

Antiplasmodial Activity shown by Secondary Metabolites Extracted from the Seeds of *Pentaclethramacrophylla* Benth

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Abstract. Oil extracts from the African oil bean seed (*Pentaclethramacrophylla* Benth.) was analyzed for its phytochemical and mineral content and proximate, physicochemical and anti-microbial analyses were also performed. Phytochemical analysis showed the presence of tannins, saponins, quinones, terpenoids, phenols and coumarins in the oil sample. Mineral determination of the cotyledon showed the presence of iron (Fe) (with the highest concentration), Cu, Zn, Mn, Cr, Pb and Cd; while proximate analysis gave the following result: moisture (14.2%), ash content (1.5%), crude fibre (4.9%), crude proteins (12.8%), oil contents (4.9%), and carbohydrate (61.8%). GC-MS analysis of the partitioned petroleum ether and chloroform fractions of the oil revealed the presence of 9-Octadecenoic acid, 9,12-Octadecadienoic acid and their methyl esters, cis-9-Hexadecenal among the many components of the oil extract. Physicochemical analysis of the oil indicated a saponification value (148.67 mg KOH/g), peroxide value (8.0 meq/g), iodine value (10.41 mg iodine/g) and free fatty acid (8.98 mg KOH/g). The need for the development of new drugs for malaria led to our study of the antiplasmodial activity of the oil from the seeds of *Pentaclethramacrophylla*. Toxicological studies were carried out to determine the LD₅₀ with chloroquine diphosphate as positive control and normal saline as negative control. Using the Peter's 4 day suppressive test a parasite inhibition rate of 47.72% (25 mg/kg), 63.63% (50 mg/kg) and 61.36% (100 mg/kg) on day 4 after treatment was recorded. A 95.45% chemo-suppression was observed for animals treated with 10 mg/kg chloroquine. This result is an indication that the extract had appreciable signs of chemosuppression.

Keywords: *Pentaclethramacrophylla*, phytochemical analysis, antimicrobial analysis, GC-MS, Plasmodium, secondary metabolites, chemo-suppression, malaria

1. INTRODUCTION

In rural Africa, people are exposed to a variety of plants, fruits and seeds, some of which are taken as food because of their nutritional value and some for treatment of various ailments because of their medicinal properties (Opara *et al.*, 2013). *Pentaclethramacrophylla* Benth. also known as oil bean tree but locally called the African oil bean tree is one such plant whose seeds are eaten by a group of people in Southeastern Nigeria and the extracts from its leaves and stem bark have been used for treatment of ailments such as diarrhea, leprosy wounds and convulsion and has been used as an anthelmintic (Fern, 2014; Akindahunsi, 2004). The seeds are gotten from perennial legume tree called *Pentaclethramacrophylla*, Benth and also commonly known as the oil bean tree. It has also been suggested that consumption of the seeds increases the hemoglobin value; increases oxygenation of tissue; enhances specific hormones and quickens the production of red blood cells (Okpala, 2015).



Antimalarial drug resistance has emerged as one of the greatest challenges facing malaria control today (Olasehinde *et al.*, 2015). Based on the emergence of *Plasmodium falciparum* resistance to artemisinin derivatives (ART) in Cambodia, which is currently threatening the world's malaria control and elimination efforts (Ariey *et al.*, 2014), development of new drugs will be a welcome initiative. There are several approaches to discovering new agents, of which discovery from natural sources is a highly desirable approach.

A high proportion of the global population still depends upon the herbal/traditional drugs for their health care. Because of their ready availability, believe in their safety and effectiveness, rural people rely on these plants for their health care issues and needs. *Pentaclethra macrophylla* Benth is widely used as food and for treatment of some ailments and is widely abundant in Nigeria; hence this study is focused on investigating its properties and harnessing them for the treatment of malaria. The investigation was done by extracting oil from the seed cotyledon with ethanol and petroleum ether as solvents.

The oil extracted from the cotyledon and seed cover was tested for its antimicrobial and antimalarial activities. These were determined along with its chemical composition using Gas chromatography–mass spectrometry (GC-MS). The cytotoxicity and in vivo toxicity; evaluation of in vitro and in vivo antiplasmodial activities as well as the determination the LD50 and chemo-suppressive properties of ethanolic extracts against *Plasmodium berghei berghei* were considered.

2. MATERIALS AND METHODS

2.1 Plant Material

The African oil bean (*Pentaclethra macrophylla*) seeds were obtained from Oyingbo market, Ebute Metta, Lagos, Lagos State, Nigeria. The seeds were authenticated at the Federal Research Institute of Nigeria (FRIN), Ibadan. It was assigned a voucher No: Pm/Bio/H806 with Ascension code: OgcUNo807. The cover of the seeds of *Pentaclethra macrophylla* were manually removed with knife and cut into small sizes of about 5 mm. These were then stored in a refrigerator until required.

2.2 Plant Extraction

The extraction was performed by taking a weighed amount of the seed and placing it in a thimble of the Soxhlet extractor. The extraction was performed exhaustively with the appropriate solvent (ethanol or petroleum ether). After the extraction, the solvent was removed using a rotary evaporator. The oil collected was kept in the refrigerator for further analysis. The oil percentage extract was calculated as:

$$\% \text{ oil content} = \frac{\text{weight of oil extracted}}{\text{weight of seed sample}} \times 100$$

The ethanolic oil extract was partitioned between chloroform, petroleum ether and distilled water. About seventeen (17) grams of ethanolic sample extract was first partitioned between water (50 mL) and petroleum ether (50 mL) in a 250 mL separating funnel. The water fraction was then poured back into the separating funnel and 50 mL of chloroform was added to the mixture and the chloroform fraction was obtained. Both the petroleum ether and chloroform fractions were allowed to evaporate and analyzed by GC/MS.

2.3 Gas Chromatography/ Mass Spectroscopy

The GC-MS analysis was carried out at Shimadzu Training Center for analytical instruments (STC) Lagos. The GC-MS instrument used for the analysis was GCMS-QP2010SE SHIMADU JAPAN. The machine comprises of injector and gas chromatograph interfaced to mass spectrophotometer. The gas

chromatography condition was: column oven temperature (60°C); injection temperature (200°C); injection mode split ratio (1:1); helium as carrier gas flow rate (1.56 mL/min); the system was temperature programmed from 60°C(at 10°C/min) to 160°C(held for 2min) then at (10°C/min) to 250°C; the injection volume was 0.5 µL. Mass spectrophotometer condition: Ion source temperature 200°C; Interface Temperature 250°C solvent cut time 4.5 min and acquisition was in the scan mode.

2.4 Physicochemical and Proximate Analysis

Physicochemical and proximate analyses were performed using the standard methods as described in the literature. Antimicrobial analysis was performed according to the method previously described by Olasehinde *et al.*, (2016).

2.5 In vivo Antimalarial Activity

2.5.1 Experimental Animals

Experimental animals used in this study were the Swiss pre-infected albino mice (*Mus musculus*) of either sex, weighing between 18 – 25 g. All animals were housed in standard cages and kept in the animal house, at Covenant University, Ota, Ogun state, Nigeria. The animals were fed with a balanced standard pellet diet and maintained under standard laboratory conditions (24 – 28°C), standard light cycle and water ad libitum according to the NRC guide, for the care of laboratory animals (Institute for Laboratory Animal Research, 2011). They were allowed to acclimatize for five days before the commencement of the experiment. Ethical approval for use of animals was obtained from the BIOSREC, Covenant University.

2.5.2 Parasites

The chloroquine sensitive *Plasmodium berghei* NK65 rodent parasite used to assess the antimalarial potential of *Pentaclethra macrophylla* was obtained from the National Institute for Medical research (NIMR), Lagos, Nigeria.

Each mouse was inoculated with 2 mL of plasmodium infected blood, containing about 0.5×10^3 of parasitized erythrocytes intra-peritoneally. This volume was prepared by determining the percentage parasitemia and the erythrocyte count of the donor mice and diluting 15 – 20 drops of blood, from the tail tip of the infected albino mice with 25 mL of Phosphate buffered solution (PBS). The animals were then left to attain maximum parasitemia for seven days.

2.5.3 Acute Oral Toxicity

Lorke's method was used to evaluate the acute toxicity of the ethanol extract of *Pentaclethra macrophylla*, which then allowed us to determine the LD_{50} (Lorke, 1983).

Twelve mice were selected and divided into three groups of four mice each. The groups of mice were administered intra-peritoneally, with doses of 25 mg/kg, 50 mg/kg and 100 mg/kg respectively. The mice were observed for signs of toxicity, which included paw licking, salivation, stretching of the whole body, weakness, sleep, respiratory disease, coma and death in the first four hours and subsequently daily for 7 days. The animals were fasted for 24 h before the commencement of the experiment.

The number of deaths in each group within 24 hours was recorded and oral median lethal dose LD_{50} was calculated using this formula:

$$LD_{50} = \sqrt{\text{minimum toxic dose} \times \text{maximum tolerated dose}}$$

2.5.4 In Vivo Schizontocidal Activity 4-Day Peters' Test

The Peter's 4-day suppressive test against chloroquine sensitive *Plasmodium berghei* NK65 infection in mice was employed to test for suppressive activity (Peters, 1968). Adult Swiss Albino mice weighing 20 – 25 g were inoculated by intra-peritoneal injection with standard inoculum of

Plasmodium bergheberghei with 1×10^7 infected erythrocytes. The mice were randomly divided into 3 groups of 4 mice each for the *P. macrophylla* extract for 25 mg/kg, 50 mg/kg and 100 mg/kg. Two control groups were used; the positive control was treated daily with 10 mg of chloroquine/kg, while the negative control group was given 2 mL/kg normal saline. The body weight of each mouse was measured on the first day, and the fifth day, while the body temperature was taken before and after drug administration (D0), and monitored daily to the fifth day.

On each day of the experiment, blood was collected from the tail of each mouse and a smear was made on the microscope slide to make a film (Saidu et al., 2000). The blood films were fixed with methanol, stained with 10% Giemsa at pH 7.2 for 10 minutes and parasitemia examined. Parasitemia was determined by Light microscopy using a $100\times$ objective lens and the following equation was used to calculate the average percentage chemo-suppression:

$$\% \text{ chemosuppression} = \frac{A - B}{A} \times 100$$

Where: A = Average parasitemia in the negative control group; B = average parasitemia in the test group.

Parasitemia estimation was done by allowing the slide to dry in a vertical position and examined under a light microscope at $\times 100$ magnification and determining the number of parasites per field on a slide.

3. RESULT AND DISCUSSION

Percentage oil extracted from the seeds of *P. macrophylla* was very low; ethanol (4.89%) and petroleum ether (2.75%). This low oil content is a confirmation of the result reported by (Sofowora et al., 2013) but contrasts significantly with values reported by other workers (Odoemelam, 2005; Ogueke et al., 2010; Oyeleke et al., 2014) whose values were obtained in the process of fermenting the seed cotyledon.

The results of the proximate analysis, phytochemical screening and physicochemical analysis of the oil extract are presented in tables 1, 2 and 3 respectively. Table 2 shows the presence of family of compounds whose activities are well known and have been reported on many occasions (Chung et al., 1998; Ntie-Kang et al., 2014; Oyeleke et al., 2014).

Table 1: Results of proximate analysis of seed

Proximate Analysis	Moisture	Ash Content	Crude Fiber	Proteins	Oil Content	Carbohydrate
Determined Values (%)	14.16	1.53	4.85	12.79	4.89	61.78

Table 2: Results of phytochemical screening of seed oil

Component	Tannins	Saponins	Quinones	Terpenoids	Phenols	Coumarins
Observation	+	+	+	+	+	+

Table 3: Results of the physicochemical properties

Test	Saponification value (mg-KOH/g)	Free fatty acid (FFA) (mg-KOH/g)	Peroxide value (meq/kg)	Iodine value (mg-iodine/g)	pH	
	148.665	8.98	8.0	10.4058	4.57 (ethanol extract)	4.20 (petroleum ether extract)

Table 4: Result of Mineral composition in seed

Minerals	Iron	Copper	Zinc	Manganese	Chromium	Cadmium	Lead
Concentration (mg/L)	3.0271	1.4102	1.0703	0.4663	0.0568	0.0075	0.0278

The minerals analyzed for are as shown table 4 above. The minerals found present apart from sodium (Na), potassium (K) and calcium (Ca), which were not analyzed for are iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), chromium (Cr), cadmium (Cd) and lead (Pb). The values obtained for these minerals compare very well with those obtained by Oyeleke *et al.*, (2014). These minerals have all been reported as essential for the body to function properly (Dana *et al.*, 2014; Ikhuria *et al.*, 2008). GC-MS analysis was carried out on the crude extract, petroleum ether and chloroform fractions to determine the components of the oil. The chromatograms of the petroleum ether and chloroform fractions are shown in Figures 1 and 2 below.

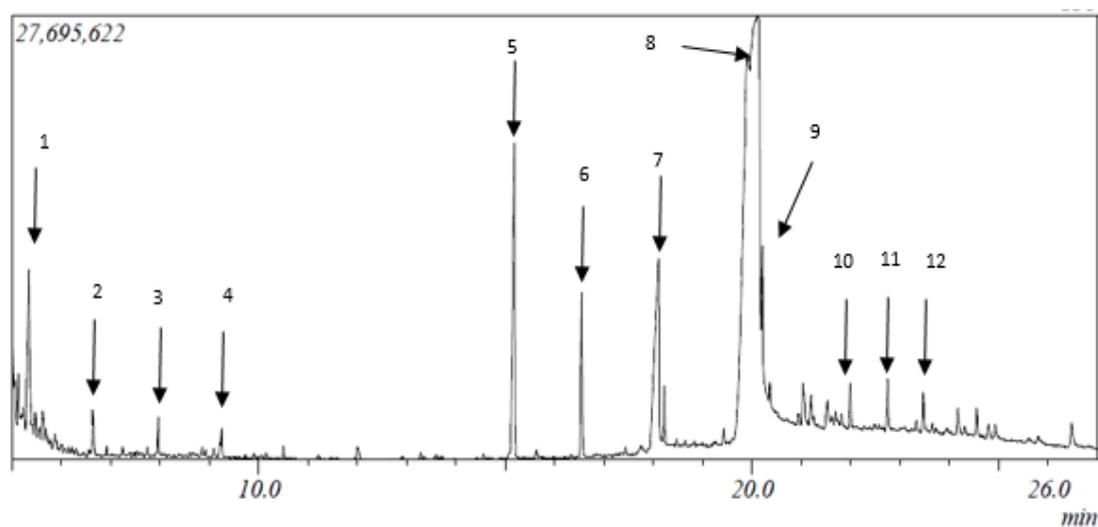


Figure 1: Chromatogram of the petroleum ether fraction

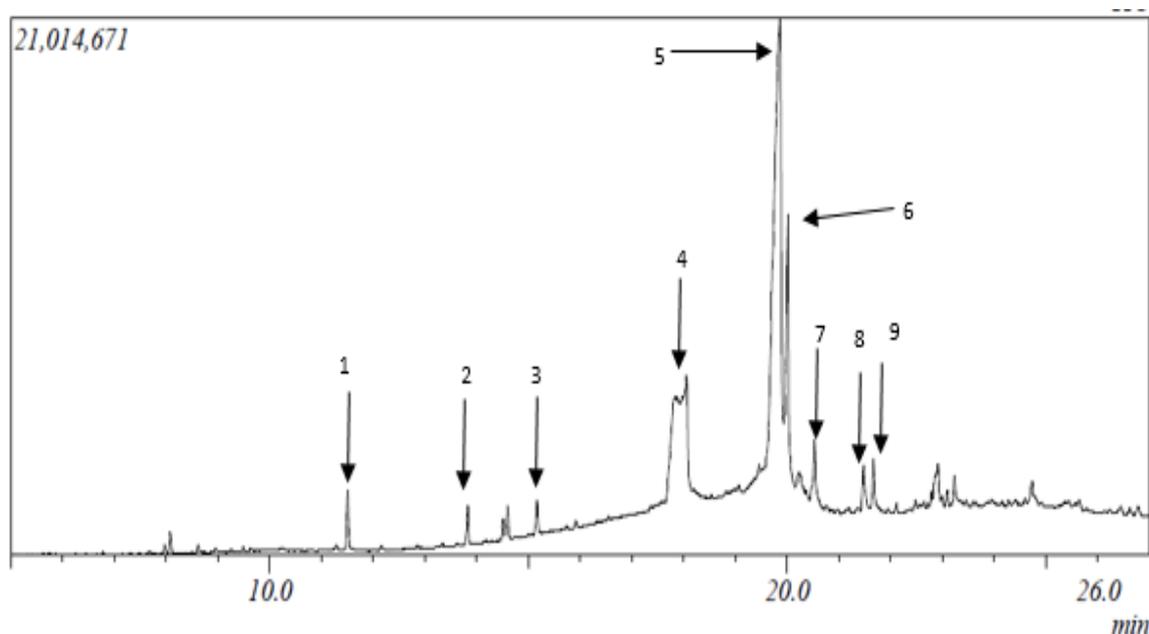


Figure 2:Chromatogram of the chloroform fraction

The identity of numbered peaks in the chromatograms was confirmed by comparison of their mass spectra with mass spectra of the authentic compound from literature. For the petroleum ether fraction, the following compounds were identified as numbered: **1** – Undecane (5.338); **2** – dodecane (6.648); **3** – tridecane (7.965); **4** – tetradecane (9.246); **5** – isobutyl, butyl glutaric acid (15.180); **6** – dibutyladipate (16.547); **7** – n-hexadecanoic acid (18.104); **8** – 9,12-octadecadienoic acid (19.985); **9** – Octadecanoic acid (20.205); **10** – 2-methylhexacosane (21.988); **11** – pentatricontane (22.744).

For the chloroform fraction, the following compounds were identified as numbered: **1** – Vanillin (11.510); **2** – 5-oxo-Pyrrolidinecarboxylic acid-ethyl ester(13.829); **3** – 1-(1-cyclohexen-1-yl)-Pyrrolidine (15.165); **4** – n-Hexadecanoic acid (17.834); **5** – 9-Octadecenoic acid (19.857); **6** – octadecanoic acid (20.014); **7** – 9,12-Octadecadienoic acid (20.525); **8** – 2-hydroxy cyclopentadecanone (21.477); **9** – Eicosanoic acid (21.665). The number in parentheses after the name of each compound is the retention time for that compound in minutes.

The anti-plasmodial activity of petroleum ether and ethanolic extracts of seeds of *Pentaclethramacrophyllais* presented in tables 4, 5 and 6. It confirmed that petroleum ether seed extracts of *Pentaclethramacrophyllais* non-toxic as high as 100 mg/kg, Table 4.

Table 5: Acute toxicity test for Ethanol and petroleum ether extract of seeds of *Pentaclethramacrophylla*

Group	Average Weight (g)	Dose	Survival at 24 h	Survival at 48 h	Survival at 72 h
Group 1	26 g	25 mg/kg	Active and healthy		
Group 2	25 g	50 mg/kg			
Group 3	25 g	100 mg/kg			

Table 5 represents test organisms treated with petroleum ether extract of *P. macrophylla* against *Plasmodium berghei*. The test subjects were treated with 25 mg/kg, 50 mg/kg and 100 mg/kg as indicated. From the table, it can be deduced that parasitemia decreased significantly over the test period, and no deaths were recorded.

Parasitemia in the negative control (Table 5) did not decrease but rather showed a significant increase as is characteristic of malaria. The positive control however showed a significant decrease in parasitemia.

Table 6 shows the percentage chemo-suppression over time for the petroleum ether extract of *P. macrophylla*. The table shows percentage chemo-suppression of parasites at different concentrations for different days. In the table chloroquine showed the highest chemosuppression rates followed by the 100mg/kg of the petroleum extract.

Table 6: Mean Daily Parasitemia at Various Concentrations of Ethanol Extract of *P. macrophylla*

Concentration (mg/Kg)	Mean Percentage Parasitemia				
	Pre-Treatment (%)	Day 0 (%)	Day 1 (%)	Day 2 (%)	Day 3 (%)
25	11.00 ±1.00	9.00±1.00	7.50±0.5	5.00±0.0	3.50±0.05
50	11.00±1.00	8.50±0.5	6.00±0.0	4.50±0.5	2.50±.050
100	13.00±1.00	10.50±0.5	8.00±0.0	5.50±0.5	2.00±0.00
Chloroquine (Positive Control)	15.00±0.00	10.00±0.00	6.50±0.5	4.00±1.0	1.00±1.00
Normal Saline	12.00±1.00	15.00±1.00	17.50±1.5	19.00±1.0	22.00±0.00

Values are expressed as mean ±SEM

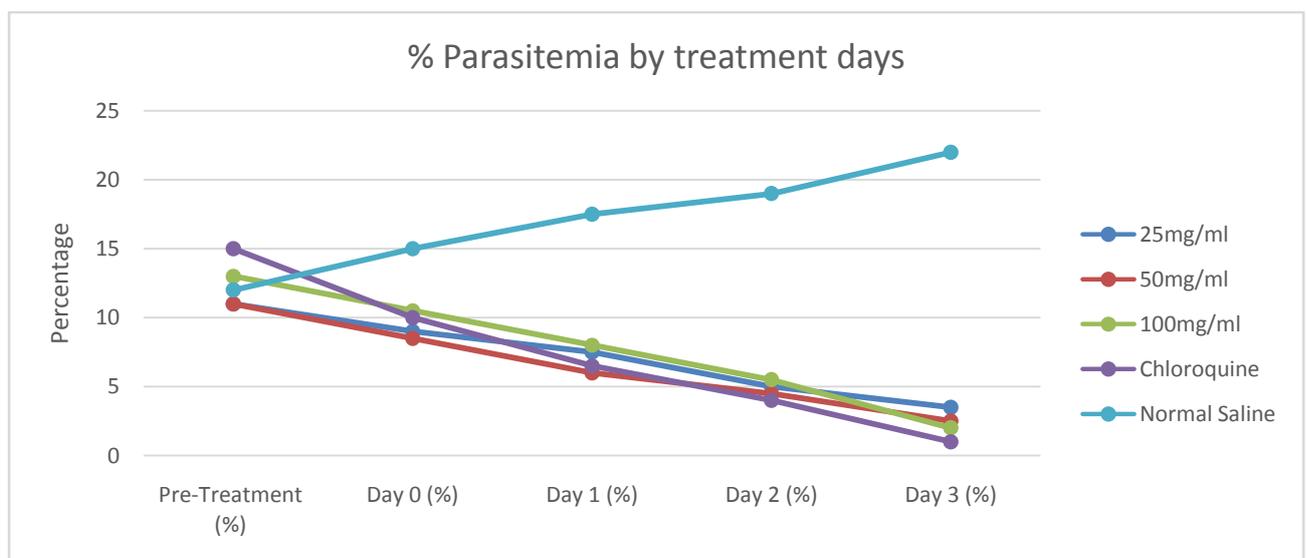


Figure 3: Percentage parasitemia at Different Concentrations of Ethanol Extract of *P. macrophylla*

Table 7: Mean Daily Parasitemia at Various Concentrations of Petroleum Ether Extract of *P. macrophylla*

Concentration (mg/Kg)	Mean Percentage Parasitemia				
	Pre-Treatment (%)	Day 0 (%)	Day 1 (%)	Day 2 (%)	Day 3 (%)
25	22.5 ±3.89	17.0±0.71	13.5±1.06	14.0±0.35	11.5±0.35
50	19.00±0.71	15.50±0.35	15.0±0.71	10.00±0.00	8.0±0.00
100	19.50±0.35	17.00±0.00	11.5±2.47	17.00±5.66	8.50±1.06
Chloroquine (Positive Control)	15.00±0.00	10.00±0.00	6.5±0.35	4.00±0.71	1.00±0.71
Normal Saline	12.00±0.71	15.00±0.71	17.5±1.06	19.0±0.71	22.00±0.00

Values are expressed as mean ±SEM

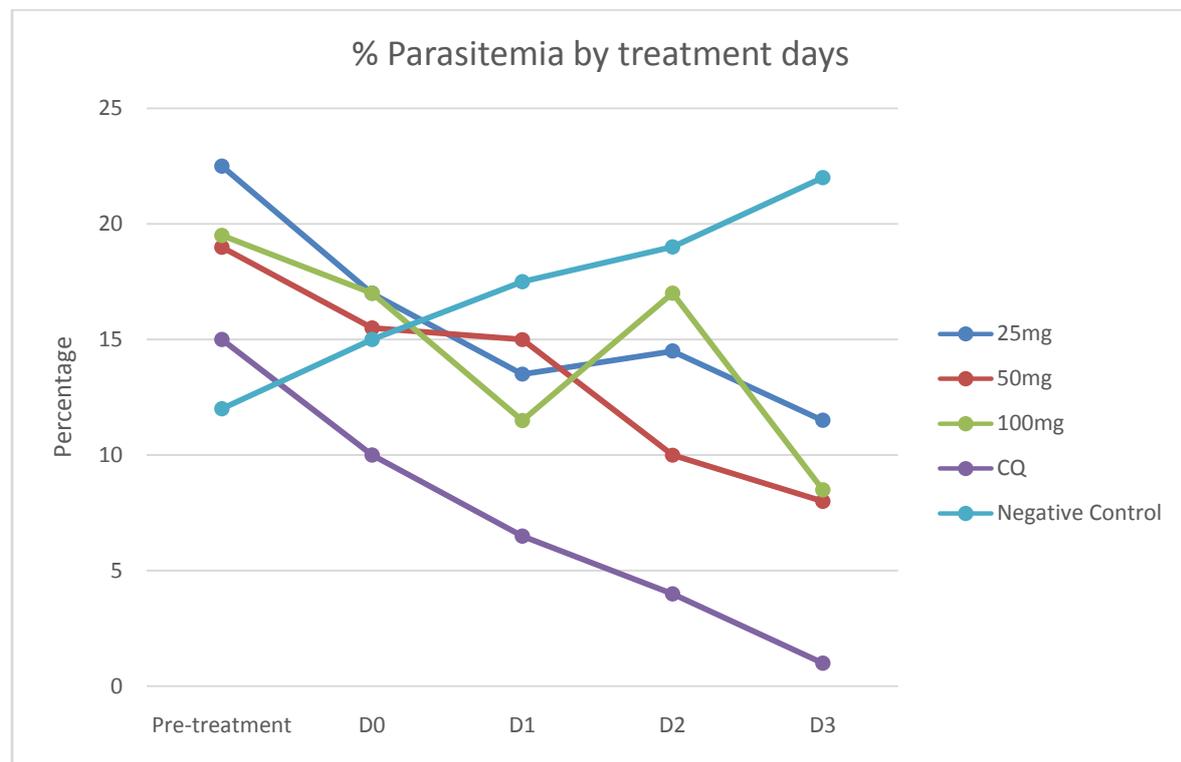
**Figure 4:** Percentage parasitemia at Different Concentrations of Petroleum Ether Extract of *P. macrophylla*

Table 8: Percentage Chemo-suppression of the Ethanol and Petroleum Ether extracts of *P. macrophylla* seed

Drug	Dose	Percentage (%) chemo-suppression Ethanol	Petroleum Ether
Physiological saline	0.5mL	-	-
<i>P. macrophylla</i>	25mL/kg	84.09	47.72
	50mL/kg	88.63	63.64
	100mL/kg	90.90	61.36
Chloroquine Phosphate	10mg/kg	95.45	95.45

Discussion

The *in-vivo* antiplasmodial activities of crude ethanolic and petroleum ether extracts of seeds of *P. macrophylla* Benth of the family *Fabaceae* with voucher No: Pm/Bio/H806 and Ascension code: OgCUNo807 were determined in this study. *In vivo* models are usually employed in anti-malaria studies because they take into account, the possible pro drug effect and probable involvement of the immune system in eradication of the pathogen (Waako *et al.*, 2005). During early infections, Peter's 4 day suppressive test was used to evaluate schizontocidal activity. In all methods, determination of percent of inhibition of the parasitemia was the most reliable parameter. A mean parasitemia level that is $\leq 90\%$ of that of the vehicle treated animals (negative control), usually indicates that the test compound is active (Peter and Anatoli, 1998). In the 4 day suppressive test, seed extracts of *P. macrophylla* significantly reduced parasitemia in animal models in a dose dependent manner, with these drugs showing anti-malarial activities compared to that of the standard drug tested. There were no deaths or any signs of toxicity observed after oral administration of single doses up to 100mg/kg of the extracts of *P. macrophylla*. This data indicates that the medium lethal dose (LD_{50}) should be 100mg/kg for both extracts, for test animals. There were no significant changes in the behavior, cutaneous breathing of both male and female mice.

The LD_{50} was calculated to be 707.11mg/kg for Petroleum ether seed extract of *P. macrophylla*. The LD_{50} is the concentration at which 50% of the test subjects will die. This shows that the extract becomes toxic at 707.11mg/kg. Also for *P. macrophylla*, the LD_{50} was 707.11mg/kg.

The seed extract of *P. macrophylla* exerted dose dependent chemo-suppressive effect against *Plasmodium berghei*. The petroleum ether extract caused a 47.72%, 63.64% and 61.36% chemo-suppressions at concentrations 25mg/kg, 50mg/kg and 100mg/kg respectively by the 4th day of the test, while the standard drug chloroquine caused chemo-suppressions of 95.45%. The ethanolic extracts of *P. macrophylla* seed at dosing concentrations of 25mL/kg, 50mL/kg and 100mL/kg body weight of mice yielded 84.09%, 88.63% and 90.90% inhibition respectively as against 95.45% for the standard drug, chloroquine. The observed higher efficacy of Chloroquine may in part be due to non-selectivity of the extract or slow absorption and poor bio-availability of the extract. This is common with medicinal plant extracts (Adzu and Haruna, 2007).

P. Berghei has been utilized in studying the activity of potential anti-plasmodials *in-vivo* in rodents (Pedroni *et al.*, 2006) and it produces diseases similar to those of human plasmodial infection (Kumar *et al.*, 2008). Agents with suppressive activity against *P. Berghei* were known for their anti-plasmodial activity (Elufioye and Agbedahunsi, 2004).

4. CONCLUSION

This study has shown the efficacy of *P. macrophylla* as an antimalarial and as such validates its use in traditional settings. Future research should focus on identifying the active fractions of the plant.

References

- [1] Adzu, B., Haruna, A.K., 2007. Studies on the use of *Zizyphus spina-christi* against pain in rats and mice. *African Journal of Biotechnology* 6, 1317–1324. doi:http://dx.doi.org/10.5897/AJB2007.000-2183
- [2] Ajaiyeoba, E., Ashidi, J., Abiodun, O., Okpako, L., Ogbale, O., Akinboye, D., Falade, C., Bolaji, O., Gbotosho, G., Falade, M., Itiola, O., Houghton, P., Wright, C., and Oduola, A., 2005. Antimalarial Ethnobotany: In Vitro. Antiplasmodial Activity of Seven Plants Identified in the Nigerian Middle Belt. *Journal of Pharmaceutical Biology* 42, 588 – 591.
- [3] Akindahunsi, A.A., 2004. Physicochemical studies on African oil bean (*Pentaclethra macrophylla* Benth.) seed. *Journal of Food Agriculture & Environment* 2, 14–17.
- [4] Anosa, G. N., Udegbunam. R. I., Okoro, J. O., Okoroafor, O. N., 2014. In vivo antimalarial activities of *Enantioplycarpa* stem bark against *Plasmodium berghei berghei* in mice. *Journal of Ethnopharmacology* 153, 531-534. doi: 10.1016/j.jep.2014.02.022
- [5] Arieu, F., Witkowski, B., Amaratunga, C., Beghain, J., Langlois, A.-C., Khim, N., Kim, S., Duru, V., Bouchier, C., Ma, L., Lim, P., Leang, R., Duong, S., Sreng, S., Suon, S., Chhor, C.M., Bout, D.M., Ménard, S., Rogers, W.O., Genton, B., Fandeur, T., Miotto, O., Ringwald, P., Le Bras, J., Berry, A., Barale, J.-C., Fairhurst, R.M., Benoit-Vical, F., Mercereau-Puijalon, O., Ménard, D., 2014. A molecular marker of artemisinin-resistant *Plasmodium falciparum* malaria. *Nature* 505, 50–55. doi:10.1038/nature12876
- [6] Charles Chukwumah, O., Inyang, I., Kelechi Angelina, I., 2013. KINETICS OF FERMENTATION OF OIL BEAN SEED. *Annals. Food Science and Technology* 14.
- [7] Chung, K.T., Wong, T.Y., Wei, C.I., Huang, Y.W., Lin, Y., 1998. Tannins and human health: a review. *Critical reviews in food science and nutrition* 38, 421–64. doi:10.1080/10408699891274273
- [8] Dana, S., Prusty, D., Dhayal, D., Gupta, M.K., Dar, A., Sen, S., Mukhopadhyay, P., Adak, T., Dhar, S.K., 2014. Potent antimalarial activity of acriflavine *in vitro* and *in vivo*. *ACS chemical biology* 9, 2366–73. doi:10.1021/cb500476q
- [9] Devi, P. B., Vijayabharathi, R., Sathyabama, S., Malleshi, N. G., and Priyadarisini, V. B. 2014. Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: a review. *J. Food Sci. Technol* 51, 1021–1040. doi: 10.1007/s13197-011-0584-9
- [10] Elufioye, T.O., Agbedahunsi, J.M., 2004. Antimalarial activities of *Tithonia diversifolia* (Asteraceae) and *Crossopteryx febrifuga* (Rubiaceae) on mice *in vivo*. *Journal of Ethnopharmacology* 93, 167–171. doi:10.1016/j.jep.2004.01.009
- [11] Ene, A. C. Atawodi, S. E., Ameh, D. A., Kwanashie, H. O. and Agomo, P. U. (2009) In vivo antiplasmodial effect of chloroform extracts of *Artemisia maciverae* Linn and *Artemisia maritima* Linn. *African Journal of Biotechnology* 8, 6612 – 6616.
- [12] Akwaji P.I.*, Eyam E. O. and Basse R. A. (2017). Ethnobotanical Survey of Commonly Used Medicinal Plants in Northern Cross River State, Nigeria. *World Scientific News*;70(2):140-157
- [13] Grimberg, B.T., and Mehlotra, R.K., 2011. Expanding the Antimalarial Drug Arsenal—Now, But How? *Pharmaceuticals* 4: 681 – 712. doi:10.3390/ph4050681
- [14] Ikhuria, E.U., Aiwonegbe, A.E., Okoli, P., Idu, M., 2008. Characteristics and Composition of African Oil Bean Seed (*Pentaclethra macrophylla* Benth). *Journal of Applied Sciences* 8, 1337–1339. doi:10.3923/jas.2008.1337.1339
- [15] Institute for Laboratory Animal Research, 2011. Guide for the Care and Use of Laboratory

- Animals: 8th Ed., Guide for the Care and Use of Laboratory Animals. doi:10.2307/1525495
- [16] Kumar, S., Das, S.K., Dey, S., Maity, P., Guha, M., Choubey, V., Panda, G., Bandyopadhyay, U., 2008. Antiplasmodial Activity of [(Aryl)arylsulfanylmethyl]Pyridine. *Antimicrobial Agents and Chemotherapy* 52, 705–715. doi:10.1128/AAC.00898-07
- [17] Lorke, D., 1983. A new approach to practical acute toxicity testing. *Archives of Toxicology* 54, 275–287. doi:10.1007/BF01234480
- [18] Ntie-Kang, F., Onguéné, P.A., Lifongo, L.L., Ndom, J.C., Sippl, W., Mbaze, L.M., 2014. The potential of anti-malarial compounds derived from African medicinal plants, part II: a pharmacological evaluation of non-alkaloids and non-terpenoids. *Malaria journal* 13, 81. doi:10.1186/1475-2875-13-81
- [19] Odoemelam, S.A., 2005. Proximate Composition and Selected Physicochemical Properties of the Seeds of African Oil Bean (*Pentaclethra macrophylla*). *Pakistan Journal of Nutrition* 4, 382–383. doi:10.3923/pjn.2005.382.383
- [20] Ogueke, C.C., Nwosu, J.N., Owuamanam, C.I., Iwouno, J.N., 2010. Ugba, the Fermented African Oilbean Seeds; its Production, Chemical Composition, Preservation, Safety and Health Benefits. *Pakistan Journal of Biological Sciences* 13, 489–496. doi:10.3923/pjbs.2010.489.496
- [21] Olasehinde, G.I., Akinlabu, D.K., Owwoye, F.T., Owolabi, E.F., Audu, O.Y., Mordi, R.C., 2016. Phytochemical and Antimicrobial Properties of Oil Extracts from the Seeds of *Ricinodendron heudelotii*. *Research Journal of Medicinal Plants* 10, 362–365. doi:10.3923/rjmp.2016.362.365
- [22] Olasehinde, G.I., Ojurongbe, D.O., Akinjogunl, O.J., Egwari, L.O., Adeyeba, A.O., 2015. Prevalence of Malaria and Predisposing Factors to Antimalarial Drug Resistance in Southwestern Nigeria. *Research Journal of Parasitology* 10, 92–101. doi:10.3923/jp.2015.92.101
- [23] Oyeleke, G.O., Odedeji, J.O., Ishola, A.D., Afolabi, O., 2014. Phytochemical Screening and Nutritional Evaluation of African Oil Bean (*Pentaclethra macrophylla*) Seeds. *Journal of Environmental Science, Toxicology and Food Technology* 8.
- [24] Pedroni, H.C., Bettoni, C.C., Spalding, S.M., Dalla Costa, T., 2006. *Plasmodium berghei*: Development of an irreversible experimental malaria model in Wistar rats. *Experimental Parasitology* 113, 193–196. doi:10.1016/j.exppara.2005.12.017
- [25] Peter, I.T., Anatoli, V.K., 1998. The current global malaria situation. *Malaria parasite biology, pathogenesis, and protection*. ASM Press. WDC 1, 1–22.
- [26] Peters, W., 1968. The chemotherapy of rodent malaria, II. *Annals of Tropical Medicine & Parasitology* 62, 246–251. doi:10.1080/00034983.1968.11686556
- [27] Saidu, K., Onah, J., Orisadipe, A., Olusola, A., Wambebe, C., Gamaniel, K., 2000. Antiplasmodial, analgesic, and anti-inflammatory activities of the aqueous extract of the stem bark of *Erythrina senegalensis*. *Journal of Ethnopharmacology* 71, 275–280. doi:10.1016/S0378-8741(00)00188-4
- [28] Sofowora, A., Ogunbodede, E., Onayade, A., 2013. The role and place of medicinal plants in the strategies for disease prevention. *African journal of traditional, complementary, and alternative medicines : AJTCAM* 10, 210–29.
- [29] Tarkang, P. A., Franzoi, K. D., Lee, S., Lee, E., Vivarelli, D., Freitas-Junior, L., Liuzzi, M., Nolé, T., Ayong, L. S., Agbor, G. A., Okalebo, F. A., and Guantai, A. N., 2014. “*In Vitro* Antiplasmodial Activities and Synergistic Combinations of Differential Solvent Extracts of the Polyherbal Product, Nefang” *BioMed Research International*, 1. doi:10.1155/2014/835013
- [30] Tarkang, P. A., Okalebo, F. A., Ayong, L. S., Agbor, G. A., and Guantai, A. N., (2014) Anti-malarial activity of a polyherbal product (Nefang) during early and established Plasmodium infection in rodent models, *Malaria Journal*; 13:456 . doi: 10.1186/1475-2875-13-456.
- [31] Tepongning, R. N., Yerbanga, S. R., Dori, G. U., Lucantoni, L., Lupidi, G., et al. (2013) *In vivo*

- Efficacy and Toxicity Studies on *Erythrina senegalensis* and *Khayaivorensis* Used as Herbal Remedies for Malaria Prevention in Cameroon. *Eur J Med Plants*3: 454 – 464. doi: 10.9734/EJMP/2013/3928
- [32] Titanji, VPK., Denis Zofou, D., and Moses N. Ngemenya, MN., (2008) The antimalarial potential of medicinal plants used for the treatment of malaria in Cameroonian folk medicine, *Afr. J. Traditional Complementary Alternative Medicine*; 5: 302 – 321.
- [33] Valderramos, S. G., Scandfeld, D., Uhlemann, A. C., Fidock, D. A., and Sanjeev K. S., 2010. Investigations into the Role of the *Plasmodiumfalciparum* SERCA (PfATP6) L263E Mutation in Artemisinin Action and Resistance. *Antimicrobial agents and chemotherapy* 54, 3842 – 3852. doi:10.1128/AAC.00121-10
- [34] Waako, P.J., Gumede, B., Smith, P., Folb, P.I., 2005. The *invitro* and *invivo* antimalarial activity of *Cardiospermum halicacabum* L. and *Momordica foetida* Schumch. Et Thonn. *Journal of Ethnopharmacology* 99, 137–143. doi:10.1016/j.jep.2005.02.017
- [35] Watts, D.L., 1990. Nutritional Interrelationships: minerals, vitamins, endocrines. *Journal of orthomolecular Medicine* 5, 11-19.
- [36] Wu, M., Atchley, D., Greer, L., Janssen, S., Rosenberg, D., Sass, J., 2009. Dosed without prescription: preventing pharmaceutical contamination of our nation's drinking water. *Natural Resources Defense Council White Paper*.60.