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Survey of ethnobotanical cocktails commonly used in the treatment of malaria in southwestern Nigeria

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Abstract

Background: Combination of different antimalarials has become the popular method of care for malaria morbidity in conventional and traditional treatment approaches due to the need to increase the efficacy and reduce the selection of drug resistance. A worrisome concern is the critical gaps with regards to the information available on antimalarial herbal cocktails. This study presents cocktail herbal remedies in ethnomedicinal approaches to malaria treatment in Oyo and Ogun states, South West Nigeria. Ethnobotanical information on indigenous antimalarials used in combination remedies was collected from herbal practitioners using a semi-structured questionnaire.

Results: Findings showed majority of respondents treat malaria with combination herbal remedies. They sighted their beliefs and customs, the efficacy, affordability and availability of these herbs as reasons for their adoption of herbal medicines as their preferred mode of treating malaria. Enquiry revealed 26 sets of cocktail antimalarials from a variety of plant species. The plants and ingredients are extracted and used as decoction, infusion or steam baths. Oral route was the most popular mode of administration. Respondents reported they drink one to two medium-sized cups of the recipe on an average of two times daily within a duration of about 10 days.

Conclusions: Herbal antimalarial remedies continue to be the popular treatments option in our localities. This study provides knowledge of the diverse ways respondents combine medicinal herbs and other local ingredients for malaria treatment. Pharmacological screening is urgently needed to validate their safety and efficacy in order to protect the health of our locals heavily relying on them to combat high burdens of malaria.

Keywords: Ethnomedicine, Indigenous antimalarials, Herbal cocktails

Background

The use of plant materials in the management of illnesses has steadily increased with about 80% of the world population dependent on the use of herbal medicine in the management of various diseases [1–3]. Malaria is a life-threatening, vector-borne parasitic disease with about 3.2 billion people globally at risk. An estimated 229 million cases of malaria occurred worldwide in 2019, with 94% of the cases occurring in African

countries [4]. Nigeria suffers the world's largest malaria burden with an estimated value of 45% prevalence in 2015 among children under 5 years of age [5]. Four species of the protozoan *Plasmodium* parasite cause malaria in humans. They are *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*, and these four species have been well reported in Nigeria [6, 7]. However, *P. falciparum* is responsible for the majority of severe malaria and malaria-associated deaths worldwide, particularly in sub-Saharan Africa [8]. Malaria can be acute, fulminant or chronic. The most frequent clinical manifestation of malaria infection is fever with other symptoms such as headache, nausea,

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vomiting or diarrhea which appear within 7–14 days following the bite of an infected female *Anopheles* mosquito [9]. When this happens in Nigeria, most people know that it is time to treat malaria either through self-medication or by visiting medical personnel for treatment [10]. The greatest impact of the disease is on the poor people mostly located in the rural settings with increased poor nutritional status and poor access to good health facilities [11].

The use of malaria preventive measures, such as the long acting insecticide-treated bed nets or insecticide-treated bed nets and indoor residual spraying, have reduced malaria burden and child mortality in Nigeria and other parts of Africa [12, 13]. However, in relative terms, malaria burden has not significantly changed in many highly endemic African countries including Nigeria despite increased coverage of insecticide-treated nets (ITN) [12, 14–17]. Studies in Nigeria showed that though the knowledge of malaria and its preventive measures especially through environment sanitation was high, adherence to use of ITN, indoor insecticide spray and other preventive measures was still below expected targets [15, 18–20]. Effective control has relied upon the success of the antimalarial quinine and artemisinin, both from plant sources [21]. However, there are evidence mounting to suggest that many *Plasmodium* strains have developed resistance to antimalarial therapies including artemisinin and its derivatives [22]. With this looming threat of artemisinin resistance coupled with limited availability and affordability of pharmaceutical antimalarials especially in poor countries with malaria endemicity, availability of monotherapy agents and lack of adequate information on appropriate use of effective antimalarial drugs [23] continues to create the need to develop new treatments that are better suited to effectively treat malaria. The various providers of health services in Nigeria can broadly be classified into two groups: government-owned health centers and those owned by private organizations and individuals. Additional forms of health providers are the private hospitals that are owned by qualified medical practitioners, licensed pharmacists, the unqualified and unlicensed chemist shop owners, the ubiquitous drug peddlers, traditional drug hawkers and other forms of health providers [24]. The greater number of malaria treatment services are provided through the private retail sector in Nigeria [25, 26]. The increased demand for private health provision which predominantly caters for the middle-class cadre is due to high cost of accessing government specialist hospitals and the bureaucratic structure of general hospitals.

In many developing countries, one-fifth of patients use indigenous herbal remedies to treat malaria [27]. According to the World Health Organization (WHO),

herbal medicines are the first line of treatment for 60% of children with high fever due to malaria in Nigeria, Ghana, Mali and Zambia [28]. Many caregivers resort to the use of various herbal medicines in the management of malaria. A wide variety of plants belonging to several families have been identified through ethnobotanical and ethnopharmacological studies as antimalarial medicinal plants [29] and are in use by majority of the infected populations in malaria endemic countries [30]. In recent time, several of these plants and/or their components are prepared and administered as monotherapy or a mixture of plant formulations by the locals [31–37]. Concoction of two or more plant species has been reported as a common method of herbal remedy preparation in Africa [32, 34, 35]. In Nigeria where the rural dwellers depend more on herbs and other forms of traditional medicines for malaria management, this method of combining two or more plant species that work in synergy [38] is believed to increase the efficacy of herbal remedies and delay the development of malaria parasite resistance [39]. These simple medicinal preparations often mediate beneficial responses due to a variety of their active chemical constituents [40, 41], which are responsible for their medicinal properties [42].

According to UNESCO [43], the usefulness of these medicinal plants may hold the key to another new and effective antimalarial drug in the future. Medicinal plants used in combination as antimalarial remedies are yet to be extensively documented and scientifically reported, despite their increasing popularity as local treatment options. In Nigeria, majority of documented antimalarial plants research has been carried out in the southwest where a lot of the people take advantage of the huge biodiversity of medicinal plants to treat and manage various ailments including the high rate of malaria incidence in the region [31, 44]. This explorative ethnobotanical survey was therefore undertaken in the southwestern regions of Nigeria to identify plants and ingredients traditionally used in some of the numerous antimalarial cocktail treatments and investigate how they are used.

Methods

Sampling sites description

A total population of 200 herbal practitioners were interviewed in different communities of two local government areas (LGAs) each in Ogun and Oyo states, South West Nigeria. Ogun state is located in the rainforest zone of southwestern Nigeria where malaria is holoendemic year round. The LGAs Ijebu North and Yewa North are two of twenty LGAs in Ogun state and are located 140 km northeast and 170 km north of Lagos in the rainforest zone of southwestern Nigeria. The inhabitants of the two LGAs are predominantly farmers and traders [45]. Oyo state with about 4.5 million people

predominantly occupied by the Yoruba tribe covers approximately an area of 28,454 km². The state consists of 33 local government areas including Ibadan South East and Ibarapa Central. The climate is equatorial, notably with dry and wet seasons with relatively high humidity. Agriculture is the main occupation of the people of Oyo state. The state is holoendemic for malaria, which is the commonest reason for hospital outpatient attendance [46].

Sample size determination

Sample size was determined according to Lemeshow et al.'s [47] table for a minimum sample size using the formula: $n = Z^2P(1-P)^2/D^2$, where n = the sample size, Z = 1.96 at 95% confidence interval; P = assumed prevalence of malaria in the states (25%), and d = 6% level of significance.

Sampling technique

A multi-stage sampling technique was adopted in selecting the 200 herbal practitioners that were interviewed. The first step was to randomly select two (Ogun and Oyo) of the six states in southwestern Nigeria using simple random technique. The second step was to select two local government areas from each of the selected states (Ogun [Ijebu North and Yewa North]; Oyo [Ibadan South East and Ibarapa Central]) using simple random technique through balloting. The list of all LGAs in each of the selected states was compiled and placed in two separate boxes. Two LGAs were then randomly picked from each box without replacement. The number of herbal practitioners interviewed is proportional to the population of each LGA. Purposive sampling method was adopted at the third stage of sample selection. Here, communities identified to have high preponderance of herbal practitioners in each of the selected LGAs were purposively selected for the study. Information were collected from males and females age 18 years and above involved in herbal practice and use via face-to-face interviews and aided by trained research assistants. The survey was carried out between October and December 2017 and lasted for five weeks.

Questionnaire design and method of administration

A semi-structured questionnaire for the survey was prepared with questions bothering on types and parts of plants often used for malaria in combination therapies, methods for preparation and administration. Questions pertaining to socio-demographic characteristics and preferred mode of malaria treatment were multiple choice, while questions about their reasons for herbal use preference, their commonly used plants and ingredients for cocktail antimalarial remedies were open-ended. A pre-test of the questionnaire was first carried out in October

2016 under the same conditions expected in the actual fieldwork at Mushin LGA of Lagos state.

Statistical analysis

The returned questionnaires were cleaned to ensure completeness and thereafter coded using a coding guide. The coded data was subsequently entered into the computer and analyzed using Statistical package for the Social Sciences (SPSS) software version 23.0. In both descriptive and inferential statistics, percentage and frequency were used to analyze data on reported medicinal plant cocktails and associated indigenous knowledge. Data was summarized using tables and charts.

Ethical considerations

The [Nigerian Institute of Medical Research] reviewed and granted approval (assigned number IRB/17/036) for this study. Each respondent had an informed consent document to read and sign before participating, and their participation was voluntary. Their identities and responses were strictly kept confidential.

Results

A total number of 111 respondents comprising 67 in Ijebu North and 44 in Yewa North responded to questionnaires in Ogun state. The 89 respondents from Oyo state comprised 64 from Ibadan South East and 25 from Ibarapa Central.

Socio-demographic characteristics of respondents

The survey showed the proportion of male respondents to be 22.5%, compared to the higher response at 77.5% observed among the female respondents. Respondents between the ages of 31 and 60 were the highest in this study at 53%. The proportion of respondents with no education was at 20.5%, while respondents with primary education were 24.0%. Respondents with secondary education were the highest in this study at 30.5%, while those with post-secondary education were at 24.0%. Statistical test showed that there is significant difference in the respondents' level of education ($p = 0.013$). Among the population of respondents, herbal practitioners with ≥ 30 years of practice were at 46.5% while those with 20–29 years practicing experience were 21%. Table 1 shows the socio-demographic characteristics of respondents.

Ways respondents diagnosed malaria

Results presented in Fig. 1 shows that respondents are aware of the malaria symptoms and identified some of those they base their diagnosis on. The more popular ways they mentioned include headache (Ogun 63.96% versus Oyo 64.0%), fever (Ogun 96.4% versus Oyo 82.0%), nausea/vomiting (Ogun 73.9% versus Oyo 68.5%)

Table 1 Socio-demographic characteristics of respondents from survey areas

Socio-demographic characteristics	Ogun state (number = 111)		Oyo state (number = 89)		Total (number = 200)		Chi-square (χ^2)	P value
	Number	%	Number	%	Number	%		
Sex							3.45	0.735
Male	26	23.4	19	21.3	45	22.5		
Female	85	76.6	70	78.7	155	77.5		
Age							3.34	18.830
18–30	23	20.7	28	31.5	51	25.5		
31–60	61	54.9	45	50.6	106	53.0		
61–90	27	24.3	16	17.9	43	21.5		
Religion							2.01	0.374
Christianity	31	27.9	32	35.9	63	31.5		
Islam	37	33.3	30	33.7	67	33.5		
Traditional	43	38.7	27	62.8	70	35.0		
Marital status							2.53	0.631
Single	19	17.1	21	23.6	40	20.0		
Married	59	53.2	46	51.7	105	52.5		
Separated	15	13.5	13	14.6	28	14.0		
Divorced	7	6.3	3	3.4	10	5.0		
Widowed	11	9.9	6	6.7	17	8.5		
Level of education							14.71	0.013*
No education	29	26.1	12	13.5	41	20.5		
Primary	30	27.0	18	20.2	48	24.0		
Secondary	27	24.3	34	38.2	61	30.5		
Post-Secondary	23	20.7	25	28.1	48	24.0		
Others	2	1.8	0	0.0	2	1.0		
Duration of herbal practice (in years)							2.86	0.963
0–9	20	18.0	16	17.9	36	18.0		
10–19	17	15.3	12	13.5	29	14.5		
20–29	22	19.8	20	22.5	42	21.0		
30 +	52	46.8	41	46.1	93	46.5		
Received herbal training							2.67	0.566
Yes	57	56.4	46	59.7	103	51.5		
No	44	43.6	31	40.3	75	37.5		

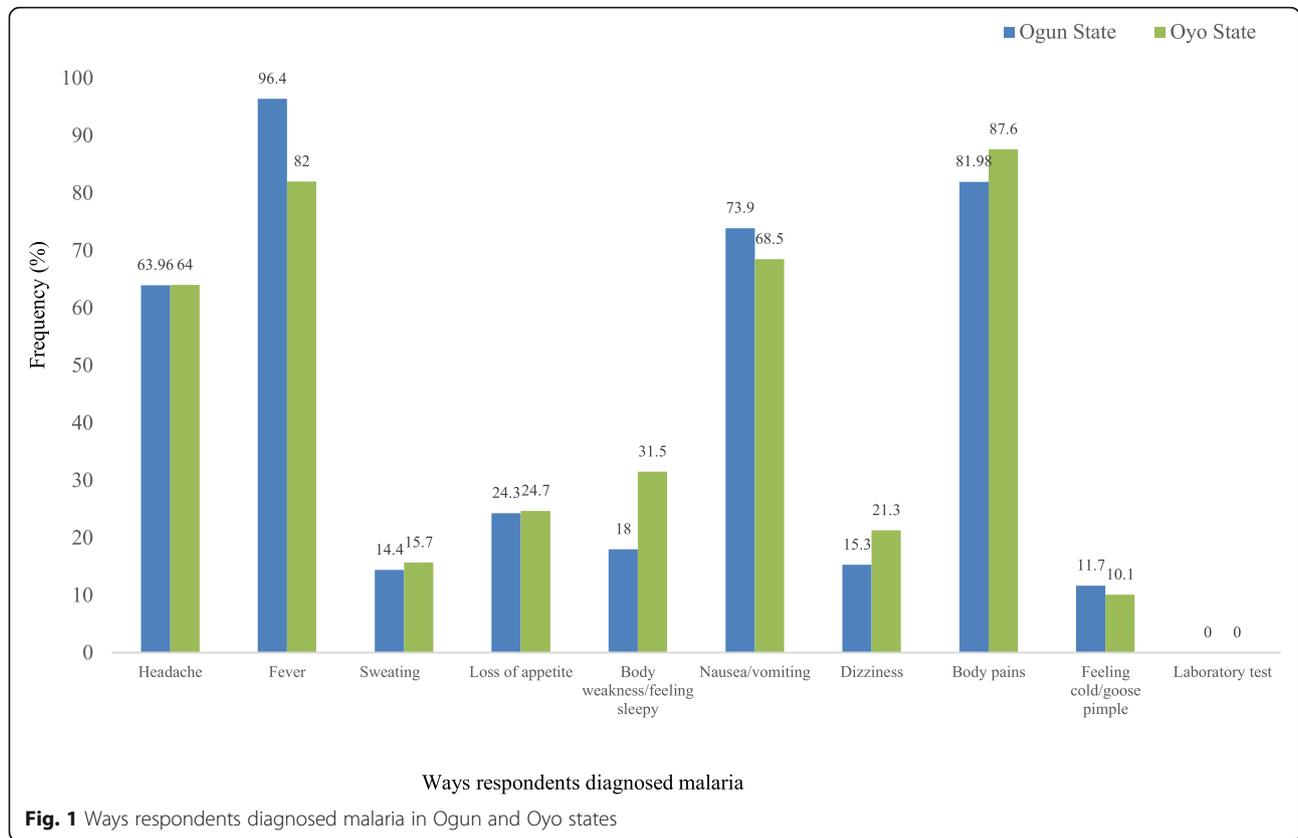
and body pains (Ogun 96.4% versus Oyo 82.0%). Respondents did not diagnose malaria by laboratory techniques.

Mode of treatment of malaria among respondents

Figure 2 shows that most (58%) of respondents (Ogun 47.3% versus Oyo 53%) mentioned using herbal remedies for malaria treatment. This is in contrast to 13.5% (Ogun 12.4% versus Oyo 10.8%) who adopt orthodox medicines for malaria treatments. Statistical test shows that there is no significant difference in the respondents' mode of treatment of malaria and their LGA of residence.

Reasons for herbal use preference among respondents

Some of the compelling reasons for respondents' preference for herbal use for malaria treatment presented in Table 2 include the following: strong belief in traditional medicine (46%), belief that herbal medicines are better absorbed, assimilated and excreted by the body (22.5%), availability around home surroundings (20.0%) and sheer belief that herbal medicines are better than orthodox medicine (16.5%). Affordability was also popularly reported as a reason their preferred choice of herbal treatment even though some respondents claimed the cost of preparing these medicines traditionally ranged between 400 and 3000 naira depending on the ingredients required.



Plants commonly combined for antimalarial cocktail remedies

Enquiries into traditional folklore revealed 26 sets of cocktail antimalarials from a variety of plant species. Tables 3 and 4 show some of the different antimalarial

cocktail preparations from medicinal plants as reported by respondents in areas surveyed. The tables detailed the plants and ingredients combined for each treatment and was compiled according to their generic names, family names, common names, local names, parts of each

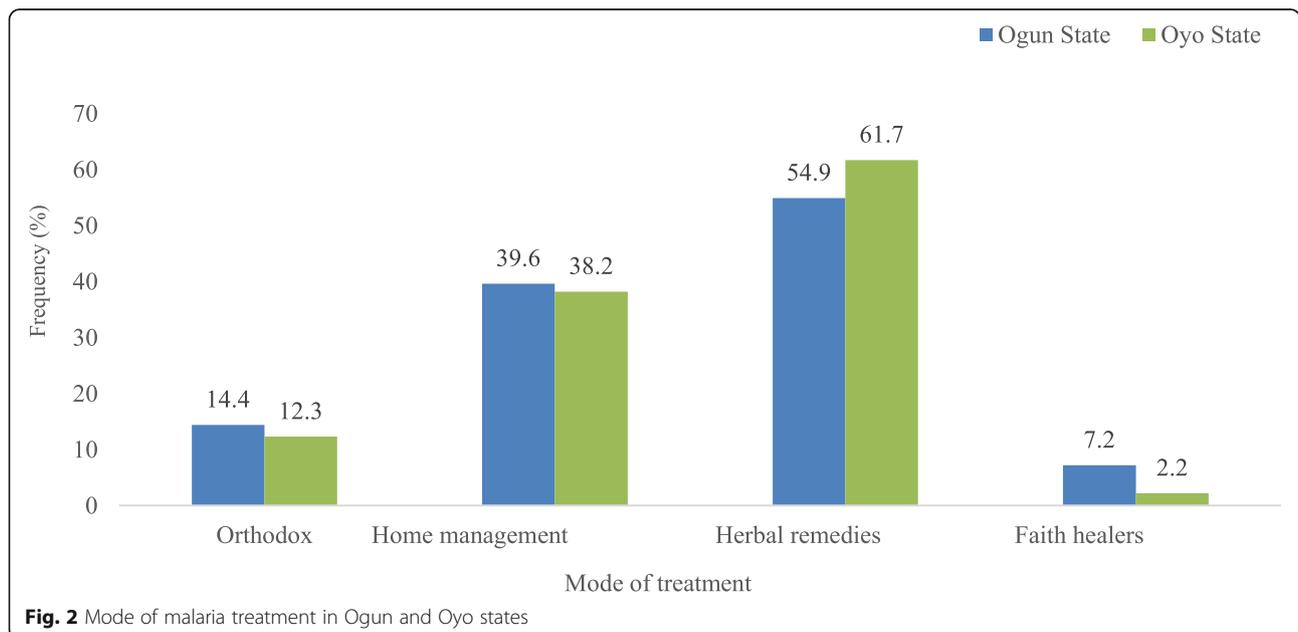


Table 2 Reasons for herbal use preference among respondents

Reasons for herbal use preference	Ogun state (number = 111)		Oyo state (number = 89)		Total (number = 200)	
	Number	%	Number	%	Number	%
Affordability	21	18.92	18	20.22	39	39.14
Effectiveness/efficacy	18	16.22	16	17.98	34	34.2
Faster recovery	9	8.11	5	5.62	14	13.73
Natural gift from God, better living	7	6.31	3	3.37	10	9.68
Orthodox medicines are harmful	19	17.12	14	15.73	33	32.85
Herbal treatments are more reliable than orthodox medicines which are usually fake	5	4.50	22	24.72	27	29.22
Herbal remedies are excreted via urine immediately, while orthodox medicines are stored in the body	25	22.52	20	22.47	45	44.99
Herbal mixtures cleanse the body system	20	18.02	12	13.48	32	31.50
Availability	29	26.13	31	34.83	60	60.96
Stressful waiting in hospital queues	1	0.90	0	0.00	1	0.9
Strong belief in traditional medicine	53	47.75	39	43.82	92	91.57

plants used, frequency each combination was mentioned, methods of preparing each cocktail treatment and mode of administering these preparations in patients. The cocktail medicines are prepared as water extracts in the form of decoction, infusion or as steam baths. Oral administration through drinking was the only mode of administration of the herbal medicine mentioned by virtually all of the respondents. Respondents reported they take a range of one to two medium-sized cups of the herbal preparation on an average of two times daily within a duration of about 10 days. A few of them however mentioned bathing with or inhaling vapour from the herbal preparation as their mode of administering the antimalarial remedies.

Discussions

The increasing level of dependence on locally prepared antimalarial therapies makes detailed investigation of them imperative for public safety. Enquiries into traditional folklore antimalarials in Oyo and Ogun states of southwestern Nigeria revealed that a variety of plants, some of which have been scientifically reported to possess antiplasmodial properties, are popularly combined in poly herbal remedies for malaria treatment [31]. A larger number of respondents were observed in the age group 31–60 years which constitutes the most popular working population in Nigeria. The role of exposure and knowledge cannot be over emphasized as it played an influencing factor in the sampled population.

The World Health Organization (WHO) advocates parasitological confirmation with Rapid Diagnostic Tests (RDTs) or microscopy prior to treatment of malaria in all patients [48]. However, respondents in this study did not diagnose malaria by laboratory tests. Rather, they

take treatment initiatives based on their recognition of symptoms and signs including fever, headache, nausea, body pains and loss of appetite. Ajibade and Alao [49] previously reported that early signs of fever that prompted mothers to take treatment initiatives were high body temperature and vomiting. The poor malaria diagnostic practice demonstrated through clinical manifestations in this study, and on which treatment is usually based, highlights the need to intensify public health education on the importance of parasitological diagnosis for appropriate case detection, improved patient care and prevention of unnecessary use of herbal remedies.

It is important to emphasize the need for increased public health education on the dangers of self-medication given that most of the respondents in this study use herbal medicines for malaria treatment, and a few others reported that they treat malaria at home. Respondents had strong belief in the use of herbal medicines and they alluded to their traditions and customs as the driver of their consumption of herbal medicines. Efficacy, availability and the fear of ‘fake’ orthodox medicines are some other popular reasons reported for their preferred choice of herbal antimalarial treatment. This concern among respondents in the study demonstrate the need for regulatory agencies for herbal medicines to intensify efforts to curb the sale and availability of fake pharmaceutical products particularly herbal antimalarials in the market as a way of increasing the confidence of people in the quality of recommended antimalarial medicines. Another very compelling reason for respondents’ preference for herbal use for malaria treatment is cost. Respondents claimed the cost of preparing these medicines traditionally ranged between 400 and 3000 naira depending on the ingredients required. It has been noted

Table 3 Plants and ingredients commonly used in cocktail antimalarial remedies in Ogun state

Scientific names of the plants (as combined)	Family	Common names	Local names	Parts used	Frequency mentioned	Source for plant	Method of preparation	Mode of administration/ duration of use
<i>Nuclea latifolia</i>	Rubiaceae	African peach	<i>Egbesi</i>	Roots	3	Herb vendors	Boiled	Drink for 5 days
<i>Carica papaya</i>	Caricaceae	Pawpaw	<i>Ibepe</i>	Leaves				
<i>Lawsonia inermis</i>	Lythraceae	Henna plant	<i>Laali</i>	Leaves	3	Forest/bush, herb vendors	Boiled in sweet water	Drink for 1 week
<i>Cajanus cajan</i>	Fabaceae	Pigeon pea	<i>Otili</i>	Leaves				
<i>Cajanus cajan</i>	Fabaceae	Pigeon pea	<i>Otili</i>	Leaves	2	Herbal homes, herb vendors	Boiled with <i>omidun</i>	Drink for 1 week
<i>Nuclea latifolia</i>	Rubiaceae	African peach	<i>Egbesi</i>	Root				
<i>Citrus aurantifolia</i>	Rutaceae	Lime	<i>Osan wewe</i>	Leaves, fruits				
<i>Alstonia boonei</i>	Apocyanaceae	Stool wood	<i>Ahun</i>	Stem bark	2	Home environment, Forest/bush	Soaked with water, 7 up, palm wine or <i>omidun</i>	Drink 1–2 schnapps cups 3 times daily for 3–4 days
<i>Mangifera indica</i>	Anacardiaceae	Mango	<i>Mangoro</i>	Stem bark				
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens	<i>Yarin</i>	Bark				
<i>Sorghum bicolor</i>	Poaceae	Guinea corn	<i>Jero</i>	Leaves				
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	<i>Awapa</i>	Stem bark	6	Herb vendors	Boil with water	Drink 3–4 cups daily till well
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Koko-oba</i>	Leaves				
<i>Curcuma longa</i>	Fabaceae	Turmeric	<i>Ata ile pupa</i>	Root				
<i>Nuclea latifolia</i>	Rubiaceae	African peach	<i>Egbesi</i>	Root	1	Forest/bush	Boiled together	Drink 3 times daily for 3 days
<i>Citrus aurantifolia</i>	Rutaceae	Lime	<i>Osan wewe</i>	Fruits				
<i>Securinega virosa</i>	Euphorbiaceae	Bush weed	<i>Iranje</i>	Leaves				
<i>Citrus limon</i>	Rutaceae	Lemon	<i>Osan gaingain</i>	Leaves				
<i>Celastrus indica</i>	Celastraceae	Bittersweet roots	<i>Ponju-owiwi</i>	Root	1	Herb vendors	Boiled with <i>omidun</i>	Drink 3 times daily for 2 days
<i>Citrullus colocynthis</i>	Cucurbitaceae	Wild gourd	<i>Bara</i>	Seed				
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	<i>Awapa</i>	Stem bark				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	<i>Ope oyinbo</i>	Unripe fruit				
<i>Zingiber officinale</i>	Zingiberaceae	Ginger	<i>Atale funfun</i>	Dried roots				
<i>Carica papaya</i>	Caricaceae	Pawpaw	<i>Ibepe</i>	Leaves	6	Home environment	Squeezed with water	Drink for 10 days
<i>Vernonia amygdalina</i>	Asteraceae	Bitter leaf	<i>Ewuro</i>	Fresh leaves				
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	<i>Awapa</i>	Stem bark	1	Herb vendors	Boiled with <i>omidun</i>	Drink 1cup 3 times for 1 day, repeat at intervals
<i>Curcuma longa</i>	Fabaceae	Turmeric	<i>Ata ile pupa</i>	Seed				
<i>Capsicum frutescens</i>	Solanaceae	Chili pepper	<i>Ata_jjosi</i>	Seed				
<i>Carica papaya</i>	Caricaceae	Pawpaw	<i>Ibepe</i>	Unripe fruit	2	Home environment, herb vendors	Soaked with water or <i>omidun</i>	Drink 1 cup 3 times a day at regular intervals
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	<i>Awapa</i>	Stem bark				
<i>Alstonia boonei</i>	Apocyanaceae	Stool wood	<i>Epo ahun</i>	Stem bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	<i>Mangoro</i>	Stem bark				
<i>Acacia auriculiformis</i>	Fabaceae	Earleaf acacia	<i>Kasia</i>	Leaves, bark	1	Home environment, herb vendors, forest/bush	Boiled together	Drink often
<i>Azadirachta indica</i>	Meliaceae	Neem	<i>Dogonyaro</i>	Leaves				
<i>Lawsonia inermis</i>	Lythraceae	Henna plant	<i>Laali</i>	Fresh leaves				
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Koko-oba</i>	Leaves				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	<i>Ope oyinbo</i>	Leaves, bark				
<i>Kigelia africana</i>	Bignoniaceae	Sausage tree	<i>Pandoro</i>	Seed				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	<i>Ope oyinbo</i>	Bark	5	Home environment, herb vendors	Boiled together	Drink till well
<i>Citrus aurantifolia</i>	Rutaceae	Lime	<i>Osan wewe</i>	Leaves, fruits				
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Koko-oba</i>	Leaves				
<i>Nuclea latifolia</i>	Rubiaceae	African peach	<i>Egbesi</i>	Roots	7	Forest/bush	Parboiled with	Adults only. Drink

Table 3 Plants and ingredients commonly used in cocktail antimalarial remedies in Ogun state (*Continued*)

Scientific names of the plants (as combined)	Family	Common names	Local names	Parts used	Frequency mentioned	Source for plant	Method of preparation	Mode of administration/ duration of use
<i>Morinda lucida</i>	Rubiaceae	Brimstone tree	Oruwo	Leaves			water	1 cup 3 times daily 3–7 days
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Leaves, bark				
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	Awapa	Stem bark	2	Herb vendors	Boiled with Lipton tea bags in <i>omidun</i>	Drink twice daily for 2 days
<i>Citrus aurantium</i>	Rutaceae	Bitter orange	Osan jaganyin	Fruit				
<i>Citrus aurantifolia</i>	Rutaceae	Lime	Osan wewe	Fruit				
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Koko-oba	Leaves				
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Leaves	1	Home environment	Soaked in hot water	Drink 1 cup daily for 5 days
<i>Anacardium occidentale</i>	Anacardiaceae	Cashew	Kaju	Leaves				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Leaves				
<i>Citrus aurantifolia</i>	Rutaceae	Lime	Osan wewe	Leaves, fruits	2	Herb vendors	Boiled in calabash	Drink ½ cup daily for 7 days
<i>Diospyros monbutensis</i>	Ebenaceae	Yoruba ebony	Egun eja	Fresh leaves				
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Koko-oba	Leaves	3	Herb vendors	Parboiled with water	Drink 1 small cup, 2 times daily for 3–4 days
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens	Yarin	Bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Bark, leaves				
<i>Naucllea latifolia</i>	Rubiaceae	African peach	Egbesi	Roots				

Table 4 Plants and ingredients commonly used in cocktail antimalarial remedies in Oyo state

Scientific names of the plants (as combined)	Family	Common names	Local names	Parts used	Frequency mentioned	Source for plant	Method of preparation	Mode of administration/ duration of use
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Fresh leaves	2	Forest/bush, home environment	Boiled with <i>omidun</i>	Drink for 7 days
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Stem bark				
<i>Vernonia amygdalina</i>	Asteraceae	Bitter leaf	Ewuro	Fresh leaves				
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Fresh leaves	1	Herb vendors	Boiled	Drink for 2–3 days
<i>Vernonia amygdalina</i>	Asteraceae	Bitter leaf	Ewuro	Fresh leaves				
<i>Psidium guajava</i>	Myrtaceae	Guava	Guaba	Fresh leaves				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	Ope oyinbo	Unripe fruit	2	Home environment	Soaked with <i>omidun</i> for 3 h	Drink for 3–5 days
<i>Citrus limon</i>	Rutaceae	Lemon	Osan gaingain	Unripe fruits				
<i>Carica papaya</i>	Caricaceae	Pawpaw	Ibepe	Unripe fruit	5	Herb vendors, home environment	Soaked with water or <i>omidun</i>	Drink 2–4 cups at regular intervals of 1 week
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	Awopa	Stem bark				
<i>Astonia boonei</i>	Apocynaceae	Stool wood	Epo ahun	Stem bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Stem bark				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	Ope oyinbo	Unripe fruit	3	Home environment	Soaked with <i>omidun</i> for 3 h	Drink for 3–5 days
<i>Carica papaya</i>	Caricaceae	Pawpaw	Ibepe	Unripe fruit				
<i>Citrus aurantifolia</i>	Rutaceae	Lime	Osan wewe	Leaves, fruits				
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Kooko-oba	Leaves				
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Fresh leaves	2	Herb vendors	Boiled	Drink, bath with, for over 1 week
<i>Lawsonia inermis</i>	Lythraceae	Henna plant	Ladli	Fresh leaves				
<i>Ocimum basilicum</i>	Lamiaceae	Sweet basil	Efinrin osho	Leaves				
<i>Azadirachta indica</i>	Meliaceae	Neem	Dogonyaro	Leaves	4	Home environment, herb vendors	Boiled	Drink for 3–7 days
<i>Carica papaya</i>	Caricaceae	Pawpaw	Ibepe Mangoro	Leaves, fruits				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Egbesi	Leaves, stem bark				
<i>Naucllea latifolia</i>	Rubiaceae	African peach		Stem bark				
<i>Naucllea latifolia</i>	Rubiaceae	African peach	Egbesi	Stem bark	2	Forest/bush, herbal homes	Boiled	Drink for 1 week
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens	Efo yarin	Stem bark				
<i>Astonia boonei</i>	Apocynaceae	Stool wood	Epo ahun	Stem bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Stem bark	3	Herb vendors, home environment	Extracted with water	Drink for 2 week
<i>Citrus aurantifolia</i>	Rutaceae	Lime	Osan wewe	Fruits				
<i>Naucllea latifolia</i>	Rubiaceae	African peach	Egbesi	Stem bark				
<i>Byrsocarpus coccineus</i>	Connaraceae	?	Amuje wewe	Stem bark, root	5	Forest/bush	Extracted with hot water	Drink for 2 weeks
<i>Astonia boonei</i>	Apocynaceae	Stool wood	Epo ahun	Stem bark, root				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Leaves, stem bark				
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens	Efo yarin	Stem bark	1	Herb vendors	Extracted with hot water	Drink for 2–3 weeks
<i>Astonia boonei</i>	Apocynaceae	Stool wood	Epo ahun	Stem bark, root				
<i>Naucllea latifolia</i>	Rubiaceae	African peach	Egbesi	Root, stem bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	Mangoro	Leaves, stem bark				
<i>Olax subscorpioides</i>	Olaaceae	Ola	Ifon	Dried bark	3	Herb vendors	Boiled with <i>omidun</i>	Drink for 7 days
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Kooko-oba	Fresh leaves				
<i>Diospyros monbottensis</i>	Ebenaceae	Yoruba ebony	Egun aja	Fresh leaves	5	Herb vendors	Extracted with hot water or <i>omidun</i>	Drink for 5 days
<i>Lawsonia inermis</i>	Lythraceae	Henna plant	Ladli	Fresh leaves				
<i>Enantia chlorantha</i>	Annonaceae	Lettuce leaves	Awopa	Stem bark	3	Forest/bush, herbal vendors	Boiled with water	Drink 2 cups daily for 1–2 weeks
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Kooko-oba	Leaves				

Table 4 Plants and ingredients commonly used in cocktail antimalarial remedies in Oyo state (Continued)

Scientific names of the plants (as combined)	Family	Common names	Local names	Parts used	Frequency mentioned	Source for plant	Method of preparation	Mode of administration/ duration of use
<i>Curcuma longa</i>	Fabaceae	Tumeric	<i>Ata ile pupa</i>	Root				
<i>Citrus aurantifolia</i>	Rutaceae	Lime	<i>Osan wewe</i>	Leaves	2	Home environment, herb vendors	Soaked with water	Drink 1 small cup 3 times daily for 3–7 days
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Kooko-oba</i>	Leaves				
<i>Morinda lucida</i>	Rubiaceae	Brimstone tree	<i>Epo ahun</i>	Leaves				
<i>Alstonia boonei</i>	Apocyanaceae	Stool wood	<i>Mangoro</i>	Bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	<i>Yarin</i>	Stem bark				
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens		Bark				
<i>Lawsonia inermis</i>	Lythraceae	Henna plant	<i>Laali</i>	Fresh leaves	4	Home environment, herb vendors	Boiled	Drink 1–3 cups daily when feverish
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Kooko-oba</i>	Leaves				
<i>Azadirachta indica</i>	Meliaceae	Neem	<i>Dogonyaro</i>	Leaves, stem				
<i>Carica papaya</i>	Caricaceae	Pawpaw	<i>Ibepe</i>	Unripe fruits	2	Home environment	Parboiled with water	Drink for 7 days
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	<i>Kooko-oba</i>	Fresh leaves				
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	<i>Ope oyinbo</i>	Unripe fruit				
<i>Nauclea latifolia</i>	Rubiaceae	African peach	<i>Egbo egbesi</i>	Stem bark	1	Herb vendors	Boiled	Drink 2 cups daily for 2 weeks
<i>Taraxacum officinale</i>	Asteraceae	Dandelion greens	<i>Efo yarin</i>	Stem bark				
<i>Mangifera indica</i>	Anacardiaceae	Mango	<i>Mangoro</i>	Stem bark	3	Home environment, herb vendors	Extracted with hot water	Drink 1 cup 3–4 times daily for 2 weeks
<i>Citrus aurantifolia</i>	Rutaceae	Lime	<i>Osan wewe</i>	Fruit				
<i>Nauclea latifolia</i>	Rubiaceae	African peach	<i>Egbo egbesi</i>	Stem bark				

that the availability of genuine conventional antimalarial drugs and the services rendered by private practitioners make the costs generally high and are thus not easily accessible to the poor masses [24]. Since introduction, ACT remains the most expensive antimalarial agent compared to commonly used monotherapy, with a median cost of between 1825 (5 US dollars) and 4015 (11 US dollars) naira per adult dose [50]. Studies on how much Nigerians pay for the less-effective medicines that are widely available and considerably cheaper in private-for-profit outlets where patients frequently seek malaria treatment [51] need to be explored and compared to the cost of antimalarial treatments with phytotherapies. This will help to identify potential avenues for effective intervention.

Different parts of medicinal plants are now commonly used in combination phytotherapies against malaria [31]. In the present study, a variety of plant parts, mainly fresh leaves are selected and combined in carefully chosen proportions before they are prepared together. These medicines are administered in variable doses and mostly taken at regular intervals over time. Majority of the remedies were administered by oral route, though there were a few mentions of bathing with them or inhaling vapour from them immediately after boiling. Though water is the most popularly mentioned solvent used for the preparations, *omidun*, a readily available sweet water from fermented corn, alcohol including local gin and palm wine are also used to extract these herbs locally. Notably, respondents failed to indicate how the dosage in the quantity of the herbal remedy was determined. More so, the quantity of the preparation administered and the duration of treatment varied from respondent to respondent. No side effects to these herbal medicines or efforts to standardize their preparation and usage were mentioned or reported. This represents the major drawback of traditional medicine [52].

This treatment strategy employing a variety of herbal preparations is majorly limited by the unavailability of required data on safety and efficacy [53]. A noteworthy observation was that though respondents use these remedies until their recovery, they still continued to administer the herbal remedies at regular intervals. This suggests that most of these remedies as locally used do not provide and maintain the ideal bioavailable level of curative effects, which does not require repeated intermittent administration of treatments. Based on respondents' claims of efficacy and the absence of side effects, the feasibility of discovering new potent antimalarials from these plant formulations vastly used in Nigeria is very promising. To protect the increasing population of people depending on these locally prepared polyherbal antimalarials, actual behaviours of these plant cocktails including their mode of action, potential adverse

reactions, contraindications and interactions with existing orthodox pharmaceuticals need to be established by scientific investigation, and findings well communicated to the end users to guide proper and safe use of these remedies. Regulatory and monitoring agencies should ensure effective steps are put in place to protect the health of consumers. Research needs for the development of these phytotherapies that have the potential to treat malaria as effective, safe and readily available antimalarial drugs include precision and standardization of methods of preparation, determining correct dosage and duration of treatments, and critical scientific research to validate efficacy and safety claims.

Conclusion

Medicinal plant cocktails contribute significantly to current malaria treatment in Nigeria due to its continuous demand to combat malaria. There is no doubt that research on traditional plants will possibly contribute to the discovery of new antimalarial drugs. From these starting points, new treatments can be developed that are better suited to effectively treat malaria. In the meantime, to protect public health, an urgent need remains to understand the divergent preparations and use patterns of antimalarial herbal remedies; to scientifically identify the safest, most effective therapies; to provide countermeasures to associated toxicity risks; and to determine their recommended doses in line with World Health Organization Guidelines and to create awareness for the best options.

Limitations of the study

Many of respondents were reluctant to part with the information sought. Some of the respondents were willing to exchange information at prices ranging between 20,000 (54.79 US dollars) and 40,000 (109.59 US dollars) naira; some others were adamant for fear of possibly going out of business if they reveal secrets of their trade and deliberately provided limited information on the methods used to prepare the remedies to make it difficult to replicate them. Yet some others insisted they would only reveal such information to their apprentices during training, or to people coming to them through their organization.

Abbreviations

WHO: World Health Organization; UNESCO: United Nations Educational, Scientific and Cultural Organization; LGAs: Local Government Areas; SPSS: Statistical Package for the Social Sciences; IRB: Institutional Review Board; p: Probability; RDTs: Rapid Diagnostic Tests

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Authors' contributions

IET conceptualized the idea for this study. OR wrote the research proposal. IET, ACG and OAO reviewed the research proposal. OR and AAK conducted the ethnobotanical survey and analyzed the data. OR drafted the manuscript. All the authors participated in reviewing and approving the manuscript for publication. The authors have read and approved the final manuscript.

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Availability of data and materials

The authors have provided data generated and analyzed in the manuscript.

Declarations

Ethics approval and consent to participate

The Nigerian Institute of Medical Research Institutional Review Board (NIMR IRB) reviewed and granted approval (assigned number IRB/17/036) for this study. Each respondent had an Informed Consent Document to read and sign before participating, and their participation was voluntary.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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