World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Ethnobotanical study of medicinal plants used for the treatment of malaria in the department of Korhogo in the north of Côte d'Ivoire

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World Journal of Advanced Research and Reviews, 2023, 20(01), 540–553

Publication history: Received on 28 August 2023; revised on 06 October 2023; accepted on 09 October 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.20.1.1842

Abstract

This study was carried out with the aim of contributing to the enhancement and preservation of medicinal plants used in the treatment of malaria in Côte d'Ivoire. For this, an ethnobotanical survey was conducted in seven markets in the city of Korhogo and among 28 herbalists. The majority of herbalists surveyed are women (71%) with an age range between 31 and 50 years (61%). The study identified 67 species of plants divided into 63 genera and 28 botanical families. The most represented family is the Fabaceae (13.4%). The most used species are *Anogeissus leiocarpus* (DC) Gill. and Perr. and *Nauclea latifolia* (Sm.). Species from the Sudano-Zambézi and Guineo-Congolese phytogeographical regions were the most represented with 26 species. Among the organs used, the leaves (77.6%) are the most used in the recipes. The decoction (76.1%) is the most used mode of preparation and the oral route (86.6%) remains the main route of administration. Regarding their accessibility, 10 of these species are disappearing. Phytochemical screening carried out with the leaves of the two most cited plants revealed the presence of polyterpenes, polyphenols, flavonoids, catechin tannins, quinones, alkaloids and saponosides.

Keywords: Medicinal Plants; Malaria; Korhogo; Côte d'Ivoire; Phytochemical Screening.

1. Introduction

Plants have always been a major and essential source of food and medicine for humans. Even today, a majority of the world's population, particularly those in developing countries, treat themselves mainly with traditional herbal remedies [1].

In Côte d'Ivoire, according to [2], traditional medicine is experiencing significant growth, and constitutes primary health care for the majority of the population thanks to its geographic, economic and cultural accessibility. According to the National Program for the Promotion of Traditional Medicine (PNPMT), it has more than 17,000 Traditional Health Practitioners located in rural, urban and peri-urban areas. Around 80% of these are phytotherapists who develop herbal medicinal recipes [3] to treat numerous diseases.

Among these pathologies, malaria has the highest mortality rate [4, 5]. Indeed, this scourge affects 500 million people worldwide each year, causing approximately 3 million deaths and threatening 2.4 billion of the world's population [6, 7]. In Côte d'Ivoire, it represents 43% of reasons for consultations and 62% of hospitalizations for children under 5 years old. It is responsible for 11.8% of infant mortality, 40% of causes of school absenteeism and 50% of loss of agricultural income [8].

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To treat malaria, science has developed pharmaceutical drugs. However, the germs of the disease have not yet disappeared and the disease is even becoming more and more emerging. This is because the mosquitoes that carry the parasites are resistant to insecticides and the parasites themselves are less and less sensitive to usual medications. Faced with this problem and in order to put on the market an effective remedy accessible to all, particular emphasis is placed on the discovery of new active molecules from plants from the pharmacopoeias of Africa and Asia [9].

The richness and floristic diversity of Côte d'Ivoire could constitute a considerable asset in the search for new bioactive molecules for the treatment of this pathology. Unfortunately, this flora is overexploited for various reasons which have a more or less accentuated impact on the floristic diversity of the natural environment. Faced with this pressure, certain species are becoming increasingly rare. The general objective of this work is to contribute to the valorization and preservation of biodiversity, particularly medicinal plants used in the treatment of malaria in Côte d'Ivoire.

2. Material and methods

2.1. Study site

The study was carried out in the town of Korhogo, located in the north of Côte d'Ivoire. It consisted of conducting a survey among some herbalists practicing in seven (7) markets in Korhogo. These are the markets of Sinistré, Soba, Grand marche, Koko, Ahoussabougou, Cocody and Petit Paris (Figure 1).

2.2. Material

2.2.1. Material used for ethnobotanical study

A survey sheet was established beforehand for the census of plants, a pruner was used to collect samples of specimens, a bag to carry the collected samples, a cardboard box and old newspapers for the conservation of these samples and adhesive tape to label the samples. The shots were taken using a camera.

2.2.2. Equipment used for phytochemical screening

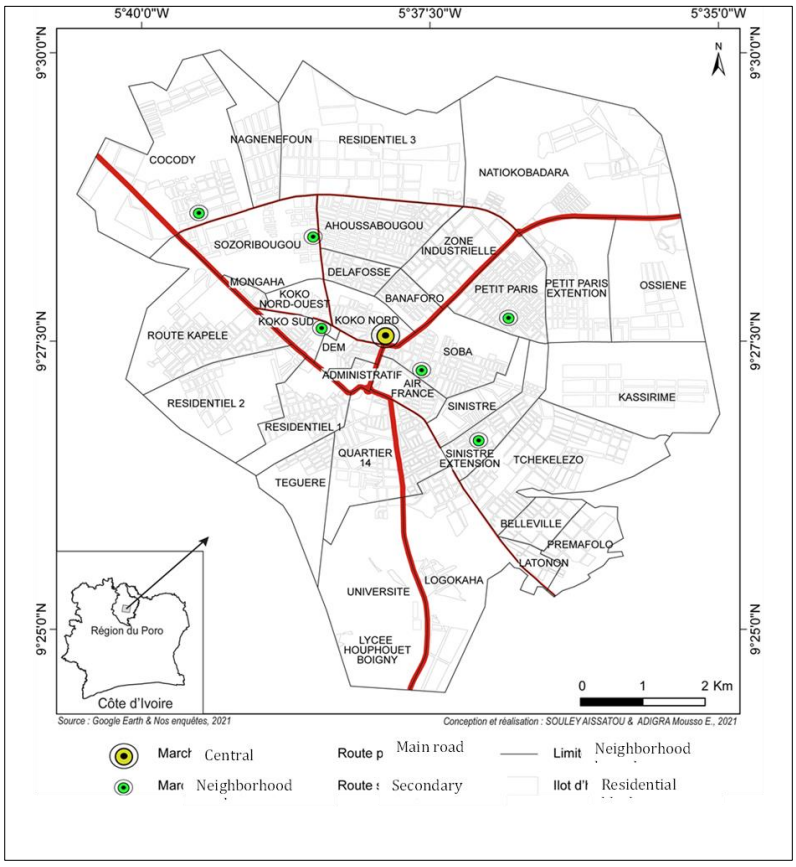


Figure 1 Map of the town of Korhogo (Study site)

It is made up of laboratory equipment. As solvents, acetic anhydride, sulfuric acid, ferric chloride, hydrochloric alcohol, magnesium, isoamyl alcohol, sodium acetate, chloroform and ammonia have been used. Concerning the reagents, Liebermann, Cyanidine, Stiasny, Bornstraëger, Bouchardat and Dragendorff were used to characterize the different chemical groups.

2.3. Methods

2.3.1. Ethnobotanical study

Choice of sites and people interviewed

The choice is made on the busiest markets in the town of Korhogo with a good supply of medicinal plants. The herbalists were chosen based on their knowledge of medicinal plants used in the treatment of malaria. Before any activity, a courtesy visit was paid to the herbalists of the seven targeted markets. Its aim was to establish a great confidence in order to facilitate the work. At the end of this visit, appointments were made with those available.

Profile of respondents

Gender (male and female), age and level of education were taken into account. Three age groups were retained: These are people under 30 years old; from 31 to 50 years old and from 51 years old and over. The level of education of the people interviewed was distributed as follows: out of school and in school (primary, Koranic, secondary and higher).

Characterization of plant species

- **Identification of listed species**

The plants listed were identified within the Botanical UPR of the Péléforo Gon Coulibaly University of Korhogo thanks to the works [10] and [11], at the National Floristic Center of Abidjan (CNF) and at the Swiss Center for Scientific Research in Côte d'Ivoire (CSRS). The nomenclature according to [12] was used to harmonize the names of the plant species recorded.

- **Species typology**

The biological types of all species present were determined based on the work of [13] and [11]. The chorological affinity was determined using the major phytogeographic subdivisions and the catalog of vascular plants of Côte d'Ivoire [11].

- **Knowledge of plants and their mode of use**

Knowledge of plants and their method of use, in particular the plant used, the organs mentioned, the method of preparation used, method of administration used, symptoms treated and the availability of species, were evaluated.

2.3.2. Phytochemical screening

The phytochemical screening was carried out in the pharmacy laboratory at the Félix Houphouët Boigny University of Cocody. The chemical groups were characterized based on the techniques described in the work of [14], [15], [16] and [17].

2.3.3. Data processing

The various data collected were subject to basic descriptive statistical analyses. These analyzes were carried out using Microsoft 365 Excel software.

3. Results and discussion

3.1. Ethnobotanical study

3.1.1. Profile of respondents

By gender, 71% of herbalists surveyed in the markets are women and 29% are men (Figure 2). Concerning the distribution by age group, people aged 31 to 50 were the most numerous (61%). For the age group 50 and over, we note (28%). The least represented are people whose age is less than 30 years (11%) (Figure 3). It appears from this study

that (58%) of the people surveyed were not educated. Those in school were distributed according to level of study: primary (14%), secondary (7%), and Koranic (21%) (Figure 4).

3.1.2. Characterization of inventoried species

These species are mainly represented by dicotyledons and two monocots (*Bambusa vulgaris* and *Imperata indica*). The most abundant families are Fabaceae with 09 species, Euphorbiaceae with 08 species, Combretaceae with 07 species and Rubiaceae 05 species (Table 1).

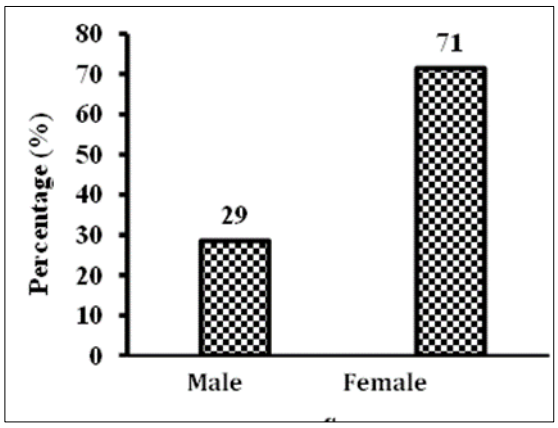


Figure 2 Distribution by sex

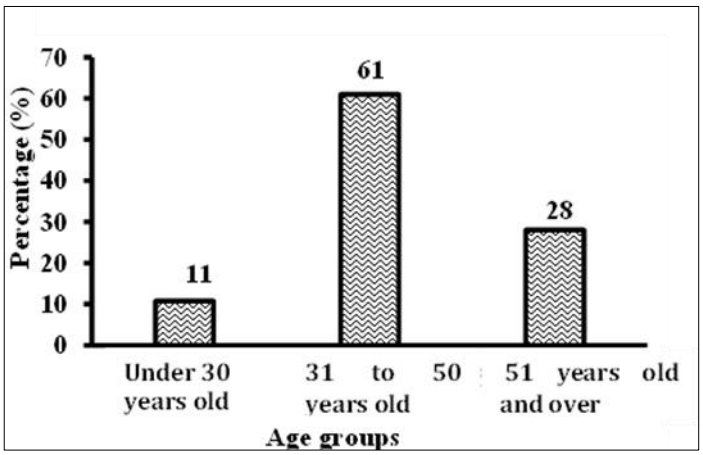


Figure 3 Distribution of respondents according to age

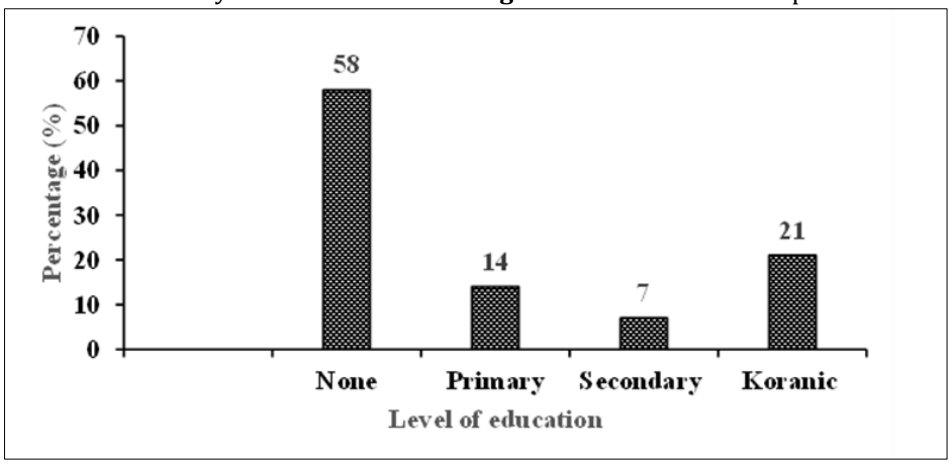


Figure 4 Distribution of respondents according to level of education

3.1.3. Distribution of medicinal plants according to biological types

The analysis of collected data indicates a dominance of microphanerophytes (mp) with 38.8%, nanophanerophytes (np) with 28.4% and mesophanerophytes (mP) with 17.9%. Megaphanerophytes (MP) are poorly represented with 7.5%. As for Therophytes (Th) and Rhizomatous Geophytes (Gr), they are very poorly represented with 4.5% and 3% respectively (Figure 5).

3.1.4. Distribution of medicinal plants according to phytogeographic types

Species from the Sudano-Zambézian and Guinea-Congolese phytogeographic regions (GC-SZ) are the most represented with 37.3%(Figure 6). They are followed by species from the Sudano-Zambézian (SZ) phytogeographic region with 34.3%. The taxon species common to Europe and Southern Asia (EAsM), for their part, are represented with a single species or 1.5%.

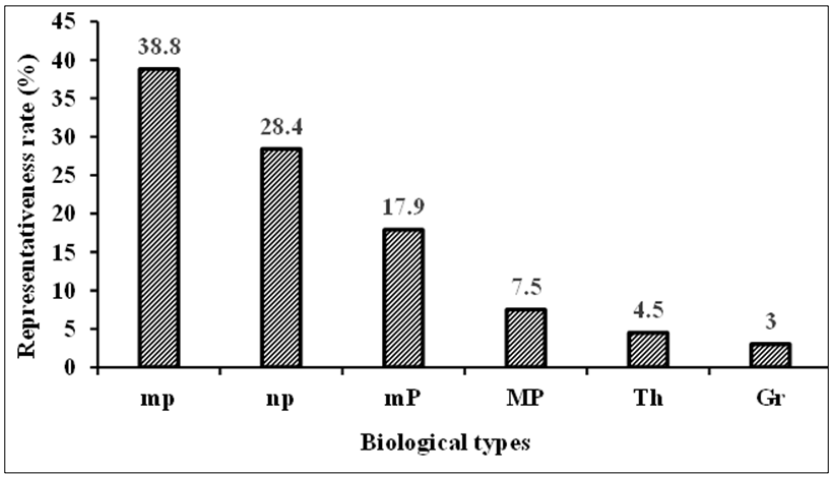
3.1.5. Knowledge of plants and their uses

Species citation frequency

The plant species most cited by the herbalists interviewed are listed in descending order of their frequency of citation. The most cited are *Nauclea latifolia* (6.8%) and *Anogeissus leiocarpus* (5.5%) (Table 2).

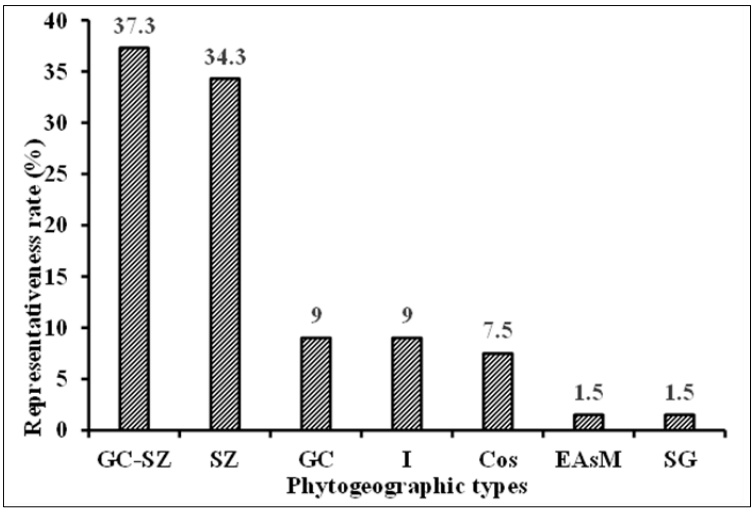
Table 1 Distribution of medicinal plants according to genus and species

Families	**Number of genres**	**Number of species**
Fabaceae	7	9
Euphorbiaceae	8	8
Combretaceae	6	7
Rubiaceae	5	5
Meliaceae	4	4
Rutaceae	4	4
Anacardiaceae	2	2
Apocynaceae	2	2
Asteraceae	2	2
Lamiaceae	2	2
Malvaceae	2	2
Moraceae	1	2
Myrtaceae	2	2
Poaceae	2	2
Annonaceae	1	1
Bixaceae	1	1
Boraginaceae	1	1
Capparaceae	1	1
Caricaceae	1	1
Convolvulaceae	1	1
Ebenaceae	1	1
Liliaceae	1	1
Moringaceae	1	1
Musaceae	1	1
Olacaceae	1	1
Papaveraceae	1	1
Polygalaceae	1	1
Sapindaceae	1	1



mp= microphanerophyte; np= nanophanerophyte; mP= mesophanerophyte; MP= Megaphanerophyte;Th= Therophyte; Gr= Rhizomatous geophyte

Figure 5 Distribution of medicinal plants according to biological types



GC-SZ = Transitional taxon between the Guineo-Congolese region and the Sudano-Zambézian region ; SZ = Taxon from the Sudano-Zambézian region ; GC = Taxon from the Guinea-Zambézian region ; I = Introduced Taxon ; Cos= Cosmopolitan Taxon ; EAsM= Taxon common to Europe and southern Asia ; SG = Taxon present in both the Sudanese and Guinea-Congolese Regional Centers of Endemism

Figure 6 Distribution of medicinal plants according to phytogeographic types

Table 2 Citation frequency of plant species

Species	Families	Citation frequency (FC) en %
Nauclea latifolia	Rubiaceae	6.8
Anogeissus leiocarpus	Combretaceae	5.5
Cinchona calisaya	Rubiaceae	4.6
Guiera senegalensis	Combretaceae	4.6
Olax subscorpioidea	Olacaceae	4.6
Bambusa vulgaris	Poaceae	4.2
Trichilia emetica	Meliaceae	4.2

Uapaca togoensis	Euphorbiaceae	3.8
Cordia myxa	Boraginaceae	3.4
Alchornea cordifolia	Euphorbiaceae	3
Saba senegalensis	Apocynaceae	3
Azadirachta indica	Meliaceae	2.1
Cochlospermum planchonii	Bixaceae	2.1
Combretum molle	Combretaceae	2.1
Securidaca longipedunculata	Polygalaceae	2.1
Carica papaya	Caricaceae	1.7
Cassia sieberiana	Fabaceae	1.7
Entada africana	Fabaceae	1.7
Khaya senegalensis	Meliaceae	1.7
Mitragyna inermis	Rubiaceae	1.7
Moringa oleifera	Moringaceae	1.7
Pteleopsis suberosa	Combretaceae	1.7
Securinega virosa	Euphorbiaceae	1.7
Terminalia glaucescens	Combretaceae	1.7
Vernonia amygdalina	Asteraceae	1.7
Citrus aurantifolia	Rutaceae	1.3
Daniellia oliveri	Fabaceae	1.3
Jatropha curcas	Euphorbiaceae	1.3
Mangifera indica	Anacardiaceae	1.3
Parkia biglobosa	Fabaceae	1.3
Piliostigma thonningii	Fabaceae	1.3
Tamarindus indica	Fabaceae	1.3
Others (35 species)		17.2

Proportion of plant organs used

The leaves are the most used with a rate of 77.6%, followed by the stem bark (10.4%), the roots (7.5%), and the whole plant (4.5%) (Figure 7).

Method of preparation

The decoction remains the most recommended method of preparation. It is recommended at 76.1%. Then follows maceration with 17.9%, infusion with 3.0%, kneading and pounding with 1.5% each (Figure 8).

Administration mode

The oral route (86.6%) in the form of a drink is the most used method of administration. The second method used is the external route (10.4%) by bath and the rectal route (3.0%) by purge (Figure 9).

Other pathologies treated

Medicinal plants used in the treatment of malaria are also used against other pathologies. These are stomach sores with 09 species, general fatigue with 05 species and marasmus with 03 species, etc. (Figure 10).

Accessibility of plant species

This study showed that 32 plant species are easy to access, 25 are moderately easy to access and 10 are starting to disappear (Table 3).

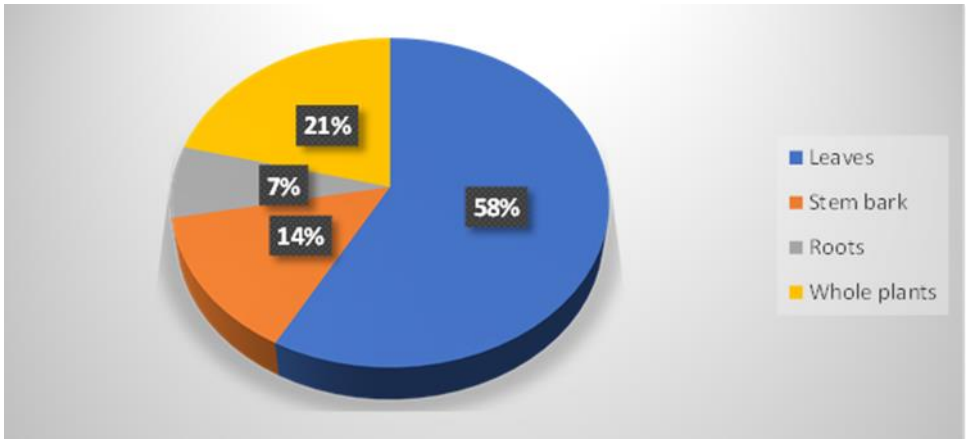


Figure 7 Proportions of plant organs used

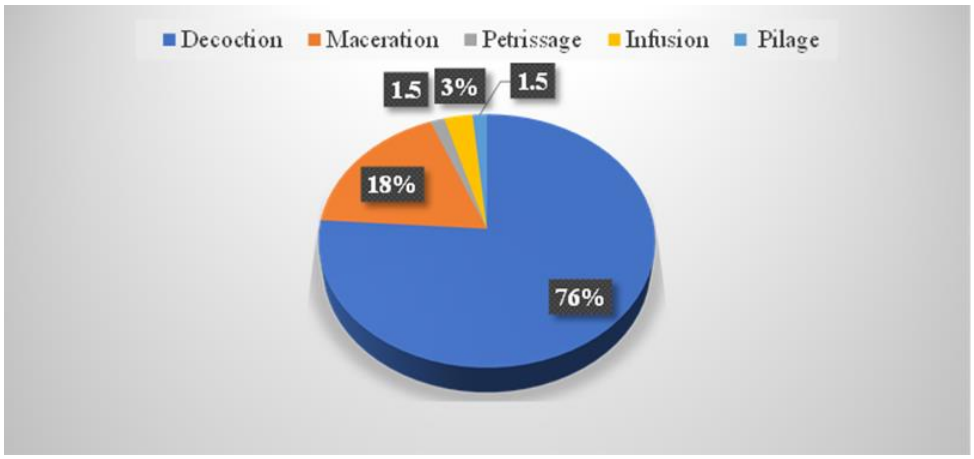


Figure 8 Method of preparation of medicinal plants

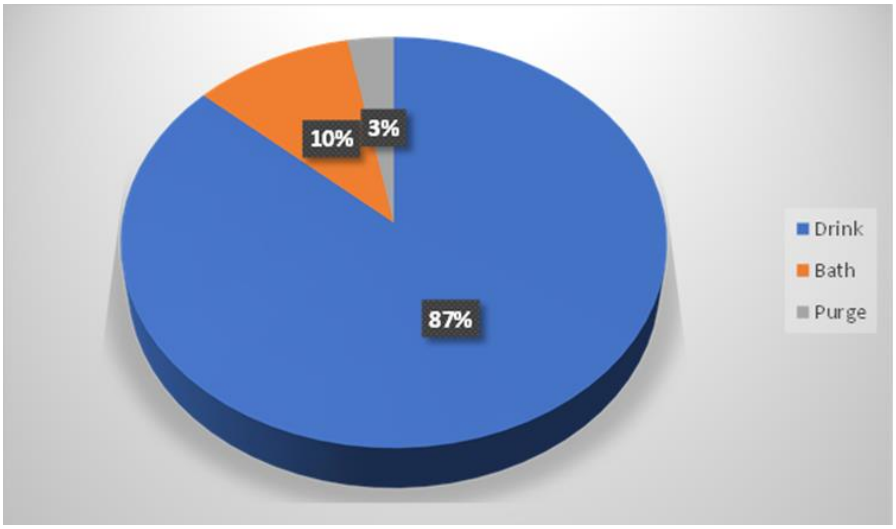


Figure 9 Method of administration of collected revenues

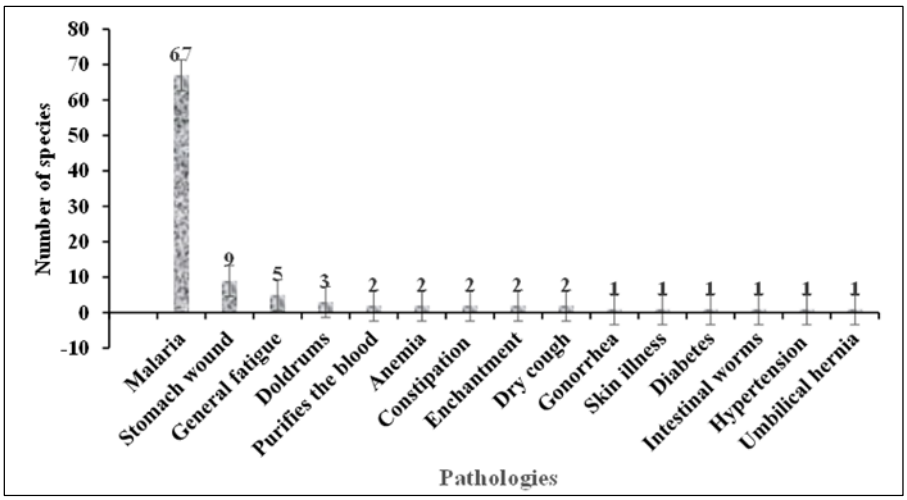


Figure 10 Other pathologies treated

Table 3 Distribution of plant species according to their availability

Accessibility	Species	Families	Vernacular names
Easy	*Aloe vera*	Liliaceae	Aloès
	Anacardium occidentale	Anacardiaceae	Anacarde
	Artemisia vulgaris	Asteraceae	Armoise
	Azadirachta indica	Meliaceae	Neem
	Bambusa vulgaris	Poaceae	Bambou de chine
	Bridelia ferruginea	Euphorbiaceae	Sabga
	Carica papaya	Caricaceae	Papayer
	Citrus aurantifolia	Rutaceae	Citronnier
	Combretum molle	Combretaceae	Magnakabrou (D)
	Daniellia oliveri	Fabaceae	Sana yiri (D)
	Entada africana	Fabaceae	Samandéré (D)

	Eucalyptus camaldulensis	Myrtaceae	Arbre à serpent
	Fagara zanthoxyloides	Rutaceae	Fagara jaune
	Ficus trichopoda	Moraceae	Panangue (S)
	Guiera senegalensis	Combretaceae	Koungbê (D)
	Hyptis suaveolens	Lamiaceae	Napanfogue (S)
	Imperata indica	Poaceae	Loley (D)
	Ipomea asarifolia	Convolvulaceae	Flogoflaga (D)
	Jatropha curcas	Euphorbiaceae	Jatropha
	Leptadenia hastata	Apocynaceae	Songnin (D)
	Mangifera indica	Anacardiaceae	Manguier
	Manihot esculenta	Euphorbiaceae	Manioc
	Moringa oleifera	Moringaceae	Moringa
	Musa paradisiaca	Musaceae	Bananier
	Nauclea latifolia	Rubiaceae	Bati (D)
	Ocimum basilicum	Lamiaceae	Basilic
	Phyllanthus amarus	Euphorbiaceae	Mille maladies
	Piliostigma thonningii	Fabaceae	Gnaman yiri (D)
	Senna senegalensis	Meliaceae	Badjia (S)
	Sida acuta	Malvaceae	Tchêgbanabélé (D)
	Tamarindus indica	Fabaceae	Tamarin
	Vernonia amygdalina	Asteraceae	Corsafinan (D)
Moderately easy	*Alchornea cordifolia*	Euphorbiaceae	Arbre de Djeman
	Annona senegalensis	Annonaceae	Madessousou (D)
	Anogeissus leiocarpus	Combretaceae	Krèkètè (D)
	Antidesma venosum	Rutaceae	Yiri koura (D)
	Blighia sapida	Sapindaceae	Finzan (D)
	Boscia angustifolia	Capparaceae	Ganivigue (S)
	Cassia alata	Fabaceae	Logbalê (S)
	Cassia siamea	Fabaceae	Cassia yiri (D)
	Cinchona calisaya	Rubiaceae	Jaune amer
	Cochlospermum planchonii	Bixaceae	Touroubara (D)
	Combretum nigricans	Combretaceae	Karidjakouman (D)
	Cordia myxa	Boraginaceae	Dolman (S)
	Diospyros mespiliformis	Ebenaceae	Sounsoufi (S)
	Gossypium arboreum	Malvaceae	Coton sauvage
	Olax subscorpioidea	Olacaceae	Nimbochi (D)
	Parkia biglobosa	Fabaceae	Néré
	Pericopsis laxiflora	Combretaceae	Koulikouli

	Psidium guajava	Myrtaceae	Goyavier
	Pteleopsis suberosa	Combretaceae	Trenifou (D)
	Saba senegalensis	Apocynaceae	Zaman
	Securidaca longipedunculata	Polygalaceae	Djoro (D)
	Securinega virosa	Euphorbiaceae	Balanbalan (D)
	Terminalia glaucescens	Combretaceae	Wolor (D)
	Trichilia emetica	Meliaceae	Sourafisan (D)
	Uapaca togoensis	Euphorbiaceae	Kogo somon (D)
Difficult	*Anthostema senegalense*	Euphorbiaceae	Djerikola (D)
	Argemone mexicana	Papaveraceae	Solvoungue (S)
	Cassia sieberiana	Fabaceae	Pongoul (S)
	Clausena anisata	Rutaceae	Selome (S)
	Erythrina senegalensis	Fabaceae	Erythrine du Sénégal
	Ficus vallis-choudae	Moraceae	Seretoro (D)
	Khaya senegalensis	Meliaceae	Cailcédrat
	Mitracarpus villosus	Rubiaceae	Gbrenangue (S)
	Mitragyna inermis	Rubiaceae	Dioum (D)
	Pavetta crassipes	Rubiaceae	Koumoubrou (D)

Meaning: Dioula (D) et Sénoufo (S)

3.2. Phytochemical screening

Tests for the detection of chemical compounds, carried out on the crude extracts of the leaves of *Anogeissus leiocarpus* and *Nauclea latifolia*, made it possible to detect sterols, polyterpenes, polyphenols, flavonoids, tannins, quinones, alkaloids and saponosides (Table 4).

Table 4 Phytochemical composition of extracts from the leaves of *Anogeissus leiocarpus* and *Nauclea latifolia*

Extracts		***Anogeissus leiocarpus***	***Nauclea latifolia***
Sterols	Polyterpene**s**	**+**	**+**
Polyphenols		**++**	**++**
Flavonoid		**++**	**++**
Tannins	Catechists	**++**	**++**
	Gallic	**-**	**+**
Quinone		**++**	**+**
Alkaloids	Bouchardat	**+**	**+**
	Dragendorff	**+**	**+**
Saponosides		**+**	**+**

(-) Absent ; (+) present with moderate concentration; (++) present with a high concentration

4. Discussion

The study showed that most of the herbalists surveyed are women (71%) and men (29%). Studies in Côte d'Ivoire have shown that the sale of medicinal plants in markets is invested by women [18]. Their age generally ranges from 31 to 50 years (61%). Indeed, knowledge of medicinal plants, their uses, and their properties are acquired following many years of experience [19].

The families most represented in this study are Fabaceae (13.4%); Euphorbiaceae (11.9%); Combretaceae (10.4%) and Rubiaceae (7.5%). These results are similar to those of [20] who indicated that these families characterize the savannah vegetation in Côte d'Ivoire. Furthermore, the preponderance of Fabaceae over other families could be linked to the fact that this family is the grouping of three subfamilies (Caesalpinioideae, Mimosoideae and Faboideae), according to the APG IV classification [12].

Analyzes of the frequency of citation of species and their contribution in the different recipes showed that *Nauclea latifolia* and *Anogeissus leiocarpus* are the most cited and used species. These species are recognized for their effectiveness in the treatment of malaria [21].

The most represented biological types are microphanerophytes (38.8%). These results corroborate those of [22] who obtained 42%; of [23] with 40% and of [24] with 36.17% during their studies. Indeed, microphanerophytes are shrubs. They are more numerous and are frequently encountered in the immediate environment of users [25].

The leaves are the most used organs with a rate of 77.6%. They. This preference for leaves in recipes has been reported by several authors including [26], [5] and [27]. However, one might be concerned about the impact of excessive use of leaves on the plant. But studies by [30] have shown that removing 50% of a tree's leaves does not significantly affect its survival. The decoction (76.1%) is the most used method of preparation. This result is similar to that of [29] (82.35%). In fact, it allows more active ingredients to be collected and attenuates or cancels the toxic effect of certain medications.

Drink (86.6%) is the most used method of administration. This result agrees with that of [30] and [31]. This method of administration is easy to use. In addition, since the drugs are in raw form, they are less dangerous orally, because the absorption of the active ingredients takes place in the small intestine [18].

This study showed that some species are difficult to access. This could be explained by the anthropogenic pressure they are under. Their intervention in the treatment of several pathologies leads to irrational use by populations [32]. Their abusive exploitation constitutes a great threat to their survival, hence the classification of several of them among vulnerable species by the International Union for Conservation of Nature (IUCN) [33].

Phytochemical screening of the leaves of *Anogeissus leiocarpus* and *Nauclea latifolia* revealed several chemical compounds, some of which are recognized for their antimalarial properties. These are quinones [34], flavonoids [35], and saponosides [36, 37]. The presence of these phytoconstituents justifies the traditional use of these plants against malaria.

5. Conclusion

Work carried out in the north of Côte d'Ivoire on medicinal plants used in the treatment of malaria has made it possible to list 67 species, divided into 63 genera and 28 families, among which Fabaceae are the most represented. The majority of people interviewed are women aged 31 to 50. In recipes, the leaves are most used in the form of a decoction. Administration is mainly done orally. Phytochemical screening of crude extracts from the leaves of *Anogeissus leiocarpus* and *Nauclea latifolia* revealed phytoconstituents with anti-malarial effects. These plants could, therefore, offer hope in relieving malaria, a real public health threat. Furthermore, raising awareness among populations on the preservation of these plants must be made to avoid their disappearance in the long run.

Compliance with ethical standards

Acknowledgments

The authors would particularly like to thank the Training and Research Unit (UFR) of Biological Sciences of the Péléforo Gon Coulibaly University of Korhogo, the Botany and Plant Resources Valorization laboratory of the Nangui Abrogoua

University, the Swiss Center for Scientific Research in Côte d'Ivoire for their material and technical support. Above all, they thank all the herbalists in the town of Korhogo (Côte d'Ivoire) for their trust and their contribution.

Disclosure of conflict of interest

The authors declare no conflict of interest

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Author contributions

YS: he validated the research protocol, participated in the execution of the work, the writing and correction of the manuscript; DS: he participated in the execution of the work, identification of plants and correction of the manuscript; YK: he provided considerable help with bibliographical research and in the preparation of the manuscript.

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