Research Article

Natural Products as Sources of Antimalarial Drugs: Ethnobotanical and Ethnopharmacological Studies

Oluwole Solomon Oladeji, Abimbola Peter Oluyori, Deborah Temitope Bankole, and Tokunbo Yemisi Afolabi

Natural Products Research Unit, Department of Physical Sciences, College of Pure and Applied Sciences, Landmark University, PMB 1001, Omu Aran, Kwara State, Nigeria

Correspondence should be addressed to Oluwole Solomon Oladeji; oladeji.oluwole@lmu.edu.ng

Received 2 October 2019; Revised 6 April 2020; Accepted 24 April 2020; Published 11 May 2020

1. Introduction

Malaria is one of the communal diseases of man contributing to stern sociocultural, economic, and health influences in humid, middle-income nations, sub-Saharan Africa, Southeast Asia, and South America [1, 2]. It is instigated by Plasmodium ovale, P. malariae, P. falciparum, P. vivax, and P. knowlesi [3]. The outburst of malarial infections in Africa, the Caribbean, Asia, and South America is symptomatic of P. falciparum, the most lethal malaria parasite. The parasite could accumulate in the brain capillaries [4, 5]. Malarial infections in India, Central American, and East Mediterranean could be concomitant to P. vivax while P. ovale and P. malariae are prevalent in Papua New Guinea and sub-Saharan Africa [6].

Malaria epidemic has been enormously high in low socioeconomic empowered regions. In Africa, nearly 19 million cases of malaria infections have been reported accounting to 89% of the global cases and almost 17 million deaths have been published [7]. Also, about 450 thousand
African children’s deaths have been reported and one-tenth of pregnancy deaths have been concomitant to malaria infections [2, 8]. It affected the morbidity and mortality rate owing to pathogenic resistance to conventional drugs, vector control agents, and human migration [9]. Several factors have been analysed and reported to control malaria infections in Africa. These are climate suitability, dams or reservoirs, migration, and vegetation. According to the report published by The World malaria in 2018, malarial cases have tremendously reduced in relation to the report of 2010. Despite this, between 2015 and 2017, no significant progress was achieved in curbing malaria cases [10]. This trend could be indicative of the widely spread of drug-resistant malaria and the intricacy of parasites’ life cycle [11].

Quinoline (QN) derivatives are undoubtedly the commonest antimalarial drugs in Africa. Examples of quinoline antimalarial drugs are quinine, amodiaquine, piperaquine, primaquine, pyronaridine, ferroquine, isooquine, amopyr-oquine, tertbutylisooquine, mefloquine, tafenoquine, and chloroquine. 4-Aminoquinoline is the most accessible antimalarial pharmacophore used in the last century. In recent times, QN derivatives have been integral component of Artemisinin-based Combination Therapy (ACT) [12]. The discovery of ACT could be considered as the most noteworthy achievements of ethnomedical research in the 20th century [13–15], enthused by the use of Artemisia annua L. (Asteraceae). The drug was found effective against all the malarial parasites and led to regulations against quinine-based drugs in Africa. However, despite the predominant achievements of ACT, concerns about the future efficacy of artemisinin have recently been on the rise due to the building-up of resistance by the parasite [7]. This event instigates the unrelenting search for promising antimalarial drugs that are cost-effective, handy, acceptable, and scientifically proven.

Human has used medicinal plants for malaria, cholera, yellow fever, and diabetes treatment [16]. In most African countries, medicinal herbs are viewed as alternative therapies. Medicinal plants have effectively helped in primary health care for the therapy of acute and chronic diseases [17, 18]. They have contributed to the discovery of novel therapeutic agents via isolation, identification, and characterization of secondary metabolites [19]. Secondary metabolites such as flavonoids, stilbenes, coumarins, lignin, tannins, terpenoids, and steroids have been reported as antimalarial compounds [20].

Tropical plants are identified to contain high proportions of natural chemical compounds and a greater diversity than plants from any other biome. Thus, they are potential sources of new medicines [21]. The increased number of drug-resistant strains makes the development of novel antimalarial urgent. The high cost of malaria treatment has left the poor masses of Nigeria heavily reliant on traditional practitioners and medicinal plants for the treatment of the disease. It seems logical to encourage studies on plants from these regions, especially since the major proportions of malaria attributable deaths occur in sub-Saharan African regions. Although several compounds had achieved success at treating malaria diseases, the emerging threats of drug resistance by some plasmodium species call for the development of new molecules with novel bioactive features. The study explores the ethnomedical and ethnomedical appraisal of antimalarial plants used by people of Omu Aran, Ogbomoso, Ado Ekiti, and Sagamu communities in Nigeria. Hence, the search for novel natural antimalarial molecules in selected plant sources via ethnomedical and ethnomedical investigation is clearly justified.

2. Methodology

2.1. Geographical Description of the Study Area. The study area comprises four states, namely, Kwara (Omu Aran), Oyo (Ogbomoso), Ekiti (Ado Ekiti), and Ogun (Sagamu) in Nigeria located on 8°08’N (5°06’E), 8°08’N (4°15’E), 7°37’16”N (5°13’17”E), and 6°50’N (3°39’E), respectively. The study areas are located in two important geopolitical zones, that is, Omu Aran (North central), Ogbomoso, Sagamu, and Ado Ekiti (Southwest) of Nigeria (Figure 1). The inhabitants are majorly from the Yoruba ethnic group. The study area falls into the category of state with most prevalence of malaria in Nigeria according to MIS report.

2.2. Typical Vegetation of the Study Area. Ado Ekiti and Sagamu fall in the rain forest region, characterized by temperature of 21°C to 28°C, high humidity, and two distinct seasons, rainy season from April to October and dry season from November to March with mean annual rainfall of 1320 mm. Ogbomoso and Omu Aran fall in the savanna region, characterized by temperature of 21°C to 33°C with heavy rainfall between April and October. The humidity is high (51.1%) with mean annual rainfall of 1885 mm. The study sites are opulently rich in evergreen floras and this promotes the use of local herbs for diseases prevention and cure.

2.3. Selection of the Informants. For this study, relevant information and data were procured from selected people in the study area via interview using structured questionnaire to procure relevant knowledge of antimalarial plants used in the vicinity. The questions were structured in a simple way and interpreted to selected respondents selected by nomination method after verbal authorization and approval by the chiefs in the study areas. In a particular study area, the leaders suggested prominent people with vast experience in herbal medicines or practitioners of herbal medicines. For reliability and reproducibility, respondents that accepted to be interviewed were briefed on the significance and objectives of the study. A disclaimer was presented to the interviewees that the views, ideas, and opinions expressed belong solely to the interviewers, and not necessarily to any committee or individual. While conducting the research, researchers were honest but not too detailed in briefing the respondents what he or she needed to do. Conducting the survey involved series of activities. These include establishing cordial relationship with respondents, selecting easy ways of interacting, observation, and recording the findings.
Respondents selected must meet the following criteria: (1) they should be indigenous people of Yoruba; (2) they are sound and knowledgeable in phytotherapy; (3) they are accessible to medicinal plants; (4) they must have used herbs for treating malaria; (5) they are approachable and organized.

2.4. Structured Questionnaire. The structured questionnaire was designed according to the technique of Olorunnisola et al. [22] and Sarquis et al. [23] with slight modification. The moderated questionnaire entails information on respondent biodata, commonly used antimalarial medicinal plants, plant parts frequently used, the most effective herbs from the respondents list, mode of preparation, and common side effects of antimalarial plants.

2.5. Data Collection. The study was piloted for 6 months, from March to August 2019. The mode of data collection was through one-on-one interviews, public discussion, and observation. The interviews were conducted mostly in Yoruba (native) language. The respondents gave the native names of plants and showed the interviewers the available plant samples. Information on the questionnaires was supplied on the spot of interview, and several observations and discussions were conducted prior to completing and cross-checking of the information provided.

2.6. Data Analysis. The antimalarial medicinal plants itemized by the respondents were structured according to the scientific, common, and local names, family, plant part used, and mode of preparation. The malarial diseases' symptoms and probable health effects or body reactions were reported. Data were statistically analysed in percentages using Graphpad Prism software (version 6.0). The comparative significance of a plant species for its ethnopharmacological activity was evaluated with the Index of Use Value (UV) and efficiency level (EL).

2.6.1. Use Value (UV). It is a quantifiable catalogue that denotes the therapeutic importance of each medicinal plant species. It is calculated by \( UV = \frac{\sum Ui}{n} \), where \( Ui \) is the total number of times plant species is cited and \( n \) is the total number of respondents interviewed. UV element helps evaluate plant species frequently mentioned for antimalaria. A high UV denotes plant mentioned mostly by respondents and low for sparingly mentioned [23].

2.6.2. Efficiency Level (EL). It is a qualitative index that signifies the efficacy of a single plant species from the list of plants given as a response by the interviewees. EL is calculated by \( CL = Ui \), where \( Ui \) is the total number of times a particular plant species is mentioned as the most effective from the list of plant species level. EL indicates plant species showing the most effective therapeutic potentials. A high EL denotes the most efficacious plant.

3. Results and Discussion

3.1. The Demographic Details of the Informants. A total of 90 interviewees (44 men and 46 women) were involved in this ethnobotanical and ethnopharmacological survey. Demographic details of the interviewees are listed in Table 1. The respective age distribution and the level of education of the respondents are shown in Figure 2.

3.2. The Effectiveness of the Medicinal Plants. In this study, 57 respondents (63%) strongly agreed and 26 respondents (29%) agreed that malaria is curable using medicinal herbs while 7 respondents (8%) were neutral. This denotes the local belief in phytotherapy of malaria. The study site has rich vegetation diversity ranging from creeping plant to shrubs and trees. A large number of these plants are used by the inhabitants in malaria therapy due to persistent spread of malaria in these regions.

3.3. Indigenous Notion of the Study Area on Malaria. The common symptoms of malaria and side effects of antimalarial plants according to the native knowledge of Ado Ekiti, Ogbomoso, Omu Aran, and Sagamu people are detailed in Table 2. Yoruba people identify malaria as “iba” and presumed malaria as a common and seasonal disease. From one-on-one interview and observations, malaria prevalence is significantly high during the rainy season in the study areas. According to the respondents, malaria is caused by long-time exposure to rain, cold, hot sun, stress, and mosquito. They believed that these could disrupt the temperature balance in the body.

Likewise, the respondents were screened to procure knowledge of malaria via the common symptoms they experienced (Figure 3) Fever, body pain, fatigue, and headache are the common symptoms in the study area and are related to temperature balance of the body system. The local people believed that it could be caused by excessive heat and long-time exposure to cold environment which forces the body to produce excessive heat. Moreover, they explained that fever
could lead to other symptoms such as headache, fatigue, body pain, and sweating. According to the respondents, probable ways of preventing malaria include reduction in exposure to rain (cold areas) or sun (hot areas), avoidance of mosquito bites, reduction in workload (stress), constant use of antimalarial herbal drugs, and burning of aromatic an- timalarial plants which could pose threats to mosquitoes.

Medicinal plants are universally reported to produce uncharacteristic effects ranging from simple to intricate. The respondents were screened to procure information on common health effects associated with antimalarial herbal drugs. Several reports were obtained, grouped as dizziness, sweating, weakness, frequent urination, itching, and no side effects (Figure 4) However, 15 (70%) respondents cited other effects produced by medicinal plants on their body systems. The respondents believed that these effects are related to the nature of medicinal plants combined, quantity of herbs taken, period when herb is used, temperature of herbal drugs (warm or cold), season drugs are taken, severity of malaria, and body capacity.

3.4. Assortment of Antimalarial Therapeutic Plants. A total of 59 medicinal plants were cited which belong to 33 families. These are Asteraceae (6), Apocynaceae (5), Anacardiaceae, Annonaceae, Fabaceae, Malvaceae, Meliaceae, Poaceae and Rubiaceae (3 each), Phyllanthaceae (2) totaling 48.83% of the sampled species while Asteraceae, Aracaceae, Asphodelaceae, Boraginaceae, Bromeliaceae, Caricaceae, Cucurbitaceae, Lamiaceae, Lythraceae, Menispermae, Moringaceae, Musaceae, Rutaceae, Sapindaceae, Myrtaceae, Solanaceae, Zingiberaceae, Solanaceae, Meliaceae, Theaceae, Labiatae, Hymenocardia, and Zingiberaceae accounted for 22.5% of families mentioned once (Table 3) The most cited plants include Azadirachta indica (42), Mangifera indica (38), Carica papaya (28), Cymbopogon citratus (27), Cassia fistula (15), Morinda lucida (14), Anacardium occidentale and Vernonia amagadina (13 each), Helianthus annuus (11), Enantia chlorantha (10), Moringa oleifera (9), Chromolaena odorata, and Psidium guajava (7 each) The efficacy of a plant species is evidenced in its number of citations, thus, becoming spotlight in pharmacological research leading to the discovery of novel antimalarial drugs. However, we cannot rule out the possibility of cultural factors unrelated to efficacy as having impacted the citation rate.

3.5. Used Medicinal Plant Parts. The commonest used parts cited are leaf (46), bark (17), fruits (9), root (9), latex (11), stem (11), and inflorescence (2) (Figure 5) Many antimalarial herbal drugs are commonly prepared from a single plant part, although they could be prepared from the assortment of two or more plant parts. In this survey, leaf and bark were the most cited plant parts contributing to 255 and 101 of the 480 plant parts cited by the respondents. Leaves are the most commonly used plant parts in Nigeria [24, 25]. This could be due to the simplicity of the collection, site of synthesizing majority of plant secondary metabolites, and diverse bioactive compounds appraised by preliminary phytochemical investigations of leaves [26–28]. Systematic harvest of leaves has little or no influence on plants survival. This explains the frequent utilization of leaves in herbal recipes [29, 30].

3.6. Forms of Herbal Drugs’ Preparations for Malaria Therapy. The common herbal drugs’ preparations according to the study were categorized as decoction, maceration, infusion, and exudation (Table 3) The most cited methods of preparation are decoction (59%), maceration (25%), infusion (9%), and exudation (7%) (Figure 6) Decoction was cited 99 times; maceration, 65 times; infusion, 35 times; and exudation, 13 times. Decoction is commonly used in herbal recipes because recipe could be stored, could have long-life span, could be taken orally, and could be used as bath. Due to heat treatment, recipe is safe to administer and more metabolites are believed to be extracted. Maceration is also

---

**Table 1: Demographic details of the informants (N=90).**

| Biodata      | Group of informants | No of informants, n (%) |
|--------------|---------------------|-------------------------|
| Age          | 20–39 years old     | 49 (54.44)              |
|              | 40–59 years old     | 22 (24.44)              |
|              | 60–79 years old     | 15 (16.67)              |
|              | >80 years old       | 4 (4.44)                |
| Sex          | Male                | 44 (48.88)              |
|              | Female              | 46 (51.11)              |
| Illiterate   | Male                | 44 (48.88)              |
|              | Female              | 46 (51.11)              |
|              | Illiterate (none)   | 16 (17.78)              |
| Education    | Primary level       | 07 (7.78)               |
|              | Secondary level     | 23 (25.56)              |
|              | Tertiary level      | 44 (48.89)              |
| Location     | Urban               | 54 (60.00)              |
|              | Rural               | 36 (40.00)              |

**Figure 2:** Age distribution and level of education of the respondents.
common among the Yorubas. It involves permeation of the plant materials (mostly bark and root) in aqueous (water) or organic (alcohol) solvents.

3.7. Assessment of the Different Indexes. In this study, UVs within 0.47 and 0.11 is appraised as frequently used anti-malarial plants by the Yorubas: *Azadirachta indica* (0.47), *Mangifera indica* (0.42), *Carica papaya* (0.31), *Cymbopogon citratus* (0.3), *Cassia fistula* (0.17), *Morinda lucida* (0.16), *Anacardium occidentale* (0.14), *Vernonia amygdalina* (0.14), *Helianthus annuus* (0.12), and *Enantia chlorantha* (0.11) (Table 3) The most significant plant species are those with high UV and should be compiled for preservation.

The EL appraised the efficacy of a particular plant from the catalogue given by the interviewees. In this study, 11 different medicinal plants were mentioned by the respondents as most efficacious from array of medicinal plants listed. 26 respondents cited *A.indica* and *C.fistula* while *M. lucida* was cited by 12 respondents; *C. odorata*, 10 respondents; *M. indica*, *E. chlorantha*, and *H. annuus*, 8 respondents each; *C. citratus* (7 respondents); *G. arboreum*, 4 respondents; *L. dulcis*, 3 respondents; and *A. vera*, 2 respondents.

The *in vitro* and *in vivo* antiplasmodial potency of medicinal plants has been appraised against *P. falciparum*, *P. berghei*, and *P. yoelii*. Some of the plants with exceptional antiplasmodial activities are *P. guajava* [31], *N. latifolia* [32], *C. citratus* [33, 34], *U. chamae* [35], *E. chlorantha* [36, 37], *O. gratissimum* [38], *A. leiocarpus* [39], *P. amarus* [40], *A. indica* [41, 42], *C. odorata* [43, 44], *M. lucida* [45, 46], *V. amygdalina* [47], *A. boonei* 44, 48], *A. senegalensis* [48], *A. occidentale* [49, 50], *B. ferruginea* [51], *G. arboreum* [48], *M. oleifera* [39], and *S. jollyanum* [44].

About four plant species are mentioned for the first time as antimalarial medicinal plant. These plants have a low UV indicating that there is little awareness on these plants in the region. The plants are *Cocos nucifera* (0.01), *Curcuma longa* (0.01), *Forkia biglobosa* (0.01), and *Musa acuminate* (0.01).

3.8. Antimalarial Assays of Medicinal Plants. Herbal plants are essential part of biodiversity which have proven to ease and remediate several diseases and infections. In tropical African countries, herbal medicine has been an undisputable therapeutic medium as alternative to conventional medicine [52]. In view of this, therapeutic potentials of medicinal

| Table 2: The common symptoms of malaria and the health effects of antimalarial herbal drugs. |
|---------------------------------------------------------------|
| Common symptoms of malaria | No of informants, n (%) | Health effects of antimalarial herbal drugs | No of informants, n (%) |
|-----------------------------|--------------------------|---------------------------------------------|--------------------------|
| Fever                       | 25 (28)                  | Dizziness                                   | 16 (18)                  |
| Fatigue                     | 33 (37)                  | Sweating                                    | 44 (49)                  |
| Body pain                   | 58 (64)                  | Weakness                                    | 22 (6)                   |
| Vomiting                    | 6 (7)                    | Frequent urination                          | 24 (5)                   |
| Sweating                    | 26 (29)                  | Itching                                     | 5 (6)                    |
| Headache                    | 65 (72)                  | No side effects                             | 36 (40)                  |

![Figure 3: Common symptoms of malaria.](image1)

![Figure 4: Health effects of antimalarial herbal drugs.](image2)
| Botanical name                                      | Local name(s)          | Family name     | Parts used | Common method of preparation     |
|---------------------------------------------------|------------------------|-----------------|------------|----------------------------------|
| (1) *Acanthospermum hispidum* (starburr, goat head) | Dagunro                | Asteraceae      | Stem, leaves | Decoction, maceration             |
| (2) *Ageratum conyzoides* (billygoat-weed, goatweed, chickweed, whitewed) | Imi-esu                | Asteraceae      | Leaves     | Decoction                         |
| (3) *Anogeissus schimperi*                         | Ayin                   | Combretaceae    | Leaves, bark| Decoction, maceration             |
| (4) *Aloe vera* (Aloe)                             | Ahon erin              | Asphodelaceae   | Leaves     | Exudate                           |
| (5) *Alstonia boonei* (cheese wood, stool wood)    | Ahun                   | Apocynaceae     | Bark, root | Decoction, infusion, maceration   |
| (6) *Anacardium occidentale* (cashew)              | Kasu                   | Anacardiaceae   | Stem, leaves, bark | Decoction, infusion, maceration |
| (7) *Ananas comosus* (pineapple)                   | Eso alade, ope oyinbo  | Bromeliaceae    | Unripe fruit| Exudate, decoction                |
| (8) *Annona senegalensis* (African custard apple, wild soursop) | Arere              | Annonaceae      | Root       | Infusion, maceration              |
| (9) *Azadirachta indica* (neem, Indian lilac, nimtree) | Dogoyaro, eka ebo    | Meliaceae       | Bark, leaves, root, | Decoction, infusion, maceration |
| (10) *Bridelia exaltata* (scrub ironbark, brush ironbark) | Ira, iran oda, ira eju | Phyllanthaceae  | Bark       | Decoction, maceration             |
| (11) *Bryophyllum pinnatum* (cathedral bells, miracle leaf, life plant) | Abamoda               | Crassulaceae    | Leaves     | Decoction                         |
| (12) *Calotropis proceras* (sodium apple, rubber bush) | Bomu-bому             | Apocynaceae     | Leaves, fruit| Decoction, exudate                |
| (13) *Camellia sinensis* (tea bush)                | Werepe                 | Theaceae        | Leaves     | Decoction                         |
| (14) *Capsicum frutescens* (chili pepper)          | Ata-ijosi, ata-wewe   | Solanaceae      | Fruit, leaves, root         | Infusion, maceration              |
| (15) *Carica papaya* (pawpaw)                      | Ibepe                  | Caricaceae      | Stem, leaves, bark | Decoction, infusion |
| (16) *Cassia fistula* (golden shower, Indian laburnum) | Igi kasia              | Fabaceae        | Leaves     | Decoction                         |
| (17) *Cela pentandra* (kapok tree)                 | Iroko                  | Malvaceae       | Leaves     | Decoction                         |
| (18) *Chromolaena odorata* (siam weed, devil weed, Christmas bush) | Ewe akintola, awolowo, | Asteraceae      | Leaves, stem | Decoction                        |
| (19) *Citrus aurantifolia* (lime, key lime, west Indian lime, bartenders lime) | Orombo                | Rutaceae        | Leaves, fruit | Decoction, exudates              |
| (20) *Citrus aurantium* (sour orange, bigarade orange, bitter orange) | Osan jagan             | Rutaceae        | Leaves, fruit | Decoction, exudates              |
| (21) *Citrus limon* (lemon)                        | Osan wewe, ilamuna     | Rutaceae        | Stem, root, leaves, fruit | Decoction, |
| (22) *Citrus paradise* (grape)                     | Ajarra                 | Rutaceae        | Fruit       | Exudates                           |
| (23) *Cocos nucifera* (coconut)                    | Agbon                  | Areaceae        | Fruit shell | Decoction, infusion               |
| (24) *Curcuma longa* (turmeric)                    | Ota-ile pupa           | Zingiberaceae   | Fruit       | Decoction, maceration             |
| (25) *Cymbopogon citratus* (lemongrass, Malabar grass) | Oka oyiino, ewe tea, koko oba | Poaceae | Leaves, | Decoction                        |
| (26) *Enantia chlorantha* (African yellow wood)    | Awopa, dokita igbo, osu pupa | Annonaceae | Leaves, bark | Decoction, maceration             |
| (27) *Parkia biglobosa* (African locust bean, eggplant) | Igi iru, sumbala       | Fabaceae        | Leaves, bark | Decoction, maceration             |
| (28) *Gardenia ternifolia*                         | Oruwon, Gangan         | Rubiaceae       | Leaves     | Decoction                         |
| (29) *Gongronema latifolium* (bush buck)           | Arokeke                | Apocynaceae     | Leaves, bark | Decoction, maceration             |
| (30) *Gossypium arboreum* (cotton plant)           | Owu                    | Malvaceae       | Leaves     | Decoction                         |
| (31) *Helianthus annuus* (sunflower)               | Fufulele, June 12, agunmoniye | Asteraceae | Leaves | Decoction                        |
| (32) *Heliotropium indicum* (Indian heliotrope, turnsole, English combs comb) | Agogo igun, ogbe akuko, akuko omade | Boraginaceae | Stems, leaves, root, bark | Decoction, maceration, infusion |
| (33) *Hibiscus sabdariffa* (Roselle, carcade)      | Zobo                   | Malvaceae       | Flower     | Decoction                         |
| (34) *Hoslundia opposita*                          | Efrin                  | Labiatae        | Leaves     | Decoction                         |
| (35) *Hymenocardia acida*                          | Aboopa, orupa          | Hymenocardiacae | Leaves | Decoction                         |
| (36) *Khaya grandifoliola* (African mahogany)      | Oganwo                 | Meliaceae       | Bark       | Decoction, maceration             |
| (37) *Lactuca canadensis* (Canada lettuce, tall lettuce) | Yanrin                | Asteraceae      | Leaves     | Decoction                         |
| (38) *Landolphia dulcis*                           | Ilobo, ibo             | Apocynaceae     | Leaves     | Decoction                         |
plants are appraised against numerous diseases such as malaria, diabetes, cancer, ulcer, hypertension, and viral infections [53]. Generally, pharmacological activities of medicinal herbs could be linked to the existence of secondary metabolites like cardiac glycosides, saponins, tannins, flavonoids, terpenoids, and alkaloids [18]. Several plants have been explored for their antimalarial potency with curative basis exploited from ethnopharmacological beliefs (Table 4) [76].

Cymbopogon citratus. Lemongrass (Poaceae) is a perennial grass, evenly distributed in the tropic region, South and Central America, and has an outstanding profile in the folk medicine [17]. The antimalarial potential of aqueous leaf extracts of *C. citratus* assessed on twenty-five Swiss albino mice demonstrated significant prophylactic and chemotherapeutic potency against mice infected with 0.2 ml O+ human parasitized blood of *P. falciparum* after 72 h. Significant inhibition was observed in parasitaemia level of blood of infected mice [55]. A larvicidal test of geranial, an essential oil in *C. citratus*, was evaluated against *Anopheles funestus* (mature larvae) and *P. falciparum* according to the WHO standard procedure. Prominent activities were recorded at LD$_{50}$ (35.5 ppm and 34.6 ppm) after 6 h. Geranial also displayed significant antiplasmodial activity with IC$_{50}$

| Botanical name                        | Local name(s) | Family name  | Parts used | Common method of preparation |
|---------------------------------------|---------------|--------------|------------|-----------------------------|
| (39) Lawsonia inermis (Henna, Egyptian privet, cypress shrub) | Laali         | Lythraceae   | Leaves     | Decoction                   |
| (40) Lecaniodiscus cupanioides        | Akika         | Sapindaceae  | Leaves     | Decoction                   |
| (41) Mangifera indica (mango)         | Mangoro, oro  | Anacardiaceae| Bark, stem, leaves | Decoction, maceration, infusion |
| (42) Morinda lucida (brimstone-tree)  | Oruwo         | Rubiaceae    | Leaves     | Decoction                   |
| (43) Moringa oleifera (moringa, drumstick) | Ewe ile, igbale igi iyanu | Moringaceae | Leaves, bark | Decoction, maceration |
| (44) Musa acuminata (banana)          | Ogede         | Musaceae     | Leaves, root bark | Decoction |
| (45) Nauclea latifolia (African peach) | Egbo igbesi   | Rubiaceae    |            | Decoction                   |
| (46) Ocimum gratissimum (clove basil, scent plant, African basil) | Efirin, aramogbo | Lamiaceae   | Leaves, stem | Decoction |
| (47) Panicum miliaceum (proso millet, hog millet) | Poporo oka, ok a baba | Poaceae    | Stem       | Decoction, maceration       |
| (48) Parquetina nigrescens            | Igi ogbo      | Apocynaceae  | Leaves     | Decoction                   |
| (49) Pennisetum purpureum (elephant grass, napier grass, Uganda grass) | Eêsún, eêsún funfun | Poaceae | Leaves | Decoction |
| (50) Phyllanthus amarus               | Eyin olobe    | Phyllanthaceae| Leaves     | Decoction                   |
| (51) Senna alata (candle bush, candletree) | Asunwon oyinbo | Fabaceae   | Leaves, flower, fruit | Decoction, maceration |
| (52) Sorghum bicolor (durra, great millet, jowari) | Poroporo okababa | Poaceae | Stem | Decoction |
| (53) Sphenocentrum jollyanum          | Aduro koko, akerejupon | Menispermaceae | Root | Decoction, maceration |
| (54) Spondias mombin (yellow mombin, hog plum) | Okika, akika, iyye | Anacardiaceae | Leaves | Decoction |
| (55) Swietenia mahagoni (mahogany)    | Igbalode, muwagun | Astereaceae | Leaves | Decoction |
| (56) Tridax procumbens (coatbuttons, tridax daisy) |            | Annonaceae   | Leaves, stem, bark | Decoction, maceration |
| (57) Uvaria chamae (finger root, bush banana) | Eru, eruju, akisan, oko aja | Astereaceae | Leaves, root, bark | Decoction, maceration |
| (58) Vernonia amygdalina (bitter leaf) | Onugbo, ewuro | Astereaceae  | Leaves, root, bark | Decoction, maceration |
| (59) Swietenia mahagoni (mahogany)    |               | Annonaceae   |            | Decoction, maceration       |

**Figure 5:** Plant parts used for herbal preparations.

[Table 3: Continued.]

Scientifica
Enantia chlorantha. Enantia chlorantha Oliver (or Annickia chlorantha) belongs to Annonaceae family, so-called Awopa, Osu pupa or Dokita igbo, Eru meru, Kakaram, and Erena-vbogo in Nigeria. It is dense and widely distributed in Nigeria, Angola, Gabon, Cameroon, and Congo [77]. Oral administration of aqueous extract of E. chlorantha inhibited Plasmodium yoelii in mice at 0.2 to 150 mg/ml while ethanolic extract inhibited the parasite at dose of 0.05 to 0.5 mg/g. The ethanolic and aqueous extracts have ED_{50} values of 0.34 mg·g^{-1} and 6.9 mg·g^{-1} which are schizonticidal in the mode of action. The activities could be linked to the presence of saponins, tannins, simple sugars, and alkaloids [78]. Synergic reactions of E. chlorantha with N. latifolia and A. altillis were reported to display significant antimalarial and prophylactic activities. This justifies the ethnomedical practice of combination of antimalarial herbal therapies in combating acute or chronic malaria [63].

Aloe vera. The methanolic extracts of Aloe vera were assessed in vivo for its antiplasmodial potency against P. falciparum strain with 50% inhibition of 32 to 77 µg/ml. The anthrone C-glucoside homonataloin isolated inhibited the strains with activity of 13.46 ± 1.36 µg/ml (IC_{50}); similarly, homonataloin displayed activities of 107.20 ± 4.14 µg/ml (IC_{50}) [79]. C-glycosylated anthrones, that is, nataloin and 7-hydroxy-laroin, two isolated compounds in Aloe pulcherrima, displayed significant dose-independent activities on plasmodia strain using 4-day suppressive test. Pronounced activity of 56.2% was observed at 200 mg/kg/day in 48 h, which support the ethnomedical claims of the plant [80].

Carica papaya. The antimalarial property of Carica papaya leaf extracts was screened against P. falciparum 3D7 and Dd2 strains using bioassay-guided fractions and dichloromethane extract. The petroleum ether and chloroform fractions of C. papaya fruit and root assessed in vivo for antimalarial activity against early P. berghei infection in mice displayed pronounced chemosuppressive effect at P < 0.001. Significant activities were observed in petroleum ether fractions (61.78%) compared to 48.11% of chloroform fraction [71]. The synergistic effects displayed by the administration of C. papaya and V. amygda-lina in ameliorating plasmodium infection in mice showed significant result at P < 0.05. The oral administration significantly surged the RBC and PCV renaissance when compared to the disease control. This underlined the importance of plants in conventional therapy of malaria infection [68]. Ethanolic leaf extract of C. papaya was appraised on chloroquine-sensitive and chloroquine-resistant strains of P. falciparum. The extracts significantly inhibited the activities of both plasmodium strains with IC_{50} = 40.75%, 36.54%, 25.30%, and 18.0% for chloroquine-sensitive and IC_{50} = 50.23%, 32.50%, 21.45%, and 23.12% for chloroquine-resistance plasmodium strains [81].

Azadirachta indica. Azadirachta indica extract is appraised to contain bioactive compounds which dictate its potencies against P. vivax and P. falciparum [82]. Ethanolic leaf extracts assessed in vivo absolutely inhibited P. berghei growth, at azadirachtin dosage of 50 mg/kg mouse body.
| S/n | Plant name                                      | Plant part used | Country | Plasmodium species treated | Solvent used for extraction | Model                          | Control                  | Antiplasmodial activity                                                                                     | Reference |
|-----|-----------------------------------------------|-----------------|---------|---------------------------|----------------------------|--------------------------------|--------------------------|----------------------------------------------------------------------------------------------------------|-----------|
| 1   | *Icacina senegalensis*                        | Leaf            | Nigeria | *P. berghei*              | Methanol                   | Swiss albino mice             | Chloroquine              | A dose-dependent chemosuppression of the parasites was observed at different dose levels of the extract tested with a considerable mean survival time Significant decrease of parasitaemia levels was observed in 120 mg/kg body weight treated group | [54]      |
| 2   | *Cymbopogon citratus*                         | Leaf            | Nigeria | *P. falciparum*           | Aqueous                    | Swiss albino rats             | Chloroquine              | Chemosuppression of 69.65, 75.76, 78.32% (ethanol) and 64.42, 70.23, 77.41% (aqueous); artemether (86.77%) | [55]      |
| 3   | *Azadirachta indica*                          | Leaf            | Ghana   | *P. berghei*              | Aqueous and ethanol        | BALB/c mice                   | Distilled water (negative) and artemether (positive) | Optimum activity was recorded on day 4. The activity was highest with water extract of the recipe at 500 mg/kg | [56]      |
| 4   | *A. djalonensis, A. indica, C. cajan, C. cujete, L. inermis, L. alata, M. preussii, N. latifolia, O. subscorpioides, and T. glaucescens* | Stem bark, leaf, and root | Nigeria | *P. berghei*              | Ethanol and aqueous          | Swiss albino mice          | Distilled water (negative) and chloroquine (positive) | Chemosuppression of 39.8–90.5, 0.2–74.8, and 34.6–78.4% observed in MLE, ABE, and CLE The extract inhibited *P. falciparum* on mature schizont stage with IC\textsubscript{50} of 3.86 μg/ml after 32 h incubation PPCPE was active against *P. berghei NK65 in vivo*, with 51.52% reduction in parasitaemia on day 4 after inoculation | [57]      |
| 5   | *Morinda lucida, Abstonia boonei, Curcuma longa* | Leaf            | Nigeria | *P. berghei*              | Ethanol                    | Swiss albino mice             | Sulphadoxine-pyrimethamine (S-P), and quinine | Chemosuppression of 39.8–90.5, 0.2–74.8, and 34.6–78.4% observed in MLE, ABE, and CLE The extract inhibited *P. falciparum* on mature schizont stage with IC\textsubscript{50} of 3.86 μg/ml after 32 h incubation PPCPE was active against *P. berghei NK65 in vivo*, with 51.52% reduction in parasitaemia on day 4 after inoculation | [58]      |
| 6   | *Azadirachta indica*                          | Leaf            | Indonesia | *P. falciparum*          | Ethanol                    | Swiss albino mice             | Sulphadoxine-pyrimethamine (S-P), and quinine | Chemosuppression of 39.8–90.5, 0.2–74.8, and 34.6–78.4% observed in MLE, ABE, and CLE The extract inhibited *P. falciparum* on mature schizont stage with IC\textsubscript{50} of 3.86 μg/ml after 32 h incubation PPCPE was active against *P. berghei NK65 in vivo*, with 51.52% reduction in parasitaemia on day 4 after inoculation | [59]      |
| 7   | *Morinda lucida*                              | Leaf            | Nigeria | *P. berghei*              | Dichloromethane-methanol   | Adult Swiss albino mice       | Chloroquine              | IC50 = 4.2 ± 0.51 μg/mL (C. citratus), 20.6 ± 3.4 μg/mL (O. canum) and 21 ± 4.6 μg/mL (O. basilicum) | [60]      |
| 8   | *Ocimum basilicum, Ocimum canum, and Cymbopogon citratus* | Leaf            | Cameroon | *P. falciparum* and mature-stage larvae of *Anopheles funestus* | Human red blood cells in RPMI 1640 medium | Giemsa-stained blood smear | Chloroquine and artemether | Alcoholic extracts displayed no activity, ethanol extracts of neem displayed increased parasitaemia gradually from day 0 (5%, 5.1%, and 7.2%) to day 4, with mean parasitaemia of 53% Prophylactic and curative ED\textsubscript{50} of 189.4 and 174.5 μg/kg for *N. latifolia* and chemosuppressive ED\textsubscript{50} of 227.2 μg/kg for *A. altilis* | [61]      |
| 9   | *Azadirachta indica*                          | Leaf            | Saudi Arabia | *P. berghei*              | Ethanol                    | Swiss albino mice             | Chloroquine and artemether | Alcoholic extracts displayed no activity, ethanol extracts of neem displayed increased parasitaemia gradually from day 0 (5%, 5.1%, and 7.2%) to day 4, with mean parasitaemia of 53% Prophylactic and curative ED\textsubscript{50} of 189.4 and 174.5 μg/kg for *N. latifolia* and chemosuppressive ED\textsubscript{50} of 227.2 μg/kg for *A. altilis* | [62]      |
| 10  | *Nauclea latifolia, Artocarpus altilis, Murraya koenigii, and Enantia chlorantha* | Stem bark, root, leaf | Nigeria | *P. berghei*              | Ethanol                    | Berghei-infected mice         | Pyrimethamine and chloroquine | Alcoholic extracts displayed no activity, ethanol extracts of neem displayed increased parasitaemia gradually from day 0 (5%, 5.1%, and 7.2%) to day 4, with mean parasitaemia of 53% Prophylactic and curative ED\textsubscript{50} of 189.4 and 174.5 μg/kg for *N. latifolia* and chemosuppressive ED\textsubscript{50} of 227.2 μg/kg for *A. altilis* | [63]      |
| S/n | Plant name | Plant part used | Country | Plasmodium species treated | Solvent used for extraction | Model | Control | Antiplasmodial activity | Reference |
|-----|------------|----------------|---------|---------------------------|-----------------------------|-------|---------|-------------------------|-----------|
| 11  | *Morinda lucida,* *Artemisia annua* | Leaf, stem, bark | Nigeria | *P. falciparum* | Ethanol | Chloroquine | MIC for chloroquine is 0.6 μg/ml, *M. lucida* is 0.6 mg/ml, and *A. Boonei* is 0.2 mg/ml. As a prophylactic treatment, the whole plant exhibited higher antimalarial activity than either the herbal infusion or chloroquine. Methanolic extract of leaves showed highest antimalarial activity with IC50 value of 1.217 μg/ml. | [64] |
| 12  | *Cymbopogon citratus* | Whole plant | Nigeria | *P. chabaudi* AS or *P. berghei* ANKA | CBA/Ca male mice | Chloroquine | | | [65] |
| 13  | *Calotropis gigantea* | Leaf, stem, and flower | India | *P. falciparum* (3D7 strain) and *P. berghei* (ANKA) | Methanol, ethyl acetate, and chloroform | Infected BALB/c albino mice | Chloroquine | | [66] |
| 14  | *Cymbopogon citratus* | Leaf and root | Nigeria | *P. berghei* | Aqueous | Infected mice | Chloroquine | | [67] |
| 15  | *Carica papaya* and *Vernonia amygdalina* | Leaf extracts | Nigeria | Chloroquine-sensitive *P. berghei* (NK65) | Aqueous | Infected mice | Halofantrine | | [68] |
|     | *Mangifera indica,* *Psidium guajava,* *Carica papaya,* *Cymbopogon citratus,* *Citrus sinensis,* and *Ocimum gratissimum* | Bark and leaf | Cameroon | *P. falciparum* | Aqueous and ethanol | 3% hematocrit in human red blood cells | Chloroquine and artemisinin | The derived EC50 (3D7/Dd2, g/mL) are nefang 96.96/55.08, MiB-65.33/34.58, MiL-82.56/40.04, Pg-47.02/25.79, Cp-1188/317.5, Cc-723.3/141s and og-778.5/118.9. Parasite suppression of day 1 (30.3%, 43.4%, and 56.4%), day 2 (32.3%, 51.3%, and 67.4%), day 3 (39.8%, 50.6%, and 64.2%), day 4 (52.6%, 69.4%, and 79.6%) was observed at doses of 100, 200, and 400 mg/kg/day. The EC50 of 0.289 to 1056 μg/mL. The antiplasmodial EC50 of chloroquine was 0.034 μg/mL and aloe and aloe-emodin was 67 μg/mL and 22 μg/mL, respectively. | [69] |
| 17  | *Aloe megalacantha* | Leaf | Ethiopia | *P. berghei* | Swiss albino mice | Chloroquine | | | [70] |
| 18  | *Aloe vera* | Leaf | India | *P. falciparum* (MRC-2). | Aqueous | Chloroquine | | | [11] |
| 19  | *Carica papaya* | Fruit rind and root | Ethiopia | *P. berghei* | Pet ether, chloroform, and methanol | Male Swiss albino mice | Chloroquine | | [71] |
| S/n | Plant name | Plant part used | Country | Plasmodium species treated | Solvent used for extraction | Model | Control | Antiplasmodial activity | Reference |
|-----|-------------|-----------------|---------|---------------------------|-----------------------------|-------|---------|------------------------|-----------|
| 20  | *Mangifera Indica* | Leaf | Nigeria | *P. Berghei* | Aqueous | Infected albino mice | Artesunate | The extract has a dose-dependent reducing effect on the level of parasitaemia | [72] |
| 21  | *Stemonocoleus micranthus* | Stem bark | Nigeria | *P. berghei* | Hydromethanol | Swiss albino mice | Chloroquine (positive) | Chemosuppressive effect ranged from 54.14 to 67.73% and 59.41 to 94.51% | [73] |
| 22  | *Lawsonia inermis*, *Tithonia diversifolia*, and *Chromolaena odorata* | Leaf | Nigeria | *P. berghei* ANKA | Dichloromethane, methanol | Swiss albino mice | Chloroquine and artemisinin | IC50 of 0.437 ± 0.02 mg/mL and 2.557 ± 0.19 mg/mL against D6 and W2, respectively | [43] |
| 23  | *Holarrhena antidysenterica* and *Azadirachta indica* | Leaves, stem, bark | India | *P. berghei* | Aqueous | Mycoplasma free male Swiss mice | Chloroquine | The parasitaemia increased gradually in all the groups, with the maximum in the control group (day 3–35, day 9–46.98) and minimum in chloroquine arm (day 3–14.06, day 9–19.92) | [41] |
| 24  | *Euphorbia hirta* and *Vernonia amygdalina* | Whole plant, leaves | Nigeria | *P. berghei* | Ethanol | Infected mice | Camosunate, ACT | ACT was slightly potent (>50%) against chloroquine-sensitive *P. berghei* | [74] |
| 25  | *Pseudocedrela kotschyi* | Leaf | Nigeria | *P. berghei* | Ethanol | Swiss Albino mice | Chloroquine | The leaf extract exhibited significant dose-dependent activity against the parasite in the suppressive and curative activity | [75] |
Table 5: The isolated compounds from medicinal plants used as antimalarial.

| S/n | Name of plant      | Phytochemical compounds         | Structure | Reference |
|-----|--------------------|---------------------------------|-----------|-----------|
| 1   | *Morinda lucida*   | Asperulosidic acid              | ![Structure](image1.png) | [46]       |
| 2   | *C. citratus*      | Geranial                        | ![Structure](image2.png) | [55]       |
| 3   | *Aloe vera*        | 6′-Malonylnataloin (nataloin)   | ![Structure](image3.png) | [79]       |
| 4   | *Fagara zanthoxyloides* | Fagaronine                  | ![Structure](image4.png) | [84]       |
| 5   | *Enantia chlorantha* | Jatrorrhizine                | ![Structure](image5.png) | [85]       |
| S/n | Name of plant     | Phytochemical compounds | Structure | Reference |
|-----|-------------------|-------------------------|-----------|-----------|
| 6   | *Azadirachta indica* | Gedunin                | ![Structure of Gedunin](image) | [86]       |
| 7   | *Morinda lucida* | Asperuloside            | ![Structure of Asperuloside](image) | [46]       |
| 8   | *Aloe vera*       | 7-Hydroxyaloin B        | ![Structure of 7-Hydroxyaloin B](image) | [79, 80]   |
| 9   | *Khaya grandifoliola* | Methyl angolensate     | ![Structure of Methyl angolensate](image) | [87]       |
| S/n | Name of plant          | Phytochemical compounds | Structure | Reference |
|-----|------------------------|-------------------------|-----------|-----------|
| 10  | *Khaya senegalensis*   | Fissinolide             | ![Structure](image1) | [88]      |
| 11  | *Azadirachta indica*   | Meldenin                | ![Structure](image2) | [89]      |
| 12  | *Morinda lucida*       | Campesterol             | ![Structure](image3) | [46]      |
| 13  | *Quassia amara*        | Simalikalactone D       | ![Structure](image4) | [90]      |
### Table 5: Continued.

| S/n | Name of plant     | Phytochemical compounds | Structure | Reference |
|-----|-------------------|-------------------------|-----------|-----------|
| 14  | *Picralima nitida*| Akuammine               | ![Structure](image1.png) | [91]      |
| 15  | *Morinda lucida*  | Cycloartenol            | ![Structure](image2.png) | [46]      |
| 16  | *Jatropha multifida* | Multifidinol          | ![Structure](image3.png) | [41]      |
| 17  | *E. chlorantia*   | Ergosterol              | ![Structure](image4.png) | [36]      |
| S/n | Name of plant         | Phytochemical compounds     | Structure | Reference |
|-----|-----------------------|-----------------------------|-----------|-----------|
|   18 | *Cylcodiscus gabunensis* | 3,4,5-Trihydroxybenzoic acid | ![Structure](image1) | [92]      |
|   19 | *Morinda lucida*      | Stigmasterol                | ![Structure](image2) | [46]      |
|   20 | *Picralima nitida,*   | Akuammigine                 | ![Structure](image3) | [91]      |
| S/n | Name of plant               | Phytochemical compounds | Structure | Reference |
|-----|----------------------------|-------------------------|-----------|-----------|
| 21  | *Diospyros conocarpa*      | Mangiferolic acid       | ![Structure](image1) | [93]      |
| 22  | *Antrocaryon klaineanum*   | Antrocarine A           | ![Structure](image2) | [93]      |
| 23  | *C. papaya*                | Anacardic acid          | ![Structure](image3) | [94]      |
| 24  | *Picralima nitida*         | Alstonine               | ![Structure](image4) | [91]      |
weight [83]. The in vivo antiplasmodial potency of aqueous and ethanolic leaf extracts was examined in P. berghei-infected BALB/c mice at dosage of 50 to 200 mg/kg/day. Both extracts exhibited significant antiplasmodial potency in a dose-dependent technique which could be due to the active antiplasmodial compounds screened [56].

4. Conclusion and Future Prospects

Malaria is a universal civic health peril, and recent drug resistance of the parasite is a persistent concern. This study shows that a highly diverse set of native medicinal herbs is currently used for the management of malaria in Nigeria. Based on the results, there is substantial indication that the traditional use of antimalarial medicinal plants by Yoruba ethnics (studied areas) is driven by important therapeutic agents, which could be elucidated structurally and further established by in vitro or in vivo investigations. In recent times, the growing interest in phytoremediation of malaria led to the isolation and characterization of bioactive compounds in medicinal plants (Table 5). The isolation, characterization, and quantification of these compounds were appraised via chromatographic and spectrophotometric methods. Likewise, different assays such as susceptibility microassay technique [95], four day suppressive test [96], 96-well microtiter plate format SYBR green florescence assay [97], and LDH method [98] are used to appraise the antiplasmodial potential of plant extracts (Table 4).

Several modes of preparation, usage factors, health risks, and countermeasures on the use of antimalarial herbal drugs should be systematically examined through advanced scientific approaches. This will aid in the identification and authentication of therapeutic potency of antimalarial compounds isolated from medicinal herbs, thereby promoting its global relevance as efficacious and safe antimalarial plants in primary health care. Individuals, societies, sociogroups, and governmental and nongovernmental organizations should devise plans which could assist in the conservation of these medicinal plants in order to prevent their extermination and exploitation of indigenous populations, as well as considerations for cultural disruptions should one or more of these plant species become a valuable resource. In the meantime, the outcomes of this study serve as a platform of appraisal for indigenous claims of medicinal plants as effective antimalarial drugs in Nigeria and the world as a whole.

Data Availability

The datasets used and/or analysed during the current study are available in the manuscript and others not included are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the submission and publication of this article.

Authors’ Contributions

All authors designed the experiment, administered the questionnaires, and analysed and discussed the data obtained.
Acknowledgments

The authors are indebted to Landmark University, PMB 1001, Omu Aran, Nigeria, for the financial assistance.

References

[1] S. Singh, “Current scenario of control of malaria,” Tropical Parasitology, vol. 1, no. 2, p. 52, 2011.
[2] WHO, World Malaria Report, World Health Organization, Geneva, Switzerland, 2014.
[3] I. Budiman, R. Tjiosoerianto, W. Widowati, F. Rahardja, M. Maesaro, and N. Fauziah, “Antioxidant and anti-malarial properties of catechins,” British Journal of Medicine and Medical Research, vol. 5, no. 7, pp. 895–902, 2015.
[4] P. N. Kalaria, S. C. Karad, and D. K. Raval, “A review on diverse heterocyclic compounds as the privileged scaffolds in antimalarial drug discovery,” European Journal of Medicinal Chemistry, vol. 158, pp. 917–936, 2018.
[5] Y.-Q. Hu, C. Gao, S. Zhang et al., “Quinoline hybrids and their antiplasmodial and antimalarial activities,” European Journal of Medicinal Chemistry, vol. 139, pp. 22–47, 2017.
[6] N. M. Anstey, N. M. Douglas, N. M. Poesspoprodjo, and R. N. Price, “Plasmodium vivax,” Advances in Parasitology, vol. 80, pp. 151–201, 2012.
[7] World Health Organization, Guidelines for the Treatment of Malaria, World Health Organization, Geneva, Switzerland, 3rd edition, 2015.
[8] UNICEF, Roll Back Malaria, Vol. 17, United Nations International Children’s Fund, New York, NY, USA, 2000.
[9] B. N. Irungu, M. J. Mbabu, D. M. Kiboi, E. Moindi, J. Kinyua, and M. Romano, “In vivo antimalarial and acute toxicity properties of hexane and chloroform extracts from Clausena anisate (Willd.) Benth,” African Journal of Pharmacology and Therapy, vol. 1, pp. 24–29, 2012.
[10] World Health Organization, World Malaria Report, World Health Organization, Geneva, Switzerland, 2018.
[11] S. Kumar, T. Bhardwaj, D. Prasad, and R. Singh, “Drug targets for resistant malaria: historic to future perspectives,” Bio-medicine and Pharmacotherapy, vol. 104, pp. 8–27, 2018.
[12] O. A. Mokuolu, A. A. Adewara, S. O. Ayetoro, and E. O. Okoro, “Effect of artemisinin-based treatment policy on consumption pattern of antimalarials,” The American Journal of Tropical Medicine and Hygiene, vol. 76, no. 1, pp. 7–11, 2007.
[13] J. O. Adebayo and S. O. Malomo, “The effect of co-administration of dihydroartemisinin with vitamin E on the activities of cation ATPas in some rat tissues,” Nigerian Journal of Pure and Applied Sciences, vol. 17, pp. 1245–1252, 2002.
[14] A. C. Boareto, J. C. Muller, A. C. Bufalo et al., “Toxicity of artemisinin (Artemisia annua L.) in two different periods of pregnancy in Wistar rats,” Reproductive Toxicology, vol. 25, no. 2, pp. 239–246, 2008.
[15] K. Borstnik, I.-H. Paik, T. A. Shapiro, and G. H. Posner, “Antimalarial chemotherapeutic peroxides: artemisinin, yinheeosu A and related compounds,” International Journal for Parasitology, vol. 32, no. 13, pp. 1661–1667, 2002.
[16] S. O. Oladeji, F. E. Adelowo, A. P. Oyeyori, and D. T. Bankole, “Ethnobotanical description and biological activities of Senna alata,” Evidence-Based Complementary and Alternative Medicine, vol. 2020, Article ID 2580259, 12 pages, 2020.
[17] O. S. Oladeji, F. E. Adelowo, D. T. Ayodele, and K. A. Odelade, “Phytochemistry and pharmacological activities of cymbopogon citratus: a review,” Scientific African, vol. 6, Article ID e00137, 2019.
[18] O. S. Oladeji, K. A. Odelade, and J. K. Oloke, “Phytochemical screening and antimicrobial investigation of Moringa oleifera leaf extracts,” African Journal of Science, Technology, Innovation and Development, vol. 12, no. 1, pp. 79–84, 2020.
[19] J. B. Calixto, “Twenty-five years of research on medicinal plants in Latin America: a personal view,” Journal of Ethnopharmacology, vol. 100, no. 1–2, pp. 131–134, 2005.
[20] J. Bero, H. Ganfon, M.-C. Jonville et al., “In vitro antiplasmodial activity of plants used in Benin in traditional medicine to treat malaria,” Journal of Ethnopharmacology, vol. 122, no. 3, pp. 439–444, 2009.
[21] M. J. Balick, E. Elizabetesky, and S. A. Laird, Medicinal Resources of the Tropical Rain Forest, Columbia University Press, New York, NY, USA, 1996.
[22] O. S. Olorunnisola, A. Adetutu, E. A. Balogun, and A. J. Afolayan, “Ethnobotanical survey of medicinal plants used in the treatment of malarial in Ogbomoso, Southwest Nigeria,” Journal of Ethnopharmacology, vol. 150, no. 1, pp. 71–78, 2013.
[23] R. F. Sarquis, I. R. Sarquis, C. P. Fernandes et al., “The use of medicinal plants in the riverside community of the Mazagão river in the Brazilian amazon, Amãpã, Brazil: ethnobotanical and ethnopharmacological studies,” Evidence-Based Complementary and Alternative Medicine, vol. 2019, Article ID 6087509, 25 pages, 2019.
[24] M. Katemo, P. T. Mpiana, B. M. Mbala et al., “Ethnopharmacological survey of plants used against diabetes in Kisangani city (DR Congo),” Journal of Ethnopharmacology, vol. 144, no. 1, pp. 39–43, 2012.
[25] O. A. Idowu, O. T. Soniran, O. Ajana, and D. O. Aworinde, “Ethnobotanical survey of antimalarial plants used in Ogun State, Southwest Nigeria,” African Journal of Pharmacy and Pharmacology, vol. 4, pp. 55–60, 2010.
[26] M. Giday, Z. Asfaw, and Z. Woldu, “Medicinal plants of the Meinit ethnic group of Ethiopia: an ethnobotanical study,” Journal of Ethnopharmacology, vol. 124, no. 3, pp. 513–521, 2009.
[27] A. Ghorbani, “Studies on pharmaceutical ethnobotany in the region of Turkmen Sahra, north of Iran,” Journal of Ethnopharmacology, vol. 102, no. 1, pp. 58–68, 2005.
[28] A. Braca, C. Sortino, M. Politi, I. Morelli, and J. Mendez, “Antioxidant activity of flavonoids from Licania licaniae-flora,” Journal of Ethnopharmacology, vol. 79, no. 3, pp. 379–381, 2002.
[29] B. Mendez, C. M. Ven’ncio, M. A. Jardim, J. C. da Silva, and C. M. Verâncio, “Informações foler’apicas ecomposiçao ao qu’imica de Mikania lindleyana DC. (Asteraceae),” Revista Brasileira de Farm acia, vol. 83, no. 1, pp. 27–29, 2002.
[30] M. G. de Carvalho, L. F. De Oliveira Cândido, P. M. Da Costa, and V. M. Rumjanek, “Chromones from Licania arianeae–(Willd.) Benth.,” Natural Product Research, vol. 19, no. 1, pp. 379–381, 2005.
[31] N. Nundikumar and J. A. O. Ojewole, “Studies on the antimalarial properties of some South African medicinal plants used as antimalarial remedies in Zulu folk medicine,” Methods and Findings in Experimental and Clinical Pharmacology, vol. 24, no. 7, pp. 397–401, 2002.
[33] G. Bidla, V. Titanji, B. Joko, G. El-Ghazali, A. Bolad, and K. Berzins, "Antiplasmodial activity of seven plants used in African folk medicine," *Indian Journal Pharmacology*, vol. 36, pp. 245–246, 2004.

[34] B. Adzu, J. Abbah, H. Vongtau, and K. Gamanjli, "Studies on the use of *Cassia singueana* in malaria ethnopharmacy," *Journal of Ethnoveterinary Pharmacology*, vol. 88, no. 2-3, pp. 261–267, 2013.

[35] J. E. Okokon, B. N. Ita, and A. E. Udokpoh, "Antiplasmodial activity of *Cyclicodiscus gabunensis*," *Journal of Ethnopharmacology*, vol. 107, no. 2, pp. 175–178, 2006.

[36] F. M. Talonstsi, M. Lamshöft, C. Douanla-Meli, S. F. Kouam, and M. Spitteller, "Antiplasmodial and cytotoxic dibenzofurans from preussia sp. harboured in *Enantia chlorantha* oliv," *Fitoterapia*, vol. 93, pp. 233–238, 2014.

[37] F. F. Boyom, E. M. Kemgne, R. Tepongning et al., "Antiplasmodial activity of extracts from seven medicinal plants used in malaria treatment in Cameroon," *Journal of Ethnopharmacology*, vol. 123, no. 3, pp. 483–488, 2009.

[38] F. Tchoumboung, P. H. Zollo, E. Dagne, and M. N. Shuaibu, P. A. Wuyep, T. Yanagi, K. Hirayama, D. V. Dapper, B. N. Aziagba, and O. O. Ebong, "Antiplasmodial activity of extracts from seven medicinal plants used in malaria ethnopharmacy," *Indian Journal of Pharmacology*, vol. 10, no. 3, pp. 387–408, 2008.

[39] K. K. Ajibesin, B. A. Ekpo, D. N. Bala, E. E. Essien, and S. A. Adesanya, "Ethnobotanical survey of akwa ibom state Nigeria," *Journal of Ethnopharmacology*, vol. 115, no. 3, pp. 387–408, 2008.

[40] P. A. Ntonga, N. Baldovini, E. Mouray, L. Mambu, P. Grellier, "Activity of Ocimum basilicum, *Ocimum* lucida, *Azadirachta indica*, and *Plasmodium falciparum* infected balb/c mice," *International Journal of Pharmacognosy and Phytotherapy*, vol. 9, no. 6, pp. 60–64, 2014.

[41] L. A. Oseni and G. M. Akwetey, "An *in-vivo* evaluation of antiplasmodial activity of aqueous and ethanolic leaf extracts of *Azadirachta indica* in Plasmodium berghei infected mice," *International Journal of Pharmaceutical Science and Research*, vol. 3, no. 5, pp. 1406–1410, 2012.

[42] R. L. Mojirayo, "In vivo anti-plasmodial activity and histopathological analysis of water and ethanol extracts of a polyherbal antimalarial recipe," *Journal of Pharmacognosy and Phytotherapy*, vol. 9, no. 6, pp. 87–100, 2017.

[43] Y. Hanifah, T. Suryawati, and G. M. Maryatun, "Potentials of traditional antimalarial phytotherapy remedies used by the Kwaile community of the Kenyan coast," *Journal of Ethnopharmacology*, vol. 170, pp. 148–157, 2013.

[44] E. O. Ajaiyeoba, O. O. Ogbole, O. O. Abiodun, J. S. Ashidi, P. J. Houghton, and C. W. Wright, "Cajachalcone: an antimalarial compound from *Cajanus cajan* Leaf extract," *Journal of Parasitology Research*, vol. 2013, Article ID 703781, 5 pages, 2013.

[45] Y. Mekonnen, "In VivoAntimalarial activity of essential oils of *Cymbopogon citratus* and *Azadirachta indica* against *Plasmodium falciparum* in mice model," *American Journal of Biomedical and Life Sciences*, vol. 3, no. 5, pp. 1406–1410, 2012.

[46] Y. Hanifah, T. Suryawati, and G. M. Maryatun, "Potentials of traditional antimalarial phytotherapy remedies used by the Kwaile community of the Kenyan coast," *Journal of Ethnopharmacology*, vol. 170, pp. 148–157, 2013.

[47] C. N. Muthaura, J. M. Keriko, C. Mutai et al., "Antiplasmodial potential of traditional antimalarial phytotherapy remedies used by the Kwaile community of the Kenyan coast," *Journal of Ethnopharmacology*, vol. 170, pp. 148–157, 2013.

[48] E. O. Ajaiyeoba, O. O. Ogbole, O. O. Abiodun, J. S. Ashidi, P. J. Houghton, and C. W. Wright, "Cajachalcone: an antimalarial compound from *Cajanus cajan* Leaf extract," *Journal of Parasitology Research*, vol. 2013, Article ID 703781, 5 pages, 2013.
canum, and Cymbopogon citratus essential oils against Plasmodium falciparum and mature-stage larvae of Anopheles funestus," Parasite, vol. 21, p. 33, 2014.

[62] M. Faralha, S. Bedri, S. Khalid, M. Idris, C. R. Pillai, and E. A. Khalil, "Anti-plasmodial effects of Azadirachta indica in experimental cerebral malaria: apoptosis of cerebellar Purkinje cells of mice as a marker," North American Journal of Medical Sciences, vol. 2, no. 11, pp. 518–525, 2010.

[63] A. C. Adebayo, S. A. Oderidan, F. A. Aliyu, P. A. Nwafor, N. T. Nwoke, and U. S. Umana, "In vivo antiplasmodial potentials of the combinations of four Nigerian traditional plants," Molecules, vol. 19, pp. 13136–13146, 2014.

[64] I. S. Bello, T. Oduola, O. G. Adeosun, N. O. A. Omisore, A. C. Adebajo, S. A. Odediran, F. A. Aliyu, P. A. Nwafor, M. Farahna, S. Bedri, S. Khalid, M. Idris, C. R. Pillai, and G. Zeleke, D. Kebebe, E. Mulisa, and F. Gashe, "Antimalarial activity of the leaf latex and TLC isolates from Aloe pulcherrima Gilbert and Sebsebe," Molecules, vol. 21, no. 11, p. 1415, 2016.

[65] U. M. Chukwuocha, O. Fernández-Rivera, and M. Legorreta-Herrera, "Exploring the antiplasmodial potential of whole Cymbopogon citratus plant therapy," Journal of Ethnopharmacology, vol. 193, pp. 517–523, 2016.

[66] P. V. V. Satish, D. Santha Kumari, and K. Sunita, "Anti-plasmodial efficacy of Cymbopogon citratus (3D7 strain) and Plasmodium berghei (ANKA)," Journal of Vector borne Diseases, vol. 54, no. 3, pp. 215–225, 2017.

[67] D. Arome, E. Chinedu, S. Ameh, and A. Sunday, "Comparative antiplasmodial evaluation of Cymbopogon citratus extracts in Plasmodium berghei-infected mice," Journal of Current Research in Scientific Medicine, vol. 2, no. 1, pp. 29–35, 2016.

[68] O. Okpe, N. Habila, J. Ikwebe, V. A. Upev, S. R. Okoduwa, and O. T. Isaac, "Antimalarial potential of Carica papaya and Vernonia amygdalina in mice infected with Plasmodium berghei," Journal of Tropical Medicine, vol. 2016, Article ID 8738972, 6 pages, 2016.

[69] P. A. Tarkang, F. A. Okalebo, L. S. Ayong, G. A. Agbor, and A. A. Ademosun, "Evaluation of anti-malarial activity of various fractions of Morinda lucida leaf extract and Alstonia boonei stem bark," Global Journal of Pharmacology, vol. 3, no. 3, pp. 163–165, 2009.

[70] G. Hintsa, G. G. Sibhat, and A. Karim, "Evaluation of antimalarial activity of the leaf latex and TLC isolates from Aloe megalacantha baker in Plasmodium berghei infected mice," Evidence-Based Complementary and Alternative Medicine, vol. 2019, Article ID 6459498, 9 pages, 2019.

[71] G. Zeleke, D. Kebebe, E. Mulisa, and F. Gashe, "In vivo antimalarial activity of the solvent fractions of fruit rind and root of Carica papaya Linn (Carcaceae) against Plasmodium berghei in mice," Journal of Parasitology Research, vol. 2017, Article ID 3121050, 9 pages, 2017.

[72] A. A. Olayode, O. S. Saka, O. C. Ajayi, and M. A. Agbaje, "Activities of aqueous extracts of mangifera indica on parasitaemia level and blood profile of Plasmodium berghei-infected albino mice," PharmaTutor, vol. 4, no. 4, pp. 36–42, 2016.

[73] C. I. Orabueze, D. A. Ota, and H. A. Coker, "Antimalarial potentials of Stemonoecoles micranthus harms (leguminosae) stem bark in Plasmodium berghei infected mice," Journal of Traditional and Complementary Medicine, vol. 10, no. 1, pp. 70–78, 2019.

[74] E. I. O. Ajayi, M. A. Adeleke, T. Y. Adewumi, and A. A. Adeyemi, "Antiplasmodial activities of ethanol extracts of Euphorbia hirtawhole plant and Vernonia amygdalinaeaves in Plasmodium berghei-infected mice," Journal of Taibah University for Science, vol. 11, no. 6, pp. 831–835, 2017.

[75] G. C. Akudosor, A. G. Ahunna, E. M. Nwakaeogo, C. K. Chimsorom, and A. E. Chile, "Antimalarial potential of the ethanolic leaf extract of Pseudocedrula kotchyi," Journal of Acute Disease, vol. 4, no. 1, pp. 23–27, 2015.

[76] M. Gupta, U. Mazumder, P. Gomathi, and V. T. Selvan, "Antimicrobial activity of methanol extracts of Plumeria acuminata Ait., Leaves and Tephrosia Purpurea (Linn.) Pers. Roots" Natural Radiance, vol. 7, no. 2, pp. 102–105, 2008.

[77] T. Tcheghebe, N. Tatong, S. Armel, K. Justin, and N. Justin, "Ethnobotanic survey of medicinal plants used for malaria therapy in western Cameroon," Journal of Medicinal Plant Studies, vol. 4, no. 3, pp. 248–258, 2016.

[78] E. O. Agbaje and A. O. Onabanjo, "The effects of extracts of Enantia chlorantha in malaria," Annals of Tropical Medicine & Parasitology, vol. 85, no. 6, pp. 585–590, 1991.

[79] R. L. van Zyl, A. M. Viljoen, and A. K. Jäger, "In vitro activity of Aloe extracts against Plasmodium falciparum," South African Journal of Botany, vol. 68, no. 1, pp. 106–110, 2002.

[80] T. Teku, D. Bisrat, M. Yeshak, and K. Asres, "Antimalarial activity of the chemical constituents of the leaf latex of Aloe pulcherrima Gilbert and Sebsebe," Molecules, vol. 21, no. 11, p. 1415, 2016.

[81] K. Kovenden, K. Murugan, C. Panneerselvam et al., "Anti-malarial activity of Carica Papaya (family: Caricaceae) leaf extract against Plasmodium Falciparum," Asian Pacific Journal of Tropical Disease, vol. 2, pp. 306–311, 2012.

[82] P. K. Deshpande, R. Gothwal, and A. K. Pathak, "Phytochemical analysis and evaluation of antimalarial activity of Azadirachta indica," The Pharma Innovation Journal, vol. 3, no. 9, pp. 12–16, 2014.

[83] L. Lucantoni, R. S. Yerbanga, G. Lupidi, L. Pasqualini, F. Esposito, and A. Habluetzel, "Transmission blocking activity of a standardized neem (Azadirachta indica) seed extract on the rodent malaria parasite Plasmodium berghei in its vector Anopheles stephensi," Malaria Journal, vol. 9, p. 66, 2010.

[84] O. O. Kassim, M. Loyevsky, B. Elliott, A. Geall, H. Amonoo, and V. R. Gordeuk, "Effects of root extracts of Fagara zanthoxyloides on the in vitro growth and stage distribution of Plasmodium falciparum," Antimicrobial Agents and Chemotherapy, vol. 49, no. 1, pp. 264–268, 2005.

[85] R. Batista, C. C. Santana, A. V. Azevedo-Santos et al., "In vivo antimalarial extracts and constituents of Prosopis juliflora (Fabaceae)," Journal of Functional Foods, vol. 44, no. 74–78, 2018.

[86] S. MacKinnon, T. Durst, J. T. Arnason et al., "Antimalarial activity of tropical Meliaceae extracts and gedunin derivates," Journal of Natural Products, vol. 60, no. 4, pp. 336–341, 1997.

[87] J. Bickii, N. Niñufie, J. Ayaofo Foyere, L. K. Basco, and P. Ringwald, "In vitro antimalarial activity of limonoids from Khaya grandifoliola C.D.C. (Meliaceae)," Journal of Ethnopharmacology, vol. 69, no. 1, pp. 27–33, 2000.

[88] S. A. Khalid, G. M. Friedrichsen, A. Kharazmi, T. G. Theander, C. E. Olsen, and S. Brogger Christensen, "Limonoids from Khaya senegalensis," Phytochemistry, vol. 49, no. 6, pp. 1769–1772, 1998.

[89] M. C. Joshi, K. J. Wicht, D. Taylor, R. Hunter, P. J. Smith, and T. J. Egan, "In vitro antimalarial activity, b-haematin inhibition and structure-activity relationships in a series of
quinoline triazoles,” *European Journal of Medicinal Chemistry*, vol. 69, 2013.

[90] S. Bertani, E. Houël, D. Stien et al., “Simalikalactone D is responsible for the antimalarial properties of an Amazonian traditional remedy made with *Quassia amara* L. (*Simaroubaceae),” *Journal of Ethnopharmacology*, vol. 108, no. 1, pp. 155–157, 2006.

[91] R. Ansâ-Asamoah, G. J. Kapadia, H. A. Lloyd, and E. A. Sokoloski, “Picratidine, a new indole alkaloid from Picralima nitida seeds,” *Journal of Natural Products*, vol. 53, no. 4, pp. 975–977, 1990.

[92] O. Aldulaimi, F. I. Uche, H. Hameed et al., “A characterization of the antimalarial activity of the bark of *Cyclicodiscus gabunensis* harms,” *Journal of Ethnopharmacology*, vol. 198, pp. 221–225, 2017.

[93] Y. Fouokeng, H. M. Feumo Feusso, J. E. Mbosso Teinkela et al., “*In vitro* antimalarial, antitrypanosomal and HIV-1 integrase inhibitory activities of two Cameroonian medicinal plants: *Antocaryon klaineanum* (Anacardiaceae) and *Diospyros conocarpa* (Ebenaceae),” *South African Journal of Botany*, vol. 122, pp. 510–517, 2019.

[94] M. M. Gimenez, T. A. Alvarenga, M. Groppo et al., “Antiplasmodial evaluation of *Anacardium occidentale* and alkylphenols,” *Revista Brasileira de Farmacognosia*, vol. 29, no. 1, pp. 36–39, 2019.

[95] R. E. Desjardins, C. J. Canfield, J. D. Haynes, and J. D. Chulay, “Quantitative assessment of antimalarial activity in vitro by a semiautomated microdilution technique,” *Antimicrobial Agents and Chemotherapy*, vol. 16, no. 6, pp. 710–718, 1979.

[96] W. Peters, “Drug resistance in *Plasmodium berghei*. I. chloroquine resistance,” *Experimental Parasitology*, vol. 17, no. 1, pp. 80–89, 1965.

[97] R. M. K. Toghueo, E. A. M. Kemgne, P. Eke et al., “Antiplasmodial potential and GC-MS fingerprint of endophytic fungal extracts derived from Cameroonian *Annona muricata*,” *Journal of Ethnopharmacology*, vol. 235, pp. 111–121, 2019.

[98] M. T. Makler and D. J. Hinrichs, “Measurement of the lactate dehydrogenase activity of *Plasmodium falciparum* as an assessment of parasitemia,” *The American Journal of Tropical Medicine and Hygiene*, vol. 48, no. 2, pp. 205–210, 1993.