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Research Article

Evaluation of Trace Elements and Antioxidant Vitamins Effect following Palm Oil Supplemented Diet on *Plasmodium berghei* Infected Mice.

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Abstract
Malaria infection induces a cascade of secondary pathological events, among which oxidative stress and inflammation are interconnected. This interaction often exacerbates tissue damage and significantly contributes to disease progression. Given the reported antioxidant property of red palm oil, this study evaluated the therapeutic potential of a red palm oil supplemented diet in mitigating oxidative stress in a murine model of *plasmodium berghei* infection concurrently administered with standard anti-malaria drugs.
Mice weighing 19 ± 2.5g were distributed into seven groups of fifteen (15) animals each for this study. The mice were infected with NK65 *Plasmodium berghei* strain. The individual effects of red palm oil supplemented diet and of anti-malaria drugs (amodiaquine (AMQ), and Chloroquine (CQ) along with their contributory effects were evaluated. The mice were fed with standard rat chow with 15% v/w red palm oil. The trace elements Selenium (Se), Copper (Cu), Zinc (Zn) and Vitamins A, C and E with its fractions were also determined spectrophotometrically.
The studies revealed that trace elements such as Se, Zn, Fe and Cu showed no significant difference between the control and the test groups. Vitamin A showed a statistically significant difference in all test groups compared to the control. Palm oil supplemented diet provided more vitamin A in circulation except group F where the anti-malaria chloroquine reduces the availability of vitamin A in circulation. Palm oil supplemented diet also increased the availability of vitamin C in circulation while chloroquine increased the vitamin level higher in control. Vitamin E levels were markedly increased in the test group compared to the control. Total β-and γ-tocopherol levels were increased significantly except for γ-tocopherol where the level remained increased even with chloroquine treatment. Levels of total tocotrienol, β-and γ-tocotrienol increased significantly except for the group receiving chloroquine treatment.
The results obtained have not necessarily shown that red palm oil modulated trace elements during oxidative stress but showed increased availability of antioxidant vitamins in circulation.

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Introduction.
Malaria is an infectious disease and a serious public health problem, with 3.3 billion people in endemic regions at risk of contracting the disease in 85 countries. According to the World Health Organization Malaria Report (WHO) in 2020, there were an estimated 241 million cases of malaria and 627,000 malaria deaths worldwide.

Infection by the parasite triggers oxidative stress that consists of the host's redox imbalance due to the high production of reactive oxygen and nitrogen species (ROS/RNS), to the detriment of the host's endogenous antioxidant defense system. The production of these oxidizing compounds occurs through the degradation of hemoglobin by the parasite, which uses it as a source of amino acids for nutrition, as well as through the host's immune response, which produces ROS/RNS inside the phagocytes, a process called respiratory burst, alongside the involvement of ischemia-reperfusion syndrome (SIR) (Esam *et al.,* 2018). The increase in oxidative stress in malaria has been implicated in systemic and tissue damage, affecting organs such as lungs and brain. This redox imbalance has been related to the most serious manifestations, such as cerebral malaria, and, depending on the lesions in the brain parenchyma, it can lead to physical and cognitive impairment (Idro *et al.,* 2016).

Dietary antioxidants have been linked to the modulation of host susceptibility or resistance to infectious pathogens and evidence relating micronutrient deficiencies to malaria incidence, especially in endemic areas have been documented (Nwachukwu, *et al.,* 2016; Barffour *et al.,* 2016). Malaria has been linked to malnutrition, and it is possible that micronutrient deficiencies, including iron (Fe), zinc (Zn), copper (Cu), and vitamin A, can predispose people to malaria (Burki, 2013; Nwachukwu, *et al.,* 2016; Barffour *et al.,* 2016). Line of defense against oxidative damage consists of antioxidants and cofactors with low molecular weight in the diet, including flavonoids, vitamin E, C, carotenoids, lipoic acid, selenium, copper, iron, zinc, GSH and coenzyme Q, among several others (Vega-Rodríguez, *et al.,* 2015; Mironczuk-Chodakowska, *et al.,* 2018). These antioxidants work by inactivating ROS/RNS and their derivatives, preventing structural damage, and exhibiting an important protective role during infection. (Gomez *et al*., 2022)

Supplementation with antioxidants or condiments with high content of antioxidants represents a promising therapeutic alternative in malaria, which would prevent or reduce the oxidative damage generated by the parasite and by antimalarials. Based on this idea, several studies have demonstrated the beneficial role of antioxidant supplementation in fighting the infection and restoring redox balance. The supplementation with vitamins A (Yakoob, and Qadir, 2018), C (Ekeh*, et al*., 2019; Qin *et al*., 2019), and E (Suzuki *et al.,* 2019) represent promising strategies, with possible beneficial effects on the disease. It has been argued that vitamin E deficiency might be protective against malaria infection in mice. It has also been documented that antioxidants such as vitamin C and E could provide protection against malaria-induced oxidative stress. To gain insight into this, we investigated the antioxidant vitamin A, C, E. and their fractions on mice infected with P*lasmodium berghei* and taking palm oil supplemented diet which is very rich in vitamin A, C, and E.

MATERIALS AND METHODS

Study Area and Design

Experimental study using mice was conducted at the Animal House, College of Health Sciences, Ladoke Akintola University of Technology, Ogbomosho. A total of 70 healthy Albino mice weighing 19±2.5gm., were used for the study. They were housed in aluminum cages at room temperature and under light/dark cycles. The mice were supplied with clean drinking water and fed *ad libitum* with standard commercial pelleted starter feed (vital feed) and were acclimatized for two weeks before administration and were maintained in accordance with the recommendations of the guide for the care and use of laboratory animals and experimental protocol was approved by the Faculty of Basic Medical Sciences Ethical Research Committee Lautech with Protocol Identification Code: ERC/FBMS/091/2005 and ERC Approval Number: ERCFBMSLAUTECH:103/04/2025.

Animals were assigned into seven groups of ten mice each; namely, control (A), *P. berghei* infected group (B), *P. berghei* infected fed with palm oil supplemented diet (C), *P. berghei* infected and treated (D), *P. berghei* infected fed with palm oil supplemented diet and treated with Amodiaquine (E), *P. berghei* infected fed, and treated with Chloroquine (F). *P. berghei* infected fed with palm oil supplemented diet and treated with Chloroquine. Group A received strictly rat feed and water albidum to serve as control mice throughout the study period while the groups B, C, D, E, F and G mice were injected with standard inoculums of $1x10^7$ *P. berghei* infected erythrocytes intraperitoneally on the first day (Day 0).

Animal

Donor mice infected with *Plasmodium berghei* (NK 65 strain) were sourced from the Institute of Medical Research and Training (IMRAT) at the University College Hospital (UCH), Ibadan, Nigeria**.** *Plasmodium berghei* ANKA-infected mice blood was passed into new mice according to the method of Basir *et al*., (2012). Antimalaria drugs Amodiaquine (AMQ) and Chloroquine (CQ) were obtained from AKOL Pharmaceutical store, Olukoko, Isale-General, Ogbomosho, Oyo state. They were dissolved in tween 80 for consistent dilution. Parasite count in each of the groups of animals was determined on days 0, 3, and 5 of drug administration. Drugs were powdered separately in a mortar and mixed with distilled water in universal bottles. They were administered in 10mg/kg body weight as recommended by the WHO (2015) with an oral cannula and were fed with palm oil-supplemented diet as described by Adeleke *et al.* (2021). The mice were orally administered CQ, and AMQ for three consecutive days and were fed with a palm oil-supplemented diet after infection was established.

Parasite inoculation

The *Plasmodium berghei* was sustained by constant re-infestation of parasitized erythrocytes which were sourced from a donor-infected mouse by the tail via a heparinized syringe and made up to 20ml with normal

saline. The animals were inoculated with 0.2ml of infected blood suspension. The donor mice were monitored for signs of infection which include lethargy, anorexia, shivering and heat-seeking environment. Parasitemia was monitored daily by microscopic examination of Giesma stained thick film and viewed at × 100 objective lens. Furthermore, malaria parasite infection was detected by thin film stained with Leishman stain by parasite count using the formula:
Parasite density =Number of parasites counted × 100white blood cells/Number of white blood cells counted.

Red Palm Oil Preparation
Fresh red palm oil (5L) was purchased from a local manufacturer at Igbona market in Osogbo, Osun state, Nigeria and kept in the dark prior to the commencement of the study. The test diet was prepared (by mixing RPO with pelletized feed) to contain 15mls per kilogram of the standard rat feed (Jeeva *et al.,* 2015).

METHODS
Determination of Trace Metals in Plasma
Sample Pre-Treatment: Serum (0.20ml) was placed into a 30ml digestion tube, 5ml concentrated H_2SO_4, 2ml of concentrated $HClO_4$ and 3ml of concentrated HNO_3 were added and the tube set in the digestion heater hole in the digestion block set at 350^0C. The mixture was left in the digestion block for 4hrs for it to digest to a clear colorless solution. The solution was washed with deionized water into a 50ml volumetric flask and made up to mark with deionized water.

Determination of Copper by Spectrophotometric Method
Digested serum (1ml) was placed into 20ml test tube, 2ml of citric acid solution, followed by the addition of 6ml of ammonia solution to remove any traces of iron and manganese that may interfere. One (1ml) of sodium diethyl dithiocarbonate was added to the mixture to develop a yellow coloration which was extracted by 5ml of amyl alcohol for spectrophotometric determination.
Working standard of 1-5mg/ml was prepared from 10mg/ml stock copper solution and treated similarly like sample. The absorbance of sample as well as working standards were read on spectronic 21D digital spectrophotometer at a wavelength of 430nm.
Copper was calculated in mg/dl = $\frac{\text{Absorbance} \times \text{gradient factor} \times \text{dilution factor}}{10}$

Determination of Zinc by Spectrophotometric Method
Digested plasma (1ml) was placed into a 20ml test-tube, 2ml of concentrated HCL, 1ml of hydroxylamine solution and 5ml of deionized water were added. The mixture was thoroughly mixed and put in a water bath set at 100^0C for complete dissolution of iron. The mixture was cooled to room temperature and transferred to 50ml volumetric flask. 10ml of ammonium acetate buffer solution and 2ml of phenanthroline solution were added to develop a brownish red coloration after 15min incubation at room temperature.
Working standard of Iron of 1 – 5mg/ml was prepared from 10mg/ml stock solution.
Absorbance of samples and standards were determined using the Spectronic 21D digital spectrophotometer at a wavelength of 430nm.
Iron was calculated in mg/dl = $\frac{\text{Absorbance} \times \text{gradient factor} \times \text{dilution factor}}{10}$

Determination of Iron by Spectrophotometric Method
Digested plasma (1ml) was placed into a 20ml test-tube; 2ml of chloroform was added, followed by the addition of 5ml of ammonium hydroxide solution to retain all the zinc in solution. The mixture was shaken thoroughly to ensure uniform mixing. 0.2ml of diphenyl thiocarbazone solution was added to develop a greenish brown colour. Working standard of Zinc of 1 – 5mg/ml was prepared from 10mg/ml stock solution.

Determination of Vitamins A, C, AND E
Reagents used include methanol (HPLC grade), acetonitrile (HPLC grade), stock solution of vitamin E (10mg/ml in chloroform), Stock solution of vitamin C (10mg/ml in chloroform). The stock solutions were further diluted in methanol to give desired working standards.

Sample Preparation
Plasma samples were spiked with concentration ranging from 100 to 5000µg/ml for Vitamin C and from 0.25 to 5µg/ml for Vitamin E and β-carotene. Extraction of vitamin E in plasma; 100µl of plasma was deproteinized with 100µl of ethanol and extracted with 600µl of chloroform. The extract was shaken for 5 min before centrifuging. The organic layer was removed and evaporated to dryness using nitrogen. The dried extract was dissolved in 100µl of methanol. The samples were injected into the HPLC and quantified using peaks area of Vitamin C and E

Principle of the method
For the determination of vitamins A and E, an internal standard and the precipitation reagent were added. During the precipitation step, high molecular substances were removed. After centrifugation the supernatant is injected into the HPLC system. The isocratic separation via HPLC at 30°C uses a "reversed phase" column. One run lasts 15 minutes. The chromatograms are recorded by a UV-detector by two different wavelengths (Vitamin A at 325 nm, Vitamin E 300 nm). The quantification is performed with the delivered plasma calibrator; the concentration is calculated by the "internal standard method" via integration of the peak heights resp. peak areas

Determination of Tocopherol and Tocotrienol.
Estimation of tocopherol: Estimates of total tocopherol, β-tocopherol and γ-tocopherol, total tocotrienol, β-tocotrienol and γ-tocotrienol were determined according to the method of Tsochatzis *et al.,* (2012).

RESULTS AND DISCUSSION

The role of serum trace metals in malaria is not clearly understood. Dietary antioxidants have been linked to the modulation of host susceptibility or resistance to infectious pathogens. Evidence linking micronutrient deficiencies to malaria incidence, especially in endemic areas have been reported (Nwachukwu *et al;* 2016; Barffour, *et al;* 2019). Malaria has been linked to malnutrition, and it is possible that micronutrient deficiencies, including iron (Fe), zinc (Zn), and copper (Cu), can predispose people to malaria (Burki, 2013; Abdulkareem et al; 2017). In this study, trace elements such as Selenium (Se), Cooper (Cu), Zinc (Zn) and Iron (Fe) were evaluated. Each of the element showed no statistically significant difference when compared to the control. This agreed with some earlier studies. (Gouado *et al.,* 2007; Baloch *et al.,* 2011). According to Baloch and his team (2011), the metal content of Iron, copper and zinc are varied in malaria patients as compared to the control. The results of the trace elements are presented in Table 1.

Table 1: Effect of palm oil supplemented diet on some trace elements

GROUP	Se (µg/dl)	Cu (µg/dl)	Zn (µg/dl)	Fe^{2+}(µg/dl)
A	0.06±0.01	0.63±0.02	0.43±0.04	61.65±3.20
B	0.08±0.01	0.79±0.13	0.61±0.09	62.65±3.97
C	0.06±0.01	0.60±0.11	0.55±0.06	56.58±2.78
D	0.06±0.00	0.79±0.11[a]	0.58±0.05	76.33±1.48[a]
E	0.07±0.01	0.73±0.12	0.65±0.08	68.08±6.05
F	0.06±0.00	0.68±0.08	0.55±0.09	65.23±6.18
G	0.06±0.02	0.53±0.05	0.64±0.08	69.30±5.73
P – Value	0.504	0.589	0.386	0.103

Data are recorded as Means ± SD
Values bearing superscript 'a' are significantly different from A
Values bearing superscript '#' are significantly different from B
Values bearing superscript '*' are significantly different from D
Values bearing superscript '^' are significantly different from F
Mean difference is significant at the level of 0.05

Malaria parasite with antimalaria drug such as chloroquine has been shown to reduce the availability of vitamin A in circulation. Antioxidants are used up to counteract the effects of free radicals generated in the cause of malaria infection. This explains why reduction in antioxidant level is dependent on the severity of malaria. With vitamin A, there was a statistically significant difference of all test groups compared to the control except for group B and F, ($p<0.05$). The significant difference might be due to the *plasmodium berghei* which is common to both groups. However, the availability of chloroquine in peripheral circulation in these test groups increases fever. While antimalarial drugs themselves don't cause increased temperature, they are often prescribed to treat malaria, which is characterized by fever. (Singhaboot et al., 2019). The drugs are effective in combating the malaria parasite, which can also cause a fever. Furthermore, some antimalarial drugs, like the quinine, are sometimes

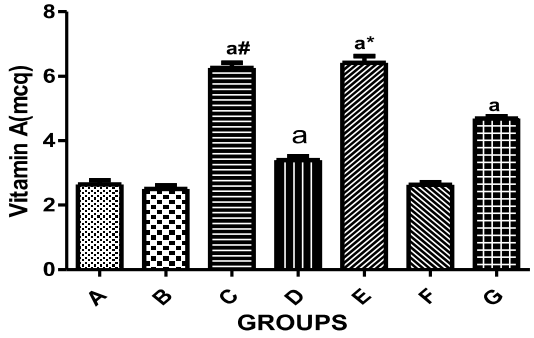


Figure 1.0: Effect of palm oil supplemented Diet on Vitamin A

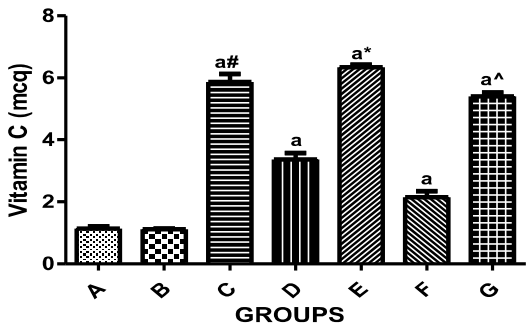


Figure 1.1: Effect of palm oil supplemented Diet on Vitamin C

Bars bearing superscript 'a' are significantly different from A
Bars bearing superscript '#' are significantly different from B
Bars bearing superscript '*' are significantly different from C
Bars bearing superscript '^' are significantly different from F
Mean difference is significant at the level of 0.05

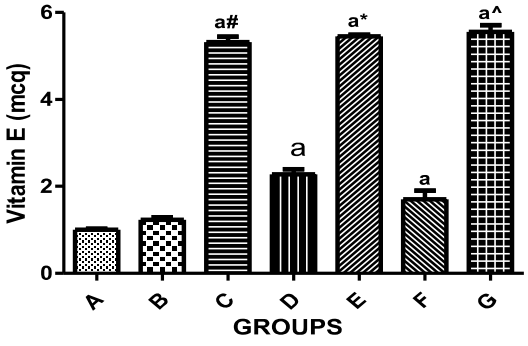
inappropriately used as "drugs for fever". It's also important to note that antimalarial drugs can have side effects, including fever, chills, and other symptoms. There was no statistically significant difference when C was compared to the other test groups ($p>0.05$). Availability of anti-malaria drug can be said to cause a statistically significant difference in all this groups. There is increased availability of vitamin A in all the groups receiving palm oil supplemented diet. Plasma vitamin A concentrations were lower in malaria patients when compared with the control subjects. The finding agreed with previous observations that re-distribution of vitamin A takes place in extravascular spaces to allow for increase bioavailability to the tissues (Esan and Oyedele 2014). Significantly lower vitamin A was observed in this work in severe malaria when compared with the levels in mild/moderate malaria. This finding implies that more vitamin A is utilized in the face of increased parasitemia seen in severe cases of malaria infection (Olubunmi *et al.,* 2018)

There was also a statistically significant difference between the estimates of vitamin C level in all the test groups compared to the control ($p<0.05$). This might be due to increased level of vitamin C in circulation. However, there is no statistically significant difference between the parasite groups taking palm oil supplemented diet (C) with the parasitized group taking palm oil in addition to taking anti-malaria drug (E) and (G). ($p>0.05$). Further, there is increased level of vitamin C in circulation. This increase is more noticeable in all the groups receiving palm oil supplemented diet. In biological system, vitamin C exhibits oxidant and antioxidant activity depending on the presence of glutathione or the source of vitamin C whether intracellular or extracellular (Chakraborty *et al.,* 2014). In the present study, there was a marked increase in the level of vitamin C especially in groups of mice receiving palm oil supplemented diet and anti-malaria drugs Amodiaquine and chloroquine. Reasons for these might not be unconnected to palm oil supplemented diet which happens to be a good source of the vitamin. This agreed with earlier study (Neelam Marwaha, 2016). According to Neelam Marwaha, (2016), vitamin C may have detrimental effects on malaria. Concurrent administration of artemether and ascorbic acid compromised the rates of parasites clearance in *Plasmodium berghei* malaria infection. In the present study, mortality was noticed as from day four. The supply of vitamin C through the palm oil supplemented diet could have accounted for this.

In the present study, there is a significant increase in the level of the vitamin E in all the group that received palm oil supplemented diet. Vitamins A, C and E are major contributors to antioxidant immune function. The increase observed in the level of vitamin E in all the test groups particularly those that received supplemented diet can be attributed either to the rich supply of vitamin E in palm oil. There is also a statistically significant difference in the level of vitamin E in all the test groups compared to the control especially in all the groups of mice receiving palm oil supplemented diet ($p<0.05$). This can be attributable to the high level of vitamin E in palm oil which was supplemented into the rat chow. There was no statistically significant difference between the parasitized mice groups receiving palm oil supplemented diet (C) and the groups parasitized receiving palm oil supplemented diet and taking antimalaria drug as E and G. This is possibly because of the antimalaria drugs which might have reduced the availability of vitamin E in peripheral circulation.

Fractions of vitamin E such as total tocopherol and total tocotrienol levels and their sub fractions such as β-tocopherol and γ-tocopherol were also estimated. Total tocopherol showed a statistically significant level ($p<0.05$) in all test groups compared to the control. Tocopherol levels increased in all the groups compared to the control group (A). There was no statistically significant difference in the group of mice parasitized and taking palm oil (C) supplemented diet compared to the group that are parasitized only ($p>0.05$). Also, there was no statistically significant difference level in the groups receiving supplemented diet and antimalaria drug E and G compared to the group without antimalaria drug such as C ($p>0.05$).

This data reinforces the fact that there is an increase in the level of total tocopherol in circulation among the groups of mice receiving palm oil supplemented diet. Palm oil in contrast to other oil seems to possess a unique blend of vitamin A and E components (Akinola *et al*., 2010). For example, Alabi *et al.,* (2020) reported that palm oil is not only rich in carotenes and tocopherols but also contain unique blend of tocotrienols content.



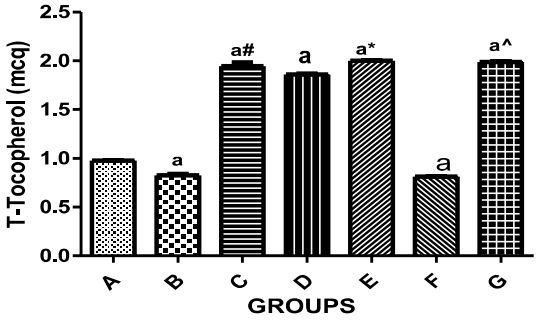
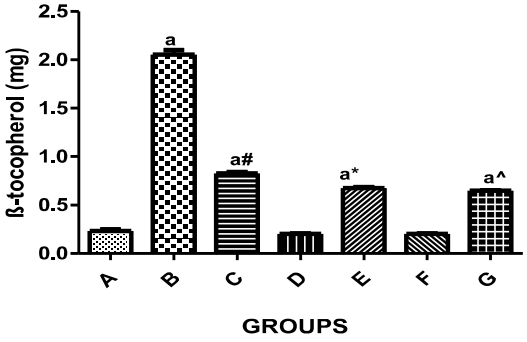


Figure 1.2: Effect of palm oil supplemented Diet on Vitamin E. Figure 1.3: Effect of palm oil supplemented Diet on Vitamin T. tocopherol

Alabi et al (2020) went on further to say that the tocotrienol- rich fractions in diabetes induced rat model significantly decreased plasma MDA and other oxidative stress markers. Aboua *et al., (*2012), also reported that palm oil reduced lipid peroxides accumulation *in vivo.* The increase observed in the level of vitamin E in all the test groups particularly those that received supplemented diet can be attributed either to the rich supply of vitamin E in palm oil. The more severe the malaria infection, the lower the antioxidant levels (Kotepui, *et al* 2024). The level of the total tocopherol and total tocotrienol and their fractions all showed statistically significant difference. The reduction in vitamin E levels during *Plasmodium* infection may indicate the reaction of the host's defensive system to the production of reactive oxygen species or their metabolites. The decrease in vitamin E levels in patients with malaria may indicate an increased requirement, increased destruction, or increased utilization of vitamin E during malaria infection (Praskash *et al,* 2011). The transfer of vitamin E to the membranes of red blood cells to combat the rise in oxidative stress during the acute phase of *Plasmodium* infection may be the cause of the drop in vitamin E levels in malaria patients (Praskash *et al,* 2011). Furthermore, vitamin E can protect erythrocyte membranes from oxidative stress, via vitamin E supplementation among healthy people (Sun *et al,* 2012). The improvement in erythrocyte membrane fluidity and reduction in erythrocyte hemolysis is another proposed mechanism for protection against *Plasmodium* infection by vitamin E (Sun *et al,* 2012). The increase in the level of tocopherol in circulation in this study might be due to the modification of host nutritional status through the inhibition of α- tocopherol transfer protein (α-TTP) which acts as an important regulator of vitamin E concentration in circulation. (Nandi *et al;* 2022; Ewelina Mlynarska et al., 2024). Previous study indicated that reduction of host vitamin E concentration through dietary restriction negatively impacted the development of *plasmodium* and malaria development (Gomes, *et al.,* 2022). Therefore, the increase seen in the level of the tocopherol (β and γ) alike especially in the groups that received palm oil supplemented diet help the mice to fight the malaria infection as α-TTP inhibit these biochemicals and conferred resistance to malarial infection. The high level of total tocopherol and γ-tocopherol observed in the group G could be because α-TTP in combination reduces vitamin E level and hence serves as an effective against drug resistance parasites.

There is little information regarding the association between vitamin E levels and parasite density. Studies showed that there is an inverse relationship between circulatory vitamin E and *plasmodium falciparum* load that is vitamin E levels increased significantly as malaria density increased (Onyesom *et al*, 2010; Ogbodo *et al*, 2016; Onyeneke *et al*, 2018; Kotepui et *al* 2023). This association suggested that patients with an increased number of parasites might be more susceptible to higher levels of oxidative stress. Nevertheless, the positive association between vitamin E levels and parasite density raised the question about the role of vitamin E in different parasite densities. There is also little information regarding the association between vitamin E levels and severity levels of malaria. In this study, no pearson's correlation was carried out. Vitamin E is transported in plasma lipoproteins and unlike other fat-soluble vitamins, has no specific plasma carrier protein, however, α-tocopherol transfer protein (α-TTP), a liver cytosolic protein, acts as an important regulator of vitamin E concentration in circulation. It does this through binding specifically to α-tocopherol amongst the other tocopherols, including β and γ-tocopherol, in the liver. The level of the β and γ-tocopherol in this study increased in the test group compared to the control. This agreed with an earlier work (Hiroyuki Arai and Nozomu Kono, 2021). The use of α-tocopherol as a membrane antioxidant can also be an alternative route to avoid intense oxidative stress caused by immune interactions on membranes of erythrocytes (Sussmann *et al.,* 2017). The hostile environment can change parasite metabolism and permit adaptation in the cell cycle to the parasite, adapting to achieve the new invertebrate host in a gametocyte formation. Many of the functions of tocotrienols are related to their antioxidant properties and their varied effects are due to signaling molecules. Tocotrienols exhibit biological activities that are also exhibited by tocopherols, such as neuroprotective, anti-cancer, anti-inflammatory and cholesterol lowering properties (Jomova, *et al*. 2024)



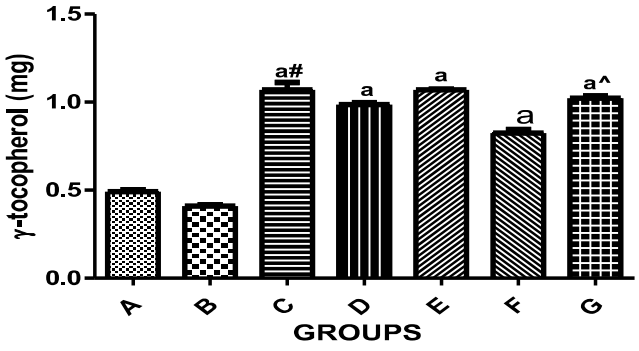
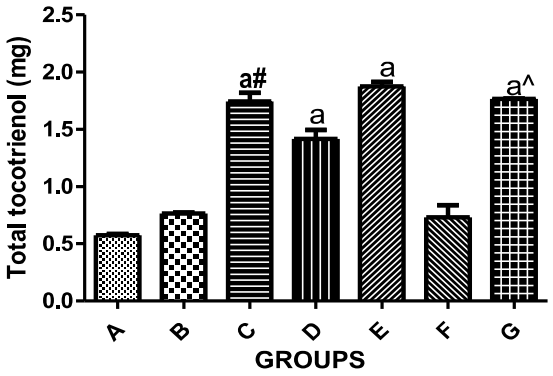


Figure 1.4: Effect of palm oil supplemented Diet on β-tocopherol
Figure 1.5: Effect of palm oil supplemented Diet on γ-tocopherol



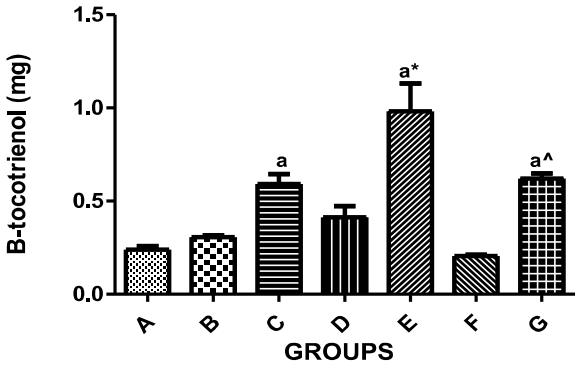


Figure 1.6: Effect of palm oil supplemented Diet on T-tocotrienol
Figure 1.7: Effect of palm oil supplemented Diet on β-tocotrienol

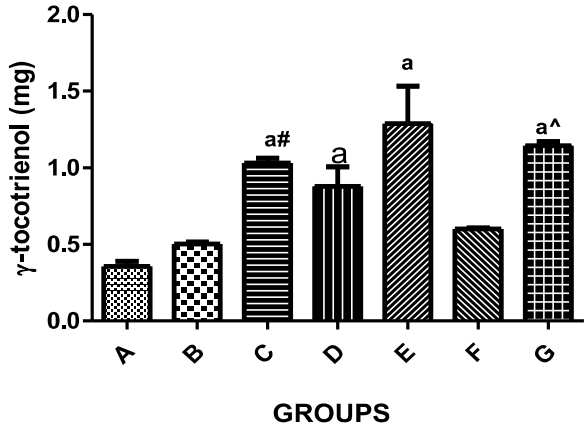


Figure 1.8: Effect of palm oil supplemented Diet on γ-tocotrienol

However, there was a marked increase in the test groups receiving palm oil supplemented diet compared to the group on amodiaquine and chloroquine respectively. This agreed with earlier works (Hiroyuki Arai and Nozomu Kono (2021). Hiroyuki Arai and Nozomu Kono (2021) stated that ascorbic acid has antioxidant properties to mop up free radicals hence the reduction in circulation of vitamin C. Since malaria infection imposes tremendous oxidative stress on the host, antimalaria is often prescribed with vitamin C or similar antioxidant supplements. The reduction in vitamin C or ascorbic acid levels during *Plasmodium* infection is also one of the proposed mechanisms that relate to the reduction in vitamin E in patients with malaria. Vitamin C or ascorbic acid is maintained in its natural form with ascorbate; therefore, ascorbic acid deficiency may hinder the regeneration of vitamin E and decrease membrane function (Alberts *et al.,* 2025).

Conclusion

The severity of malaria parasite infection has no effect on the electrolytes level in biological system. However, increase availability of vitamin E in circulation reduces the chances of resistances to malaria infection. Increased availability of vitamin C in circulation, increases the chances of high parasitemia level and possible mortality, while vitamin A availability are reduced in active malaria infection.

References

1. Aboua, Y. G., Brooks, N., Mahfouz, R. Z., Agarwal, A., & Du Plessis, S. S. (2012). A red palm oil diet can reduce the effects of oxidative stress on rat spermatozoa. *Andrologia*, *44*, 32-40.
2. Adeleke, T. D., Adejumobi, O. A., Akinola, F. F., Salau, O. A., and Uthman-Izobo, O. S. (2021). Potential Role of Palm oil Supplemented Diet on Oxidative Stress Enzymes in Plasmodium Berghei Induced Malaria. *BioRxiv*, 2021-03.
3. Akinola, F., Oguntibeju, O., Adisa, A., Owojuyigbe, O. S, (2010): Physico-Chemical Properties of Palm Oil from Different Palm Oil Local Factories in Nigeria. *Journal of Food, Agriculture & Environment,* 8, 264-269.
4. Alabi, D. L., Famakinwa, M., & Akinnawonu, O. E. (2020). Involvement of rural households in oil palm (Elaeis guineensis) fruits postharvest activities in Ondo State, Nigeria. *Journal of Agricultural Extension*, *24*(1), 42-53.
5. Alberts A, Moldoveanu ET, Niculescu AG, Grumezescu AM. Vitamin C. (2025): A Comprehensive Review of Its Role in Health, Disease Prevention, and Therapeutic Potential. Molecules Feb 6;30(3):748. doi: 10.3390/molecules30030748. PMID: 39942850; PMCID: PMC11820684.

6. Analike Rosita Chinechelum, Okwara John Ekenedilichukwu, Meludu Samuel Chukwuemeka, Analike Rosemary Adamma, Ogbodo Emmanuel Chukwuemeka. (2022). Evaluation of dyslipidemia prevalence among undergraduate university students., *Journal of Clinical Research and Reports,* 12(1) DOI:10.31579/2690-1919/274.
7. Barffour, M.A.; Schulze, K.J.; Moss, W.J.; West Jr, K.P.; Chileshe, J.; Siamusantu, W.; Palmer, A.C. (2019): Relative contributions of malaria, inflammation, and deficiencies of iron and vitamin A to the burden of anemia during low and high malaria seasons in rural Zambian children. *J. Pediatr*. 2019, 213, 74–81. (Cross Ref.)
8. Burki, T.K. (2013): Malaria and malnutrition: Niger's twin crises. *Lancet*, 382, 587–588. (Cross Ref)
9. Chen, G.; Du, Y.T.; Liu, J.H.; Li, Y.; Zheng, L.; Qin, X.S.; Cao, Y.M. (2019): Modulation of anti-malaria immunity by vitamin A in C57BL/6J mice infected with heterogenic Plasmodium. Int. *Immunopharmacol.*, 76, 105882. [CrossRef].
10. Ekeh, F.N.; Ekechukwu, N.E.; Chukwuma, C.F.; Aguzie, I.O.N.; Ohanu, C.M.; Ebido, C.; Oluah, S.N. (2019): Mixed vitamin C and zinc diet supplements co-administered with artemether drug improved haematological profile and survival of mice infected with *Plasmodium berghei*. *Food Sci. Hum. Wellness*, 8, 275–282. [CrossRef].
11. Esam M. Al-Shaebi, Walid F. Mohamed, Saleh Al-Quraishy, Mohamed A. Dkhil (2018): Susceptibility of mice strains to oxidative stress and neurotransmitter activity induced by *Plasmodium berghei Saudi Journal of Biological Sciences*. Volume 25, Issue 1, January, Pages 167-170
12. Esan, Ayodele J, Omisakin C.T, Titilayo Oyedele E and Fasakin Kolawole (2014): Evaluation of Severity of Malaria Infection and Effect of Anti-malaria Drugs on Gender Differences Using Blood Cell Lines Parameters. *American Journal of Medical Sciences and Medicine*, Vol. 2, No. 5, 89-95
13. Ewelina Młynarska, Laura Biskup 1, Maria Mozdzan, Olivia Grygorcewicz, Zofia Mozdzan, Jan Semerad, Michał Uramowski, Jacek Rysz and Beata Franczyk (2024): The Role of Oxidative Stress in Hypertension: The Insight into Antihypertensive Properties of Vitamins A, C and E. A*ntioxidants* 13(7), 848; (Cross Ref)
14. Gomes, A.R.Q.; Cunha, N.; Varela, E.L.P.; Brígido, H.P.C.; Vale, V.V.; Dolabela, M.F.; De Carvalho, E.P.; Percário, S. (2022): Oxidative Stress in Malaria: Potential Benefits of Antioxidant Therapy. *Int. J. Mol. Sci*, *23*, 5949. https://doi.org/10.3390/ijms23115949
15. Hiroyuki Arai and Nozomu Kono (2021): α-Tocopherol transfer protein (α-TTP). *Free radical Biology and Medicine*. Vol. 176, (20) November, Pg 162-175
16. Idro, R., Kakooza-Mwesige, A., Asea, B. *et al*. (2016): Cerebral malaria is associated with long-term mental health disorders: a cross sectional survey of a long-term cohort. *Malar J* 15, 184. https://doi.org/10.1186/s12936-016-1233-6
17. Jomova, K., Alomar, S.Y., Alwasel, S.H. *et al.* (2024): Several lines of antioxidant defense against oxidative stress: antioxidant enzymes, nanomaterials with multiple enzyme-mimicking activities, and low-molecular-weight antioxidants. *Arch. Toxicol.* 98, 1323–1367 https://doi.org/10.1007/s00204-024-03696-4
18. Kotepui, K.U., Mahittikorn, A., Mala, W. *et al*. (2024): Total antioxidant status levels in malaria: a systematic review and meta-analysis. *Malar J* **23**, 198 https://doi.org/10.1186/s12936-024-05003-z
19. Kotepui, M.; Masangkay, F.R.; Mahittikorn, A.; Kotepui, K.U. (2023): Effect of Malaria on Blood Levels of Vitamin E: A Systematic Review and Meta-Analysis*. Nutrients*, 15, 3472. https://doi.org/10.3390/ nu15153472
20. Miro´nczuk-Chodakowska, I.; Witkowska, A.M.; Zujko, M.E. (2018): Endogenous non-enzymatic antioxidants in the human body. *Adv. Med. Sci*. 63, 68–78. [CrossRef]
21. Nandi, S., Ahmed, S., and Saxena, A. K. (2022): exploring the Role of Antioxidants to combat Oxidative Stress in Malaria Parasite. *Current topics in medicinal chemistry*, 22 (24), 2029-2044.
22. Nwachukwu, N.F.; Mishra, M.; Marcelle, T.; Owolabi, J.B. (2016): Effects of vitamins in augmentation of malaria treatment: A review. *Asian Pac. J. Health Sci*. 2016, 3, 34–43. [CrossRef]
23. Olubunmi Adeola Lawal, Samuel Ademola Adegoke, Saheed Babajide Oseni, Oyeku Akibu Oyelami (2018): Low serum vitamin A is prevalent in under five children with severe malaria and is associated with increased risk of death. *J Infect Dev Ctries*; 12(5):365-372. doi:10.3855/jidc.9572
24. Onyesom, R. C. Ekeanyanwu and N. Achuka. (2010): Correlation between moderate *Plasmodium falciparum* malarial parasitemia and antioxidant vitamins in serum of infected children in South Eastern Nigeria I. *African Journal of Biochemistry Research Vol. 4(12*), pp. 261-264, December
25. Pranesh K. Chakraborty, Klaus Schmitz-Abe, Erin K. Kennedy, Hapsatou Mamady,1 Turaya Naas, Danielle Durie, Dean R. Campagna, Ashley Lau, Anoop K. Sendamarai, Daniel H. Wiseman, Alison May, Stephen Jolles, Philip Connor, Colin Powell, Matthew M. Heeney, Patricia-Jane Giardina, Robert J. Klaassen, Caroline Kannengiesser, Isabelle Thuret, Alexis A. Thompson, Laura Marques, Stephen Hughes, Denise K. Bonney, Sylvia S. Bottomley, Robert F. Wynn, Ronald M. Laxer, Caterina P. Minniti, John Moppett, Victoria Bordon, Michael Geraghty, Paul B. M. Joyce, Kyriacos Markianos, Adam D. Rudner, Martin Holcik, and Mark D. Fleming Sun *et al,* (2012): Mutations in TRNT1 cause congenital sideroblastic anemia with immunodeficiency, fevers, and developmental delay (SIFD) *Blood* 30 October, Vol.124. (**18**).
26. Qin, X.; Liu, J.; Du, Y.; Li, Y.; Zheng, L.; Chen, G.; Cao, Y. Different doses of vitamin C supplementation enhances the Th1 immune

response to early *Plasmodium yoelii* 17XL infection in BALB/c mice. *Int. Immunopharmacol*., 70, 387–395. [CrossRef

27. Singhaboot Y, Keayarsa S, Piaraksa N, Phumratanaprapin W, Kunawut P, Dondorp A, Chotivanich K. (2019): Temperature Dependence of *Plasmodium falciparum* Erythrocytic Stage Development. *Am J Trop Med Hyg.* May;100(5):1191-1195. doi: 10.4269/ajtmh.18-0894. PMID: 30938284; PMCID: PMC6493921.
28. Sussmann, R.A.C., Fotoran, W.L., Kimura, E.A. *et al. Plasmodium falciparum* uses vitamin E to avoid oxidative stress. *Parasites Vectors* **10**, 461 (2017). https://doi.org/10.1186/s13071-017-2402-3
29. Suzuki, H.; Kume, A.; Herbas, M.S. (2019): Potential of vitamin E deficiency, induced by inhibition of α-tocopherol efflux, in murine malaria infection. *Int. J. Mol. Sci*., 20, 64. [CrossRef]
30. Tsochatzis ED, Bladenopoulos K, Papageorgiou M. (2012): Determination of tocopherol and tocotrienol content of Greek barley varieties under conventional and organic cultivation techniques using validated reverse phase high-performance liquid chromatography method. *J Sci Food Agric.* Jun;92(8):1732-9. doi: 10.1002/jsfa.5539. Epub 2012 Jan 6. PMID: 22228588.
31. Vega-Rodríguez, J.; Pastrana-Mena, R.; Crespo-Lladó, K.N.; Ortiz, J.G.; Ferrer-Rodríguez, I.; Serrano, A.E. (2015): Implications of glutathione levels in the *Plasmodium berghei* response to chloroquine and artemisinin. *PLoS ONE*, 10, e0128212. [CrossRef]
32. World Health Organization. WHO: World Malaria Report 2021 Geneva Switzerland, 2015.
33. World Health Organization. WHO: World Malaria Report 2021; World Health Organization: Geneva, Switzerland, 2022; Available online: https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021 (accessed on 1 January 2020).
34. Yakoob, M.Y.; Qadir, M. Vitamin A supplementation for prevention and treatment of malaria during pregnancy and childhood: A systematic review and meta-analysis. J. Epidemiol. Glob. Health 2018, 8, 20–28. (CrossRef)