Antimalarial Effects of Ethanolic Leaf Extracts of *Azadirachta indica* and *Ocimum gratissimum*, and their Histologic Effects on Some Organs (Liver, Kidney and Heart) of *Plasmodium berghei* Infected Albino Mice

ABSTRACT

Azadirachta indica (Neem) and *Ociumum gratissimum* (clove Basil) have long been employed locally for the management of malaria. The present study compared antimalaria activities of the ethanolic leaf extracts of the individual plants, and assessed their combined effects on some organs of malaria-infected mice, at the Parasitology and Histopathology units, Federal Medical Centre (FMC), Owerri, from January to March, 2021. The leaves of the different plants were extracted with absolute ethanol (BDL 95%) for the test. Clean albino mice were experimentally infected intraperitoneally with chloroquine-sensitive *Plasmodium berghei* NK65 strain. Parasitaemia level was determined before parasite inoculation and at 24 hours post treatment period. Histopathological study on the liver, kidney, and heart was carried out using the Paraffin Setions method. Extracts of the leaves were administered orally, while chloroquine administration was intramuscular. The efficacy of the leaf extracts was tested on the *P. berghei* infected albino mice using the 4-day curative test. The lethal median dose (LD_{50}) recorded for neem and clove basil leaf extracts were 31.62 and 1246.9 mg/kg body weight, respectively. Significant activity against the parasite was produced by infected mice treated with extracts of *A. indica* and *O. gratissimum*, and their combinations throughout the treatment period ($P<.05$). Highest reduction of parasitaemia was observed on day 4. Maximum parasitaemia reduction (78.65%) was attained with 30mg/kg of the combined extracts on the 7^{th} day. Mild pathological lesions were observed in mice treated with *A. indica* leaf extract. These observations indicate better anti-malaria activity of the combination therapy as compared with the individual extracts of *A. indica* and *O. grassimum*, and indicate good antimalarial and protective roles of the plant extracts on the parasitized mice at large, as it slows down development of resistance.

Keywords: Malaria treatment; phytotherapy; drug resistance; synergism of phytochemicals; histology; organs.

1. INTRODUCTION

"Malaria is a disease caused by *Plasmodium* species and vectored by the female *Anopheles* mosquitoes" [1,2]. "Of over forty recognized species of the *Plasmodium* parasites, five species namely: *Plasmodium vivax, P. ovale, P. malariae, P. falciparum,* and *P. knowlesi* have been reported to infect humans" [3,4]. "A few other species such as *P. berghei, P. yoelii, P. chabaudi,* and *P. vinckei,* have also been reported to be infective in other mammals like rodents, and monkeys" [5].

"According to the World Health Organization (WHO), approximately 219 million cases and 440 thousand deaths were reported due to malaria in 2018" [6]. "Nigeria accounts for more cases and deaths than any other country in the world and there is an estimated 100 million malaria cases with over 300,000 deaths per year in Nigeria" [7]. "*Plasmodium falciparum,* the most virulent of the malaria parasites, is responsible for the vast majority of the mortality and morbidity associated with malaria infections in Nigeria. Pregnant women and children less than five years are most vulnerable to malaria attack" [8,9].

"The widespread resistance of malaria parasites against many antimalaria drugs is a factor in the economic constraints of malaria control. There is evidence of resistance against most antimalarial drugs, which is worsened by the emergence of chloroquine-resistant strains of *P. falciparum,* the malaria parasite responsible for most of the death cases every year. This led to the use of artemisinin combination therapy (ACT) and further search for new phytotherapeutic agents" [10,11].

"If not promptly treated with effective medicines, malaria can cause severe illness that is often fatal" [7]. "Hence, treatment of malaria with combination drug regimens have become the practice of choice because of their increased therapeutic efficacy over monotherapy and the other benefits including decreased cytotoxicity, delay or prevention of the development of drug resistance" [12].

"But affordability and accessibility limit the use of artemisinin combination therapy, and these can lead to poor treatment practices, production of substandard forms of the drug, inadequate patient adherence to prescribed antimalaria regimen, which may in turn lead to treatment failures. Following the problems associated with the implementation of ACT, majority of the populations depend on traditional medical remedies, mainly from plants, which are often more available, affordable, and sometimes perceived as being more effective than conventional anti-malarial drugs including artemisinin combination therapy (ACT)" [13,14].

"Traditional herbs have been used to treat malaria for thousands of years. Most of these plants are used in the form of monotherapies and only a few plants are taken in combined therapies" [15]. "Antimalarial plants used in combination may promote the effectiveness of each plant, with efficacy being achieved by the use of a lower dose of each plant extract. This would profer pharmacological benefits, as one extract of the plants clears infection from one body system, and the other clears it from a different site of the same body" [16]. "Also, synergism with antimalarial agents could be utilized to prevent or delay the emergence *in vivo* of resistant populations of the parasite" [17].

"*Azadirachta indica* (Neem) plants from the Meliaceae family are extensively used as traditional medicinal remedies against malaria in the tropics" [18,19,20]. "Several studies demonstrated that *A. indica* leaf, seed and stem bark extract possess *in vivo* inhibitory activity on *P. falciparum* asexual stages" [18,21,10]. "Antimalarial activity of *Ocinum gratissimum* (African basil/clove basil) has also been demonstrated" [11]. Although these plants are used in the traditional treatment of malaria, there is the need to scientifically assess the efficacy of the individual plant extract and their combinations in the treatment of malaria.

The main aim of the present study was to compare the antimalarial effects of *Azadirachta indica* and *Ocimum gratissimum* extracts with chloroquine in *Plasmodium berghei*- infected mice. The specific objectives were to assess the effects of the ethanolic leaf extracts of *A. indica, O. gratissimum*, and their combined extracts in reducing parasitaemia in the albino mice; pathological effects of the extracts on the liver, heart, and kidneys of the treated mice; and

synergistic effects of the combined extracts in treating rodent malaria.

2. MATERIALS AND METHODS

2.1 Study Area

This study was undertaken in Owerri at the Federal Medical Centre Laboratory. Owerri is the capital city of Imo State of Nigeria, located between latitudes 5^0 31^1 and 6^0 27^1 N and Longitudes 7^0 00^1 and $7^0 05^1$, and approximately 100 square kilometers (40sq miles) in area, and consists of three Local Government Areas including Owerri Municipal, owerri North, and Owerri West (Fiqure 1). Owerri has an estimated population of 1,401,873 according to the 2006 census. It is bordered by the Otamiri River to the East and the Nworie River to the South [22].

Owerri has an annual temperature of 20^0C-30^0C, relative humidity of 71%, rainfall distribution of 113.5m. Tropical rainforest is the predominant vegetation in Owerri although its density has drastically reduced due to anthropogenic activities such as urbanization, deforestation and agricultural activities.

2.2 Study Design

The work was an experimental study aimed at investigating the in vivo antimalarial effects of ethanolic leaf extracts of *A. indica* and *O. gratissimum* in *Plasmodium berghei*-infected Swiss albino mice (*Mus musculus* L: Muridae), using chloroquine as the standard drug. The parasites and the mice were sourced from the National Institute of Medical Research (NIMR), Yaba, Lagos, Nigeria. The plant materials (*A. indica* and *O. gratissimum*) were collected from the Botanical Garden of the Ministry of Agriculture and Natural Resources, Owerri, Imo State, Nigeria. Assessment of parasitaemia, acute toxicity studies, antimalarial effects of the plant extracts, and histopathological changes were done using standard laboratory analytical procedures at the Federal Medical Centre, Owerri.

2.3 Preparation of Plant Materials

Two kilogrammes (2kg) of each plant material was harvested, washed twice in clean water, and allowed to drip dry. The plants leaves were air-dried separately in the laboratory at room temperature for three weeks to a constant weight before pulverizing. A 100g each, of the pulverized leaves of the plants was measured and soaked in 500ml of absolute ethanol (BDL 95%) for 24 hours. The mixture was then filtered using Watman 2.0 filter paper. The filtrate was evaporated to dryness in a Rotary evaporator at a temperature of 40^oC. The extracts were kept in a tightly closed bottle in a refrigerator until needed for anti-malaria testing.

The stock solution of each plant filterate was prepared by dissolving 10g of the extract in 100ml of distilled water to give a stock concentration of 0.10g/ml [23].

2.4 Maintenance of Study Animals

Seventy five mature Swiss albino mice (*Mus musculus*) (25-30g) of either sex free from infection, were used. The animals were housed in mosquito screened-cages lined with wood chip beddings and were stabilized for ten days in the laboratory before being used for the experiments. The mice were maintained on a standard rat diet (Pfizer) and water *ad libitum*. They were kept at ambient room temperature of 12hour light and dark exposure cycles.

2.5 Maintenance of Parasites

Plasmodium berghei (NK65 strain) was used as the rodent malaria parasite in the study. The chloroquine sensitive cyropreserved parasites stored at -80^0C were revived, stabilized and maintained by serial passage of blood from infected mice to clean mice that served as donor mice in the study.

2.6 Collection, Preparation of Inoculum, Parasite Inoculation and Establishment of Infection

The blood of a donor mouse was collected in heparinized syringe and diluted in phosphate buffered saline to 10^8 parasitized erythrocytes per ml. The infection of mice was initiated by needle passage of the *P. berghei* parasite preparation from the donor mouse to healthy test mice via an intraperitoneal route [24,25].

The drug chloroquine was administered intramuscularly while the plant extracts and distilled water were administered orally with the aid of an intravenous medicut/mediflon cannula used as an improvised oral cannula [26].

2.7 Acute Toxicity Studies

Albino mice (25-30g) of either sex were used. The median lethal dose (LD_{50}) was determined for each of the neem leaf and love leaf extracts using the method previously described by Lorke [27]. In the first phase, the mice were divided into three groups with three mice in each group and were administered with the ethanol leaf extracts at doses of 10, 100, and 1000 mg/kg body weight respectively via the oral route. The mice were then observed for signs of toxicity and death for 24 hrs. In the second phase, groups of one mouse each were treated with more specific doses of the extract respectively depending on the result obtained from the first phase and observed for signs of toxicity and death in 24hrs. The final LD_{50} was calculated as the geometric mean of the lowest dose that caused death and the highest dose for which the animal survived.

LD_{50} = $\sqrt{}$ Mean of the lowest dose that caused death and the highest dose for which the animal survived.

Matsumura [28] and Corbett et al. [29] classified chemicals based on their LD_{50} values as follows:

Extremely toxic	$LD_{50} \leq 1$ mg/kg
Highly toxic	LD_{50} 1-50 mg/kg
Moderately toxic	LD_{50} 50-500 mg/kg
Slightly toxic	LD_{50} 500-5000 mg/kg
Practically non-toxic	LD_{50} 5000-15000 mg/kg
Harmless	$LD_{50} > 15$g/kg

Deriving from the outcome of the acute toxicity studies, dosage ranging from 20-60 mg/kg body weight for both extracts of *Azadirachta indica* and *Ocimum gratissimum* leaves were screened for therapeutic activities from which the dose (s) that gave optimum and consistent results were selected. The graded dose used in this study was 50mg/kg body weight for both extracts.

2.8 Experimental Set up and Treatments

The experimental group of mice for the assessment of the efficacy of the plant materials had fifty four (54) mice that were divided into six (6) groups (A,B,C,D,E and F) of nine (9) mice each. The nine (9) mice in each group were sub-grouped into three (1,2,3), of three (3) mice in each subgroup to represent the experimental mice and control mice (i.e po sitive and negative controls). The mice were infected by method described by Peter and Anatoli [24], and David et al. [30], with 0.2ml of diluted (10^8 parasitised erythrocytes/ml) infected blood each intraperitoneally (i.p), except those in group F that formed control group. Treatment of mice in experimental groups A to E commenced on day four when parasitaemia was well observed in the infected mice and percentage parasitaemia was assessed beginning from 24h post treatment. Fifty milligram per kilogram body weight of *A. indica* leaf extract, 50mg/kg body weight of *O. gratissimum* leaf extract, 10ml/kg body weight of

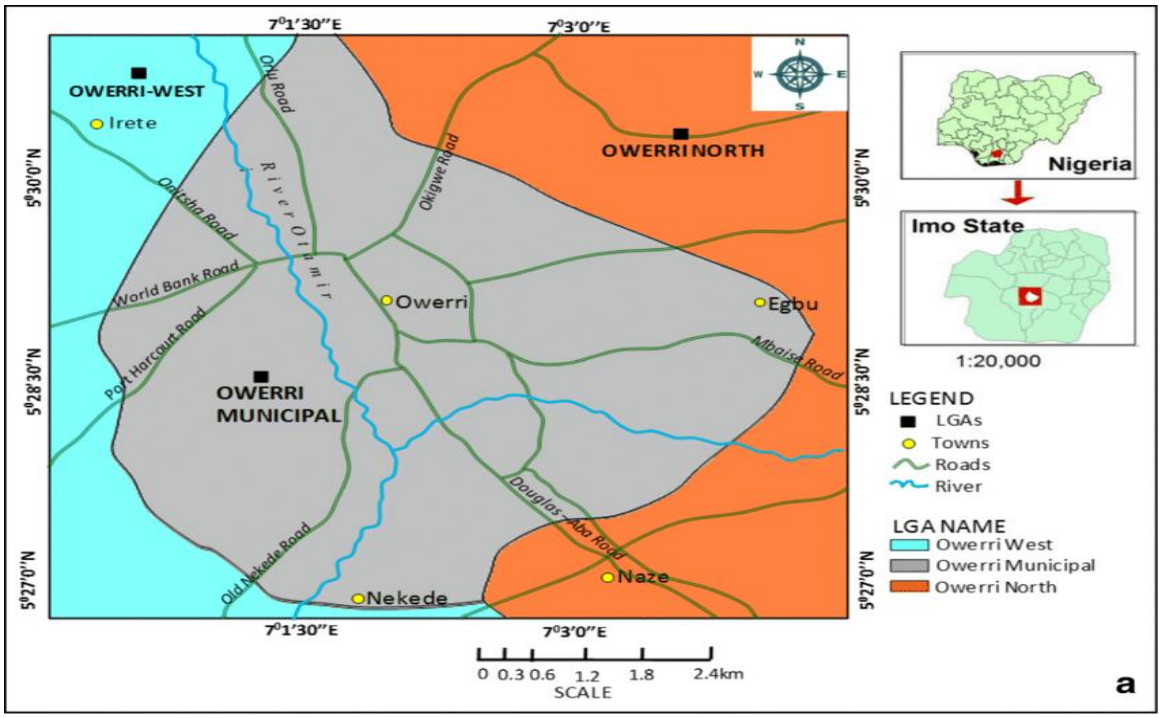

Fig. 1. Showing the map of Owerri

chloroquine, and 30mg/kg body weight each of *O. gratissimum* leaf extract and *A. indica* leaf extract were used for the treatment, and treatment was repeated daily with the same dose for 72 hours. Percentage parasitaemia was assessed beginning from 24 hours post treatment, and was repeated on daily basis throughout the treatment period.

Group A - Control (Infected with no treatment).
Group B- Infected and treated with chloroquine (CHQ) (10ml/kg)
Group C- Infected and treated with *A. indica* leaf extract (50mg/kg).
Group D - Infected and treated with *O. gratissimum* leaf extract (50mg/kg).
Group E- Infected and treated with combined extract each of *A indica* and *O. gratissimum* leaf extracts (30mg/kg).
Group F- Not infected (Normal Control).

Twenty four hours after the last treatment (96 hours post-infection) blood smears from all the mice were prepared and stained with Giemsa stain for assessment of parasitaemia levels

2.9 Assessment of Parasitaemia

Before parasite inoculation and at 24hours post treatment period,the experimental mice were bled from their tails, thin blood smears were made by fixing for 5 minutes using methanol stained with 10% Giema stain in phosphate buffer, P^H 7.2, and examined microscopically under oil immersion at x100. Parasitaemia level was determined by counting the parasites observed in 10 fields of approximately 100 erythrocytes per field. The difference between the mean values of the experimental group was calculated and expressed as percentage parasitaemia inhibition using the following equation:

% Inhibition = (Parasitized RBC in Negative Control – Parasitized RBC in study group x 100) / Parasitized RBC in Negative Control

2.10 Assessment of Histopathological Changes

The animals were sacrificed by cervical dislocation 24 hours (one day) after the last dose of the treatments, and the organs were harvested.

Pathological changes were observed in three main organs – heart, kidney, and liver of the different groups of experimental mice. For light microscopic examination, tissues from each group were fixed with 10% buffered formalin, embedded with paraffin, and processed. After

routine processing, paraffin sections of each tissue were cut into 5um thickness and stained with haematoxylin and eosin. The photomicrographs of the relevant stained sections were taken with the aid of a light microscope.

The following scores were used to grade the degree of histopathological changes or lesions observed in the organs: not present (“), very mild (+), mild (++), moderate (+++), and severe (++++). The degrees of damages caused in the organs were scored or assigned as follows: not present (“), 1 to 4 foci/section examined (+), 5 to 8 foci/section examined (++), 9 to 12 foci/section examined (+++), >13 foci/section examined (++++). Tubular nephrosis was graded (++) when scattered cells were detected with pyknotic, karorrhexis, karyolysis nuclei, or loss of polarity, (+++) when these changes were present in larger sections of a tubule, and (++++) when multiple tubules in an area were affected.

2.11 Data Analysis

Data was analysed using the statistical package for social sciences (SPSS) version 2.0. Tabulations, percentages and graphs were used to present results. Statistically significant differences were analyzed using Analysis of variance (ANOVA). Graphs were plotted using Microsoft excel, version 2007.

3. RESULTS

3.1 Acute Toxicity Study and Behavioural Effects of the Plants' Leaf Extracts

Acute toxicity test of the A. indica leaf extract at concentrations of 100 and 1000 mg/kg produced mortality after 24hrs of observation. The median lethal dosage (LD_{50}) of this extract was 31.80 mg/kg. However, the animals were observed to experience slow movement within the first six hours of the extracts. The O. gratissimum leaf extract did not show any mortality for the 100mg/kg dose and it recorded a higher lethal dosage of 1264.9 mg/kg (Table 1). According to Matsumura [28] and Corbett et al. [29], the *A. indica* leaf is highly toxic while the *O. gratissimum* is classified as slightly toxic.

3.2 Intensity of Parasitaemia

Table 2 shows that few minutes prior to infection, there were no significant differences in parasite intensity in both the control groups A,B,.and F, and treatment groups C, D, and E, (P<.05; P=.00). No parasite was observed in the peripheral blood of all the experimental mice.

Table 1. lethal Dose (LD_{50}) of the Ethanol Extracts of *Azadirachta indica* and *Ocimum gratissimu*

Extract	LD_{50} (mg/kg)	Verdict
A. indica	31.62	Highly toxic
O. gratissimum	1264.9	Slightly toxic

Twenty-four hours after infection, parasite intensity was between 136853±1022.01 and 138633±852.31 in all the infected mice. Parasite intensity was not significantly different in treatment groups B,C,D, and E (P>.05; P=.995, .599, .990, and 1.00), that were infected with the parasites.

Twenty-four hours after last treatment with 30mg/kg and 50mg/kg body weight of the mice, parasite intensity in groups A (infected but not treated) rose significantly from 138083±1.00 to 181358.00±1.00 (P<.05; P=.00). The parasite intensity in groups B (infected and treated with chloroquine) significantly decreased to 3.00±0.58 (P<.05; P=.00). There were non-significant reductions in parasite intensity among those treated with plant extracts of *A indica* and *O. gratissimum* and their combined regimens (P>.05; P=1.00).

3.3 Antimalarial Effects of the Plant Leaf Extracts

The therapeutic effect of the leaf extracts of the plants on the infected animals Fig. 2 showed that the animals responded to the extracts within the first seven days of treatment with 69.89% reduction of parasitaemia for *O. gratissimum* treated group, 71.11% for *A. indica* treated group, and 82.70% for combined extracts of *A. indica* and *O. gratissimum* treated groups before the parasitized red blood cells started to increase which later led to the deterioration of the health condition of the animals.The antimalaria action of the combined leaf extracts of *A. indica* and *O. gratissimum* (82.70%) was close to that of chloroquine (97.98%).

3.4 Malaria-induced Pathological Lesions and Effects of Plant Leaf Extracts

Physical examination of some internal organs (liver, kidney and heart) of the experimental animals did not show any macroscopic changes.

Histological studies revealed some damages caused by the malaria parasites on the liver (Plates 2-6)[Table 3], on the kidney (plates 7-12)[Table 4], and on the heart (Plates 13-18)[Table 5], and the extent of reduction of these damages by the administered drugs. The accumulation of iron in the liver (Haemosiderosis), death of cells of the liver (Hepatic necrosis), and marked damages of the nephron in the kidney (Tubular nephrosis), were severe in group A (Infected and not treated). Reduction of the lesions and other damages were observed in the groups treated with *A. indica* extract, *O. gratissimum* extract, and the combined extracts of *A. indica and O. gratissimum*. The absence of any pathological damage in the untreated infected group (Tables 3, 4, and 5) is an indication that it was not caused by the malaria parasite.

3.5 Malaria-induced Pathological Lesions and Effects of Plant Leaf Extracts on the Liver

Plate 1 shows the micrograph of liver of normal mice with absence of lesions. The leaf extract of *O. gratissimum* and combined extracts of *O. gratissimum* and *A. indica* reduced pathological damages caused by the parasite (Plates 4 and 5) better than the *A. inidca* leaf extract (Plate 3). The reduction of the pathological damages in this organ by *O. gratissimum* leaf extract, and the combined extracts of *A. indica* and *O. gratissimum* is similar to that of chloroquine (Plates 4, 5, and 6). This is evident in their very mild/mild reduction of Kupffer cells, haemosiderosis, and reduction of hepatic necrosis irrespective of the dosage. The lesions were more persistant in the group treated with *A. indica* extracts (plate 3), while those treated with *O. gratissimum* extracts recovered quickly (Plate 4).

3.6 Malaria-induced Pathological Lesions and Effects of Plant leaf Extracts on the Kidney

Plate 7 shows the micrograph of kidney of normal mice with absence of lesions
The leaf extract of *O.gratissimum* reduced pathological damages (Plate 10) better than *A. indica* leaf extract (Plate 9), and chloroquine (Plate 12). This is indicated in its total reduction of tubular nephrosis, and perivascular interstitial mononuclear cell infiltration. The combined extracts each of *O. gratissimum* and *A. indica* (Plate 11) had the same effect with that of *O. gratissimum.* The reduction by *A. indica* was mild as well as that of chloroquine.

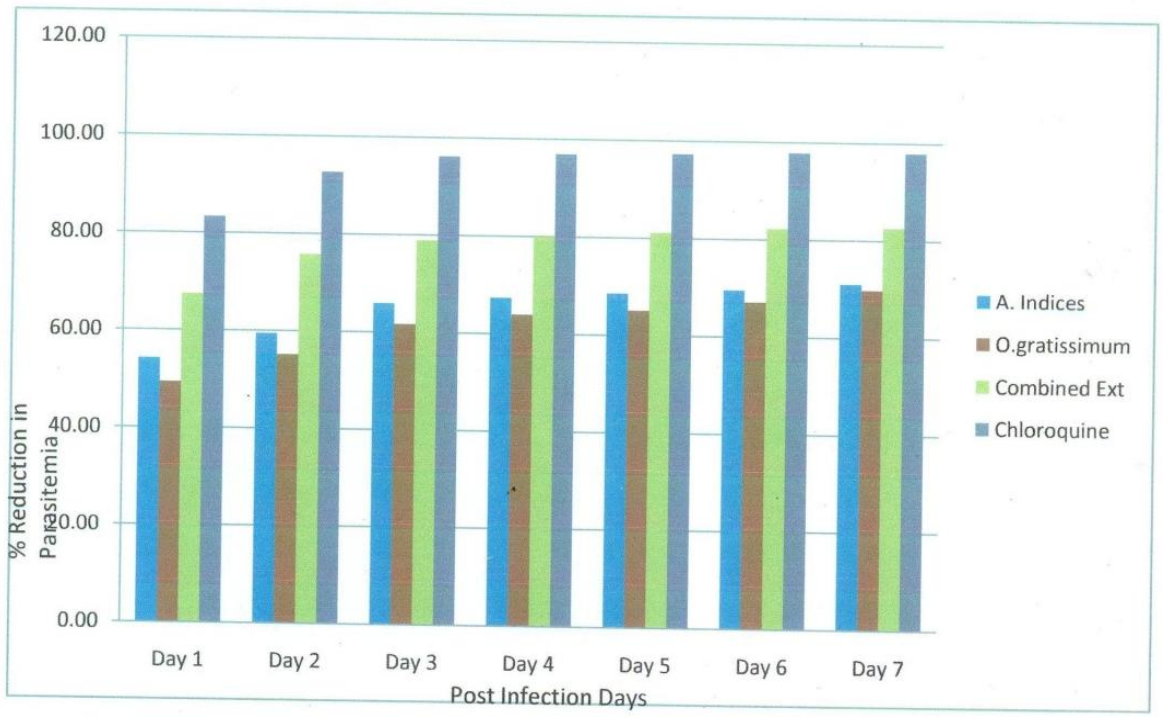

Fig. 2. Therapeutic effect of ethanolic extracts of the plants leaves on albino mice infected with *P. berghei*

Table 2. Changes in parasite intensity before infection, after infection, and after administration of ethanolic leaf extracts of *A. indica*, and *O. gratissimum* in *P. berghei*-infected mice (therapeutic effects of *A. indica and O. gratissimum*)

Experimental groups	Parasite intensity					
	Before infection($x10^3$)		After infection ($x10^3$)		After treatment ($x10^3$)	
A – Infected, No Treatment	0.000 ± 0.00	0.000 Sig P<0.00	138083.00 ± 1.000	0.000 Sig P<0.05	181358.00 ± 1.00	0.000 Sig P<0.00
B – 10ml/kg of Chloroquine	0.000 ± 0.00	0.000 Sig P<0.00	138633.00 ± 852.31	0.995 NS P> 0.05	3.00 ± 0.58	0.000 Sig P<0.05
C – 50/mg/kg *A. indica*	0.000 ± 0.00	0.000 Sig P<0.00	136853.00 ± 1022.01	0.599 NS P> 0.05	1957.00 ± 694.54	0.137 NS P>0.05
D - 50mg/kg of *O. gratissimum*	0.000 ± 0.00	0.000 Sig P<0.00	137971.00 ± 903.51	0.9902NSP> 0.05	3083.00 ± 93.54	0.625 NS P>0.05
E - 30mg/kg each of *A.i & O.g*	0.000 ± 0.00	0.000 Sig P<0.00	137634.00 ± 2301.11	1.000 NS P> 0.05	1235.00 ± 111.53	0.172 NS P>0.05
F – Not Infected, Normal Control	0.000 ± 0.00	0.000 Sig P<0.00	0.00± 0.00	0.000 Sig P< 0.05	0.00 ± 0.00	0.000 Sig P<0.05

Key: (A.i)=Azadirachta indica, (O.g)=Ocimum gratissimum

Table 3. Pathological effects of the plants leaf extracts on the liver of infected mice

	***A. indica* Leaf Extract**	***O. gratissimum* Leaf Extract**	**Combined Extract each of *A. indica* and *O. gratissimum***	**Chloroquine**	**Control (INT)**
	50mg/kg	**50mg/kg**	**30mg/kg**	**10ml/kg**	
Kupffer cell Hyperplasia	+++	+	+	-	++++
Haemosiderosis	++	++	++	-	++++
Hepatic Necrosis	+++	+	+	++	++++
Periportal Mononuclear cells infiltration	+++	++	+	+	-

The following scores indicate the degree of lesions/histopathological changes observed in the organ: (-) not present, (+) very mild, (++) mild, (+++) moderate, (++++) severe. (INT)-infected but not treated (A.i)=Azadirachta indica, (O.g)= Ocimum gratissimum

Table 4. Effect of plant extracts on pathologies caused in the kidney of infected mice

	***A. indica* Leaf Extract**	***O.gratissimum* Leaf Extract**	**Combined Extract each of *A. indica* and *O. gratissimum***	**Chloroquine**	**Control (INT)**
	50mg/kg	**50mg/kg**	**30mg/kg**	**10ml/kg**	
Tubular Nephrosis	++	_	+	++	++++
Perivascular interstitial mononuclear cell infiltration	+	_	_	_	++++

The following scores indicate the degree of lesions/histopathological changes observed in the organ: (-) not present, (+) very mild, (++) mild, (+++) moderate, (++++) severe. (INT)-infected but not treated (A.i)=Azadirachta indica, (O.g)= Ocimum gratissimum

Table 5. Effect of plant extracts on pathologies caused in the heart of the infected mice

	***A. indica* Leaf Extract**	***O .gratissimum* Leaf Extract**	**Combined Extract each of *A. indica* and *O. gratissimum***	**Chloroquine**	**Control (INT)**
	50mg/kg	**50mg/kg**	**30mg/kg**	**10ml/kg**	
Myofibres degeneration and necrosis	++	+	-	-	-

The following scores indicate the degree of lesions/histopathological changes observed in the organ: (-) not present, (+) very mild, (++) mild, (+++) moderate, (++++) severe. (INT)-infected but not treated (A.i)=Azadirachta indica, (O.g)=Ocimum gratissimum

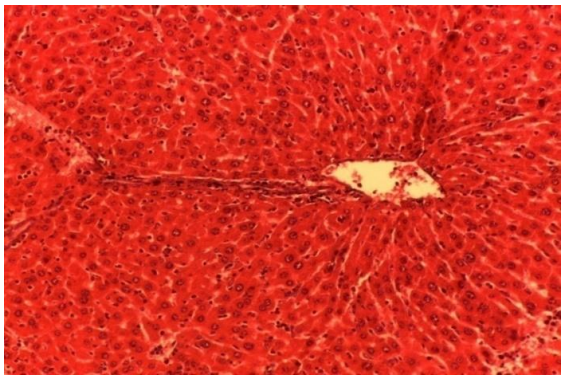

Plate 1. Histologic section of Liver of normal control Mice without infection under high magnification (40x) showing the absence of lesions in the liver of the mice

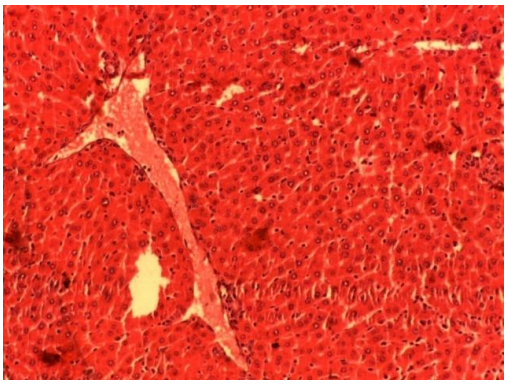

Plate 2. Histologic section of infected and not treated Liver (INT) under high magnification (40x) showing severe histopathological lesions in the mice

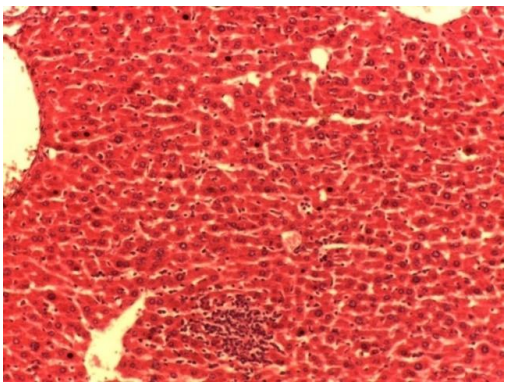

Plate 3. Histologic section of Liver of infected Mice treated with *A.indica* leaf Extract under high magnification (40x) showing moderate histopathological lesions observed in the mice

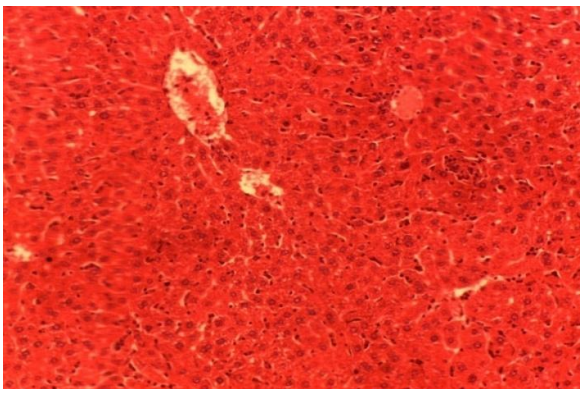

Plate 4. Histologic section of Liver of infected Mice treated with *O.gratissimum* leaf Extract under high magnification (40x) showing mild histopathological lesions observed in the liver of the mice

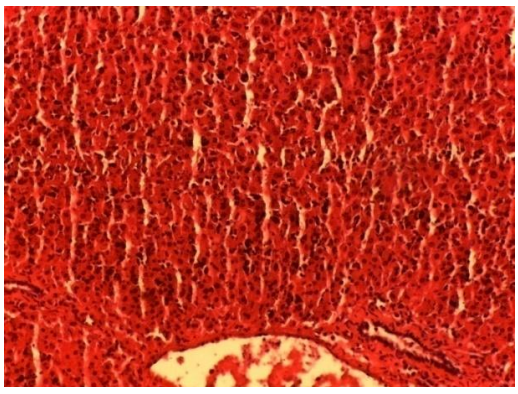

Plate 5. Histologic section of Liver of infected Mice treated with combined leaf extracts each of *A.indica* and *O.gratissimum* under high magnification (40x) showing very mild lesionsobserved in the liver of the mice

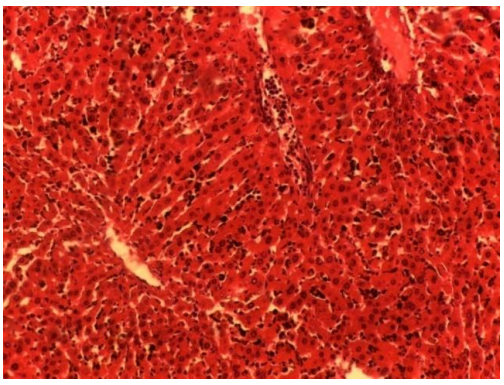

Plate 6. Histologic section of Liver of infected Mice treated with Chloroquine under high magnification (40x) showing very mild lesions observed in the liver of the mice

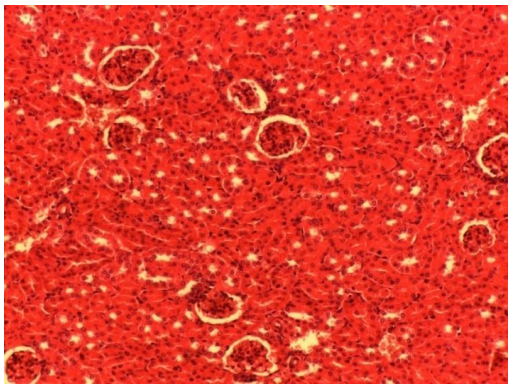

Plate 7. Histologic section of Kidney of normal control Mice without infection under high magnification (40x) showing absence of lesions in the kidneys of the mice

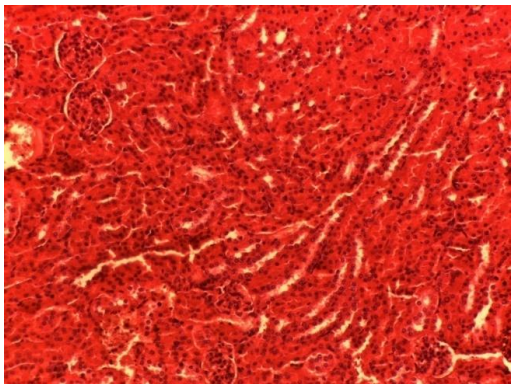

Plate 8. Histologic section of KIDNEY of infected and not treated (INT) Mice under high magnification (40x) showing moderate lesions observed in the kidneys of the mice

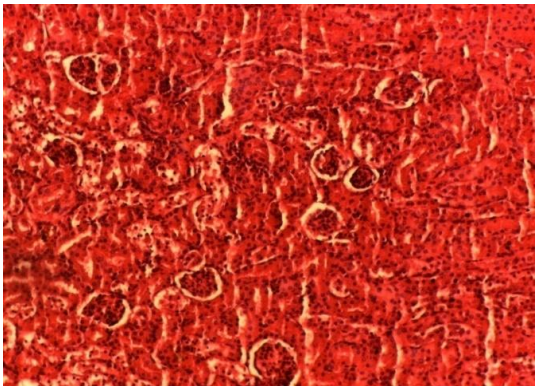

Plate 9. Histologic section of Kidney of infected Mice treated with *A.indica* leaf Extract under high magnification (40x) showing very mild lesions observed in the Kidneys of the Mice

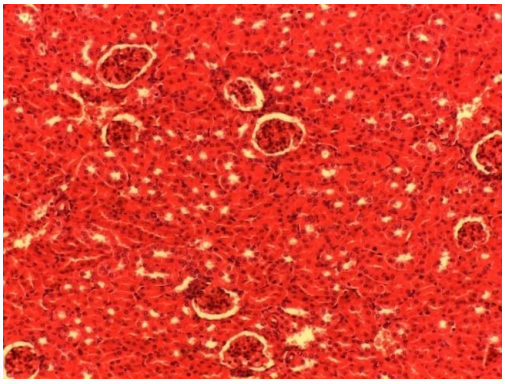

Plate 10. Histologic section of Kidney of infected Mice treated with *o.gratissimum* leaf Extract under high magnification (40x) showing absence of lesions observed in the Kidneys of the Mice

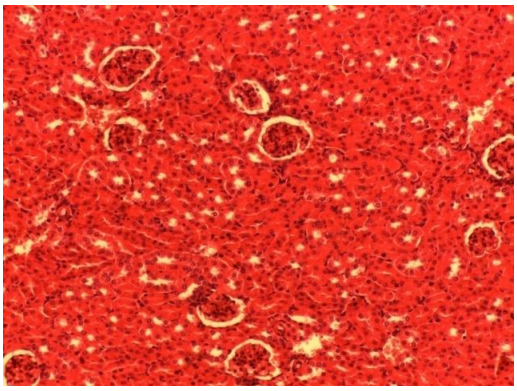

Plate 11. Histologic section of Kidney of infected Mice treated with combined leaf extracts each of *A.indica* and *O.gratissimum* under high magnification (40x) showing absence of lesions in the kidneys of the mice

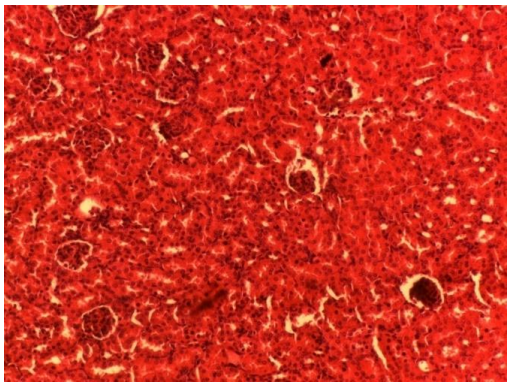

Plate 12. Histologic section of Kidney of infected Mice treated with Chloroquin under high magnification (40x) showing mild lesions observed in the kidneys of the mice

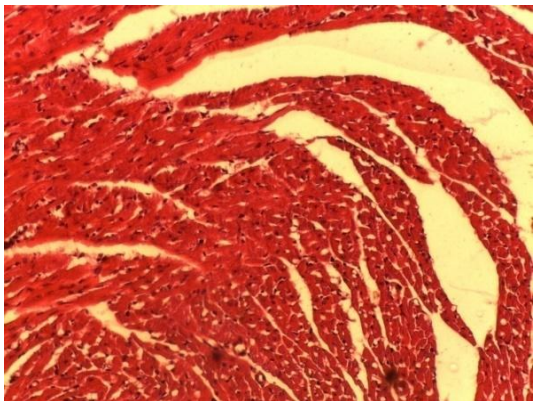

Plate 13. Histologic section of Heart of normal control Mice without infection under high magnification (40x) showing absence of lesions in the heart of the mice

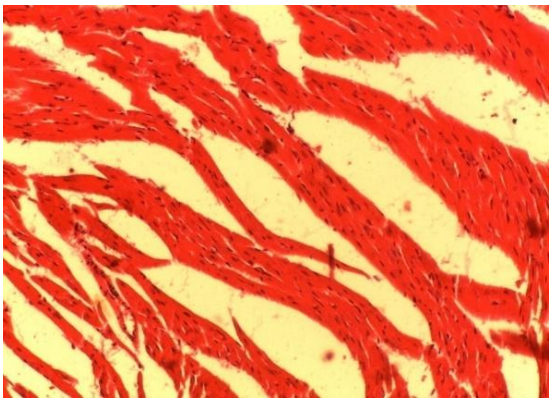

Plate 14. Histologic section of Heart of infected and not treated (INT) Mice under high magnification (40x) showing absence of lesions in the heart of the mice

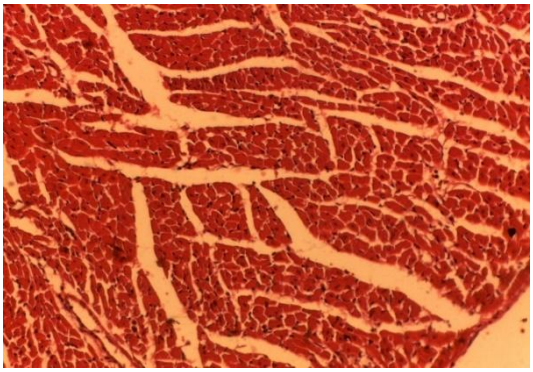

Plate 15. Histologic section of Heart of infected Mice treated with *A.indica* leaf Extract under high magnification (40x) showing very mild lesions observed in the heart of the mice

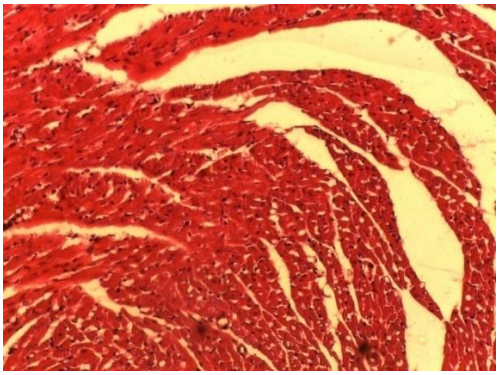

Plate 16. Histologic section of Heart of infected Mice treated with *O. gratissimum* leaf Extract under high magnification (40x) showing very mild/absence of lesions in the heart of the mice

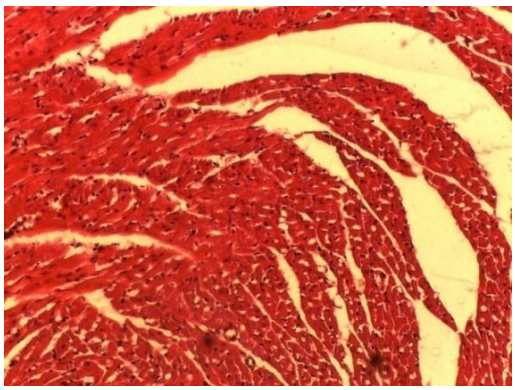

Plate 17. Histologic section of Heart of infected Mice treated with combined leaf extracts each of *A.indica* and *O.gratissimum* under high magnification (40x) showing absence of lesions in the heart of the mice

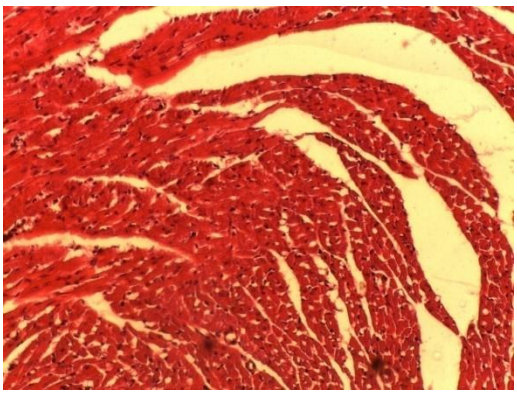

Plate 18. Histologic section of Heart of infected Mice treated with Chloroquine under high magnification (40x) showing absence of lesions in the heart of the mice

3.7 Malaria-induced Pathological Lesions and Effects of Plant Leaf Extracts on the Heart

Plate 13 shows the micrograph of heart of normal mice with absence of lesions.

The combined extract of *A. indica and O. gratisssimum,* and the leaf extract of *O. gratissimum* had almost similar effects on the pathological damages because no lesion was recorded (Plates 17 and 16, respectively), though it was very mild with the *O. gratissimum* leaf extract. Also the control groups (group infected without treatment and the group infected and treated with chloroquine) did not record any pathological damage (Plates 14, and 18), respectively. The *A. indica* leaf extract recorded very mild pathological damage (Plate 15).

4. DISCUSSION

The *in vivo* antimalarial activities of *A. indica* and *O. gratissimum* leaf extracts were studied in *P. berghei*-infected mice to determine the treatment outcomes of the extracts from January to March, 2021

Before parasite inoculation and at 24 hours post treatment period, parasitemia was monitored by microscopic examination of Giemsa-stained thin blood smears in all the experimental mice. The significant increase in the level of parasitaemia in the infected untreated group recorded from day 1 to day 7, as symptomised by the enlargement of the red blood cells, anaemia, loss of appetite, and loss of weight as major clinical signs observed during the course of treatment is in tune with the view that parasitaemia increases progressively after infection until the point of death if no suitable treatment is administered [10].

The reduction in parasitaemia was highest in the group administered with the combined extracts of *A. indica* and *O. gratissimum* (Figure 2, [82.70%]) than those administered with single plant extracts. This may be attributed to the antiplasmodial activities of the various ethanolic extracts, on one hand, and result of the synergistic effect of the compounds or their metabolites on the other hand. These findings agree with the reports of Awe and Makinde [31], Tona et al. [32], Iwalokun [33], Adebajo et al. [34], Somsak et al. [35], Ekpo and Ekanemesang [36], Cissy et al. [37], and Igbokwe et al. [38], which indicate that phytochemicals are responsible for the antimalarial activities of many plants. Also, these metabolites may be acting individually or in synergy with one another to produce antimalarial activity.

Pathologically, the severe damages observed in the liver of the animals in group A (infected but not treated) were as a result of the parasite life cycle during erythrocytic stages in the blood stream. Responding to the damage caused, macrophages (Kupffer cells) in the liver proliferated actively (Kupffer cell hyperplasia), breaking down ruptured red blood cells by phagocytic action thereby splitting up the haemoglobin molecules. This results to pathological effects such as accumulation of iron in the liver (haemosiderosis). Extensive and rapid death of parenchyma cells of the liver (Hepatic Necrosis) also occurred. These findings agree with the reports of Soniran et al. [39], and Idowu et al. [40].

In the liver, it was observed that the combined extract of *A. indica* and *O. gratissimum* reduced pathological damages better than the single extracts of *A. indica,* or *O. gratissimum (*Plate 5). Proliferation of Kupffer cells and accumulation of haemosiderin were mild while destruction of liver cells was not observed in this group. All these damages were severe in the untreated infected group. Reduction in the Kupffer cells which are phagocytic in nature may be due to few parasitized red blood cells in the liver as a result of the antiplasmodial effect of the extracts. Observation of liver cells necrosis in the infected and untreated group (Group A) showed the efficiency of the combined extract of *A. indica,* and *O. grastissimum* at reducing this pathological damage. This may be as a result of synergistic effect of phytochemicals present in the combined extracts but not present in the single/individual extracts, which prevented the exo-erythrocytic schizogony of the malaria parasites in the liver [41].

In the kidney, observations indicated that the leaf extracts reduced pathological damages to the bearest minimum. This is evident in the groups treated with *O. gratissimum* extract, and that treated with the combined extracts of *A. indica,* and *O. gratissimum* without any trace of pathological lesion in the kidney (Plates 10 and 11). Destruction of the nephron (Tubular Nephrosis) was moderate at 50mg/kg dose of the *A. indica* leaf extract-treated group, while infiltration of mononuclear cells was not present in the combined extract, and *O. grastissimum*

group, but very mild in the *A. indica* treatment group at 50mg/kg dose, thus, indicating the absence of foreign substances that could activate the infiltration of the mononuclear cells as observed in the infected and untreated group. This indicates the renal protective role of the combined extract each of *A. indica* and *O. gratissimum,* and *O. gratissimum* individual extract on inoculated mice. This finding agrees with the reports of Elsheikha and Sheasha [41], Bussayo et al. [42], Elias et al. [43], Koul et al. [44], and Somsak et al. [35].

In the heart, *O. gratissimum* leaf extract, and the combined extract each of *O. gratissimum* and *A. indica* did not record any lesions at all, in addition to the control treatment (Plates 16 and 17), and untreated control. The *A. inidica* leaf extract recorded mild lesions. The absence of the pathological damage in the untreated infected group is an indication that it was not caused by the malaria parasite. Therefore, certain chemical substances present in the *A. indica* leaf extract had led to the degradation and necrosis of myofibers in the heart. The activity of the combined leaf extracts of *A. indica* and *O. gratissimum* was also observed to be better than the individual/separate extracts of *A. indica,* and *O. gratissimum,* which corroborates the results observed in their antiplasmodial activity [40,10,45].

5. CONCLUSIONS

From observations, the individual leaf extracts of *A. indica* and *O. gratissimum* have been shown to be effective in the treatment of malaria parasite in mice by reducing the parasite intensity. The leaf extracts also proved good at reducing pathological damages caused by *P. berghei*, as evident in the restoration of hepato-, renal-, and cardiac integrity upon administration of the extracts. All these therapeutic observations were more pronounced in the combined extracts treatments indicating synergistic action of the extracts. It is therefore recommended that the coadministration of these locally used plants investigated in this study be taken for the treatment and management of malaria as their action is very close to that of the antimalarial drug, chloroquine which was the standard drug used in this study.

ETHICAL APPROVAL

Approval for the study was obtained from the Ethical Committee, Public Health Unit of the Owerri Municipal Council (OWMC), Owerri, Imo State, Nigeria. The caring and experimental use of the mice was in accordance with the National Institute of Health Guidelines for care of Laboratory Animals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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