



Full Length Article

Ethnopharmacological Study of Anti-Malaria Plant Species from African Pharmacopeia in Man, Côte d'Ivoire

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Abstract

This study was executed in the city of Man to fight against malaria which is a public health problem in Africa and particularly in Côte d'Ivoire. One hundred and two (102) people were interviewed for this purpose, among which they were 70 herborists and 32 traditional healers. The study led to the inventory of 28 plant species distributed into 18 botanical families with a predominance of Fabaceae. The main plants are *Albizia lebeck* (Fabaceae), *Costus afer* (Costaceae), *Tectona grandis* (Verbenaceae) and *Griffonia simplicifolia* (Fabaceae). Several plant's parts are used for medicinal recipes. The leaf (64.28%) is the most concerned. Phytomedicines preparations are either decoction (68.42%), either kneading (15.79%), either trituration (9.89%) or maceration (4.63%). Many modes of administration are practiced, where oral route by drinking is the main way (42.10%) followed by body bath (28.94%) and anal route (23.68%). The phytochemical screening of aqueous extracts from the mentioned plants exhibited sterols, polyterpens, polyphenols, flavonoids, alkaloids and saponosides. The presence of such chemical groups helped to understand the anti-malaria potential of these plants. Which one could justify their empirical use in the treatment of that disease. Therefore, *A. lebeck*, *C. afer*, *T. grandis* and *G. simplicifolia* should be investigated in dept pharmacologically for implementing novel solutions to overcome malaria.

Keywords: Decoction; Ethnopharmacology; Malaria; Fabaceae; Côte d'Ivoire

Introduction

Since the antiquity, human beings have needed plants for many purposes (Ta and N'Guessan 2021). They use plants in several domains of life: inhabitation, food and health (N'Guessan 2008). The relationship between human beings and plants brought out an emergence of many sciences: ethnobotany, ethnomedicine or ethnopharmacology. Ethnopharmacology is so defined as the scientific interdisciplinary study of the combination of material from plant, animal or mineral origin and the relating knowledges or practices, which ones are vernaculars statements expressed to modify the states of the living organisms in the goal to meet therapeutic, curative, preventive or diagnostic (Fleurentin 2012). In other words, it is the traditional medicine based on empirical use of plants. Nowadays, the use of plants for health is spreading in low incomes countries and in developed societies (Doh *et al.* 2023).

Regarding other countries, the Ivorian traditional medicine suggests solutions to any kinds of human diseases whatever modern medicine can heal them or not. The treated disorders are various, which include but not limited to diabetes, blood pressure or more and more malaria, which is the subject of this study.

Malaria is parasitosis that affects human beings, birds and monkeys (Bétti 2003). It is due to a haematozoa of the genus *Plasmodium* including four species: *P. falciparum*, *P. malariae*, *P. ovale* and *P. vivax* (N'Guessan *et al.* 2009). It is a real public health problem for African countries. The strategy recommended by WHO for a rapid and efficient treatment against the disease is biotherapy, which associates Artemether and Lumefantrine. Since the year 2012 (Noufo 2019), malaria has become a health priority for the government of Côte d'Ivoire. Although the national authorities have made efforts to eradicate this disease, 33% of people visit the country's hospitals for the treatment of

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malaria (Noufo 2022). In the city of Man, in western Côte d'Ivoire, health authorities establish the prevalence of malaria to 45%. Facing this sanitary preoccupation, research for novel solutions based on phytotherapy is required. The present study meets this vision. Therefore, it is a contribution to the search of new plants with anti-malaria properties. In the first approach, an inventory of plants with anti-malaria potentialities was listed by the herborists and traditional healers of Man. In a second approach, phytochemical screening for the scientific-based understanding of traditional recipes has been made.

Materials and Methods

Presentation of the study area

The city of Man is located in western Côte d'Ivoire at about 600 km from Abidjan (the economical capital). It is the biggest town of western Côte d'Ivoire and is situated at 7°24'0" latitude N and 7°33'0" longitude W (Fig. 1).

Material for ethnopharmacological survey

The biological material is composed of the whole plants and organs of plants encountered by the traditional healers and herborists. The technical material used during the study included a questionnaire to collect data, a secateur for collecting samples of specimens, black plastic bags, and newspaper sheets for the preservation of samples. We also needed a digital camera to take pictures and a laptop.

Material for the phytochemical screening

Plant material: That concerns all anti-malaria plant species encountered by the traditional healers.

Technical material: Classical kitchen material was necessary to prepare decoctions. We used a stove at 40°C for getting dried extracts from the decoctions. An electrical balance helped in the weighing. They were a water bath at 37°C and water heater. We also used spatulas, hydrophilic cotton as filter, a trituration ring and pincers.

Chemical products: The phytochemical screening was performed from the aqueous extracts. Distilled water was the solvent. The search for the several chemical groups molecules needed many reagents. The reagent of Stiansny served in the search of catechic and gallic tannins. The reagent of Bornstraëgen was choosen for the search for quinonic substances. Burchard and Dragendorff reagents helped in characterizing alkaloids. The catechic and gallic tannins were measured with sodium acetate and ferric chloride, respectively. To analyze sterols and polyterpens, the acetic anhydride and sulfuric acid were used. To characterize flavonoids, sulfuric alcohol, magnesium chips and isoamylic alcohol were used. A 2% alcoholic solution of ferric chloride and alcohol (90%) served respectively for the analysis of polyphenols and alkaloids. The

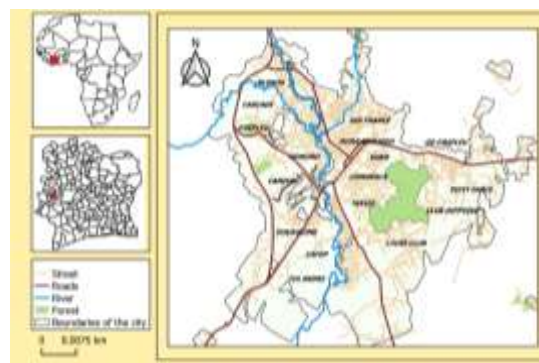


Fig. 1: Geographical localization of the town of Man in Côte d'Ivoire and in Africa

characterization of quinonic substances was realized with chloroform, bi-diluated ammoniac and chloridric acid.

Method for ethnopharmacological survey

The ethnomedecinal investigations were done in the city of Man from the fall November 2023 to April 2024 nearer traditional healers and herborists. These traditional medicine practionners were selected on the basis of information got from the National Program for Traditional Medicine (NPTM). Among 118 individuals accredited by the NPTM in the city of Man, 102 agreed to share their medicinal knowledges. Though we met 102 collaborators with their agreement at their homes or at job. Every person interviewed was questioned on the plants they use to treat malaria. Data recorded focused on parts of plants used, method of preparation and modes of administration of the phytomedicines.

Collect and identification of plant material

A prospection was performed inside many ecological areas to get samples of plants mentioned by traditional healers and herborists. Samples of plants were identified by a crew of systematians of the National Centre of Floristic of the Félix Houphouët-Boigny University of Abidjan, Ivory Coast.

Frequency of citation (FC) for species

The FC is an index in ethnobotany indicating the relation between the number of people interviewed who mention one plant species and the total number of people interviewed during the survey. The formula to determine the frequency of citation was (Sidio *et al.* 2019):

$$FC = 100 \left(\frac{\text{Number of individuals interviewed who have mentioned the plant species}}{\text{Number of individuals interviewed during the survey}} \right)$$

Phytochimal screening method

The phytochemical screening focused on the 4 plants the most mentioned during the survey, which were *Albizia*

lebbeck (Fabaceae), *Costus afer* (Costaceae), *Griffonia simplicifolia* (Fabaceae) and *Tectonia grandis* (Verbenaceae).

Aqueous extracts preparation: The aqueous extract was performed from the leaves' decoction of each of the 4 plants. We followed the classical method for the preparation of each decoction (N'Guessan *et al.* 2014). Fresh leaves (800 g) were boiled in 3 L of water for 30 min using a 5 L capacity pot. The decoction obtained (2 L) was filtered and we got 1200 mL. For phytochemical screening 1 L of the filtrate was concentrated through a sandy bath giving finally 25 mL of dried plant extract.

Tri-phytochemical characterization tests: The detection of chemical groups was based on the principle that they can induce color variations visible to the naked eye, inside an experimental medium, and in the presence of adequate reagents. In this study, the tri-phytochemical tests were performed with the aqueous extracts according to the classical method of chemical groups characterization described in previous reports (Békro *et al.* 2007).

Sterols and polyterpens test: The characterization of the chemical groups was performed throughout Liebermann's method (Kolling *et al.* 2010). We put 5 mL of each aqueous solution into a capsule posed on a sandy bath for dry evaporation avoiding turning dark. Then the residue was dissolved into 1 mL of acetic anhydride and the obtained solution was put into a test tube. We also added 0.5 mL of sulfuric acid inside the test tube to observe the chemical reaction. When purple ring turned to blue and then to green indicated a positive reaction.

Polyphenols test: The chemical reaction with FeCl_3 was carried out to detect polyphenols. A drop of the alcoholic solution of FeCl_3 (2%) was added to 2 mL of each solution. Appearance of a deep dark-blue or green color indicated polyphenol agents were presents (N'Guessan *et al.* 2009).

Flavonoids test: Flavonoids were detected throughout the chemical reaction using cyanide. Two mL of the samples evaporated to dryness in a test tube and let it cool down. The residue was solubilized in 5 mL chloridric alcohol. Then, the solution was added 2-3 chips of magnesium in the test tube and observed release of smoke. Thereafter, pink-orange or purple was obtained. Then, 3 drops of isoamyl alcohol was added, which intensified the color indicating the presence of flavonoids.

Tannins test: The search for catechic tannins was performed using the Stiasny reagent (Doh 2015). A 5 mL of the extract were evaporated to dryness. After adding 15 mL of the Stiasny reagent to the residue, the mixture stayed for 30 min in water bath at 80°C. Appearance of a precipitate characterized the catechic tannins. To investigate gallic tannins, we filtered the previous solution. Then the filtrate was saturated with sodium acetate. The adding of 3 drops of FeCl_3 made an intense dark-blue color indicating the presence of gallic tannins.

Test for free or bound quinonic substances: Free quinonic substances were detected with the Bornstraëgen reagent (Ta *et al.* 2023). To detect bound quinonic substances 2 mL sample evaporated to dryness in a test tube.

Then triturated the residue with 5 mL of chloridric acid (1/5), followed by a boiling water bath for 30 min. After cooling, the hydrolysate was mixed into a test tube with 20 mL of chloroform. The chloroform phase was decanted into another test tube to which we added 0.5 mL of diluated ammonia (1/2) was added. The appearance of a red color turning to purple indicated the presence of bound quinones.

Alkaloids test: Alkaloids were detected with the reagents of Dragendorff and Burchard (Ouattara *et al.* 2016). A 6 mL of sample was evaporated to dryness using a capsule, and the residue was mixed with 6 mL of 60% alcohol before dividing the solution into two parts (in two test tubes). Inside the first test tube, we added 2 drops of the Dragendorff reagent and inside the second test tube; we put 2 drops of the Burchard reagent. The production of orange color precipitate was proof of a positive reaction.

Saponins test: We transferred 15 mL of each extract into a test tube and Shaked it for 10 sec followed by 10 min of rest. Persistence of foam at 2 or 3 cm above solution inside the test tube indicated the presence of saponins (Adou *et al.* 2018).

Statistical analysis of data

Data regarding the FC of the plant species served for the establishment of hierarchical clusters analysis using the SPSS 20.0 software. For that, we coded plants using the Bayer's code model which consisted of designating a plant species by five letters, which letters are initials of the three first letters of the genus followed by the two first letters of the species (Aké *et al.* 2019).

Results

Repertory of plants encountered and ethnomedicinal characteristics

Inventory of plants: Ethnopharmacological investigations of the anti-malaria plants led to the inventory of 28 plants species belonging to 18 families. List of the plant species, the botanical families and their ethnomedicinal characteristics are mentioned in Table 1. Data recorded in Table 1 exhibits a dominance of the Fabaceae family with 5 species.

Ethnomedicinal characteristics: Parts of plants used were the leaf (64.28%), the root (10.71%), the fruit (7.14%), the stem bark (7.14%) and sometimes the whole plant (7.14%). The leaves were the most employed organs of plants to cure malaria (Fig. 2). The techniques of preparation of medicinal recipes were as follows: the decoction (68.42%), the kneading (15.79%) the trituration (9.89%) and the maceration (4.63%). Traditional drugs were mainly prepared as decoction (Fig. 3). In a decreasing rank, phytomedicines were administered as drink (42.10%), body bath (28.94%) or by anal route (23.68%).

FC of inventoried plants

The hierarchical cluster built from the FC values given as

Table 1: Plants inventoried and ethnomedicinal characteristics

Plants species	Botanical Families	Organs used	Technicals of preparation	Administration modes
<i>Albizia lebbbeck</i>	Fabaceae	Leaf	Decoction	Drink
<i>Alchornea cordifolia</i>	Euphorbiaceae	Root Leaf Seed	Decoction Kneading	Drink, Anal route
<i>Allamanda cathartica</i>	Apocynaceae	Leaf Bark	Decoction	Body bath
<i>Amphicarpaea bracteata</i>	Fabaceae	Whole plant	Decoction	Body bath
<i>Azadirachta indica</i>	Meliaceae	Leaf Stem bark	Decoction	Drink Body bath
<i>Blighia sapida</i>	Sapindaceae	Leaf Fruit	Decoction Trituration	Anal route
<i>Cassia siamea</i>	Fabaceae	Leaf Root	Decoction	Body bath (+black soap)
<i>Centrosema virginianum</i>	Fabaceae	Whole plant	Decoction	Drink
<i>Chromolaena odorata</i>	Asteraceae	Leaf	Decoction trituration	Body bath Anal route
<i>Clausea lansium</i>	Rutaceae	Leaf	Maceration	Body bath
<i>Cnestis ferruginea</i>	Connaraceae	Leaf Fruit	Decoction Trituration	Anal route
<i>Combretum indicum</i>	Combretaceae	Leaf	Decoction	Drink
<i>Combretum micranthum</i>	Combretaceae	Leaf	Decoction	Drink
<i>Combretum paniculatum</i>	Combretaceae	Leaf	Decoction	Body bath
<i>Costus afer</i>	Costaceae	Leaf	Decoction	Drink
<i>Cyperus eragrostis</i>	Cyperaceae	Whole plant	Kneading	Drink Anal route
<i>Elaeis guineensis</i>	Arecaceae	Leaf	Decoction Kneading	Body bath Anal route
<i>Erigeron sumatrensis</i>	Asteraceae	Leaf	Decoction	Anal route
<i>Euphorbia hirta</i>	Euphorbiaceae	Leafy branch	Decoction (+ peper) Kneading	Drink Anal route
<i>Ficus exasperata</i>	Moraceae	Leaf Stem bark	Decoction Kneading	Drink Anal route
<i>Griffonia simplicifolia</i>	Fabaceae	Leaf	Decoction	Drink
<i>Heliotropium indicum</i>	Boraginaceae	Leaf	Decoction	Body bath
<i>Markhamia lutea</i>	Bognoniaceae	Leaf	Decoction	Drink
<i>Solanum mauritianum</i>	Solanaceae	Leaf	Decoction	Drink Bain corporel
<i>Solenostemon monostachyus</i>	Lamiaceae	Leaf	Decoction	Drink Body bath
<i>Synedrella nodiflora</i>	Asteraceae	Leaf	Decoction Kneading	Drink
<i>Tectona grandis</i>	Verbenaceae	Leaf	Decoction	Drink
<i>Tithonia diversifolia</i>	Asteraceae	Leaf	Decoction	Drink

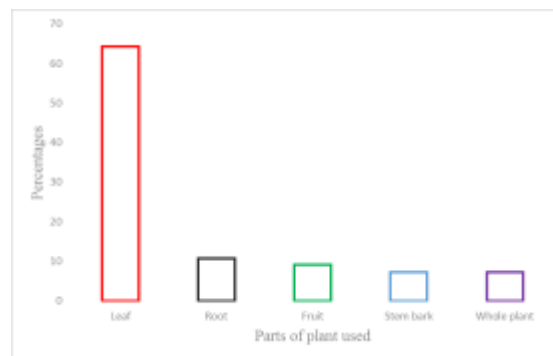
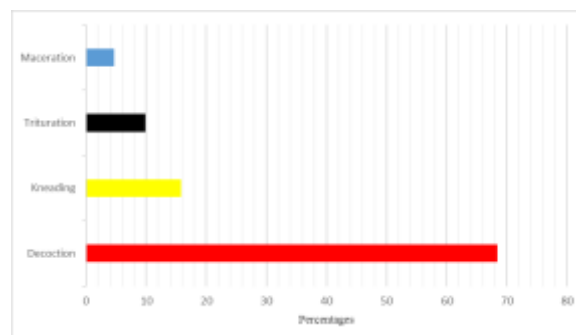
dendrogram highlighted two groups of plants at the distance cluster of 3 (Fig. 4). The first group was composed of 4 plants, the most mentioned during the ethnopharmacological survey. They were *A. lebbbeck* (FC=0.153), *C. afer* (FC=0.151), *T. grandis* (FC=0.145) and *G. simplicifolia* (FC=0.149). The second group constituted other plants species for which the FC values varied between 0.003 and 0.057.

Phytochemical screening

Results of the phytochemical screening are given in Table 2. Sterols and polyterpens were presents in medium proportions in the most mentioned four plants species. Polyphenols were abundant in the aqueous extracts of *A. lebbbeck*, *C. afer* and *T. grandis*. Saponi were also present in the plant extracts, while there were no quinonic substance in these plants. On the other side, four plants investigated contained alkaloids (with Dragendorff reagent).

Discussion

The study led to inventory of 28 plants specie used against malaria in traditional medicine in the city of Man. These plants belonged to 18 botanical families with a Fabaceae dominance. The predominance of plants from the Fabaceae family in the fight against plasmodium was already reported in a previous study in Agboville, Côte d'Ivoire (Kipré et al. 2017). The report of only three plants species i.e., *Alchornea cordifolia*, *Azadirachta indica* and *Cnestis ferruginea*

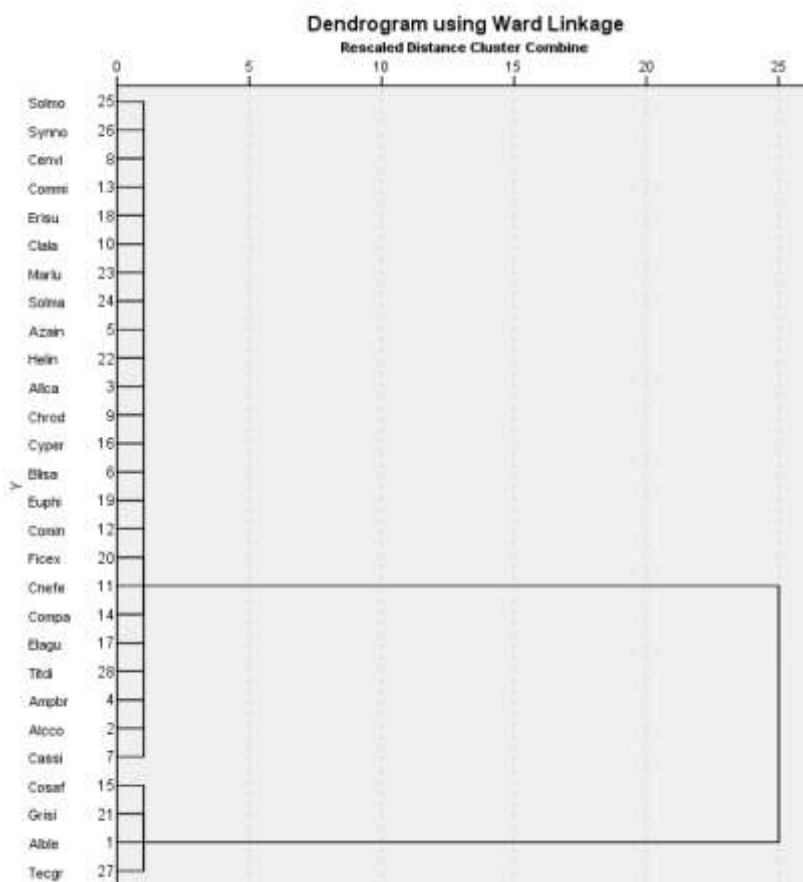
**Fig. 2:** Parts of plants used in medicinal recipes**Fig. 3:** Technicals of preparation of medicinal recipes

inventoried was done in Côte d'Ivoire for their anti-malaria potential (Sylla et al. 2018). The other 25 plants were kept

Table 2: Results of the phytochemical screening of the aqueous extracts of the 4 plants investigated

Chemical groups		<i>Albizia lebbek</i>	Plants <i>Costus afer</i>	<i>Griffonia simplicifolia</i>	<i>Tectona grandis</i>
Sterols and polyterpens		+	+	+	+
Polyphenols		++	++	+	++
Flavonoids		++	++	++	++
Tannins	Gallics	—	—	—	—
	Catechics	—	—	+	+
Quinonic substances		—	—	—	—
Alkaloids	Dragendorff	++	+	+	+
	Burchard	+	=	++	+
Saponosides		+	++	+	+

Legend: ++: Abundant +: Medium —: Absence

**Fig. 4:** Hierarchical cluster of plants inventoried according to FC values

secret. In regard to the ethnomedicinal characteristics, this work showed that the parts of plants employed were leaf (64.28%), root (10.71%), fruit (7.14%) and stem bark (7.14%) or the whole plant (7.14%). Healers focused more on leaves to prepare anti-malaria recipes as reported earlier (Zirihi 2006; Bla *et al.* 2015).

Results further revealed that preparation of the phytomedicines were decoction (68.42%), kneading (15.79%), trituration (9.89%) and maceration (4.63%). This indicated that decoction was more employed in the treatment of malaria, which corroborated the findings of Ambé *et al.* (2015) and Béné *et al.* (2016). In fact, the

decoction concentrates sufficient active compounds from the drug and has the advantage of reducing the toxicity of some plants (Soro *et al.* 2015). This information is beneficial for the progress in science, because in traditional medicine drugs obtained after decoction are well known. This work underlines that phytomedicines are more administered orally (42.10%). This is similar with the results of N'Guessan *et al.* (2015) who mentioned that drink (46.98%) is the main way to administer traditional anti-malaria preparation.

The phytochemical screening focused on the plants mainly cited in this study included *A. lebbek* (FC=0.153),

C. afer (FC=0.151), *T. grandis* (FC=0.145) and *G. simplicifolia* (FC=0.149), revealing the chemical groups responsible of the anti-malaria activity of the plants. All these four plant species contained sterols, polyterpens, polyphenols, flavonoids, alkaloids (Buchard) and saponins. In a previous report, Esseh *et al.* (2019) assigned alkaloids, flavonoids and saponins among the chemical groups which contain molecules with anti-plasmodial property. Elsewhere, Nassirou *et al.* (2015) assigned the anti-plasmodial activity to polyphenols. The presence of these phytochemicals in the aqueous extracts of the anti-malaria plants probably could justify the empirical use of the plants mainly mentioned in this study.

Conclusion

This work inventoried 28 anti-malaria plant species in the city of Man in Côte d'Ivoire but *A. lebeck*, *C. afer*, *T. grandis* and *G. simplicifolia* were predominant. Parts of the plants mostly used was leaf for anti-malarial medicinal purpose. The phytomedicines mostly prepared were decoction taken orally. The efficacy of these anti-malaria treatments could be justified by the presence of sterols, polyterpens, polyphenols, flavonoids, alkaloids and saponosides, which evidence has been established throughout the phytochemical screening. This study contributed significantly to the research of novel plants with anti-malaria potentials. More plant species could be investigated in pharmacology to find new solutions malaria treatment.

Acknowledgements

The botanical identification of the plants inventoried and the phytochemical screening performed in this work, have been realized at the Félix Houphouët-Boigny University of Abidjan. The authors are thankful of all the authorities of the University and its researchers who have participated to these steps of the work.

Authors Contributions

BIHT conceptualized research work and collected field data. KT directed the botanical identification of plants and the phytochemical screening at the Félix Houphouët-Boigny University of Abidjan. CBA and KSD analyzed data and contributed actively to the writing of the manuscript with BIHT. Authors reviewed the final version of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest in this work.

Data Availability

The data shown in this study will be available on request to

the corresponding author.

Ethics Approval

Not applicable to this study.

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