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Original Research Article

Phyllanthus amarus Chemical Fractions Defend the Brain and Liver from Oxidative Assault Induced by *Plasmodium berghei* Malarial Parasite Infection

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ABSTRACT

Phyllanthus amarus is being promoted for treating various ailments, including malaria. While its antiplasmodial properties are documented, little is known about the antioxidant potential of its chemical fractions and their protective effects on the brain and liver. This study aimed to assess the ability of different chemical fractions of *Phyllanthus amarus* to protect these organs from oxidative damage induced by *Plasmodium berghei* infection. Crude ethanolic leaf extract and chemical fractions (alkaloids, tannins, saponins, flavonoids, carbohydrates, and anthraquinones) were administered to mice at 150, 300, and 450 mg/kg daily for 21 days. A total of 240 adult Swiss albino mice (20–30g) were divided into 24 groups (n=10/group). On day 22, mice were sacrificed under chloroform anesthesia following an overnight fast. Liver and brain tissues were harvested, homogenized, and centrifuged to obtain supernatant for biochemical analysis of total antioxidant capacity (TAC) and malondialdehyde (MDA). Results revealed that the crude extract and its flavonoid, carbohydrate, and anthraquinone fractions significantly ($p<0.05$) increased TAC and reduced MDA levels in both liver and brain compared to infected controls. These findings suggest that *Phyllanthus amarus*, particularly its flavonoid, carbohydrate, and anthraquinone fractions, confers antioxidant protection to the liver and brain during *Plasmodium berghei* malaria. The observed protective effect may be attributed to the high phenolic content of these fractions. This study demonstrates the bioavailability and antioxidant potential of *Phyllanthus amarus* and supports its therapeutic role in malaria-associated oxidative stress.

Keywords: *Phyllanthus amarus*, Antioxidant capacity, *Plasmodium berghei*, Oxidative assault.

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Introduction

According to the World Health Organization, in 2022, the global tally of malaria cases reached 249 million – significantly higher than the estimated number of cases before the COVID-19 pandemic, and an increase of five million over 2021. In 2022, the global number of malaria cases rose by five million compared to the previous year, with five countries accounting for the majority of this rise. Pakistan experienced the most dramatic surge, reporting approximately 2.6 million cases—up from 500,000 in 2021. Notable increases were also recorded in Ethiopia, Nigeria, Papua New Guinea, and Uganda.

Plants have provided an alternative strategy in research for new drugs. A wide variety of plants known in traditional medicine are recognized for their protective and healing properties. These plants remain an essential source for discovering new compounds that could undergo chemical modification and lead to the development of more effective drugs[1]. Many herbs have been studied for their antioxidant potential[2], and medicinal plants rich in bioactive compounds with strong antioxidant activity are crucial in the prevention of numerous degenerative diseases.[3]

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Numerous researchers have explored the role of free radicals and oxidative stress in the pathophysiological mechanisms of malaria.[4] This connection appears to involve the generation of free radicals[5] and the host's antioxidant defenses[6] aimed at counteracting the infection. Evidence indicates that reactive oxygen and nitrogen species (ROS and RNS), produced during oxidative stress, significantly contribute to the systemic complications observed in malaria. The infection triggers the formation of hydroxyl radicals (OH*) in the liver, which are likely the primary drivers of oxidative stress and programmed cell death (apoptosis)[7]. Moreover, Atamna and Ginsburg[8] reported that erythrocytes infected with *Plasmodium falciparum* generated nearly twice the amount of OH* radicals and hydrogen peroxide (H_2O_2) compared to uninfected cells. Hepatic dysfunction, a frequent complication in malaria, is linked to apoptosis in liver cells triggered by elevated oxidative stress. Findings suggest that this liver damage involves a mitochondrial apoptosis pathway driven by oxidative stress mechanisms.

As the brain ages, its natural antioxidant defense systems become less effective, making it more susceptible to the harmful effects of oxidative damage[9]. For instance, the activities of key antioxidant enzymes such as superoxide dismutase (SOD), catalase, glutathione peroxidase, and glutathione reductase are notably reduced in the brains of individuals with Alzheimer's disease[10]. It is widely believed that free radicals originating from mitochondria play a major role in causing damage to mitochondrial DNA (mtDNA).

Antioxidants can abstract lone electron from free radical molecules such as reactive oxygen species (ROS) and help humans to control these harmful substances. ROS are usually produced in the body by chemical reactions which occur during normal or pathologic cellular processes [11]. Halliwell et al [12], opined that the sum of endogenous and food derived antioxidants represents total antioxidant capacity of the system. Antioxidants function to neutralize reactive oxygen intermediates

within the body. As a result, enhancing antioxidant levels can reduce oxidative stress and the damage it causes, thereby lowering the risk or delaying the onset of diseases linked to free radical activity.[13]
Protective antioxidants bestowed by many plants extracts and products make these agents promising therapeutic drugs for free radicals induced pathologies. *Phyllanthus amarus* (family Euphorbiaceae) is a small, upright annual herb that typically reaches a height of 10 to 60 cm and features green capsules along its stem. The plant is known for its bitter, astringent, and cooling properties, and also functions as a diuretic, stomachic, febrifuge, and antiseptic. Traditionally, it has been used to treat conditions such as dropsy, jaundice, diarrhea, dysentery, intermittent fevers, urinary and genital disorders, scabies, ulcers, wounds, and the common cold. Additionally, it exhibits antiviral effects against the hepatitis B virus and possesses anti-nociceptive, anti-inflammatory, anti-diabetic, and anti-lipidemic properties.[14]
Phytochemicals identified in the leaf extract include alkaloids, flavonoids, tannins, saponins, terpenoids and glycosides, with potent *in vivo* antiplasmodial activities.[15]
The plant has also demonstrated antioxidant properties during malarial infection. Studies have identified the alkaloid extract of *Phyllanthus amarus* as the primary phytochemical responsible for its antiplasmodial effects. [16,17]
Phyllanthus amarus is used as a chemoprotective agent,[18] and it has been observed to exhibit hypoglycaemic property.[19]
Phyllanthus amarus has been reported to contain antioxidant in its crude ethanolic extract, but this study, however, investigates the bioavailability and impact of its phytocompounds in brain and liver total antioxidant capacity and associated level of oxidative stress in experimental mice.

Materials and Methods

Harvesting and preparation of plant extracts
Fresh whole plants of wild type *Phyllanthus amarus* growing in an uncultivated land space in Abraka, (Latitude 5.79023° N, Longitude 6.10473° E) Ethiope East Local Government Area of Delta State, Nigeria were obtained and authenticated (NO: FHI 109728) in the Herbarium Unit, Forest Research Institute of Nigeria, Ibadan. Crude ethanolic leaf extract and phytocompounds of the harvested plant was prepared as earlier described Onyesom *et al*.,[15]
The fresh leaves were plucked, washed, air-dried and grounded to produce a fine powder which was extracted using a Soxhlet apparatus (Corning, U.S.A) sequencially with ethanol (BDH Chemicals). The extract was evaporated to dryness using rotary evaporator (Buchi R-20, Hana, China) under reduced pressure. The yield was 36mg/ml. The dried extract obtained was dissolved in distilled water.

Alkaloid Extraction
The dried, powdered plant material is first defatted with a non-polar solvent like hexane. Subsequently, it is treated with an acidic aqueous solution (e.g., 1% hydrochloric acid) to extract the alkaloids. The acidic extract is then basified (e.g., with ammonium hydroxide) to precipitate the alkaloids, which are collected by filtration.[20]

Flavonoid Extraction
Method
The dried plant material is macerated or subjected to Soxhlet extraction with 80% methanol. The extract is then filtered and concentrated under reduced pressure.[21]

Saponin Extraction
The extract is filtered, and the solvent is removed under reduced pressure. The concentrated extract is then partitioned with n-butanol, and the butanol layer is collected and evaporated to obtain crude saponins.[22]

Tannin Extraction
Tannins are extracted by macerating the dried plant material in 70% aqueous acetone or methanol for 24 hours. The extract is filtered, and the solvent is removed under reduced pressure. The crude tannin extract can be further purified if necessary.[23]

Carbohydrate Extraction
The extract is filtered while hot, and the filtrate is concentrated under reduced pressure. The presence of carbohydrates can be confirmed using standard phytochemical tests such as Molisch's test.[24]

They were maintained at the Laboratory Animal Centre in the Faculty of Basic Medical Sciences, Delta State University, Abraka, Nigeria. Three (3) *Plasmodium berghei* infected (donor) mice were obtained from the Department of parasitology, Nigerian Institute of Medical Research (NIMR), Yaba, Lagos, Nigeria and were used to inoculate the experimental mice.

Animal Care and Handling
The selected mice were kept in plastic cages under controlled condition of 12hr light/12hr dark cycle and allowed access to standard mouse feed and water. The mice were fed on growers' mash obtained from Top Feeds Flour Mill, Limited, Sapele, Delta State, Nigeria and given clean drinking water in bottles *ad libitum*. The animals were maintained in accordance with the guidelines approved by the Animal Ethics Committee, Delta State University, Abraka, Nigeria.

Animal Grouping and Extract Administration
One hundred and twenty (240) adult Swiss albino mice of both sexes weighing between 20 to 30g were assigned into twenty four (24) groups (n=10/gp). Group 1: Normal control (uninfected and untreated), Group 2: Infected mice treated with 5mg/kg chloroquine, Group 3: Infected mice treated with 150mg/kg alkaloid, Group 4: Infected mice treated with 300mg/kg alkaloid, Group 5: Infected mice treated with 450mg/kg alkaloid, Group 6: Infected mice treated with 150mg/kg saponin, Group 7: Infected mice treated with 300mg/kg saponin, Group 8: Infected mice treated with 450mg/kg saponin, Group 9: Infected mice treated with 150mg/kg tanin, Group 10: Infected mice treated with 300mg/kg tanin, Group 11: Infected mice treated with 450mg/kg tanin, Group 12: Infected mice treated with 150mg/kg flavonoid, Group 13: Infected mice treated with 300mg/kg flavonoid, Group 14: Infected mice treated with 450mg/kg flavonoid, Group 15: Infected mice treated with 150mg/kg carbohydrate, Group 16: Infected mice treated with 300mg/kg carbohydrate, Group 17: Infected mice treated with 450mg/kg carbohydrate, Group 18: Infected mice treated with 150mg/kg anthraquinone, Group 19: Infected mice treated with 300mg/kg anthraquinone, Group 20: Infected mice treated with 450mg/kg anthraquinone, Group 21: Infected mice treated with 150mg/kg *P. amarus* crude ethanolic leaf extract, Group 22: Infected mice treated with 300mg/kg *P. amarus* crude ethanolic leaf extract, Group 23: Infected mice treated with 450mg/kg *P. amarus* crude ethanolic leaf extract and Group 24: Mice Infected with 5mg/kg *P. berghei*. The ethanolic leaf extracts of *P. amarus* was administered once a day as designed. The volume equivalent to the dose administered was then calculated (equation 1):
V (ml) = D (g/kg) x P (kg) / C (g/ml) (Equation 1) [15]; where
D = Dose studied (g/kg b.wt), P = Body weight (kg), C = Concentration of the extract (g/ml)
V = Volume of extract (ml) administered, using intragastric canula for a period of seven (7) days.

Animal Sacrifice and Collection of Specimen
On the 21st day of the experiment, the mice were fasted overnight and sacrificed the next day under chloroform anesthesia. Then liver and brain samples were excised, homogenized and prepared (centrifuged for 10minutes at 2,000rpm) to obtain supernatant used for the assay of Total Antioxidant Capacity (TAC) and malondialdehyde levels.
The TAC was estimated by ABTS (2,2-Azino-di-[3-ethylbenzoline sulphonate]) method described by Miller and Rice Evans, [25] The assay method of Halliwell and Gutteridge, [26] was adopted to estimate lipid

oxidation in terms of thiobabituric acid reactive species (TBARS) using malondialdehyde (MDA) as a standard.

Results and Discussion

Free radicals and other reactive species present in the body can be generated both endogenously and exogenously. Oxidative damages caused by free radicals to living cells mediate the pathogenesis of many chronic diseases, such as atherosclerosis, Parkinson's disease, Alzheimer's disease, stroke, arthritis, chronic inflammatory diseases, cancers and other degenerative diseases.[27] Under normal circumstances, the free radicals generated in the body can be removed by the body's natural antioxidant defenses, e.g. glutathione peroxidase, catalase and superoxide dismutase.[28] However, endogenous antioxidants defenses are not completely efficient and therefore, dietary antioxidants are required to diminish the cumulative effects of oxidative damage due to excess ROS that remain in our system. Antioxidants are not only needed by our body to combat ROS but are also important as food additives. They can be either synthetic or naturally occurring. Synthetic antioxidants possess carcinogenic activity, which lead to the replacement of synthetic antioxidant, with naturally occurring ones.[29] Numerous natural antioxidants have been isolated from different varieties of plant materials such as leafy vegetables, fruits, seeds, cereals and algae.[30] Also, phytochemical are known to be biologically active compounds which act as free radical scavengers to help eliminate highly Reactive Oxygen Species (ROS) that are by-products of metabolized oxygen and are rich in offering numerous health benefits.[31] This study shows the total antioxidant capacity and levels of oxidative damage in brain and liver of experimental mice infected with *P. berghei* and administered chemical fractions and ethanolic crude extract of *P. amarus*. The estimation of malondialdehyde levels in brain and liver of experimental mice was use to ascertain levels of oxidative damage. Malondialdehyde is one of the final products of polyunsaturated fatty acids (PUFAs) peroxidation in cell. An increase in free radical causes overproduction of MDA. Hence, malondialdehyde level is commonly used as oxidative stress marker.
The results (Tables 1-6) shows that *P. berghei* infected mice for twenty-one days observation caused a significant increase ($p<0.05$) in the levels of malondialdehyde and a significant decrease in the amount of total antioxidant capacity.

Table 1: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Alkaloid content of *Phyllanthus amarus*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86^a	0.16±0.06^a	38.33±1.16^a	0.24±0.01^a
2	29.33±9.07^a	0.21±0.05^a	35.33±3.51^a	0.25±0.06^a
24	72.67 ±6.81^b	0.06±0.00^b	71.33±3.22^b	0.08±0.10^c
3	46.67±1.53^b	0.10±0.05^b	49.33±2.52^b	0.15±0.02^b
4	44.00±1.00^b	0.14±0.02^b	54.33±3.79^b	0.13±0.01^b
5	45.67±2.52^b	0.16±0.04^b	58.00±2.00^b	0.17±0.11^b

Values with different superscripts are significantly different ($p < 0.05$)
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 3 = Experimental (treated with 150mg/kg Alkaloid)
Group 4 = Experimental (treated with 300mg/kg Alkaloid)
Group 5 = Experimental (treated with 450mg/kg Alkaloid)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Table 2: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Saponin content of *Phyllanthus amarus.*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86^a	0.16±0.06^a	38.33±1.16^a	0.24±0.01^a
2	29.33±9.07^a	0.21±0.05^a	35.33±3.51^a	0.25±0.06^a
24	72.67 ±6.81^b	0.06±0.00^b	71.33±3.22^b	0.08±0.10^c
6	44.67±2.52^b	0.09±0.02^b	44.00±3.61^b	0.18±0.04^b
7	45.33±10.41^b	0.11±0.04^b	47.00±2.00^b	0.17±0.07^b
8	49.33±11.93^b	0.08±0.08^b	43.00±2.65^b	0.12±0.08^b

Values with different superscripts are significantly different ($p < 0.05$)
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 6 = Experimental (treated with 150mg/kg Saponin)
Group 7 = Experimental (treated with 300mg/kg Saponin)
Group 8 = Experimental (treated with 450mg/kg Saponin)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Table 3: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Tanin content of *Phyllanthus amarus*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86^a	0.16±0.06^a	38.33±1.16^a	0.24±0.01^a
2	29.33±9.07^a	0.21±0.05^a	35.33±3.51^a	0.25±0.06^a
24	72.67 ±6.81^b	0.06±0.00^b	71.33±3.22^b	0.08±0.10^c
9	48.33±2.89^b	0.09±0.03^b	46.33±1.53^b	0.12±0.03^b
10	47.33±9.50^b	0.09±0.03^b	46.33±1.53^b	0.12±0.03^b
11	45.00±10.58^b	0.11±0.02^b	47.00±0.00^b	0.15±0.12^b

Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 9 = Experimental (treated with 150mg/kg Tanin)
Group 10 = Experimental (treated with 300mg/kg Tanin)
Group 11 = Experimental (treated with 450mg/kg Tanin)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Early research workers reported increased lipid peroxidation in malaria patients, particularly on *P. falciparum* infection.[32,33] Instantaneous reduction in antioxidant potency in tandem with increased lipid peroxidation is also reserved to be equally accountable for development

of oxidative stress in malaria patients. [33,34,35] Any infection including malaria, activates the immune system of the body, thereby causing release of reactive oxygen specie such ads antimicrobial action.[32]
In this study also, the changes in experimetal mice infected with *P. berghei* and administered chemical fractions and crude ethanolic leaf extract of *P. amarus* was observed. Results (Tables 4-7) shows that the administration of varying doses (150, 300 and 450mg/kg/d) of flavonoid, carbohydrate, antroquinone chemical fractions of *P. amarus* and athanolic crude extract of *P. amarus* yield significant increase ($p<0.05$) in the amount of total antioxidant capacity with a corresponding significant decrease ($p<0.05$) in the MDA levels in the brain and liver of experimental mice.

Table 4: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Flavonoid content of *Phyllanthus amarus*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86[a]	0.16±0.06[a]	38.33±1.16[a]	0.24±0.01[a]
2	29.33±9.07[a]	0.21±0.05[a]	35.33±3.51[a]	0.25±0.06[a]
24	72.67 ±6.81[b]	0.06±0.00[b]	71.33±3.22[b]	0.08±0.10[c]
12	36.33±1.53[a]	0.19±0.01[a]	44.00±4.58[a]	0.17±0.02[a]
13	27.33±8.74[a]	0.18±0.09[a]	46.33±3.22[a]	0.24±0.07[a]
14	35.33±10.79[a]	0.18±0.03[a]	43.00±5.29[a]	0.27±0.07[a]

Values with different superscripts are significantly different ($p < 0.05$)
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 12 = Experimental (treated with 150mg/kg Flavonoid)
Group 13 = Experimental (treated with 300mg/kg Flavonoid)
Group 14 = Experimental (treated with 450mg/kg Flavonoid)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

The observed increase in total antioxidant capacity of ethanolic leaf extract of *P. amarus* is in agreement with the report of Lim and Murtijaya.[36] According to Lim and Murtijaya,[36], *Phyllanthus amarus* extracts possessed high phenolic content, and exhibited strong free radical scavenging activity and ferric reducing property. Lim and Murtijaya,[36] continued by saying that large quantity of phenolic compounds in *Phyllanthus amarus* extract makes it a strong free radical scanvenger, which indicates that *Phyllanthus amarus* extract has good potential as a source for natural antioxidants to prevent free radical mediated oxidative damage.
The increase in total antioxidant capacity of carbohydrate chemical fraction of *P. amarus* and eventual reduction in liver and brain MDA corrobrate with the report of Igwe et al.[37] According to Igwe *et al.* [37] because of *P. amarus* high and readily available carbohydrate content, the plant's extract is purportedly used as tonic. Tonic herbs (perhaps carbohydrate content of *P. amarus*) are capable of regulating and protecting from free radicals and oxidative assaults. Flavonoids are phenolic substances and act in plants as antioxidants. The antioxidant activity of flavonoids is due to their ability to reduce free radical formation and to scavenge free radicals,[38] as observed in this study where a significant increase ($p<0.05$) in the amount of total antioxidant capacity with a corresponding significant decrease ($p<0.05$) in the MDA levels in the brain and liver of experimental mice.

Table 5: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Carbohydrate content of *Phyllanthus amarus*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86[a]	0.16±0.06[a]	38.33±1.16[a]	0.24±0.01[a]
2	29.33±9.07[a]	0.21±0.05[a]	35.33±3.51[a]	0.25±0.06[a]
24	72.67 ±6.81[b]	0.06±0.00[b]	71.33±3.22[b]	0.08±0.10[c]
15	42.00±2.00[b]	0.33±0.05[a]	43.67±5.51[a]	0.31±0.08[a]
16	39.00±6.08[b]	0.33±0.03[a]	42.00±3.61[a]	0.32±0.03[a]
17	48.33±10.79[b]	0.31±0.02[a]	39.00±2.00[a]	0.34±0.01[a]

Values with different superscripts are significantly different ($p < 0.05$)
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 15 = Experimental (treated with 150mg/kg Carbohydrate)
Group 16 = Experimental (treated with 300mg/kg Carbohydrate)
Group 17 = Experimental (treated with 450mg/kg Carbohydrate)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Table 6: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of Anthraquinone content of *Phyllanthus amarus*

Group	Brain	
	MDA	TAC
1	34.33±5.86[a]	0.16±0.06[a]
2	29.33±9.07[a]	0.21±0.05[a]
24	72.67 ±6.81[b]	0.06±0.00[b]
18	40.67±2.52[a]	0.30±0.02[a]
19	38.33±10.07[a]	0.27±0.06[a]
20	39.00±8.54[b]	0.25±0.04[a]

Values with different superscripts are significantly different ($p < 0.05$)
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 18 = Experimental (treated with 150mg/kg Anthraquinone)
Group 19 = Experimental (treated with 300mg/kg Anthraquinone)
Group 20 = Experimental (treated with 450mg/kg Anthraquinone)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Antroquinone in this study shows to exibit antioxidant potentials as it significantly reduced ($p<0.05$) MDA levels and increased significantly ($p<0.05$) the total antioxidant capacity in the liver and brain of experimental mice. Although anthraquinone has not been reported early to exibit antioxidant properties, studies on five antroquinone derivatives (purpurin, xanthopurpurin, rubiadin, kermisic acid and flavokermisic acid) by Baghiani et al., [38] revealed that purpurin fraction of anthraquinone has a scavenging effect. Also, kermisic and flavokermisc

acids fractions of anthraquinone inhibits lipid peroxidation.[39] The results indicate that *Phyllanthus amarus* and its flavonoid, carbohydrate and antroquinone chemical fractions contributes to the improvement of antioxidant defense and provides health benefit at both low and high doses.

Table 7: Total antioxidant capacity and levels of malondialdehyde in brain and liver of experimental mice infected with *Plasmodium berghei* and administered ethanolic leaf extract of *Phyllanthus amarus*

Group	Brain		Liver	
	MDA	TAC	MDA	TAC
1	34.33±5.86[a]	0.16±0.06[a]	38.33±1.16[a]	0.24±0.01[a]
2	29.33±9.07[a]	0.21±0.05[a]	35.33±3.51[a]	0.25±0.06[a]
24	72.67 ±6.81[b]	0.06±0.00[b]	71.33±3.22[b]	0.08±0.10[c]
21	40.00±5.00[a]	0.32±0.01[a]	37.00±5.20[a]	0.26±0.05[a]
22	41.33±7.37[a]	0.29±0.02[a]	39.00±4.00[a]	0.28±0.02[a]
23	42.00±4.36[a]	0.23±0.04[a]	41.00±3.46[a]	0.23±0.14[a]

Values are expressed as Mean±SD for n=10 mice per group. Values that bear a different superscript on a column differ significantly (p<0.05) when compared with Control.
Group 1 = Normal control (given placebo normal saline)
Group 2 = Negative control (treated with 5mg/kg Chloroquine)
Group 21 = Experimental (treated with 150mg/kg P. amarus)
Group 22 = Experimental (treated with 300mg/kg P. amarus)
Group 23 = Experimental (treated with 450mg/kg P. amarus)
Group 24 = Infected with P. berghei
TAC = Total antioxidant capacity
MDA = Malondialdehyde

Conclusion

Ethanolic leaf exract of *Phyllanthus amarus* and its flavonoid, carbohydrate and anthraquinone chemical fractions defend the brain and liver from oxidative assault caused by *P. berghei* malaria. The ability of this defense capacity could be attributed to the scavenging of free radical species that was introduced by malaria infection and possibly the phenolic contents in these (flavonoid, carbohydrate and anthraquinone) chemical fractions which display significant antioxidant activity.
The chemical fractions (flavonoids, carbohydrates and anthraquinone) of *P. amarus* leaf extract that possessed significant increase in liver and brain total antioxidant capacity should be further studied.

Conflict of Interest

The authors declare no conflict of interest.

Authors Declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them

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