



## **Prophylactic Effects of Some Nigerian Higher Fungi on Malaria Parasite, *Plasmodium berghei berghei* in BALB/c Strain Albino Mice**

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### **Authors' contributions**

This work was carried out in collaboration among all authors. Author SGJ designed the study. Author OOO wrote the protocol and the first draft of the manuscript. Author OJO performed the statistical analysis and interpreted the analyses of the study. All authors managed the literature searches, read and approved the final manuscript.

### **Article Information**

DOI: 10.9734/JABB/2018/v20i330076

#### Editor(s):

(1) Dr. Kuo-Kau Lee, Professor, Department of Aquaculture, National Taiwan Ocean University, Taiwan.

#### Reviewers:

(1) Abdu Umar, Usmanu Danfodiyo University, Sokoto, Nigeria.

(2) S. Murugesan, Pachaiyappa's College, University of Madras, India.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/47595>

**Original Research Article**

**Received 13 November 2018**

**Accepted 19 February 2019**

**Published 12 March 2019**

### **ABSTRACT**

The preventive abilities of some Nigerian higher fungi; *Pleurotus pulmonarius*, *Fomes lignosus*, *Lentinus subnudus*, *Termitomyces robustus*, *Pleurotus tuber-regium* collected from wood substrates, and the combined extracts (40 mg/mL) were studied against malaria parasite, *Plasmodium berghei berghei* to exploit them as medicinal agents. The fruit bodies were extracted with ethanol using soxhlet apparatus. Six hundred and twelve 4- 5 weeks old BALB/c mice (average weight 21 g) were assigned into 30 groups of twelve mice each. They were orally treated with 0.1 mL extracts of 4, 0.4, 0.04, 0.004, 0.0004 mg/mL before infecting with 0.2 mL of 5x10<sup>6</sup> parasitized erythrocytes. Chloroquine, CQ (20 mg/kg) served as controls. Liver and kidney were examined for histological changes. Parasitemic level, packed cell volume (PCV) and weights of animals were checked using standard methods. Descriptive statistics and ANOVA (at p= 0.05) were used for data analysis. *Lentinus subnudus* produced the highest decrease of parasitemia (30%), and recorded the

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least loss of PCV (27%), while *Pleurotus tuber-regium* produced the least weight loss of 26.5%. All the mushroom extracts produced same effect as CQ at concentrations 0.4 and 0.04 mg/mL. The tissues of infected animals without extracts had abnormalities. There were no histological damage in tissues of uninfected animals. Pre-infection treatment produced mild abnormal conditions from severe periportal infiltration and marked sinusoidal congestion. The extracts could be formulated into drugs against malaria however, appropriate dosage must be known.

**Keywords:** Prophylactic; *Plasmodium berghei berghei*; albino mice; mushrooms; malaria.

## 1. INTRODUCTION

Malaria is the world's most devastating human parasitic infection [1] that causes death of their victims especially children and pregnant women [2,3]. It is one of the major health challenges that is endemic in West Africa, and African countries including Nigeria [4,5].

Malaria is caused by species of *Plasmodium*, in which *P. malariae*, *P. vivax*, *P. ovale*, *P. falciparum* and the species responsible for malaria in humans [6]. Untreated malaria in tropics caused by *Plasmodium falciparum* can lead to lethal effect. Malaria characterized by fever, anaemia, splenomegaly and some complications vary considerably, depending on the species of *Plasmodium* causing the infection and the stage of development of the parasite [7,8].

*Plasmodium berghei berghei* is one of the four *Plasmodium* species described in African murine rodent, and infect mammals other than humans [9,10]. *P. berghei berghei* had sensitized the development of new drugs or vaccine through their resistance and susceptibility potentials [11,12]. Mushrooms are fleshy fungi, known to possess antimicrobial and immunomodulatory properties [13,14]. Examples of *Pleurotus* species include *Pleurotus tuber-regium*, *P. pulmonarius*, *Termitomyces* and *Lentinus* species. Reishi medicinal mushroom had reduced the amount of malaria parasites in infected mice [15].

The treatment of malaria is becoming difficult and challenging due to the occurrence of drug resistant to parasites causing infections. Also, some antimalarial drugs are ineffective [16]. Many local antimalarial plant species had been reported to be useful in treating malaria and fevers, but there are limited information on antiplasmodial potentials of mushrooms. This study therefore investigated the antiplasmodial potentials of some higher fungi in Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Fungi Samples and Preparation of Extracts

Samples of *Pleurotus tuber-regium*, *P. pulmonarius*, *Termitomyces robustus* and *Lentinus subnudus* were collected from Bodija market, Forestry Research Institute of Nigeria (FRIN), Iwo road market, University of Ibadan campus, all in Ibadan (Longitude 3.9°E, Latitude 7.4°N) in Oyo state and Bowen University, Iwo (Longitude 4.1°E, Latitude 7.6°N) in Osun state, Nigeria respectively. The extracts were prepared by cleaning the samples using cotton swab, cutting into small pieces before oven-drying the fresh fruit bodies at 40°C, and extracting with ethanol using a soxhlet apparatus [17]. Combined extract was prepared by combining equal proportion of each of the fungi before extraction.

### 2.2 Grouping of Experimental Mice and Parasite Inoculation (Passaging)

BALB/c strain albino mice (*Mus musculus*) of 4-5 weeks old with average weight of 22 grammes were used as experimental animals. One millilitre (1ml) parasitized blood was withdrawn from mouse infected with *Plasmodium berghei berghei* (NK-65 strain) and injected into an uninfected mouse.

### 2.3 Prophylactic Experiment

0.1 ml of ethanol extract from the higher fungi were prepared into different concentrations of 4 mg/ml, 0.4 mg/ml, 0.04 mg/ml, 0.004 mg/ml and 0.0004 mg/ml, and were orally administered to the mice separately for 4 consecutive days. This was followed by the intraperitoneal injection of the animals with 0.2 ml of  $5 \times 10^6$  parasitized blood on the 8th day after extract administration. The percentage parasitemia, PCV (Packed cell volume) and the weight loss

of the albino mice were monitored for 12 days.

The livers and kidneys of the dead animals were removed and kept in 10% formalin before carrying out histological studies. Animals used for chloroquine (CQ) experiment were indicated as standard, and orally administered at the dosage of 20 mg/kg.

### 2.4 Histological Studies

The excised livers and kidney kept in the formalin (10%) were studied for abnormalities using the procedures described by Yoshida et al. [18].

### 2.5 Statistical Analysis

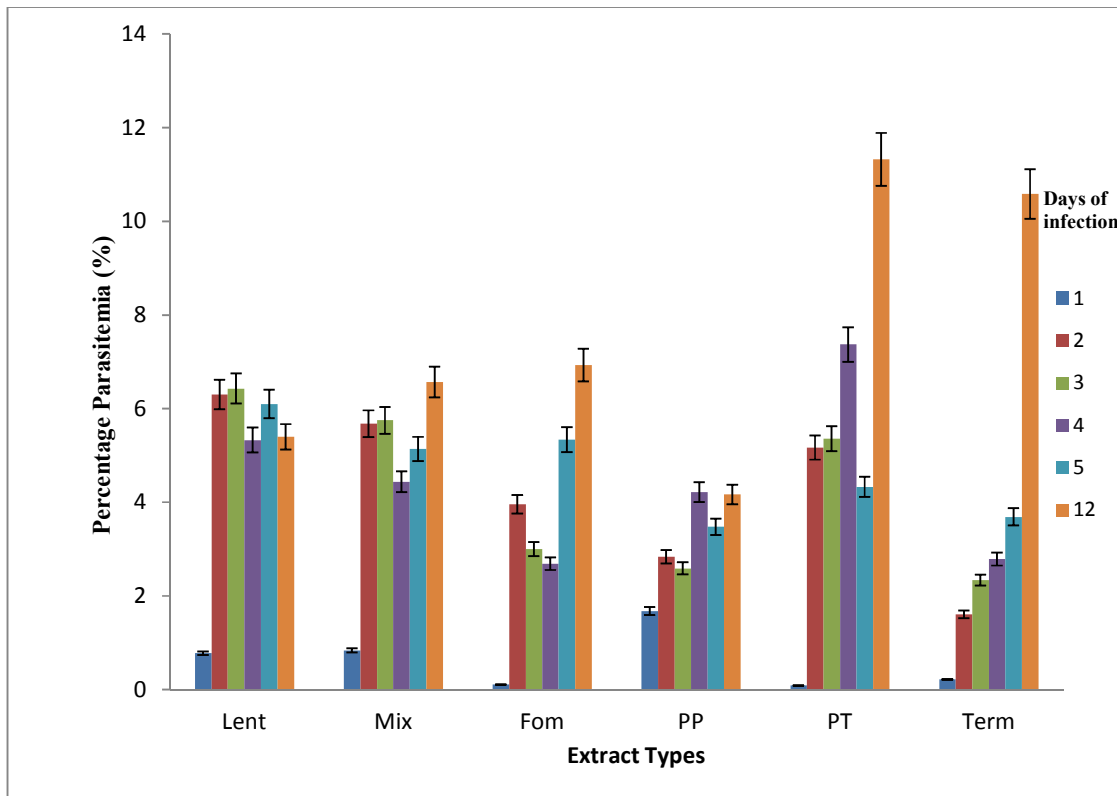
The effects of concentration of the extracts, extract types and their replicates were deduced

from Analysis of variance (ANOVA) using SAS version (2.0), while the means were separated by Duncan's Multiple Range Test (DMRT) at  $P < 0.05$ .

### 3. RESULTS AND DISCUSSION

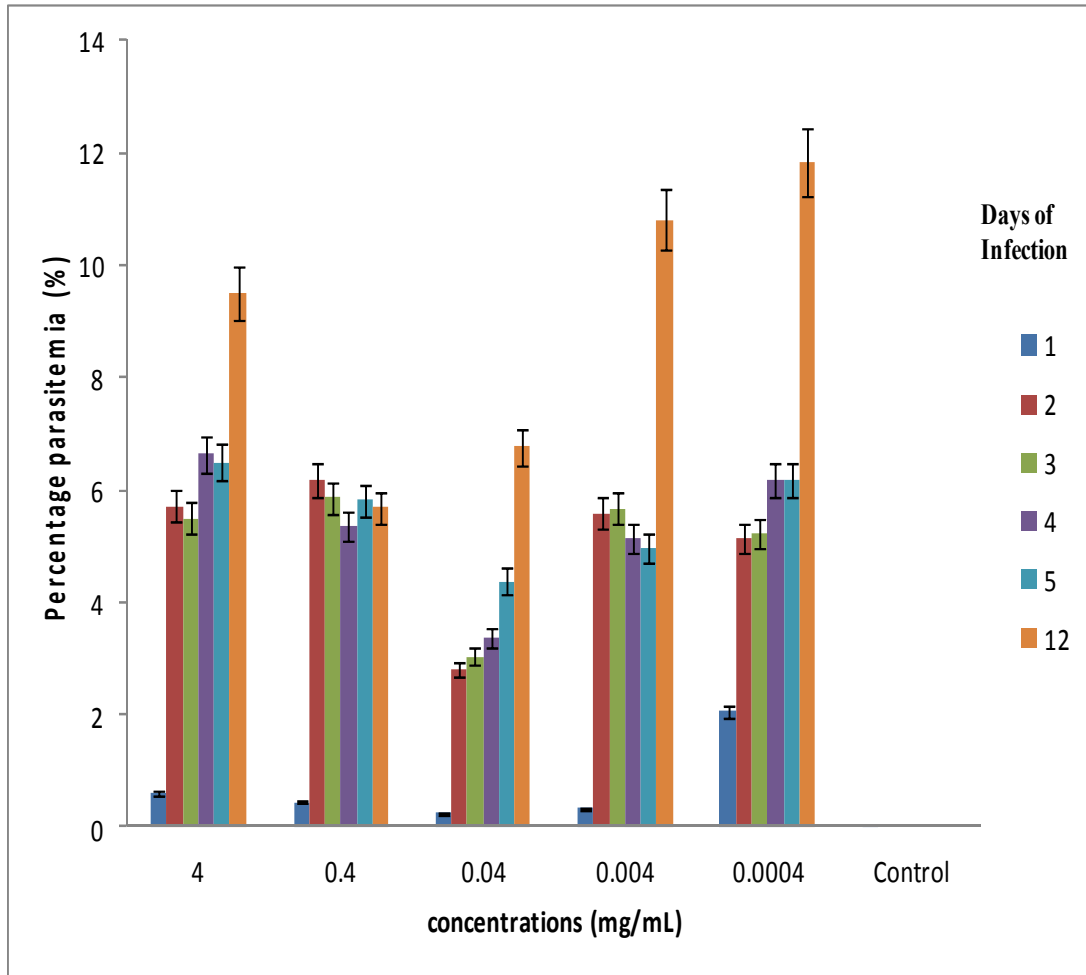
The prophylaxis of the higher fungi extracts had significant effect ( $p < 0.05$ ) on the parasitemia throughout the days of infection in the albino mice (Fig. 1).

The percentage parasitemia infection was generally low with all the extracts on the first day of infection. The parasitemic effect of *Plasmodium berghei berghei* was reduced by *Pleurotus tuber-regium* (0.09%) followed by *Fomes lignosus* (0.11%), *Termitomyces robustus* (0.22%), *Lentinus subnudus* (0.78%), combined extract (0.84%), while the least parasitemic effect was in *Pleurotus pulmonarius* (1.68%).



**Fig. 1. The effects of mushroom extracts types on parasitemia in mice infected with *Plasmodium berghei berghei***

Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error



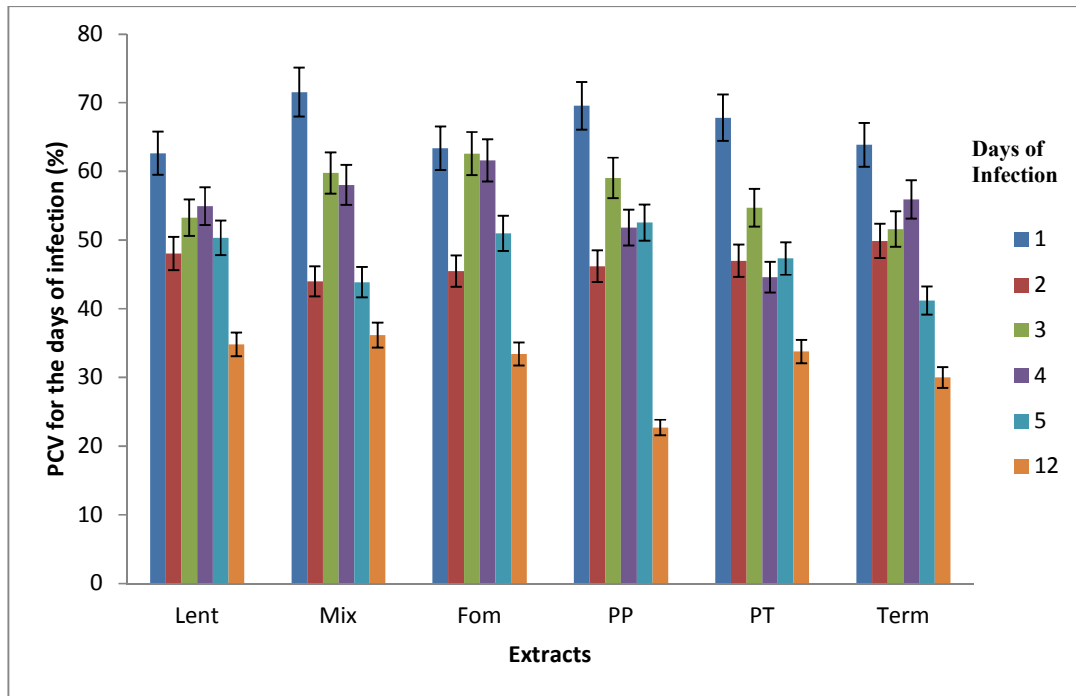
**Fig. 2. The effects of different concentrations of mushroom extracts on parasitemia in mice infected with *Plasmodium berghei berghei***

Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error

The low parasitemic effect could be due to the efficacy of the fungi extracts in the blood of the animals after the infection [19]. On the second day, there was an increase in the parasitemic level with highest percentage in *L. subnudus* (6.3%) and the least in *T. robustus* (1.61%). The increase in the infection level of the animals increased on the second day could be due to rapid multiplication and acclimatization of malaria parasites in the host to develop more resistance potentials to injected fungi extracts. There are profound changes in the parasites morphology which transform into new entities.

There was a decrease in parasitemia at the end of the experiment with *Lentinus subnudus*. This

is in contrast to the increase in parasitemia after the administration of combined extracts; *F. lignosus*, *P. pulmonarius*, *P. tuber-regium* and *T. robustus*, which compared the second, fifth and twelfth days of infection. The decreased parasitemic infection could be due to prophylactic effect of *Lentinus subnudus* [20,21]. *Lentinus* species had been reported to contain some pharmacological compounds such as lentinan which can be extracted from the cell wall of the fruiting body of mushrooms [22]. Lentinan confers resistance against bacterial, parasitic and viral infections [23]. Also, it was reported that the presence of lentinan in *L. subnudus* contributed to the prophylactic potential of the fungi in the treatment of malaria [24].



**Fig. 3. The effect of mushroom extracts on packed cell volume (PCV) of mice infected with *Plasmodium berghei berghei***

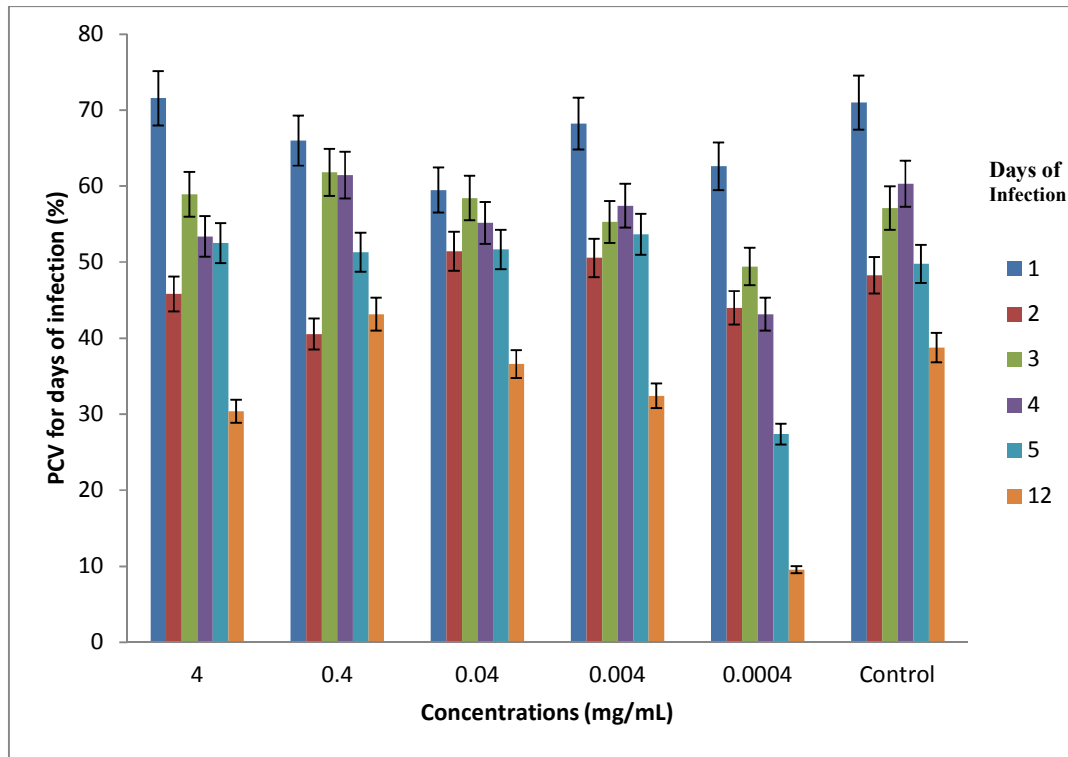
Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error

There are variations in the efficacy of the different concentrations of the extracts on the parasitemia infection in the experimental mice (Fig. 2). On the first and twelfth days of infection, the least concentration (0.0004 mg/ml) had the highest parasitemia infection of 2.06 and 11.84 respectively. The infection levels of animals administrated with extracts of concentrations 0.4 and 0.0004 mg/mL had the least percentage parasitemia value of 3.03, 3.38 and 4.3%, 5.67, 5.13 and 4.97%, between the third and fifth day. Comparing the second and twelfth days of infection, there was a decrease in parasitemia with extracts concentration of 0.04 mg/mL. Others had increase in parasitemia with the least percentage of 5.69 at the end of the experiment.

The concentrations of 0.4 mg/mL and 0.04 mg/mL gave the best prophylactic effects against the malaria parasite in the albino mice, thereby resulting to least parasitemia infection at the end of the experiment compared to concentration 0.0004 mg/mL with the highest parasitemia. This is in agreement with the observation that increased dilution of a compounded drug decrease the percentage of the larger particles

in the drug [25]. Therefore, the efficacy of the extract is determined by the higher dilution of the extract. Also, minimum inhibitory concentrations are important in confirming resistance of microorganisms to antimicrobial agents [26,27]. There was virtually no infection in the control animals during the prophylactic assay.

The effect of the prophylactic administration of the extract could be attributed to the low parasitemic infection in the mice on the first day after the seventh day of fungi administration. The fungi extracts which are prophylactically active in the order, *L. subnudus*, combined extract, *P. pulmonarius* similarly conforms to the observation made by [28]. Significant effects of the extract on the PCV of animals were also recorded in the prophylactic experiment. There was a general decrease in the packed cell volume (PCV) of the animals during the experimental period (Fig. 3). Though the combined extract had highest PCV values at the beginning and end of the experiment, the least PCV decrease of 27% was observed in *L. subnudus*. The highest PCV loss of 46% was in *P. pulmonarius*.



**Fig. 4. The effects of different concentrations of mushroom extracts on packed cell volume (PCV) of the mice infected with *Plasmodium berghei berghei***

Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error

The general decrease in PCV of animals could be due to the destruction or lysis of red blood cells targeted by the malaria parasite [29,30]. They undergo metamorphosis after invasion of the red blood cells leading to the subsequent lysis of the cells and the release of merozoites that invade new cells [31]. The mechanisms contributing to malarial anaemia are increased destruction of red blood cells, lowering the level of iron in the body, decreased production of red blood cells, development of badly functioning ones and destruction of uninfected red blood cells. The changes in red blood cells functioning affects the level of iron within the body hence the body begins to show signs of iron deficiency anaemia [29].

The least PCV loss of *L. subnudus* could be attributed to its best prophylactic effect least parasitemia level against the malaria parasite. PCV and parasitemia are interdependently related to each other with respect to invasion of malaria parasites in red blood cells [32]. The result from Fig. 4 shows that concentrations 0.04 mg/ml and 0.004 mg/ml had similar effects on the

PCV of the mice with the highest values of 51.44% and 50.56% respectively on the second day. Both had the least loss of PCV while concentration 0.0004 mg/ml had the highest PCV loss and the least PCV value of 49.44% at the end of the experiment.

The effects of the extracts on the weight of the albino mice are shown in Fig. 5. There was a general loss of weight in on the weight only on the first, third and fifth days of infections. *L. subnudus* extract on the first day had significant higher weight (22.89 g) than other fungi extracts. It maintained the highest weight of mice (23.67 g) followed by *F. lignosus* (21.50 g), *P. pulmonarius* (22.78 g), *T. robustus* (21.00 g), while the least weight of 20.83 g was observed in mice using combined extract. The least weight loss of 26.5% was observed in *P. tuber-regium* during the experiment. The weight decrease observed at the beginning and end of the experiment had been confirmed by [33]. The highest weight loss was observed in *P. pulmonarius* extract. The effect of the different concentrations of the extracts on the weight is shown in Fig. 6. There

was a general increase in weight from the first day till the fourth whereas, a loss in weight was 0.0004mg/ml had the least weight while there was no significantly loss of weight in the control animals throughout the experimental period.

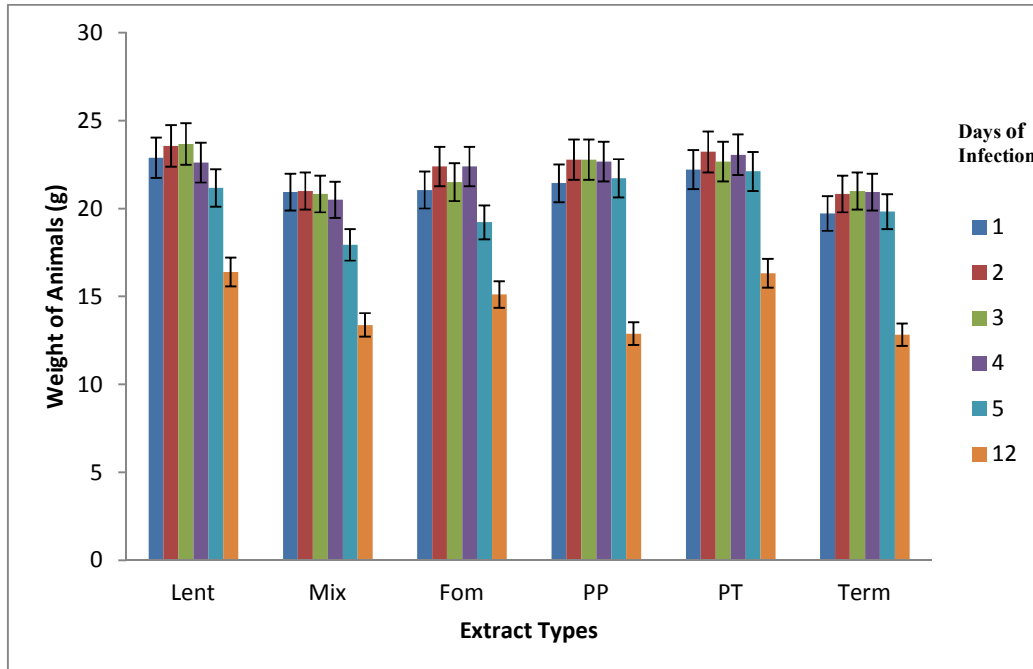
The general decrease in weights of the experimental mice could be associated with heavy parasite infection. Though the least weight of 26.50% was recorded with *P. tuber-regium*, there was a minimal weight loss with *L. subnudus* proving as the best prophylactic against the malaria infection. Weight loss is one of the evidences of malaria attack because it often causes loss of appetite leading to weight loss [34]. Also, a number of nutritional factors are associated with malaria. In pregnant women, maternal malaria contributes to up to 30% of low birth weight cases [35-37].

The pathological changes on the tissues of the mice infected with the malaria parasite after oral administration of extract of *L. subnudus* 0.4 mg/mL, 0.04 mg/L; and control experiment (without extract) are shown in plates 1, 2 and 3 respectively. In the histological studies, the abnormalities in the infected animals without

extract (Plate 3) and the absence of visible lesions in uninfected mice showed the damaging effects of the malaria parasite, *P. berghei berghei* on the organs of the mice. The livers of the mice administered with *L. subnudus* (4 mg/mL) before infection with malaria parasite had severe; and mild portal congestion and periportal cellular infiltration (Plate 5). At concentration 4mg/mL, the extract is not as effective as concentrations 0.4 and 0.04 mg/mL.0020

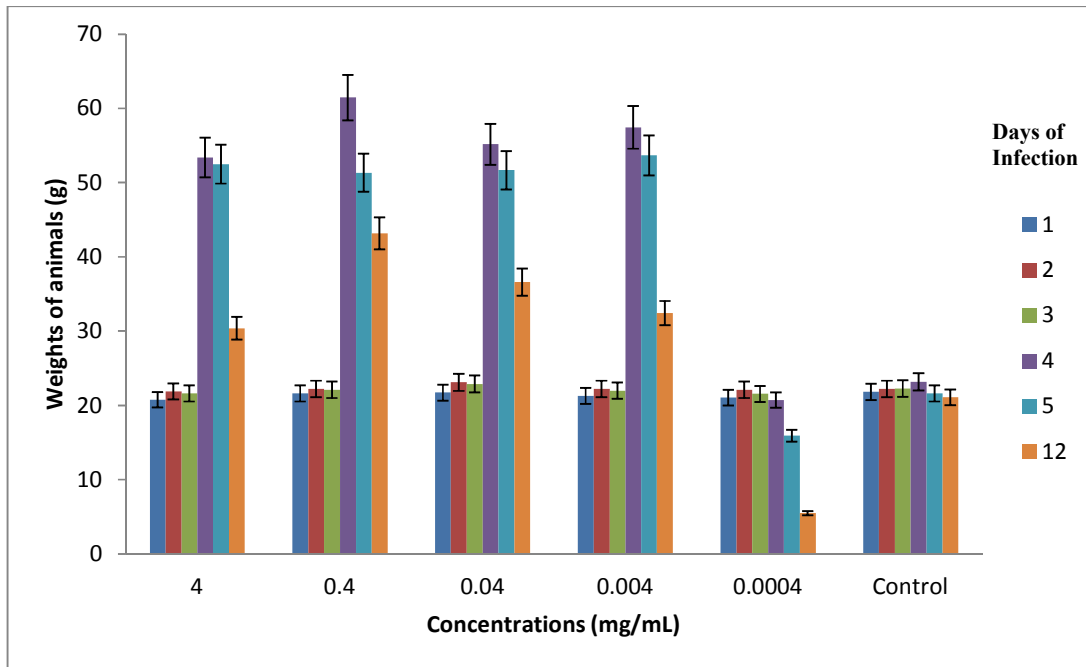
The visible pathological changes on tissues of animals administered with chloroquine (20 mg/kg) shown in plate 4 were similar to those treated with extracts of concentrations 0.4 and 0.004 mg/mL. There were mild conditions with two different concentrations and the chloroquine pre-infection experiment. This could be due to the preventive ability of the extract at concentrations of 0.4 and 0.004 mg/mL for prophylactic (pre-infective) administration. Plates 2, 3 and 4 revealed that concentrations 0.4 and 0.04 mg/mL had the same effect as the chloroquine.

*L. subnudus* can be considered a good prophylaxis in the prevention of malaria especially at concentrations 0.4 and 0.04 mg/mL.



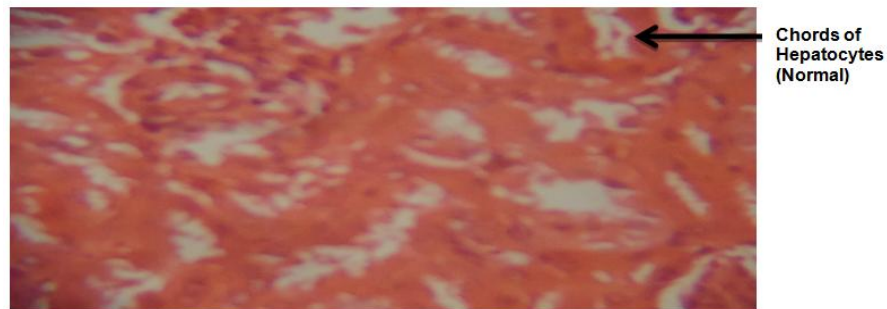
**Fig. 5. The prophylactic effects of Extracts on weights of mice infected with *Plasmodium berghei berghei***

Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error

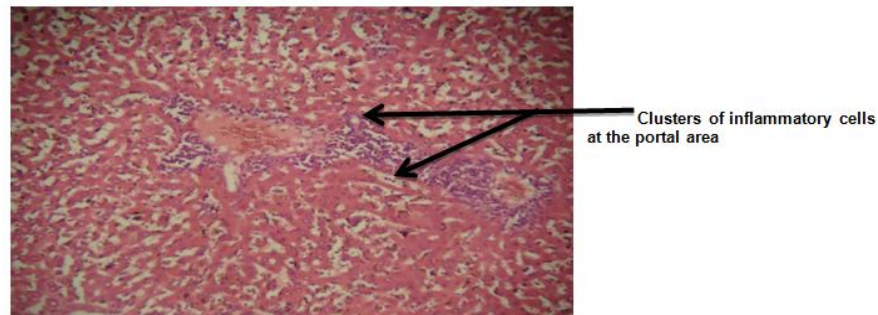


**Fig. 6. The prophylactic effects of different concentrations of Extracts on weights of mice infected with *Plasmodium berghei berghei***

Key: FOM = *Fomes lignosus*; PT = *Pleurotus tuber-regium*; PP = *Pleurotus pulmonarius*; Term = *Termitomyces robustus*; Lent = *Lentinus subnudus*; Mix = Combined extract; I= Standard error



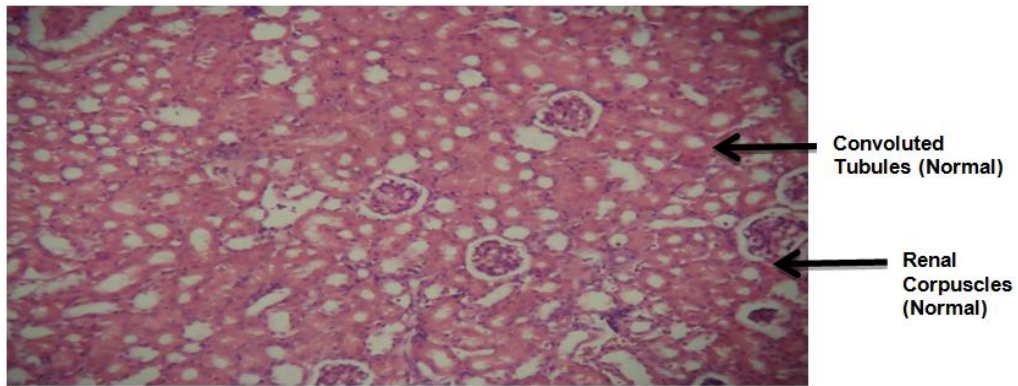
**A. No visible lesions X400**



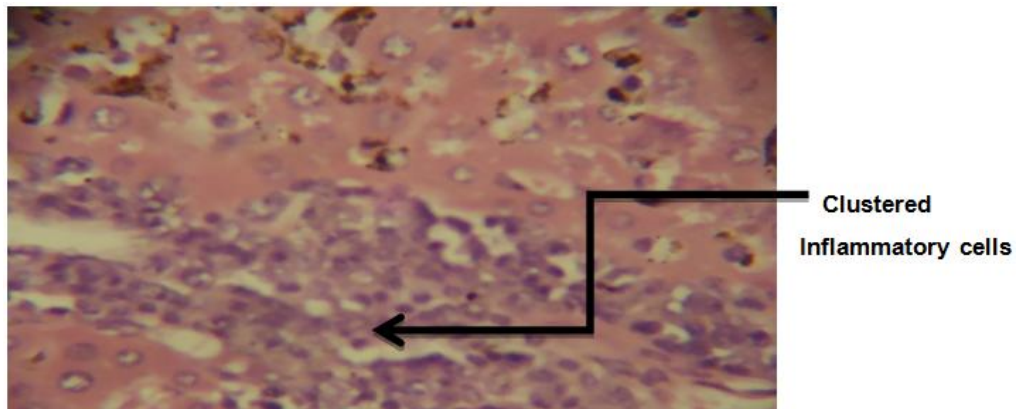
**B. There is moderate periportal cellular infiltration by mononuclear cells**

**Plate 1. Photomicrograph of the kidney of mice infected with *P. berghei berghei* and administered with *L. subnudus* (0.4 mg/mL) with no visible lesions (A) and the liver with moderate portal congestion and periportal infiltration by mononuclear cells (B)**



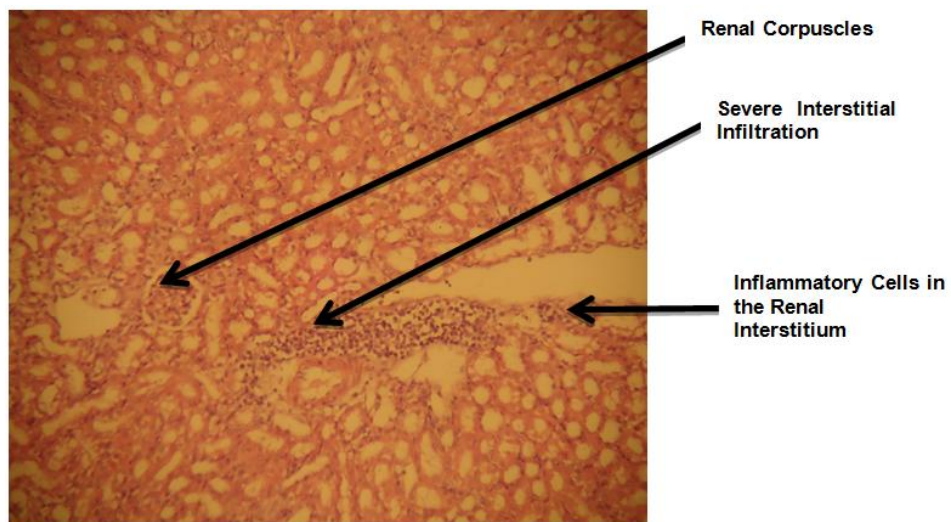


A No visible lesions X400

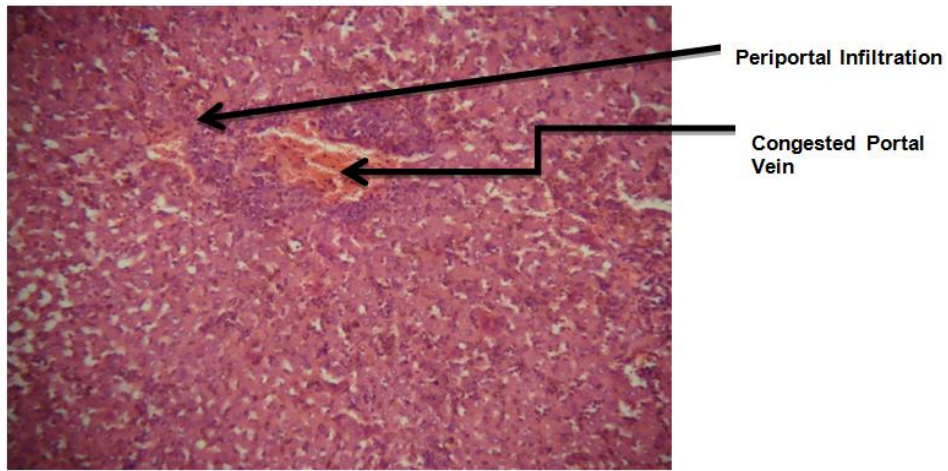


B There is severe periportal cellular infiltration by mononuclear cells X400

Plate 2. Photomicrograph of the kidney of mice infected with *P. berghei berghei* with no visible lesions (A) and the liver with severe periportal infiltration after oral administration with *L. subnudus* (0.04 mg/mL) (B)

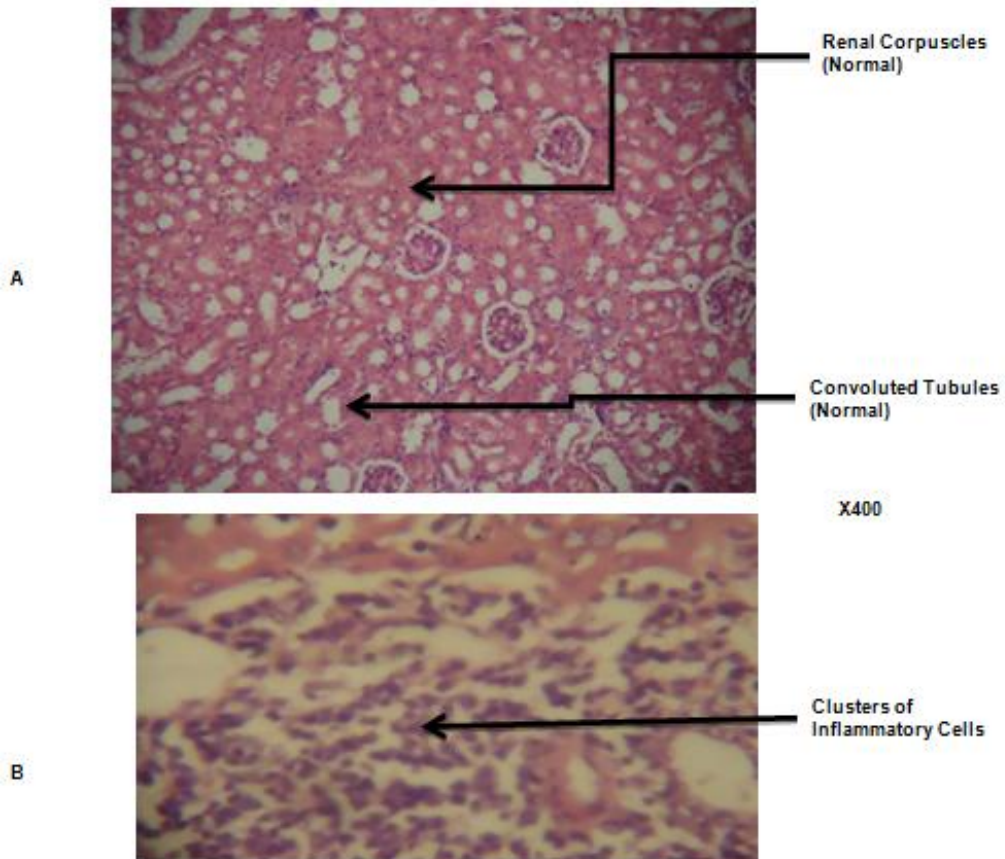


A There is severe interstitial cellular infiltration X400

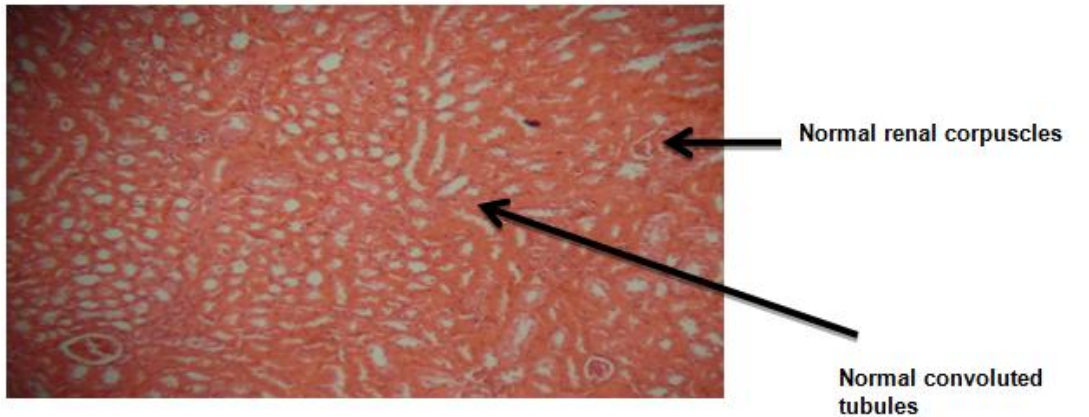


**B** There is severe periportal infiltration and marked sinusoidal congestion X400

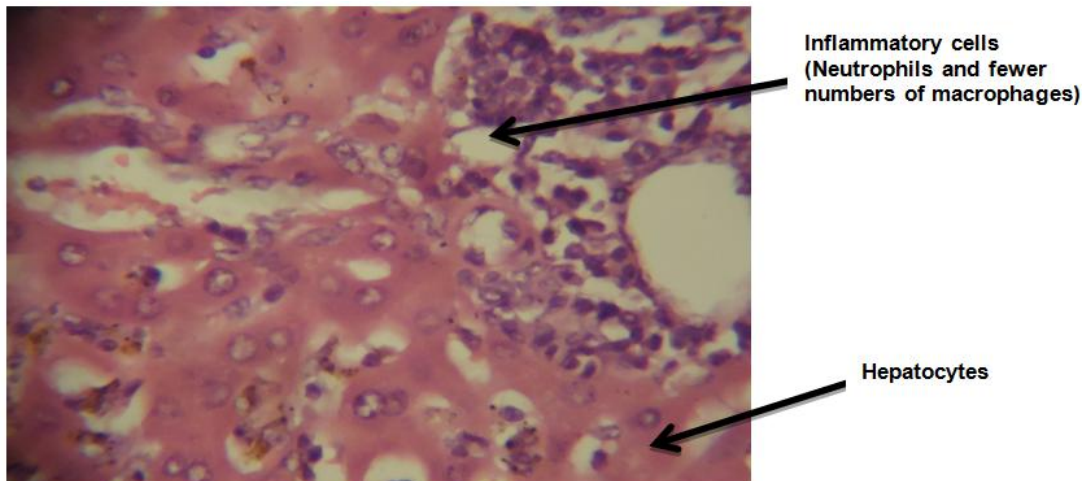
**Plate 3. Photomicrograph of the kidney (A) and liver (B) of mice infected with *P. berghei berghei* without extract (Control Experiment)**



**Plate 4. Photomicrograph of the kidney (A) and liver (B) infected with *P. berghei berghei* and administered with chloroquine**



A No visible lesions



B There is moderate portal congestion and periportal cellular infiltration

**Plate 5. Photomicrograph of the Kidney of Mice Infected with *Plasmodium berghei berghei* After Oral Administration of *Lentinus subnudus* (4mg/mL) (A) and the Liver with No Visible Lesions (B)**

#### 4. CONCLUSION

It is apparent from this study that the higher fungi had prophylactic antiparasmodial potentials and can be formulated into antimalarial drugs. The extracts exerting prophylactic effect within 7 days at such low concentration confirms the potentials of the higher extract against *Plasmodium* species. *Lentinus subnudus* and *Fomes lignosus* produced the highest antiparasmodial effect against *Plasmodium berghei berghei* with a decrease of 30% and 36% respectively in parasitemia. These extracts could be potential sources of bioactive compounds and can be suggested as prophylaxis. However, further pharmacological studies are important.

#### ETHICAL APPROVAL

As per university standard guideline ethical approval has been collected and preserved by the authors.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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