode of administration	Number of informants (Ni)	Number of citations (NC)
Marantochloa purpurea	Leaf Leaf	Expressed Infused	Oral, Ocular, Nasal Oral	2	4
Macaranga sp. 1	Stem bark	Raw material	Oral	1	1
Meiocarpidium lepidotum	Stem bark	Raw material	Nasal, Oral	1	1
Megaphrynium macrostachyum	Leaf	Infused	Oral	1	2
Milicia excelsa	Sap Stem bark	Exsudated Decocted	Oral Cutaneous	2	4
Microdesmis puberula	Leaf Leaf Stem bark	Decocted Raw material Ash	Oral Cutaneous Oral, Rectal	4	4
Mondia whitei	Leaf	Macerated	Oral	2	3
Musanga cecropioides	Stem bark Sap	Decocted Exsudated	Oral Vapor bath, Cutaneous	3	3
Musa × *paradisiaca*	Leaf	Decocted	Cutaneous	2	2
Myrianthus arboreus	Leaf Root Root Stem bark	Infused Ash Decocted Ash	Cutaneous Oral Cutaneous, Oral Cutaneous	10	11
Neoboutonia mannii	Stem bark	Raw material	Nasal	1	1
Nicotiana tabacum	Leaf	Ash	Nasal, Oral	1	1
Ocimum gratissimum	Leaf Leaf	Infused Macerated	Rectal, Oral Cutaneous	4	6
Palisota bracteosa	Leaf	Decocted	Cutaneous	1	1
Panda oleosa	Stem bark Stem bark	Macerated Raw material	Cutaneous, Oral Oral	13	13
Persea americana	Leaf	Macerated	Oral	1	1
Petersianthus macrocarpus	Leaf Stem bark Stem bark	Macerated Ash Infused	Cutaneous Cutaneous Oral	3	3
Pentaclethra macrophylla	Stem bark	Macerated	Oral	5	5
Picralima nitida	Sap Fruit/Seed Fruit/Seed Fruit/Seed Stem bark Stem bark Stem bark Whole plant	Exsudated Decocted Macerated Raw material Decocted Infused Macerated Decocted	Oral, Rectal Oral Oral Oral Oral Oral, Rectal Oral Cutaneous, Oral	69	95
Piper umbellatum	Leaf Leaf	Decocted Macerated	Cutaneous, Rectal Oral	3	4
Pterocarpus soyauxii	Wood	Decocted	Oral	1	1
Pycnanthus angolensis	Sap Stem bark	Exsudated Decocted	Oral Oral, Rectal	4	4
Rauvolfia macrophylla	Stem bark Stem bark	Decocted Macerated	Oral Oral	3	5
Raphia sp. 3	Leaf	Ash	Oral	1	1
Rauvolfia vomitoria	Stem bark	Infused	Oral	2	2
Ricinus communis	Fruit/Seed Leaf	Expressed Decocted	Oral Oral	1	2
Ricinodendron heudelotii	Stem bark	Decocted	Cutaneous	1	1
Rinorea keayi	Root	Ash	Oral, Rectal	1	1
Rourea obliquifoliolata	Leaf	Macerated	Cutaneous	1	2
Santiria trimera	Stem bark	Raw material	Oral, Rectal	1	1
Schumanniophyton magnificum	Stem bark	Macerated	Cutaneous	10	10
Scleria secans	Stem	Raw material	Oral	3	3
Scorodophloeus zenkeri	Stem bark Stem bark	Decocted Macerated	Oral Oral	2	2
Senna hirsuta	Root Root	Decocted Macerated	Oral Cutaneous	3	3

Table 4 Continued.

Scientific name	Parts plant	Pharmaceutical forms	Mode of administration	Number of informants (Ni)	Number of citations (NC)
Sida rhombifolia	Leaf Leaf	Infused Macerated	Cutaneous, Oral Oral	8	8
Solanum anguivi	Fruit/Seed	Decocted	Oral	8	9
Spathodea campanulata	Stem bark	Decocted	Cutaneous	1	1
Spondias dulcis	Leaf	Decocted	Cutaneous	1	1
Spermacoce intricans	Leaf	Macerated	Cutaneous	1	1
Staudtia kamerunensis	Stem bark	Raw material	cutaneous	1	1
Strombosia pustulata	Stem bark	Raw material	Cutaneous	1	1
Tabernaemontana crassa	Stem bark Stem bark	Decocted Macerated	Oral Oral	3	3
Tabernaemontana pachysiphon	Fruit/Seed Fruit/Seed Stem bark Stem bark	Decocted Macerated Decocted Macerated	Oral Oral Oral Oral	2	5
Terminalia superba	Stem bark Stem bark Stem bark Stem bark	Ash Decocted Macerated Raw material	Cutaneous Cutaneous, Oral Oral Oral	8	9
Thomandersia hensii	Leaf Leaf Stem bark	Decocted Macerated Decocted	Oral Oral Oral	3	3
Thonningia sanguinea	Leaf	Decocted	Oral	1	1
Tithonia diversifolia	Leaf Leaf Leaf	Expressed Infused Macerated	Rectal Cutaneous Oral	2	3
Trilepisium madagascariense	Sap	Exsudated	Oral	1	1
Trichoscypha oddonii	Stem bark Stem bark	Decocted Macerated	Oral Oral	3	3
Triplochiton scleroxylon	Stem bark	Raw material	Cutaneous	1	1
Xanthosoma sagittifolium (L.) Schott	Tuber	Decocted	Oral	1	1
Zingiber officinale	Fruit/Seed	Expressed	Rectal	1	1

raw material (6.9%), infused (4.8%), ash (3.7%), expressed (2.1%), and exsudated (1.1%).

Several routes were used for the administration of remedies. The oral route was the most used (71.5% of the total citations), followed by the cutaneous (15.0%), rectal (11.4%), nasal (1.3%), vapor bath (1.0%), and ocular (0.3%).

III. Relative importance of plants cited

A total of 119 species recorded, 43 species were cited across different subdivisions. Among them, 6 species were cited in all the four subdivisions (SUC = 1), 13 in three subdivisions (SUC = 0.75), 24 in two subdivisions (SUC = 0.5).

The plant species among those listed with the highest use agreement value indice are: *Alstonia boonei* (1.05), *Capsicum frutescens* (0.46), *Picralima nitida* (0.46), *Annickia affinis* (0.44), *Drypetes gossweileri* (0.15), *Diospyros crassiflora* (0.14) and *Cylicodiscus gabunensis* (0.12).

Table 5 presents top 20 species based on the use agreement value index (UAV) and spatial use convergence index (SUC), along with the number of citations, the number of informants who cited the plant, and use value index (UV).

Table 5 Top 20 species for antimalarial treatment based on the UAV and SUC

Species plant	Number of citations	Number of informants	UV	UAV	SUC
Alstonia boonei	218	160	1.35	1.05	1
Capsicum frutescens	96	54	1.78	0.46	1
Picralima nitida	95	69	1.38	0.46	1
Annickia affinis	91	63	1.44	0.44	1
Drypetes gossweileri	31	18	1.72	0.15	0.25
Diospyros crassiflora	29	17	1.71	0.14	0.5
Cylicodiscus gabunensis	24	17	1.41	0.12	1
Elaeis guineensis	17	12	1.42	0.08	0.75
Aframomum daniellii	16	10	1.6	0.08	0.75
Lepidobotrys staudtii	16	8	2	0.08	0.25
Panda oleosa	13	13	1	0.06	0.5
Myrianthus arboreus	11	10	1.1	0.05	0.5
Carica papaya	10	7	1.43	0.05	1
Schumanniophyton magnificum	10	10	1	0.05	0.5
Solanum anguivi	9	8	1.13	0.04	0.75
Terminalia superba	9	8	1.13	0.04	0.75
Chromolaena odorata	8	7	1.14	0.04	0.75
Sida rhombifolia	8	8	1	0.04	0.75
Holoptelea grandis	7	7	1	0.03	0.25
Irvingia gabonensis	6	5	1.2	0.03	0.75

Discussion

I. Major species and less cited species used for antimalarial treatment

Alstonia boonei (23.6% of the total citations), *Capsicum frutescens* (10.4%), *Picralima nitida* (10.3%), *Annickia affinis* (9.9%), *Drypetes gossweileri* (3.4%), *Diospyros crassiflora* (3.0%) were the most represented species. This results were similar with Betti et al. (2013a), who also finds *Alstonia boonei* (11%), *Enantia chlorantha* syn. *Annickia affinis* (10.0%) and *Capsicum frutescens* (4.1%) among the Baka in Gabon. This diversity seems similar to that among the Bantu farmers distributed in the same area with the Baka. Indeed, it is from the Baka that they sometimes learned about medicine (Mallart 1977), although Bla et al. (2015) pointed out that the variability of antimalarial plants from one region to another was due to community specific beliefs and doctrines. Apocynaceae (36.0%), Annonaceae (11.6%), Solanaceae (11.6%) and Euphorbiaceae (5.3%), Fabaceae (4.7%), Ebenaceae (3.3%) were the most represented families. This family diversity is close to that found in Andom, located in a northern part of East Region of Cameroon (Betti et al. 2013a), where they observed rather a predominance of Apocynaceae (23.7%), Asteraceae (14.2%), Annonaceae (11.4%), Rubiaceae (6.9%), Solanaceae (4.6%), and Caricaceae (4.6%).

The analysis of UAV and SUC revealed that several species showed a broad convergence of use by the Baka people both within a subdivision and across different subdivisions: in particular, *Alstonia boonei*, *Capsicum frutescens*, *Picralima nitida*, and *Annickia affinis*. The convergence of uses, or the less apparent dissimilarity of uses between certain areas,

testifies that the Baka living currently in different areas maintain the uses shared before they migrated to each area. On the other hand, the species cited in a single subdivision characterize the particularity of the zone in terms of medicinal flora.

Table 6 shows the species reported in the previous studies on antimalarial treatment outside our study sites. Among our recorded species, 26 of them were cited in other regions of Cameroon and other African countries including Democratic Republic of Congo (13 species), Ivory coast (9), Nigeria (8), Gabon (4). The most cited plants out of our site are *Alstonia boonei* (15 references, 5 countries), *Carica papaya* (14, 3), *Rauvolfia vomitoria* (10, 4), *Annickia affinis* (9, 4), *Picralima nitida* (8, 5), *Cymbopogon citratus* (7, 3), *Tithonia diversifolia* (5, 3), *Chromolaena odorata* (4, 3). In summary, *Alstonia boonei*, *Capsicum frutescens*, and *Picralima nitida*, are the species used for antimalarial treatment very widely in Africa, as well as in our study sites.

On the other hand, it should be noted that 98 species were cited only by five informants or less out of 207, and 51 species were cited only by one informant (Table 4). This implies that individuals have their own knowledge that are not shared with others. Hattori (2020) argued that the Baka had widely varying degrees of knowledge about medicinal plants. Generally, the Baka do not share observations about effects of medicinal plants. They have fewer opportunities to share medicinal plant knowledge in their social lives because they use medicinal plants mainly within the family, and the Baka's knowledge of medicinal plants likely reflects their individual and family medical histories (Hattori 2020). In other words, Baka individuals are always attempting new medicinal plants. Our results support Hattori's argument.

II. Characterization of recipes used for antimalarial treatment by the Baka

The traditional uses of plants vary from one culture or region to another. They are mainly characterized by elements such as plant parts used, pharmaceutical forms and administration mode which constitute the medicinal recipe.

The predominance of tree use over other plant forms is strongly observed in the surveyed populations. This high representation of woody plants, particularly trees, would be due to the availability of these forms during all seasons of the year (Albuquerque 2006). Zakariyya et al. (2021) mentionned tree (75%) as most cited followed by shrubs (33.3%), which is in line with Suleman et al. (2018), alghouth Anywar et al. (2016) reported herbs (50%), followed by trees (25%), were frequently used for treating malaria.

A total of ten plant parts were recorded. The stem bark was the most used (68.1%), by the fruit/seed (15.5%), and the leaves (12.3%). Barks, fruits and leaves are organs which contain an enormous quantity of secondary metabolites that may have antimalarial properties. However, for the same amount, the concentration of metabolites would be higher in barks compared to leaves or fruit (Mpondo et al. 2017). Also, the preference for bark is explained by its ease of harvesting by collectors (Betti 2002). This result is similar to those of Betti (2001a, 2003) in the Dja reserve, south Cameroon, where the populations mainly use the stem bark (60%) in the recipes, followed by fruit/seed (20%) and leaves (11%).

In contrast, among the Kafin Hausa in northwestern Nigeria, Zakariyya et al. (2021) found the leaves were the most used (75% of the total citations), followed by the bark (42%). In Andom, east Cameroon, fresh leaves (49%) and stem bark (33%) were used in recipes (Betti et al. 2013a). In Cegere, northern Uganda, Anywar et al. (2016) found leaves (64%) were the most frequently used in recipes for antimalarial treatment. In Agboville, southeast Ivory Coast, leaves (49.3%), stem bark (40.0%), roots (9.3%), and leafy branches (1.3%) were used in recipes (Kipre et al. 2017). In the city of Bamako, leaves (78.4%)

Table 6 Plants used for antimalarial treatment in Africa

Species plant	Country/Region (references)
Alstonia boonei	CI (3, 4, 9), DRC (5, 6, 7), Cam (1, 8, 10, 11, 2, 12), Gab (13, 1), Nig (24)
Annickia affinis syn. *Enantia chlorantha*	Cam (25, 11, 26, 8, 10, 1), DRC (6), CI (27), Gab (1)
Baillonella toxisperma	Cam (11)
Capsicum frutescens	Cam (11, 16), Gab (1)
Carica papaya	CI (4, 9, 27), DRC (14, 15, 34, 19, 35, 36, 29, 37), Cam (23, 8, 11)
Ceiba pentandra	Cam (11)
Chromolaena odorata	Nig (20, 24), CI (18), Cam (11)
Citrus medica	Nig(24)
Clerodendrum umbellatum	Cam(11)
Cymbopogon citratus	DRC (21, 18, 19, 15, 22), Cam (23), Nig (24)
Elaeis guineensis	Cam (16, 11)
Eleusine indica	Cam (8)
Harungana madagascariensis	Cam (11, 17)
Manihot esculenta	DRC (25), CI (27), Cam (2, 11)
Mangifera indica	Nig (24)
Mondia whitei	DRC (18)
Nicotiana tabacum	DRC (19)
Ocimum gratissimum	Nig (24)
Pentaclethra macrophylla	DRC (6)
Picralima nitida	Mg (32), CI (4), Cam (16, 33, 10, 11), DRC (6), Gab (1)
Polyalthia suaveolens syn. *Greenwayodendron suaveolens*	Cam (11)
Rauvolfia vomitoria	DRC (14, 28, 29, 30, 19, 10), CI (4), Cam (8), Nig (24, 31)
Spathodea campanulata	DRC (36), Cam (8), CI (9)
Thomandersia hensii	DRC (6), Cam (26)
Tithonia diversifolia	DRC (14, 15, 19), CI (27), Cam (11)
Zingiber officinale	Nig (24)

Authors: 1 = Betti et al. (2013a); 2 = Dibong et al. (2011a); 3 = Bla et al. (2015); 4 = N'guessan et al. (2009); 5 = Terashima & Ichikawa (2003); 6 = Ngbolua et al. (2014); 7 = Mongeke et al. (2018); 8 = Etame-loe et al. (2018) ; 9 = Béné et al. (2016); 10 = Tajeukem et al. (2021); 11 = Betti et al. (2013b); 12 = Kidik et al. (2015); 13 = Betti et al. (2012); 14 = Kasali et al. (2014a); 15 = Kasali et al. (2014b); 16 = Betti (2010); 17 = Agbor et al. (2007); 18 = Ngbolua et al. (2019); 19 = Mbuyi et al. (2019); 20 = Afolayan et al. (2016); 21 = Ngbolua et al. (2016); 22 = Nzuki (2016); 23 = Maffo et al. (2019); 24 = Idowu et al. (2010); 25 = Tsabang et al. (2012); 26 = Boyom et al. (2009); 27 = Koulibaly et al. (2016); 28 = Makumbelo et al. (2008); 29 = Ilumbe (2010); 30 = Kasika et al. (2015); 31 = Aderopo et al. (2020); 32 = Randrianarivelojosia et al. (2003); 33 = Betti & Van Essche (2001); 34 = Kasali et al. (2014); 35 = Manya et al. (2020); 36 = Muya et al. (2014); 37 = Kalonda et al. (2014)
Countries: Cam = Cameroon; DRC = Democratic Republic of Congo; Mg = Madagascar; CI = Côte d'Ivoire; Gab = Gabon; Nig = Nigéria

were used (Diarra et al. 2016). The difference between these studies and our results is likely due to the difference in environmental conditions. For example, Andom is located in a forest-savanna transition zone with a high proportion of herbaceous plants compared to our study sites, which are located in the humid dense forest.

The decoction was the most used mode of preparation. This would be due to the plant organ used in the recipes, i.e., barks, and also due to the fact that the heat allows to extract the maximum of active substances contained in the plant. This is in line with a study conducted in northwest Nigeria (Zakariyya et al. 2021). Boiling as a method of preparation is frequently used for the treatment of malaria (Idowu et al. 2010). Betti (2001a, 2001b) stated that decoction seemed to be the most widely used pharmaceutical form in traditional medicine throughout Africa. The addition of the plant organ to an aqueous solution brought to a boil allows the release of many more active ingredients and mitigates or cancels the toxic effect of some ingredients (Salhi et al. 2010).

The ingestion of the drug by the surveyed populations was done preferentially by the mouth. The action of the drug is rapid when it is introduced internally, as it facilitates the absorption of active molecules to the deep organs. Indeed, in most cases, the aqueous decoction is taken orally (Diafouka 1997). Similar studies also reveal the oral route as the most used (Dibong et al. 2011b; Betti et al. 2012).

Conclusion

This study has the particularity to further refine the existing scientific database for a selective use of plants in traditional medicine in the treatment of malaria. The ethnopharmacological approach on the one hand for certain species used in the recipes but very little quoted or still quoted in only one site, would be also indicated to reinforce the catalogs of antimalarial plants. On the other hand, it would also be interesting to make a toxicological study of the inventoried active plants in order to evaluate the effective dose not harmful for the organism. This will help to designing less expensive phytomedicines that are accessible to the poor population. All this information will allow to promote the development of a specialized ethnomedical tourism for malaria, as well as for any other disease among Baka people.

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