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Comparative Study of Pharmaceutical, Herbal Medicine, and Low-Value Alternating Electromagnetic Radiation as Anti-Malaria Treatment

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ABSTRACT

Malaria is a significant global health burden, particularly in regions with limited healthcare resources. Pharmaceutical interventions, specifically artemisinin-based combination therapies (ACTs), have long been the mainstay of malaria treatment due to their proven efficacy in eliminating Plasmodium parasites. Herbal medicine has also gained attention as a potential alternative or adjunctive therapy. Nevertheless, the emergence of drug-resistant strains, notably in Southeast Asia and Africa, poses a considerable challenge to the effectiveness of these pharmaceutical treatments. Using low-value alternating electromagnetic field (EMF) radiation as an anti-malaria treatment is a novel approach that requires further investigation to determine its therapeutic potential. This research studies the comparative analysis of the effect of pharmaceutical intervention, herbal medicine, and low-value alternating EMF as anti-malaria treatments. The research methodology involves a systematic literature review of relevant scientific databases, design, construction, and administration of 20mT & 30mT electromagnetic field, Lumartem and Thitonia Diversifolia (Jume 12) to plasmodium berghei-infected mice for four days consecutively at the same time interval. Results revealed that all treatments were significantly effective. Lumartem is maximally effective from the third day, while Tihonia Diversifolia was maximally effective on the second day. EMF 10mT was maximally effective on the third day, while EMF 20mT did not fully align with the non-infected mice trend, but it is likely to align if treatment continues. The results of this comparative study will contribute to the body of knowledge regarding the effectiveness of pharmaceutical, herbal medicine, and low-value alternating electromagnetic field treatments for malaria.

INTRODUCTION

Malaria remains a significant public health concern worldwide, particularly in regions with limited healthcare resources. According to the World Health Organization (WHO), there were an estimated 229 million cases of malaria and approximately 409,000 malaria-related deaths in 2019 alone (WHO, 2020). Several scholars reported that the biggest challenge remains in sub-Saharan Africa (Bethencourt et al., 2023; Rosenthal & Rabinovich, 2019). The high burden of this disease necessitates developing and evaluating effective treatment strategies. Research reveals that the prevalence of Plasmodium falciparum infection in endemic Africa reduced by 50%, and the occurrence of clinical disease decreased by 40% from 2000 to 2015. Due to various interventions, a significant number of 663 (with a credible interval of 542–753 million) clinical cases have been prevented since the year 2000 (Briët et al., 2015).

Traditionally, pharmaceutical interventions have been the primary approach for malaria treatment (Kazaz et al., 2016; Sinha et al., 2014). Drugs such as artemisinin-based combination therapies (ACTs) have demonstrated remarkable efficacy in clearing Plasmodium parasites from infected individuals (Calleri, Balbiano, & Caramello, 2013; Mishra, Kashaw, Iyer, & Kashaw, 2017). However, the emergence of drug-resistant strains, particularly in Southeast Asia, poses a significant threat to the effectiveness of current pharmaceutical interventions (Ashley et al., 2014; Panda et al., 2017). In light of these challenges, there is growing interest in exploring alternative treatment options for malaria. Herbal medicine, derived from plant sources, has been used for centuries in various cultures to manage infectious diseases, including malaria (Wells et al., 2015; Pan et al., 2018; Alkandahri et al., 2022). Plant-based compounds offer a vast reservoir of potential anti-malarial agents that may possess unique mechanisms of action and lower toxicity profiles than synthetic drugs (Onguéné et al., 2014; Teng, Kiat, Suwanarusk, & Koh, 2016; Devillers, & Devillers, 2019). Investigating the efficacy and safety of herbal medicine as an anti-malaria treatment could provide valuable insights for improving malaria control and management.

In recent years, an innovative approach utilizing low-value alternating electromagnetic fields (EMF) has emerged as a potential treatment modality for malaria (Cosic, Cosic, & Lazar, 2016). The rationale behind this approach is based on the observation that specific electromagnetic frequencies may have detrimental effects on the survival and reproduction of malaria parasites (Abajingin, 2015; Coronado et al., 2016; Coronado et al., 2023). Preliminary studies have shown promising results, suggesting that low-value alternating EMF could be a non-invasive and potentially cost-effective adjunctive therapy for malaria (Nik, Mohammed, & Mustaffa, 2017; Varo et al., 2018). Furthermore, a similar study suggested that the Resonant Recognition Model (RRM) frequency of f = 0.002 can enhance Plasmodium infectivity and possibly resist the invasion process of Plasmodium (Cosic, Caceres, & Cosic, D. 2015). Electromagnetic radiation plays a vital role in combating the malaria virus. Similarly, the use of microwave irradiation for DNA extraction can also enable the detection of as many as five malaria parasites (Port, Nguetse, Adukpo, & Velavan, 2014).

Moreover, for alternating electromagnetic fields to be considered a reliable and safe alternative to the traditional method of curing malaria, several factors, like its effect on the patient's blood parameters, must be investigated (Gilson et al., 2018; Wei, & Wang, 2022). Blood is a crucial component of the body responsible for transporting oxygen and nutrients throughout the body and removing waste products (Garg, Singh, Singh, & Rizvi, 2020). It is crucial to examine the effect of EMF on blood parameters and to develop guidelines for safe exposure limits.

Several studies have investigated the potential effects of EMF exposure on blood parameters, including red blood cell count, white blood cell count, hemoglobin concentration, hematocrit levels, platelet count, and total leukocyte count. A study conducted by Cakır et al. (2009) found that exposure to EMF led to changes in red blood cell count, hemoglobin concentration, and hematocrit levels. Similarly, a study by Mhaibes, A.A., & Ghadhban, R.F. (2018) showed alterations in white blood cell count, platelet count, and total leukocyte count after exposure to EMF. Mustafa, B.T., Yaba, S.P., & Ismail, A.H. (2020) reported that the time of exposure to EMF influences the white blood cells (WBCs) significantly, and one hour of vulnerability has increased the WBCs counts tremendously in all weeks. However, the 8hrs of exposure reduced WBC counts highly. Kivrak et al. (2017) showed that exposure to EMF caused oxidative stress in many body tissues. It caused an increase in oxidative stress markers, such as malondialdehyde and superoxide dismutase, in the blood.

Another study by Wu et al. (2016) demonstrated that increased plasma concentrations of a1-antitrypsin, a2-plasmin inhibitor, and a2-macroglobulin were significantly elevated in coronary artery ectasia (CAE) patients compared with coronary atherosclerosis disease (CAD) patients and normal controls. The study suggests that exposure to low-valued EMF may significantly affect blood parameters, potentially leading to various health risks. Sarookhani et al. (2012) examined the effects of 950 MHz electromagnetic radiation on blood cells and reported changes in red blood cell count, hemoglobin concentration, and hematocrit levels. Similarly, a study by Shojaeifard et al. (2018) found that exposure to Mobile phone electromagnetic fields disturbs the endless number of hematological parameters in male rabbits. The EMF led to significant changes in total leukocyte count, erythrocyte sedimentation rate, and hemoglobin concentration.

In addition, studies have shown that plant-derived drugs can be the source of novel lead compounds to control malaria (Pohit et al., 2013;

Noronha et al., 2020). Likewise, the recent mini-review reports by Ribeiro et al. (2023) explore natural sources, mainly from flora, as anti-malarial therapy. The study focused on plant extracts and their isolated natural products with at least in vitro antiplasmodial effects. Novel techniques are presently being investigated to treat the malaria parasite asides pharmaceutical therapy and prevent its spread and relapse (Dash, & Das, 2016; Saini et al., 2021). To date, limited research has been conducted to comprehensively compare the effect and safety of pharmaceutical interventions, herbal medicine, and low-value alternating electromagnetic fields as anti-malaria treatments. Therefore, this research aims to conduct a comparative study to evaluate these treatment modalities and provide evidence-based insights for healthcare professionals and policymakers.

By undertaking this comparative study, we hope to contribute to the existing body of knowledge regarding the effect of pharmaceutical interventions, herbal medicine, and low-value alternating electromagnetic fields as anti-malaria treatments. The findings may guide healthcare professionals and policymakers in making informed decisions regarding malaria treatment strategies. Nevertheless, this research may stimulate further investigations and innovations in the field of malaria treatment, ultimately leading to improved outcomes for individuals affected by this devastating disease.

METHODS

The materials and equipment used for this study are Electromagnetic field (EMF) boxes, A wooden cage kept in the animal house of the Adekunle Ajasin University, Cereal pellets, Saw-dusts, Slides, dissecting set, Lumartem anti-malaria drug, Microscope, refrigerator, microplate reader, centrifuge machine, 30V Step down transformer, Copper wire, 13mH Inductor, A.C Variac, Multimeter, Cutter and Soldering Iron.

Thirty Plasmodium berghei-infected and Ten non-infected mice about three weeks old and weighing about 65g were obtained for this study. The rats were received from the Department of Parasitology, University College Hospital (UCH), Ibadan, Nigeria. Lumartem and Thitonia Diversifolia (Jume 12) were also obtained for the pharmaceutical and herbal treatment from the Institute for Advance Medical Research and Training (IAMRAT), College of Medicine, University Teaching Hospital, Ibadan, Oyo, Nigeria. The animals were treated per the Rules and Regulations laid down by the National Institute of Health.

Figure 1. Pictorial view of plasmodium berghei-infected mice used for the experiment

The Electromagnetic field (EMF) system used for this experiment was constructed from a wooden rectangular box, on which 220 turns of 18 standard wire gauge (SWG) coil conductor (solenoid) with an inner radius of 750 mm, and thickness of 102.5 mm at room temperature was wound around by the sides of the wooden box. An alternating current power source (AC) is supplied to the solenoid of self-inductance 13mH through a 30 V step-down transformer, which helps to produce an AC current output of 6.00A. A variable regulator (Variac) is connected to the front of the wooden rectangular box to regulate the electromagnetic field intensity and change the magnitude of the radiation in a range of 20mT to 30mT.

Figure 2. Pictorial view of EMF system used for treating the plasmodium berghei-infected mice

The mice were housed in a plastic cage at room temperature (25 to 27°C) under normal 12-hour-light-dark cycle conditions for five days. They were fed regularly with cereal pellets and water for those five consecutive days. The reason for doing that was meant to ascertain the full maturation of the plasmodium-berghei in the mice. After the fifth day, nine of the parasite-infested rats died. The remaining parasite-infected mice were randomly divided into five experimental groups (A, B, C, D, E), while the non-infected rats were used as the control group. The groups are named Lumartem, JUME 12, EMF 10mT, EMF 20mT, and Non-infested. The parasite-infected mice in the experimental group were all labeled 1-5 and placed in the electromagnetic box where they were exposed to different values of OSMF of 10mT and 20mT for 6 hours per day for four consecutive days at the same time for those treated with EMF. At the same time, those treated with Lumartem and Thitonia Diversifolia (Jume 12) were administered with the same dose of the drugs and herbal for the same number of days. Blood samples of about 0.5 ml were collected from the vein of the experimental mice and control group into slides containing lithium heparin daily.

The samples were collected in the Biology laboratory at Adekunle Ajasin University for biochemical analysis and parasite density check. The slides were stained with Giemsa stain and left to dry before subjecting them to a light microscope for parasite screening. Whole blood was obtained from a puncture of the retro-orbital sinus. The blood samples were labeled in anticoagulated bottles. Hematological parameters such as white blood cell (WBC), red blood cell (RBC), hemoglobin concentration (HGB), hematocrit (HCT), mean corpuscular hemoglobin concentration (MCHC), Lymphocytes (LYM), mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MGH) were analyzed. The hematological tests were analyzed by using an automated method with an automatic analyzer (Haematology Autoanalyzer Sysmex KX-21N) in the Animal and Environmental Biology laboratory of Adekunle Ajasin University, Akungba-Akoko, Ondo state, Nigeria. The Sysmex XN-series represents a recently developed automated hematology analyzer with the primary objective of enhancing the precision of cell counts and the specificity of flagged events (Seo, Lee, & Kim, 2015).

RESULTS AND DISCUSSION

The following shows the results of analyzing the data collected from the experiments and discussing the findings based on the research objectives. The data collected were subjected to descriptive and inferential statistics. The results were compared descriptively using graphs and mean. The purposes of the research were discussed based on the results from the subjection of the data collected to Analysis of Variance and t-test analysis. All the hypotheses in this research were tested at a 0.01 significance level. The results were presented in Tables 1 to 3 and graphically in Figures 3 to 8. The experiments were conducted on the effect of treatments using Lumartem, Thitonia Diversifolia (Jume 12), 10mT, and 20mT EMF(s) on the Plasmodium berghei-infected Mice.

The following abbreviations should be noted:

GRAH - Granulocyte Cell Count
GRA % - Granulytes Cell Percentage
HGB - Haemoglobin content
HCT/PCV - Heamatocrit
LYMH - Lymphocyte count
LYM% - Lymphocyte Percentage

MCV - Mean Corpuscular Volume
MCH- Mean Corpuscular Haemoglobin
MCHC - Mean Corpuscular Haemoglobin Concentration
MPV - Mean Platelet Volume
PCT- Plateletcrit
PLT - Platelet Count
RBC - Red Blood Cell Count
WBC -White Blood Cell Count

Table 1. Effect of treatments on hematological parameters

Days	Parameters	Non-Infected	Lumartem	Thitonia Diversifolia	EMF 20mT	EMF 10mT
1	WBC (10^9/L)	6.61	2.55	5.77	9.26	14.19
	LYM# (10^9/L)	6.03	2.09	5.12	8.68	13.04
	GRA# (10^9/L)	0.20	0.17	0.18	0.17	0.17
	LYM (%)	91.23	78.83	87.10	93.51	94.59
	RBC (10^{12}/L)	6.51	2.09	3.37	3.77	3.44
	GRA (%)	3.40	9.54	3.87	2.21	1.61
	HGB (g/L)	107.00	33.00	52.25	206.00	142.00
	MCHC (g/L)	250.23	279.32	270.90	264.85	275.77
	MCH (pg)	16.87	15.62	17.12	17.25	17.49
	MCV (fL)	65.94	56.48	64.59	64.02	62.50
	HCT (%)	42.82	12.49	22.44	77.65	61.69
	PLT (10^9/L)	1,212.00	676.75	734.25	2,537.67	1,688.00
	PCT(%)	1.48	2.94	0.98	2.85	2.16
	MPV(fL)	12.26	13.91	9.90	10.68	11.48
2	WBC (10^9/L)	6.61	17.52	9.71	12.20	10.79
	LYM# (10^9/L)	6.03	16.73	8.86	7.73	8.10
	GRA# (10^9/L)	0.20	1.14	0.22	0.28	0.63
	LYM (%)	91.23	88.52	91.88	77.27	70.91
	RBC (10^{12}/L)	6.51	5.35	7.46	5.39	0.11
	GRA (%)	3.40	3.97	2.25	4.77	23.15
	HGB (g/L)	107.00	121.00	114.00	80.83	179.00
	MCHC (g/L)	250.23	253.06	217.61	272.64	262.60
	MCH (pg)	16.87	16.03	14.46	17.03	16.48
	MCV (fL)	65.94	62.86	67.65	64.43	65.06
	HCT (%)	42.82	56.46	57.59	88.98	68.63
	PLT (10^9/L)	1,212.00	1,880.75	1,272.75	10.50	2,102.00
	PCT(%)	1.48	1.81	1.11	3.60	2.35
	MPV(fL)	12.26	9.85	8.71	12.13	11.77
3	WBC (10^9/L)	6.61	3.59	7.31	6.68	22.11
	LYM# (10^9/L)	6.03	3.11	5.75	5.38	21.20
	GRA# (10^9/L)	0.20	0.20	0.25	0.25	0.42
	LYM (%)	91.23	66.96	81.00	84.15	93.61
	RBC (10^{12}/L)	6.51	4.94	1.79	4.95	0.68
	GRA (%)	3.40	8.20	5.99	5.51	1.17
	HGB (g/L)	107.00	77.00	111.34	177.67	211.33
	MCHC (g/L)	250.23	243.80	296.45	265.56	285.24
	MCH (pg)	16.87	15.49	19.97	17.35	17.61

	MCV (fL)	65.94	63.57	68.55	65.65	61.87
	HCT (%)	42.82	31.69	11.49	64.04	68.95
	PLT (10^9/L)	1,212.00	1,291.00	994.67	2,340.00	1,220.10
	PCT(%)	1.48	1.37	1.03	2.62	3.18
	MPV(fL)	12.26	10.80	10.77	11.71	11.14
4	WBC (10^9/L)	6.61	4.36	8.20	5.66	10.18
	LYM# (10^9/L)	6.03	2.92	7.11	5.06	15.90
	GRA# (10^9/L)	0.20	0.22	0.41	0.41	0.36
	LYM (%)	91.23	71.65	78.69	81.92	90.48
	RBC (10^{12}/L)	6.51	5.21	3.15	4.61	0.77
	GRA (%)	3.40	7.10	4.08	6.45	1.65
	HGB (g/L)	107.00	80.67	93.67	184.00	202.67
	MCHC (g/L)	250.23	255.20	301.10	246.76	251.66
	MCH (pg)	16.87	16.67	18.92	18.10	16.59
	MCV (fL)	65.94	63.91	62.41	70.79	63.92
	HCT (%)	42.82	37.37	23.52	70.00	72.02
	PLT (10^9/L)	1,212.00	1,310.00	963.00	2,162.00	1,619.11
	PCT(%)	1.48	1.60	1.13	3.19	2.59
	MPV(fL)	12.26	10.96	10.20	13.26	10.63

Comparative Analysis of the Treatments on Haematological Parameters

At the end of the experiment, a comparative analysis was carried out on the test results. From Table 1, it can be observed that on the last day of the investigation, which was on the fourth day, the specimen treated with Lumartem was the most effective on the parameter RBC (10^{12}/L) with 5.21 x 10^{12}/L because it was the closest to non-infected mice with 6.51 x 10^{12}/L. Then, followed by the specimen treated with 20mT EMF (4.61 x 10^{12}/L), the specimen treated with Thitonia Diversifolia (3.15 x 10^{12}/L), and lastly, the specimen treated with 10mT EMF (0.77 x 10^{12}/L).

The effect of Thitonia Diversifolia on HGB (g/L) is most effective with 93.67 g/L because it was the closest to non-infected mice with 107 g/L. This result is similar to previous research on Thitonia diversifolia extract which significantly decreased the level of blood glucose and cholesterol concentrations compared to the positive control group. (Solfaine, Muniroh, & Hamid, 2022). Likewise, the study of Kang, H.C., & Koppula, on the hepatoprotective effect of houttuynia cordata thunb extract, exhibited significant hepatoprotective properties in carbon tetrachloride-induced hepatotoxicity in mice (Kang, & Koppula, 2014). Then, followed by the specimen treated with Lumartem (80.67 g/L), then the specimen treated with 20mT EMF (184 g/L), and lastly, the specimen treated with 10mT EMF (202,67 g/L). Also, the effect of 10mT EMF on MCHC (g/L) is most effective with 251.66 g/L because it was the closest to non-infected mice with 250.23 g/L. Then, followed by the specimen treated with 20mT EMF (246.76 g/L), the specimen treated with Lumartem (255.20g/L), and lastly, the specimen treated with Thitonia Diversifolia (301.10 g/L).

From the table, it can also be observed that the effect of Lumartem on MCH (pg) is most effective with 16.67pg because it was the closest to non-infected mice with 16.87 pg. Then, followed by the specimen treated with 10mT EMF (16.59 pg), then the specimen treated with 20mT EMF (18.10 pg), and lastly the specimen treated with Thitonia Diversifolia (18.92 pg). The effect of 10mT EMF on MCV (fL) is most effective with 63.92 fL because it was the closest to non-infected mice with 65.94 fL. Then, followed by the specimen treated with Lumathem (63.91 fL), the specimen treated with Thitonia Diversifolia (62.41 fL), and lastly, the specimen treated with EMF 20 (70.79 fL).

The table further revealed that the effect of Lumartem on the HCT (%) parameter is most effective at 37.37% because it was the closest to non-infected mice with 42.82%. Then, followed by the specimen treated with Thitonia Diversifolia (23.52%), the specimen treated with 20mT EMF (70%), and lastly, the specimen treated with 10mT EMF (72.02%).

Graphical Representation and Interpretation of Variations in the Effect of Treatments on Haematological Parameters

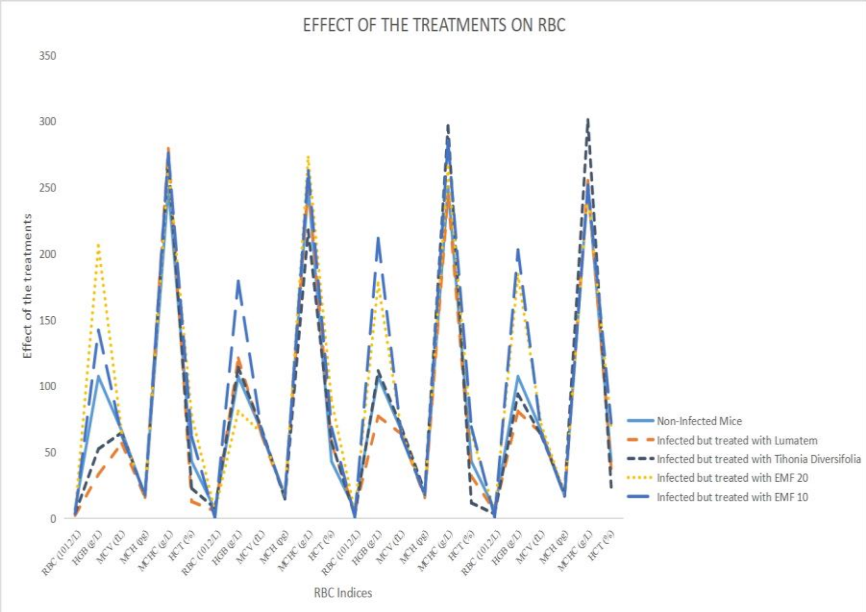

Figure 3. Effect of the Treatments on RBC Indices

Figure 3 shows the graph of the effect of the treatment on the RBC indices of Plasmodium berghei-infected mice. The trend of the infected mice and those treated with Thitonia Diversifolia is the closest to the direction of non-infected mice; this implies that Thitonia Diversifolia treatment is the most effective, followed by Lumartem, then 10mT EMF and 20mT EMF in that order.

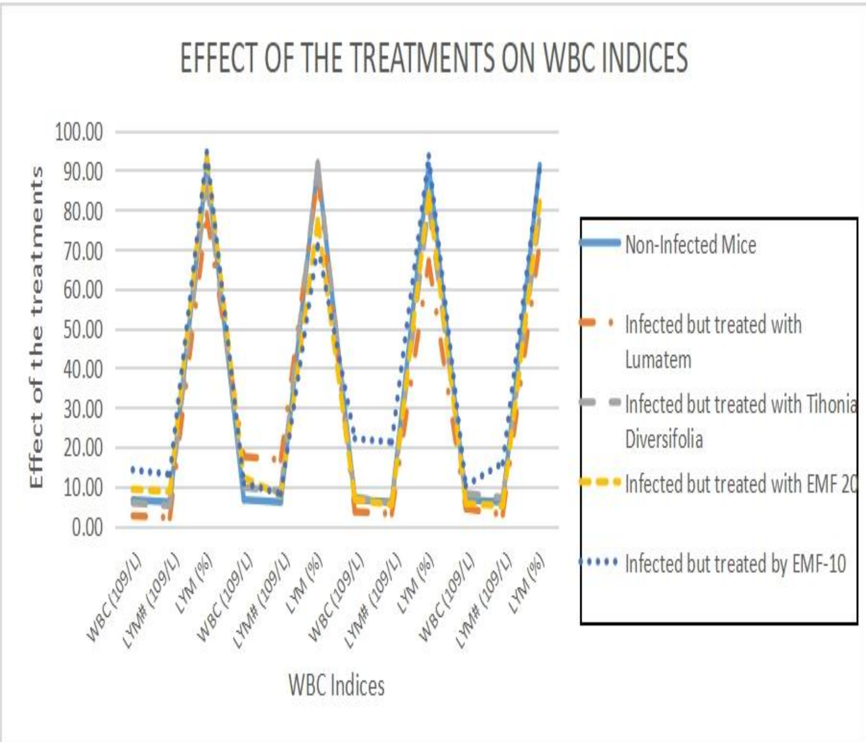

Figure 4. Effect of the treatments on WBC Indices

Figure 4 shows the graph of the effect of the treatment on the WBC indices of Plasmodium berghei-infected mice. The trend of the infected mice treated with Thitonia Diversifolia is the closest to the direction of non-infected mice, and this situation also implies that Thitonia Diversifolia treatment is the most effective, followed by Lumartem, then 20mT EMF and 10mT EMF in that order.

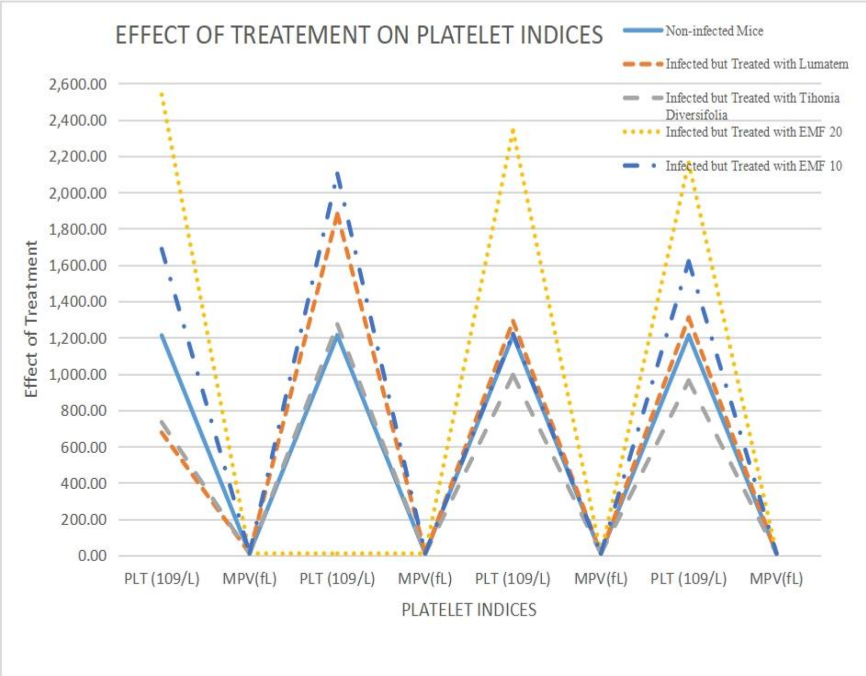

Figure 5. Effect of the Treatments on Platelet Indices

Figure 5 is the graph of the effect of the treatment on the Platelets indices of Plasmodium berghei-infected mice. The trend of the infected mice treated with Lumartem is the closest to non-infected mice. We also observed that the treatments' effect was insignificant ($P > 0.01$). It implies that the effect of the treatments on Platelets indices was not significantly effective on Plasmodium berghei-infected mice.

Table 2 reveals the significant differences between the density of the parasite of non-treated infected mice and treated infected mice using the treatments (Lumartem, Thitonia Diversifolia, 20mT EMF 20 and 10mT EMF). It was discovered that the treatments' effect was insignificant ($P>0.01$) on the mean density of the parasite. There is a high probability that the treatments were only able to render the parasite inactive.

Table 2: T-test analysis on the effect of the treatments on the Parasite density in plasmodium berghei-infected mice

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	99% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Non Treated Infected Mice - Infected but treated with Lumathem	1677.708	683.310	341.655	-317.870	3673.285	4.911	3	.016
Pair 2	Non Treated Infected Mice - Infected but treated with Thitonia Diversifolia	1766.458	642.839	321.419	-110.924	3643.839	5.496	3	.012
Pair 3	Non Treated Infected Mice - Infected but treated with EMF 20	1632.500	615.748	307.874	-165.765	3430.765	5.302	3	.013
Pair 4	Non Treated Infected Mice - Infected but treated with EMF 10	1494.165	862.911	431.455	-1025.926	4014.256	3.463	3	.041

From our results, we plotted the graph as shown in Figure 6 to compare the trend of the effect of treatment on Plasmodium berghei-infected mice using Lumartem and non-infected mice. It was discovered through the trends that the direction was aligned on the third and fourth days. This implies that the treatment using Lumartem is generally effective and maximally effective from the third day till the fourth day of the experiments.

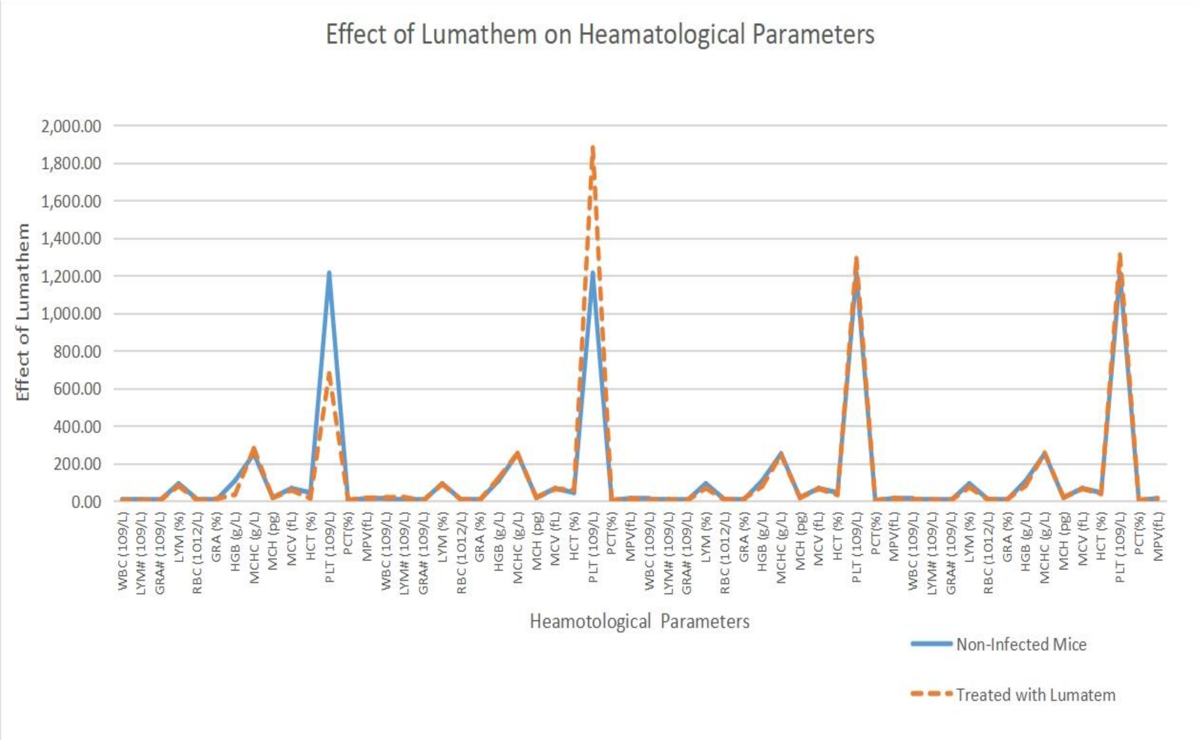

Figure 6. Effect of Lumathem on Hematological Parameters

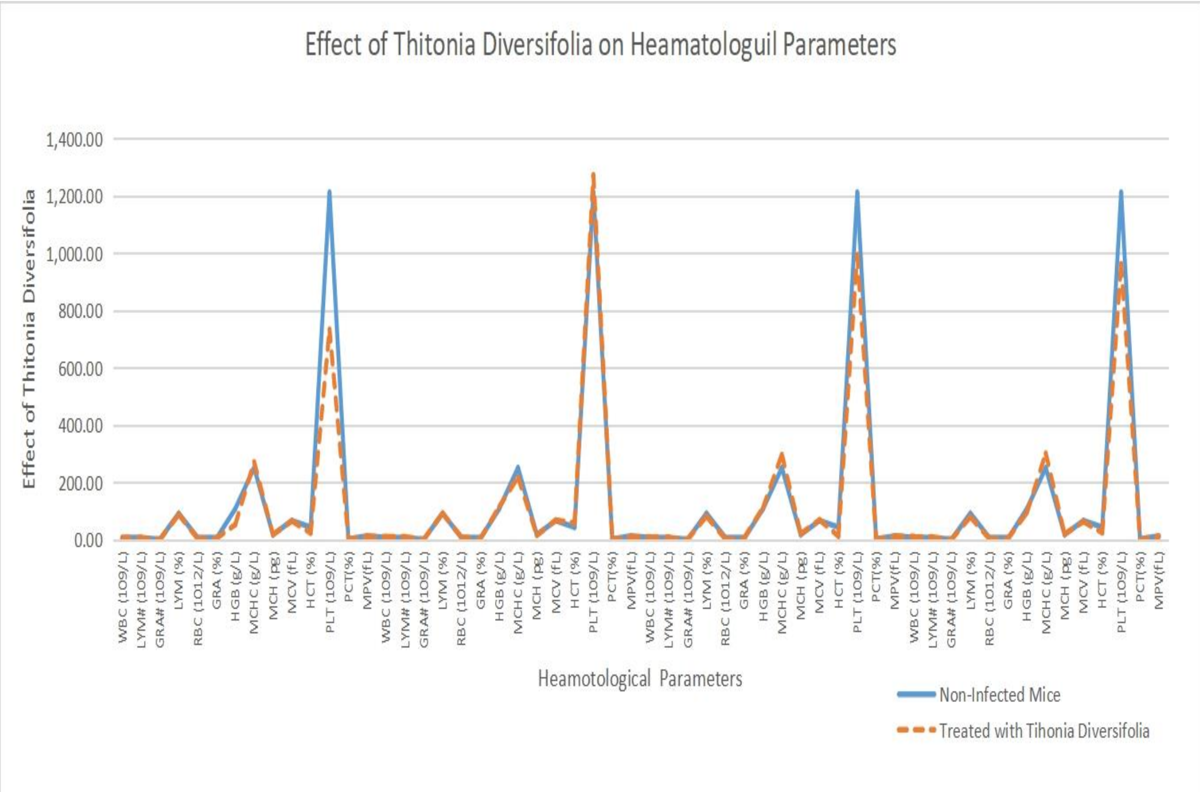

Figure 7. Effect of Thitonia Diversifolia on Haematological Parameters

Figure 7 graph compares the trend of the effect of treatment on Plasmodium Beighei infected mice using Tihonia Diversifolia (JUME 12) on the hematological parameters and non-infected mice. It was discovered through the trends that the direction was aligned on the second day and began to deviate after the second day. This implies that Tihonia Diversifolia treatment was maximally effective on the second day.

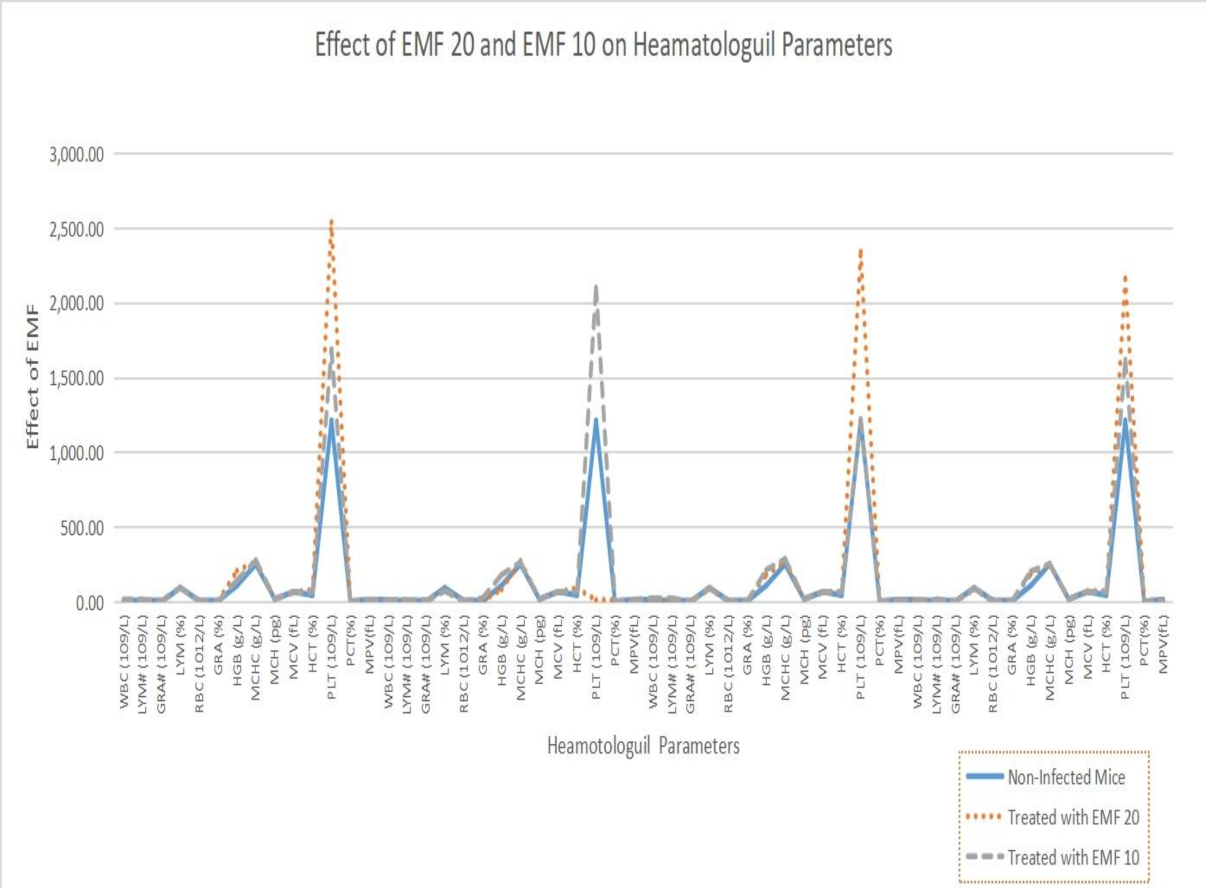

Figure 8. Effect of 20mT EMF and 10mT EMF on Hematological Parameters

Figure 8 is the graph to show and compare the trend of the effect of treatments on Plasmodium berghei-infected mice using 20mT EMF and 10mT EMF on the Hematological parameters and non-infected mice. It was discovered through the trends that the direction was aligned on the third day and began to deviate after the third day using 10mT EMF. This implies that the treatment using 10mT EMF was maximally effective on the third day. In the case of 20mT EMF, it was not fully aligned on any of the days.

Table 3: Comparisons of Treatments on Hematological Parameter of Plasmodium berghei-infected mice

Dependent Variable: Treatments						
LSD						
(I) Factor Treatment	(J) Factor Treatment	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound
Non-Infected Mice	-Infected but Treated with Lunatem	-2.1441	30.45986	.944	-81.3228	77.0346
	-Infected but treated with Tihonia Diversifolia	16.8977	30.45986	.580	-62.2810	96.0764
	-Infected but treated with 20mT EMF	-46.2457	30.45986	.130	-125.4244	32.9330
	-Infected but treated with 10mT EMF	-41.0095	30.45986	.180	-120.1881	38.1692

Table 3 compares treatments' effects on the Hematological parameter of the Plasmodium berghei-infected mice with non-infected mice. The difference between the non-infected mice and the plasmodium berghei-infected mice treated with treatments (Lumartem, Thitonia Diverssifolia, 20mT, and 10mT EMF) was not significant ($P > 0.01$). This implies that the treatment on the Hematological parameter using any of the treatments was significantly effective on Plasmodium berghei-infected mice to restore the Hematological parameter of the infected mice to normal.

The comparative analysis revealed that pharmaceutical drugs (Lumartem, artemisinin-based combination therapies) remain the most effective treatment for malaria. They have a proven track record of efficacy and are supported by extensive clinical research. However, these drugs' widespread availability and affordability remain a challenge, especially in resource-limited settings where malaria is endemic (Ahmad et al., 2014).

Herbal medicine (Thitonia Diverssifolia) showed promising results as an alternative treatment for malaria. Several plant-based compounds exhibited anti-malarial properties and demonstrated the potential to be developed into effective therapies. However, further research is needed to identify and isolate specific compounds, determine their safety profiles, and establish standardized dosage regimens.

Also, based on this research findings, 10mT EMF treatment proved to be maximally effective on the third day as the treatment trend aligns with that of the group of non-infected mice. The results confirm that some electromagnetic-based methods can have a niche role in the treatment and diagnostics of malaria infections. EMF is also very useful in certain conditions, such as bone healing, cancer treatment, neurological conditions, and diathermy (Mattsson, & Simkó, 2019; Vaca-González, 2022).

CONCLUSION

This research aims to carry out the comparative study of pharmaceutical, herbal medicine, and low-value alternating electromagnetic fields as anti-malaria treatment. Additionally, to check the post-effect of each therapy on blood parameters of the plasmodium berghie-infected mice. The research findings have provided valuable insights into the effect and potential of these treatment modalities. Pharmaceutic treatment was maximally effective from the third day of the experiment, while herbal therapy using Thitonia Diversifolia (JUME 12) was maximally effective on the second day, and 10mT EMF was maximally effective on the third day. 20mT EMF did not fully align with the non-infected mice trend, but it will likely align if treatment continues. The study of low-value alternating electromagnetic fields as an anti-malarial treatment is relatively novel and requires more extensive investigation. While initial studies have shown some positive effects, the mechanism of action and optimal treatment protocols are not yet fully understood. Further research should focus on elucidating the biological mechanisms involved, optimizing the treatment parameters, and conducting rigorous clinical trials to assess its efficacy and safety.

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