

Investigations on the antimalarial properties of *Cleistopholis patens* (Annonaceae) leaf methanol extract and its partitioned fractions in mice

ABSTRACT

Aim: The methanol extract and partitioned fractions of *Cleistopholis patens* leaf were evaluated for antiplasmodial activities with a view to establishing its antimalarial potential and identifying the most active partitioned fraction.

Method: The leaf was collected, authenticated, air-dried and powdered. The extract, prepared by maceration in methanol was tested (0-800mg/kg) against *P. berghei berghei* in mice using Peter's four-day test. Normal saline and Chloroquine (10mg/kg) were negative and positive control respectively. Percentage parasitemia, percentage chemosuppression, effective doses, survival times and percentage survivors were the parameters used for the assessment. The extract was thereafter suspended in water and successively partitioned into n-hexane, dichloromethane and ethyl acetate and the resulting fractions and the aqueous phase were similarly tested at doses 10-80mg/kg.

Result: The methanol extract which was comparable ($P = .06$) in activity to chloroquine gave 1.05 ± 0.09 percentage parasitemia, 77.45 ± 4.39 percentage chemosuppression at 40mg/kg and an ED_{50} and ED_{90} of 255.83 ± 3.60 and 471.35 ± 15.05 mg/kg. The most active n-hexane fraction elicited a percentage chemosuppression of 82%, 0.87 percentage parasitaemia at 80mg/kg, moderately high percentage survivor and relatively low ED_{50} and ED_{90} of 28.87 ± 5.29 and 56.30 ± 8.44 mg/kg.

Conclusion: The methanol extract of *C. patens* leaf is active against *P. berghei berghei* and the antimalarial compounds is likely to be concentrated in the n-hexane fraction.

Key words: *Cleistopholis patens* leaf; antimalarial investigation, chemosuppression, partitioned fraction, activity-directed

1.0. INTRODUCTION

Effective herbal remedies are potential sources of drugs that are used in combating a variety of ailments and diseases, malarial inclusive [1]. The use of infusions of plant barks to treat human malaria since the 17th century, is an encouragement to search for molecules from plants especially those used ethnomedicinally in the treatment of malaria [2]. That the first antimalarial drug, quinine, was obtained from the bark of the *Cinchona* (Rubiaceae) species and the fact that artemisinin was discovered from *Artemisia annua* in the seventies encourage further research into other medicinal plants for antimalarial molecules [3; 4]. Artemisinin-combined therapies (ACT) was formally adopted as first-line treatment of uncomplicated malaria for Nigeria in 2005 [5-6]. It is only reasonable that indigenous plants are investigated for chemical compounds that may serve the same purpose in the nearest future. More so, many plants that are used in ethnomedicine as antimalarial have not been investigated for antimalarial

potency. *Cleistopholis patens* (Annonaceae), commonly called salt and oil tree, is a small to medium-sized tree up to 20-30m high. The extract of the plant alone, as decoctions or infusions or crushed preparations of the leaf, bark or of grounded and roasted seeds, and in some instances, in combination with other plants like *Cymbopogon spp* and *Caricapapaya* have been used in the treatment of fever, sleeping sickness, infective hepatitis, measles, menstrual irregularities, tuberculosis, rheumatic arthritis, headaches, and as vermifuge and purgative [7-11]. Hypolipidemic, haematological, antimicrobial, entomotoxic and anti-arthritic activities have also been reported for this plant [12-16]. The plant contains alkaloids, terpenoids and oligorhamnosides [17- 18]. Since *C. patens* have ethnomedicinal claims of anti-fever and antimalarial activities, there is a need to investigate it for its antimalarial potential [19].

The stem bark and leaf oils of the plant when assessed against chloroquine-resistant strain of *P. falciparum* in an *in vitro* antiplasmodial evaluation elicited an IC_{50} values of 9.19 and 15.19 $\mu\text{g/mL}$ respectively [11]. Also, the leaf methanol extract of the Ghanaian species similarly tested was found to have appreciable activity with an IC_{50} = 8.7 $\mu\text{g/mL}$ [20]. On the other hand, the root extract gave an IC_{50} of 21.43 ± 2.45 and 14.68 ± 1.02 $\mu\text{g/mL}$ against CQ-sensitive and CQ-resistant strains of *P. falciparum* respectively [21].

In this work, the methanol extract of the leaf of *C. patens* and its partitioned fractions were investigated for antimalarial activities against chloroquine-sensitive *Plasmodium berghei berghei* infected mice with a view to complementing the *in vitro* result and so establish its antimalarial efficacy. The fraction(s) containing the antimalarial constituents will also be identified.

2.0. METHODOLOGY

2.1. Plant collection and preparation

The leaf of *C. patens* was collected beside the Department of Botany, Obafemi Awolowo University (OAU), Ile-Ife, Osun State, Nigeria. It was identified and authenticated at the Faculty of Pharmacy Herbarium by Mr. I. I. Ogunlowo, a botanist and taxonomist of the Department of Pharmacognosy, Obafemi Awolowo University, Ile-Ife and voucher specimen number FPI 2212 was deposited. The leaf was subsequently air dried, powdered and kept in a cool, dry place before further use.

2.2. LD₅₀ Determination

The methanolic extract of *C. patens* leaf was subjected to LD₅₀ determination using Lorke's method. Briefly, the extract was administered at 10, 100, 1000 mg/kg doses respectively to 3 groups of three mice per group in a phase I evaluation. The mice were observed for 24 hours for mortality. No mortality in the first phase will enable the experiment to move to phase 2. In the second phase, three mice grouped into three groups of one mouse each were administered with higher doses of 1600, 2900 and 5000 mg/kg of the extracts respectively. They were also observed for 24 hours for mortality. Usually the LD₅₀ is determined from the formula: $LD_{50} = \sqrt{D_0 \times D_{100}}$ when the mice dies at any of the doses administered. When the highest dose that gave no mortality (D_0) and lowest dose that produced mortality (D_{100}) were determined, the formula will be used to calculate the LD₅₀ of the extracts. No mortality was recorded at the highest dose of

5000mg/kg for the leaf methanolic extract of *C. patens*, giving the LD₅₀ at a value of greater than 5000mg/kg from which the doses were decided [22].

2.3. Extraction and Partitioning

The powdered leaf (8kg) was macerated in two batches (2x 4kg) with methanol (3L) each for 72 hours with intermittent shaking. Thereafter, the extract was filtered and the process was repeated two times for each batch. The filtrates were pooled and concentrated using rotary evaporator to obtain 650g (8.13% yield) of the methanol extract. The extract (422 g) was suspended in 500 mL of distilled water and successively partitioned into n-hexane, dichloromethane and ethyl acetate, allowing each solvent to exhaust its constituents (by colour and thin layer chromatography) before shifting to the next in order to obtain their respective partitioned fractions, n-hexane (CPH, 45 g), dichloromethane (CPD, 205 g), ethyl acetate (CPE, 21 g) and aqueous phase (CPA, 143.1 g) after *in vacuo* concentration of each solvent fraction.

2.4. Preparation of extract, fractions and drugs for the assay

The 0.05g, 0.1g, 0.2g, and 0.4g of the extract was solubilized in normal saline (5.0 mL) with the aid of Tween 80 to give doses 100, 200, 400 and 800 mg/kg respectively which was used for the antimalarial experiment. For each of the partitioned fractions, 0.005 g, 0.01 g, 0.02 g and 0.04 g was similarly solubilized in 5.0mL of normal saline to give 10, 20, 40 and 80 mg/kg respectively. A 0.005g of chloroquine was similarly dissolved in 5.0 mL of normal saline to give a 10.0 mg/kg dose as the positive control. Normal saline (0.2mL) was utilized as the negative control.

2.5. Mice

Thirty (30) Swiss albino mice weighing between 18 to 22g (male and female), were purchased from the animal house, Faculty of Pharmacy, OAU, Ile-Ife. The mice were housed in aluminum cages in groups of five (5) mice each, fed with grower's mash and clean water and were acclimatized for 5 days before use. The same process was followed for the preparation of the mice to be utilized in all the experiments.

2.6. Parasite

The rodent parasite *Plasmodium berghei berghei* NK 65 harboured in a donor mouse was obtained from the Institute of Advanced Medical Research and Training (IMRAT), University College Hospital, Ibadan. The parasite was maintained by serial intraperitoneal passaging in mice. The mouse with about 30% parasitaemia was subsequently euthanized and blood containing the parasite obtained from the mouse by cardiac puncture. The resulting blood obtained was diluted so that 0.2mL contain 1×10^7 infected erythrocytes. An inoculum of 0.2mL of diluted blood was given to each of the test animals intraperitoneally in all the experiments [23].

2.7. Chemosuppressive Antimalarial Assay

The chemosuppressive antimalarial model was used to evaluate the activities of the extract and the partitioned fractions in *Plasmodium berghei berghei* infected mice. The acclimatized and grouped mice (I-

VI) were infected with 1×10^7 *P. berghei bergheion* the first day, two hours later, they were treated orally with various volumes (depending on the weight of the animal) of the previously prepared extract and partitioned fractions. The dose range used are 100, 200, 400 and 800 mg/kg and 10, 20, 40 and 80 mg/kg for the methanol extract and the partitioned fractions respectively. The positive (V) and the negative (VI) control groups received 10mg/kg chloroquine and 0.2mL of normal saline respectively. The above treatment was carried out for four consecutive days (D₀-D₃). On the fifth day, thin blood films were prepared from the tail blood of each experimental animal, fixed in methanol, stained with Giemsa and evaluated. Percentage parasitemia, percentage chemosuppression, survival time and percentage survivor obtained from the evaluation of each slide was used to assess the activities of the different doses of the extract and partitioned fractions.

UNDER PEER REVIEW

2.8. Laboratory Determination of Percentage Parasitemia in Mice

2.8.1. Blood film preparation

Clean slides were arranged and masking tapes were placed at the base of these slides in order to identify the surface on which to make the smear. Drops of blood from each animal's tails were put on each slide. The blood was spread thinly horizontally using another clean slide at 45°. The blood film was allowed to dry and fixed with drops of methanol and allowed to dry.

2.8.2. Staining of blood film

Stain was prepared by diluting a 10 ml of Giemsa stain (3%) to 100 ml with tap water and mixed thoroughly in a staining tank. The fixed slides were arranged in the solution and left for 30 minutes. It was then removed, rinsed, air-dried and neatly packed inside tissue paper and labelled.

2.8.3. Microscopical examination of stained film

The stained slide was then mounted on the microscopic stage and observed using the oil immersion objective (×100 magnification). Ten fields were viewed and result taken from each. The percentage parasitemia, calculated as a percentage ratio of the number of parasitized and total number of parasitized and unparasitized red blood cells, was determined from an average of ten fields of count on a microscopic slide. The percentage parasitaemia was calculated for each mouse in a group of five and the result was recorded as average percentage parasitaemia ± standard error of mean (SEM).

2.9. Analysis of Results

The results were analysed using the parameters percentage parasitemia, percentage chemosuppression, and survival time and percentage survivor.

2.9.1. Percentage parasitemia

The percentage parasitemia, calculated as a percentage ratio of the number of parasitized and total number of parasitized and unparasitized red blood cells was determined from an average of ten fields of count on a microscopic slide.

$$\frac{\text{Number of parasitised erythrocytes}}{\text{Number of Parasitised + unparasitised erythrocytes}} \times 100$$

2.9.2. Percentage chemosuppression

The percentage chemosuppression of parasitemia per test dose was calculated relative to the untreated group (negative control) from the percentage parasitemia, using the formula:

$$\frac{\text{Percentage parasitemia in negative control} - \text{Percentage parasitemia in test dose}}{\text{Percentage parasitemia in negative control}} \times 100$$

2.9.3 Effective Doses (ED₅₀ and ED₉₀)

From the percentage chemosuppression, the ED₅₀ and ED₉₀ were forecasted using Microsoft Office Excel 2019 and Vinstat graph pad software.

2.9.4 Survival time

The mice were monitored for mortality for 28 days. The number of days each mouse survived from the commencement of the treatment was taken as survival time while the average for the group was recorded as mean \pm SEM.

2.9.5. Statistical Analysis

One-way analysis of variance followed by Student New-man Keuls post hoc test was used for comparison to determine the source of significant differences for all values. Values of $p < 0.05$ were considered to be of statistical significance, and data analysis was performed using Vinstat graphpad software.

3.0. RESULTS AND DISCUSSION

The need to find new effective drugs, which have novel modes of action for the treatment of life-threatening malaria disease is urgent. This is because if the disease is not treated promptly with effective medicines, it may rapidly progress to severe illness and death [24]. The increasing number of cases of resistance to the majority of currently available antimalarial drugs by the *Plasmodium* parasite, even to new ACT drugs has made the management of malaria a big challenge. This is much compounded by increasing resistance by mosquitoes to available insecticides, and the unavailability of effective vaccines and other novel interventions to control the cases [25]. Also, the rural inhabitants are unable to afford very expensive antimalarial drugs like the artemisinin combined therapy (ACTs). All these issues call for an urgent action to counteract these developments and further affirms the need to resort to ethnomedicine to investigate herbal remedies for their activities against the malarial parasite [26]. Herbal remedies are usually potential sources of medicine, therefore plants used in those remedies and which possess known activities against fever can be tested for antiplasmodial activities [19]. This may eventually lead to the isolation of lead chemicals for the development of new antimalarial drugs [27]. *Cleistopholis patens* is widely used in ethnomedicine for the treatment of a myriad of health problems like headache, fever, malaria, infection, hyperlipidemia, rheumatoid arthritis, measles and as anti-fertility [7-11]. This explains its choice for investigation against malarial parasites. In this study, the antimalarial activity of the leaf methanol extract and the partitioned fractions were assessed in chloroquine-sensitive *P. berghei berghei* infected mice using activity-guided methods. The similarity of the *P. berghei berghei* to human malaria expressed by Africans is a motivation for utilizing the *in vivo* chemosuppressive antimalarial model in this research [28]. Therefore, the possibility of extrapolating the results to humans is high [29-31]. Chloroquine (10mg/kg) was used as the positive control because the plasmodium parasite used for infection of the mice is a chloroquine-sensitive strain [28].

3.1. Antimalarial activity of the methanol extract

The parasitaemia values obtained for all the tested doses of the extract and the positive control were significantly ($P = .001$) different from that of the negative control (Table 1) indicating an intrinsic antiplasmodial activities of the extract and so prove it to be a suitable source of some antimalarial drug molecules [30]. Furthermore, that the activities of the extract at the tested doses were comparable ($P = .06$) to that of the positive control (Table 1) further showed that it has very high antiplasmodial activity and

may be as effective as the positive control [33]. The highest percentage chemosuppression of 77.5 was attained at 400mg/kg while 200 mg/kg and 800 mg/kg gave 76% and 73% suppression respectively. All these activities were comparable ($P= .06$) to that of CQ, the positive control which gave 72%. Only at relatively low dose of 100 mg/kg was the extract significantly ($P= .04$) lower in activity with 66% chemosuppression (Table 1). The percentage chemosuppression (65.88 %) at 200 mg/kg reported for *Plumeria alba*, 67.72 % for *Morinda lucida* at 400 mg and similar values for the methanolic extracts of *Murraya koenigii* and *Artocarpus altilis* rightly shows that *C. patens* is an active antimalarial drug [34-37]. The median effective dose ED_{50} (255.83±3.60 mg/kg) and ED_{90} (471.35±15.05 mg/kg) also depicted a relatively high activity of the extract (Table 4). A similarly-active aqueous and ethanol extract of *Moringa oleifera* elicited effective doses, 216.80; 475.58 and 253.46; 426.60 mg/kg respectively in a similar antiplasmodial experiment [20]. However, the survival times elicited in mice by the same extract at all the doses tested was comparable ($P= .1$) to the negative control (Table 2) implying that the extract cannot prolong the life of mice beyond the day of drug administration. The lowest dose tested however elicited the highest percentage survivor of 60% (Table 2) in the experiment. The extract at such a dose definitely contain some factors or compounds that promote the survival of a better percentage of the mice after the experiment than in other higher doses.

Table 1: Average percentage parasitemia and percentage chemosuppression of the methanol extract

Doses (mg/kg)	%PARA±SEM	%CHEMO±SEM
0	4.69±0.25 ^b	0.00±0.00 ^a
100	1.63±0.26 ^a	65.68±9.72 ^b
200	1.16±0.09 ^a	75.45±3.04 ^c
400	1.05±0.09 ^a	77.45±4.39 ^c
800	1.24±0.04 ^a	73.40±2.96 ^c
CQ (10mg/kg)	1.28±0.11 ^a	72.24±7.19 ^c

Keys: Data shows the mean ± SEM, CQ: chloroquine (positive control). Only values with different superscripts a, b or c within the column are significantly different ($p<0.05$, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test), %PARA: percentage parasitaemia, %CHEMO: percentage chemosuppression. Superscripts a, b or c are statistical notations to depicts significantly different activities in the values.

3.2. Antimalarial activities of the partitioned fractions

In traditional medicine, whole plants or mixtures of plants are used rather than isolated compounds. However, extended studies have shown that crude extract contains a conglomerate of medicinal compounds and often possess greater *in vitro* or/and *in vivo* antiplasmodial activity than isolated constituents at an equivalent dose. Also, it was discovered that the activities of one compound may either mask or potentiate the other. Fractionation of an extract, therefore usually help to eliminate potentially toxic or inactivating compounds while enhancing the potentiating compounds present in the original

extract [16]. The partitioned fractions, CPH, CPD, CPE and CPA were tested at 0-80mg/kg. The n-hexane fraction CPH, like the other partitioned fractions gave significantly ($P= .04$) lower parasitaemia levels from that of the negative control at all the doses tested. This showed that each of the fractions retain the antimalarial potency of the original extract and the antimalarial compounds in the extract have varying polarities. Furthermore, for CPH, the parasitaemia levels obtained at most of the doses (10-40mg/kg) tested were comparable ($P= .29$) to that of chloroquine, the positive control drug. The highest dose tested, 80mg/kg, gave a significantly ($P= .001$) lower percentage parasitaemia (Fig. 1).

Table 2: Survival time and percentage survivor of the methanol extract.

Dose (mg/kg)	Average survival time (days)	Percentage survivor (%)
0	16.4±2.09 ^a	20
100	12.2±2.20 ^a	60
200	19.2±2.04 ^a	20
400	22.2±2.09 ^a	40
800	11.8±4.15 ^a	20
CQ (10mg/kg)	18.2±3.90 ^a	60

Keys: Data shows the mean ± Standard error of mean, CQ: chloroquine (positive control). Only values with different superscripts a, b or c within the column are significantly different ($p<0.05$, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test). Superscripts a, b or c are statistical notations to depicts significantly different activities in the values.

and higher percentage chemosuppression, which was higher than that of the positive control (Table 3). The n-hexane partition fraction of *Stemonocoleus micranthus* stem bark extract gave a high percentage chemosuppression of 68 % but lesser than that of the ethyl acetate fraction which gave 95% chemosuppression [38]. Like CPH, the ethyl acetate partition fraction, CPE gave significantly lower ($P= .001$) % parasitaemia than that of the positive control drug at the highest dose tested. Fraction CPD gave comparable ($P= .29$) parasitaemia values to that of positive control while CPA gave higher ($P= .001$) parasitaemia values than that of the positive control. CPH and CPE may contain constituents that give better activities on the *Plasmodium* than the positive control. For CPA, there was significantly ($P= .001$) higher parasitaemia levels than that of the positive control at all doses tested, particularly, 10mg and 20 mg/kg but those of 40 and 80 mg/kg were significantly ($P= .01$) lower than those of higher doses but comparable ($P= .14$) to that of the positive control .

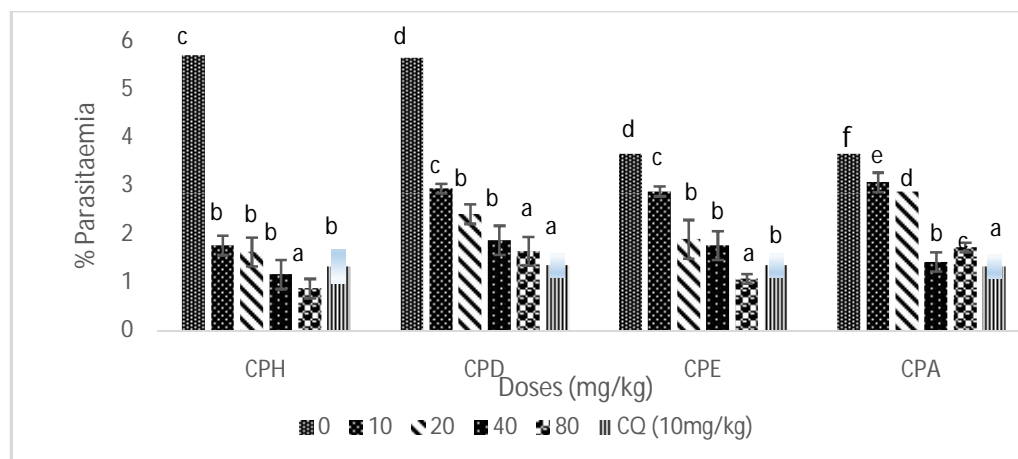


Fig. 1: Percentage parasitaemia elicited by the partitioned fractions.

Keys: CPH: n- hexane fraction; CPD: dichloromethane fraction; CPE: ethyl acetate fraction; CPA: aqueous fraction. Data show the mean \pm SEM, $n = 5$. CQ: chloroquine (10 mg/kg) used as the positive control. Only values with different superscripts a, b or c within the column are significantly different ($p < 0.05$, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test), Superscripts a, b or c are statistical notations to depicts significantly different activities in the values.

Table 3: Percentage chemosuppression of the partitioned fractions

DOSE (mg/kg)	CPH	CPD	CPE	CPA
0	0.00 \pm 0.00 ^a	0.00 \pm 0.00 ^a	0.00 \pm 0.00 ^a	0.00 \pm 0.00 ^a
10	62.56 \pm 2.07 ^b	37.45 \pm 2.75 ^b	38.81 \pm 2.63 ^b	34.63 \pm 3.99 ^b
20	65.38 \pm 3.17 ^b	48.81 \pm 4.51 ^b	59.79 \pm 8.63 ^b	38.72 \pm 0.94 ^b
40	75.33 \pm 2.67 ^c	60.13 \pm 6.96 ^{b,c}	62.64 \pm 4.98 ^c	69.91 \pm 3.62 ^d
80	81.55 \pm 1.64 ^d	65.11 \pm 6.16 ^c	77.19 \pm 1.81 ^c	63.4 \pm 2.20 ^c
CQ	71.6 \pm 3.22 ^c	71.6 \pm 3.22 ^c	71.6 \pm 3.22 ^c	71.6 \pm 3.22 ^d

Keys: CPH: n- hexane fraction; CPD: dichloromethane fraction; CPE: ethyl acetate fraction; CPA: aqueous fraction. Data show the mean \pm SEM, $n = 5$. CQ: chloroquine (10 mg/kg) used as the positive control. Only values with different superscripts a, b or c within the columns are significantly different ($p < 0.05$, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test), Superscripts a, b or c are statistical notations to depict significantly different activities in the values within columns.

Table 4: Effective doses (ED₅₀ and ED₉₀) of the extract and the partitioned fractions.

Fraction	ED ₅₀	ED ₉₀
CPH	25.37±0.41 ^a	52.21±0.83 ^a
CPD	36.67±1.86 ^b	70.69±3.42 ^{b,c}
CPE	32.47±1.69 ^b	64.86±4.56 ^b
CPA	37.83±1.10 ^b	75.39±3.00 ^c
Extract	255.83±3.60 ^c	471.35±15.05 ^d

Keys: CPH: n- hexane fraction; CPD: dichloromethane fraction; CPE: ethyl acetate fraction; CPA: aqueous fraction. Data show the mean ± SEM, n = 5. Only values with different superscripts a, b or c within the column are significantly different (p<0.05, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test). Superscripts a, b or c are statistical notations to depict significantly different activities in the values within columns.

Table 5: Survival time and percentage survivor (in parenthesis) of the partitioned fractions

DOSE (mg/kg)	CPH	CPD	CPE	CPA
0	11.6±3.33 ^a (20)	10.6±1.08 ^a (20)	10.6±1.08 ^a (20)	11.0 ± 1.14 ^a (20)
10	17.2±1.77 ^a (20)	11.2± 2.18 ^a (40)	9.6±1.9 ^a (40)	11.8±4.32 ^a (40)
20	13.4±2.02 ^a (60)	9.8±2.15 ^a (40)	17.8±2.82 ^a (60)	20.8±4.93 ^a (60)
40	15.8±0.73 ^a (40)	12.4±1.94 ^a (60)	15.4±5.12 ^a (40)	18.6±3.23 ^a (40)
80	14.8±2.82 ^a (60)	15.0±1.90 ^a (60)	15.0±1.90 ^a (60)	17.2±3.73 ^a (40)
CQ	17.6 ± 4.63 ^a (60)	11.00 ± 1.27 ^a (60)	11.0 ± 1.27 ^a (60)	11.8 ± 1.16 ^a (60)

Keys: CPH: n- hexane fraction; CPD: dichloromethane fraction; CPE: ethyl acetate fraction; CPA: aqueous fraction. Data show the mean ± SEM, n = 5. Only values with different superscripts a, b or c within the column are significantly different (p<0.05, one-way analysis of variance followed by the Student-Newman-Keul's post hoc test). Superscripts a, b or c are statistical notations to depict significantly different activities in the values within columns.

3.2.1. Percentage chemosuppression and effective doses of the partitioned fractions

Percentage chemosuppression elicited by extract or partition fractions in an antiplasmodial test is a direct measure of their activities on the *Plasmodium* and so their potency as antimalarial agents. From this study, relative to the positive control drug, CPH is the most active as it gave a significantly ($P = .00$) higher percentage chemosuppression at all doses than the other partitioned fractions. This is confirmed by the relatively lower percentage chemosuppression each of them elicited compared to 82% given by CPH at the highest dose tested (Table 3). CPH also gave a significantly ($P = .00$) better activity than chloroquine at 80 mg/kg and a comparable ($P = .001$) activity at 40mg/kg (Fig. 1). CPD and CPE gave comparable ($P = .001$) activities to chloroquine, the positive control drug at 40 and 80mg/kg. However, CPA was comparable ($P = .001$) to chloroquine in activity only at 40mg/kg. The above result indicated that all the partitioned fractions have strong potential as antimalarial agent pointing out to the plant as an antimalarial drug and strongly validating its use in ethnomedicine as such.

Also, the significantly ($P = .0001$) lower effective doses, ED₅₀ and ED₉₀ of CPH (25.37±0.41 and 52.21±0.83 mg/kg) when compared to that elicited by the other partitioned fractions, supported the activity profile

shown above, CPD, CPE and CPA being comparable ($P= .002$) to each other but lower in activity to the most active CPH (Table 4). The order of activity of the fraction is CPH>CPE>CPD>CPA. This implies that CPH contains more of the antimalarial constituents of the plant and so, it should be further evaluated for the antimalarial compounds of the plant. The effective doses elicited by the partition fractions when compared to that of the methanol extract showed they were more active and that the antimalarial compounds were distributed in the fractions and may have different polarities. Antiplasmodial compounds of different polarities have been isolated from the stem and root of *Gongronema latifolium* [38].

3.2.2. Survival times and percentage survivor of the partitioned fractions

Survival times and percentage survivors are complementary to other parameters like percentage chemosuppression and effective doses in assessing the antiplasmodial activities of the extracts of medicinal plants. Survival times is the number of days taken for the mouse to live from the day it started to receive drug against the inoculated parasite while percentage survivors is the percentage of the total number of mice in a group that survived within the average survival time of the group. At all the doses of the methanol extract of *C. patens* tested, the survival times elicited were comparable ($P= .1$) to each other and the negative control. The ability of the extracts and fractions to arraign enough immunity against the parasite after its suppression in the mice was not strong enough. Hence, the doses tested were not able to prolong the life of the mice beyond the day of drug administration. The percentage survivor, (also called survival rate), is an indirect measurement of the survival of the mice against the effect of the suppressed parasite after series of drug administration to suppress it. The percentage survivor of 60% attained at 100mg/kg was the highest, others were very low. This pattern did not easily correlate with the high % chemosuppression elicited at similar doses (Tables 1 & 2). Such high doses could not produce higher immunity though it produced higher suppression of parasites. In previous similar works, high percentage chemosuppression have been correlated with percentage survivors rather than survival times [39].

Similarly, the survival times for the partitioned fractions were comparable at all the doses including that of the positive control. This implies that neither the extract nor the partitioned fractions could prolong the life of mice better than the negative control (Table 5). However, it was observed that a moderately high, 60% percentage survivor was obtained in all the fractions at 20mg/kg except CPD which incidentally produced 60% at its higher doses of 40 and 80mg/kg. All the fractions elicited percentage survivor of 60% at the highest dose except CPA. Fraction CPA gave its highest percentage survivor and survival times at a relatively lower dose of 20mg/kg (Table 5). In further works, compounds which enhance chemosuppression and those that can increase percentage survivor should be identified while those that can both increase suppression and enhance survivors should be projected as antimalarial compounds. In summary, the methanol extract of *C. patens* is an active antimalarial agent because of its high chemosuppression of the plasmodium parasite. Its solvent fractions retained the same antiplasmodial activities in the relatively high chemosuppression in the n-hexane fraction, CPH. The moderately high percentage survivor of 60% obtained at the lowest dose of the extract and at 20mg/kg of most of the

partitioned fractions vividly confirms *C. patens* as a potential candidate for sourcing antimalarial compounds.

4.0. Conclusion

The methanol extract of the leaf of *C. patens* which gave a high reduction of *Plasmodium berghei berghei* parasite in mice is an antiplasmodial agent. Its most active n-hexane partition fraction with a relatively high percentage chemosuppression and moderately high percentage survivor is most likely to contain antimalarial constituents of the plant.

ETHICAL APPROVAL

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the Animal Research Ethics Committee is Health Research Ethic Committee [HREC] Institute of Public Health, Obafemi Awolowo University, Ile Ife with Ethical Approval Number is IPH/OAU/12/2194

REFERENCES

1. Duke JA, Ayensu ES. Medicinal Plants of China. Reference Publications, Inc. 1985.
2. Baird JK, Caneta-Miguel, Masba ES, Bustos DG, Abrenica JA, Layawen AV, Calulut JM, Leksana B, Wignall FS. Survey of resistance to chloroquine of *falciparum* and *vivax* malaria in Palawan, Trans.R.Soc.Trop. 1996;(90):413-414.
3. Tse EG, Korsik M, Todd MH. The past, present and future of anti-malarial medicines. Malar J. 2019; 18:93.
4. Saxena S, Pant N, Jain DC, Bhakhuni RS. Antimalarial Agents from plant sources Curr. Sci. 2003; 85(9):1314–1329.
5. Balick JB, Elisabetsky E, Laird AS. Medicinal resources of the tropical Forest Biodiversity and its importance to human health, Columbia University Press, New York 1996; 440pp.
6. Mokuolu OA, Ntadom GN, Ajumobi OO, Alero RA, Wammanda RD, Adedoyin OT, et al. Status of the Use and Compliance with Malaria Rapid Diagnostic Tests in Formal Private Health Facilities in Nigeria. Malar J. 2016;15:4.
7. Bolza E, Keating WG. African: the properties timbers, uses and characteristics of 700 species. Division of Building Research, CSIRO, Melbourne, Australia. 1972;710.
8. Burkhill HM. The useful plants of West Tropical Africa. 2nd Edition. Volume 1, Families A–D. Royal Botanic Gardens, Kew, Richmond, United Kingdom. 1985;960.
9. Akendengué B, Champy P, Nzamba J, Roblot F, Loiseau PM, Bories C. Antifungal and anthelmintic activities of *Cleistopholis patens* (Annonaceae). *Planta Med.* 2009;75(10):143–1145.
10. Amadi CN, Odigie JO Siminialayi IM. The effects of methanol extracts of *Cleistopholis patens* on the reproductive system of female Wistar rats. *Asian Pac.J.Trop.Med.* 2009;2(1):6–12.

11. Boyom FF, Ngouana V, Kemgne EAM, Zollo PHA, Menut C, Bessière JM, Gut J, Rosenthal PJ. Antiplasmodial volatile extracts from *Cleistopholis patens* Engl. & Diels and *Uvariastrum pierreanum* Engl. & Diels (Annonaceae) growing in Cameroon. *Parasitol. Res.* 2011;108(5):1211–1217.
12. Udem SC, Ezeonuegbu UC, Obidike RI. Experimental Studies on the Hypolipidemic and Haematological Properties of Aqueous Leaf Extract of *Cleistopholis Patens* Benth. & Diels. (Annonaceae) in Hypercholesterolemic Rats. *Ann.med.health sci.res.* 2011; 1:115-21.
13. Aloke C, Ibiama UA, Orji OU, Ugwuja EI, Ezeani NN, Aja PM, Obasi NA. Anti-arthritic potential of ethanol and aqueous extracts of stem bark of *Cleistopholis patens* on complete Freund's adjuvant-induced rheumatoid arthritis in rats. *J-AIM.* 2021,12(1):28-34.
14. Osuntokun O. Evaluation of Inhibitory Zone Diameter (IZD), Phytochemical Screening, Elemental Composition and Proximate Analysis of *Crude Cleistopholis patens* (Benth) on Infectious Clinical Isolates. *J. mol. biomark. diagn.* 2018;9:385. doi:10.4172/2155-9929.1000385.
15. Onaolapo JA. Entomotoxic activity of powder of *Cleistopholis patens* Benth against the Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera: pyralidae). *Int. J. Entomol. Res.* 2017;5:2.
16. Waterman PG, Ilias M. Sesquiterpenes and alkaloids from *Cleistopholis patens*. *Phytochemistry.* 1985;24(3):523-527.
17. Ouattara ZA, Boti JB, Antoine CA, Joseph C, Felix T, Ange B. Analysis of *Cleistopholis patens* Leaf and Trunk Bark Oils Using Combined GC-Flame Ionisation Detection, GC-Retention Index, GC-MS and C-13-NMR. *Phytochem Anal.* 2013;24(6):574-80.
18. Pérez-Moreno G, Cantizani J, Sánchez-Carrasco P, Ruiz-Pérez LM, Martín J, El Aouad N, Pérez-Victorial, Tormo JR, González-Menéndez V, González de Pedro N, Reyes F, Genilloud O, Vicente F, González-Pacanoska D. Discovery of New Compounds Active against *Plasmodium falciparum* by High Throughput Screening of Microbial Natural Products. *PLoS One.* 2016;611(1):e0145812. doi: 10.1371/journal.pone.0145812. ECollection 2016.
19. Olaniran O, Adetuyi FC, Omoya FO, Odediran SA., Hassan-olajokun RE, Awoyeni EA, Odetoyin BW, Adesina, A, Awe, A, Bejide RA, Odujoko O, Akinyemi LO, Oyetoke OO, Afolayan D.O. (). Antiplasmodial, Antipyretic, Haematological and Histological Effects of the Leaf Extracts of *Moringa oleifera* in *Plasmodium berghei berghei* Infected Mice, *J.adv.med.* 2019;29(4):1-13.
20. Abubakar AR, Haque M. Preparation of Medicinal Plants: Basic Extraction and Fractionation Procedures for Experimental Purposes. *J Pharm Bioallied Sci.* 2020;12(1):1-10.
21. Iyiola OA, Tijani AY, Lateef KM. Antimalarial Activity of Ethanolic Stem Bark Extract of *Alstonia boonei* in Mice. *Asian J. Biol. Sci.* 2011;4(3):235-243.
22. Lorke D, A new approach to practical acute toxicity testing. *Arch.Toxicol.* 1983;54(4):275-287.
23. Nosten F, White NJ. Artemisinin-Based Combination Treatment of *Falciparum* Malaria. In: Breman JG, Alilio MS, White NJ, Defining and Defeating the Intolerable Burden of Malaria III: Progress and

Perspectives: Supplement to Volume 77(6) of Am.J.Trop.Med.Northbrook (IL): American Society of Tropical Medicine and Hygiene; 2007Dec. Available from:
<https://www.ncbi.nlm.nih.gov/books/NBK1713/>

24. Beeson JG, Drew DR, Boyle MJ, Feng G, Fowkes FJI, Richards JS. Merozoite Surface Proteins in Red Blood Cell Invasion, Immunity and Vaccines against Malaria. *FEMS Microbiol.* 2016; 40:343–372.
25. Smith N, Obala A, Simiyu C, Menya D, Khwa-Otsyula B, O'Meara WP. Accessibility, availability and affordability of anti-malarials in a rural district in Kenya after implementation of a national subsidy scheme. *Malar J.* 2011;10: 316.
26. Somsak V, Polwiang N, Chachiyo S. *In Vivo* Antimalarial Activity of *Annona muricata* Leaf Extract in Mice Infected with *Plasmodium berghei*. *J Pathog.* 2016;2016:3264070. doi: 10.1155/2016/3264070.
27. Picot S, Bienvenu A. *Plasmodium*. *Infect.Immun.* 2022;2:655-665
28. National Academies of Sciences. Issues in Risk Assessment. Extrapolation from Rodents to Humans Engineering, and Medicine.1993; 6.2.
29. Jolivet LJ, Ward KW. Extrapolation of human pharmacokinetic parameters from rat, dog, and monkey data: Molecular properties associated with extrapolative success or failure. *J Pharm Sci.* 2005;94(7):1467-83. doi: 10.1002/jps.20373. PMID: 15920768.
30. Ram R. Extrapolation of animal research data to humans: an analysis of the evidence. In *Animal Experimentation: Working Towards a Paradigm Change 2019*; pp. 341-375.
31. Hailesilase GG, Rajeshwar Y, Hailu GS, Sibhat GG, Bitew H. *In Vivo* Antimalarial Evaluation of Crude Extract, Solvent Fractions and TLC-Isolated Compounds from *Olea europea* Linn subsp. *cuspidata* (Oleaceae). *Evid Based Complement Alternat Med.* 2020;6731485. doi:10.1155/2020/6731485. PMID: 32508951
32. Nwaeze AC, Ajayi OI, Ezenyi IC, Tijani AY, Salawu OA. Evaluation of ethanol extract of *Artemisia maciverae* aerial part for antiplasmodial activity in mice. *JOPAT.*2017;16(2):77- 85.
33. Aliyu FA. *Murraya koenigii* and *Artocarpus altilis* in malaria and dengue fever control. M. Sc. Dissertation. OAU Ile Ife. 2013;185pp.
34. Umar MB, Ogbadoyi EO, Ilumi JY, Salawu OA, Tijani AY. Antiplasmodial efficacy of methanolic root and leaf extracts of *Morinda lucida*. *J.Nat.Sci.Res.*2013;2:112-121.
35. Adepiti AO, Elujoba AA, Bolaji OO. *In vivo* antimalarial evaluation of MAMA Decoction on *Plasmodium berghei berghei* in mice. *Parasitol. Res.* 2014;113(2):505-511.
36. Ojorongbe O, Ojo, JA, Adefokun DI, Abiodun OO, Odewale G, Awe EO. *In vivo* antimalarial activities of *Russelia equisetiformis* in *Plasmodium berghei* infected mice. *Indian J Pharm Sci.* 2015;77(4):504-510.

37. Orabueze CI, Ota DA, Coker HA. Antimalarial potentials of *Stemonocoleus micranthus* Harms (Leguminosae) stem bark in *Plasmodium berghei* infected mice. J. Tradit. Complement. Med. 2020;10(1):70-78.
38. Adebajo AC., Odediran SA, Nneji CM, Iwalewa EO, Rukunga GM, Aladesanmi AJ, Gathirwa JW, Ademowo OG, Olugbade TA, Schmidt TJ and Verspohl EJ. Evaluation of Antimalarial Claim of *Gongronema latifolium* Root and Stem. J Herbs Spices Med Plants.2013;19(2):97-118.
<http://www.tandfonline.com/loi/whsm20>
39. Adesida AS, Odediran SA. Elujoba A.A. Investigation on the Antimalarial Properties of *Plumeria alba*Linn (Apocynaceae) Cultivated in Nigeria.Niger J Nat Prod Med. 2021;25:34-42.
<https://dx.doi.org/10.4314/njnpm.v25i1.2>

UNDER PEER REVIEW