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Haematoprotective effects of Aqueous *Morinda lucida* leaf extract on *Plasmodium berghei*-induced Haematological alterations in Wistar Rats

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Abstract

Malaria remains a major global public health challenge and is frequently accompanied by haematological abnormalities that contribute significantly to disease severity and poor clinical outcomes. This study evaluated the haematoprotective effects of aqueous *Morinda lucida* leaf extract in *Plasmodium berghei*-infected Wistar rats. Thirty male Wistar rats were randomly allocated to six groups (n = 5): normal control, infected untreated control, artesunate-treated (10 mg/kg), and infected groups treated orally with aqueous *M. lucida* leaf extract at doses of 100, 200, and 400 mg/kg. Experimental malaria was induced with *P. berghei*, and treatments were administered once daily for four consecutive days using the Rane curative model. Haematological parameters were determined using an automated haematology analyser, while data were analysed using one-way analysis of variance followed by Duncan's Multiple Range Test ($p < 0.05$). Acute oral toxicity was also evaluated. The extract was well tolerated, with no mortality or observable signs of toxicity at 2,000 mg/kg. *P. berghei* infection caused significant reductions in erythrocytic, leukocytic, and platelet indices compared with the normal control ($p < 0.05$). Treatment with aqueous *M. lucida* leaf extract significantly and dose-dependently restored these parameters, with the 400 mg/kg dose producing effects comparable to those of artesunate. These findings demonstrate that aqueous *M. lucida* leaf extract effectively ameliorates malaria-induced haematological alterations and highlight its potential as a promising source of bioactive compounds for the development of plant-derived antimalarial therapies.

Keywords: *Morinda lucida*; Malaria; *Plasmodium-berghei*; Haematological parameters; Haematoprotection; Wistar rats.

1 Introduction

Malaria remains one of the most devastating vector-borne infectious diseases and continues to pose a major public health challenge despite substantial advances in prevention, diagnosis, and treatment. Caused by protozoan parasites of the genus *Plasmodium* and transmitted through the bites of infected female *Anopheles* mosquitoes, malaria remains endemic in many tropical and subtropical regions where it contributes significantly to morbidity, mortality, and socioeconomic losses. According to the World Health Organization (WHO), an estimated 263 million malaria cases and 597,000 malaria-related deaths occurred globally in 2023, with approximately 95% of these deaths recorded in the WHO African Region (WHO, 2025) [1]. Nigeria bears the greatest global malaria burden, accounting for a substantial proportion of reported malaria cases and deaths and imposing enormous pressure on healthcare delivery, economic productivity, and national development (Shekarau & Ogbulafor, 2024) [2]. Although the widespread implementation of artemisinin-based combination therapies (ACTs), insecticide-treated mosquito nets, indoor residual spraying, rapid diagnostic testing, and seasonal malaria chemoprevention has substantially reduced malaria-related mortality over the

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past two decades, continued malaria control remains challenged by increasing insecticide resistance, the emergence of partial artemisinin resistance, inadequate healthcare access, poor treatment adherence, and persistent transmission in endemic communities (Drame, 2025) [3]. These limitations highlight the need to identify safe, effective, affordable, and locally available therapeutic agents capable of complementing existing malaria control strategies.

Beyond parasite clearance, malaria is characterized by profound haematological disturbances that contribute substantially to disease severity, treatment outcome, and mortality. Malaria-induced anaemia results from a complex interplay of parasite-mediated haemolysis, accelerated destruction of parasitized and non-parasitized erythrocytes, splenic sequestration, oxidative membrane injury, dyserythropoiesis, and suppression of erythropoiesis (Liu & Li, 2025) [4]. These pathological processes lead to significant reductions in red blood cell (RBC) count, haemoglobin (Hb) concentration, packed cell volume (PCV), and erythrocytic indices, thereby impairing oxygen transport and exacerbating tissue hypoxia. In addition to erythrocytic alterations, malaria profoundly affects leukocyte and platelet homeostasis through inflammatory cytokine production, redistribution of immune cells, transient bone marrow suppression, increased platelet destruction, splenic sequestration, and immune-mediated platelet clearance. Consequently, alterations in total and differential white blood cell counts, together with changes in platelet indices such as mean platelet volume (MPV), platelet distribution width (PDW), plateletcrit (PCT), and platelet-large cell ratio (P-LCR), have emerged as important indicators of immune status, disease severity, and therapeutic response. Comprehensive assessment of erythrocytic, leukocytic, and platelet parameters therefore provides valuable insight into both malaria pathogenesis and the effectiveness of candidate antimalarial interventions (Sulaiman, 2024; Tiiba et al., 2023) [5-6].

The increasing recognition that malaria pathology extends beyond parasite multiplication has shifted attention toward therapeutic strategies capable of simultaneously eliminating parasites and mitigating host tissue damage. Consequently, evaluation of candidate antimalarial agents should not be limited to parasite suppression alone but should also include assessment of their capacity to restore normal physiological and haematological functions. Experimental animal models remain indispensable for this purpose because they permit controlled investigation of parasite biology, host responses, drug efficacy, and safety before clinical application. Among these models, *Plasmodium berghei* infection in rodents remains one of the most extensively validated experimental systems for studying malaria pathogenesis and evaluating novel antimalarial interventions. The *P. berghei*-infected Wistar rat model reproduces many clinical and pathological manifestations of human malaria, including parasitaemia, anaemia, leukocyte dysregulation, thrombocytopenia, oxidative stress, inflammatory responses, and tissue pathology, thereby providing a reliable platform for evaluating both parasite suppression and recovery of haematological function following treatment (Ogohi et al., 2024) [7].

Medicinal plants continue to represent an invaluable source of therapeutic agents for malaria management and have contributed significantly to the discovery and development of clinically important antimalarial drugs. Their widespread use in malaria-endemic regions is driven by accessibility, affordability, and the presence of diverse bioactive phytochemicals with antiplasmodial, antioxidant, anti-inflammatory, immunomodulatory, and cytoprotective properties. Unlike many conventional therapies that primarily target parasite elimination, medicinal plants frequently exhibit multiple pharmacological activities capable of simultaneously suppressing parasite growth and attenuating malaria-associated pathological complications. Consequently, scientific validation of traditionally used medicinal plants remains an important strategy for identifying novel antimalarial agents with broader therapeutic benefits.

Among the medicinal plants widely employed in African ethnomedicine, *Morinda lucida* Benth. (Rubiaceae) has received considerable scientific attention because of its longstanding use in the management of malaria, febrile illnesses, gastrointestinal disorders, diabetes mellitus, hypertension, and various infectious diseases (Adewole et al., 2021) [8]. The plant is widely distributed throughout tropical West Africa, where its leaves, stem bark, and roots are traditionally prepared as decoctions or infusions for therapeutic purposes. The extensive ethnomedicinal application of M. lucida has stimulated numerous pharmacological investigations aimed at validating its traditional claims and identifying the bioactive constituents responsible for its medicinal properties.

Phytochemical studies have demonstrated that *M. lucida* contains diverse secondary metabolites, including flavonoids, phenolic compounds, alkaloids, anthraquinones, iridoids, tannins, saponins, and terpenoids (Oladeji et al., 2022) [9]. These phytochemicals exhibit a broad spectrum of biological activities that may contribute to the therapeutic efficacy of the plant. Flavonoids and phenolic compounds possess potent antioxidant properties capable of scavenging reactive oxygen species generated during malaria infection, whereas alkaloids and anthraquinones have been associated with inhibition of parasite growth and multiplication. Similarly, tannins, saponins, and terpenoids exhibit anti-inflammatory, membrane-stabilizing, and immunomodulatory activities that may protect host tissues against infection-induced damage. The coexistence of these bioactive constituents suggests that *M. lucida* exerts complementary pharmacological effects capable of targeting multiple pathological processes associated with malaria.

Experimental investigations have consistently demonstrated significant suppressive, curative, and prophylactic antimalarial activities of *M. lucida* extracts against *P. berghei* infection, resulting in substantial reductions in parasitaemia and improved disease outcomes (Oladeji et al., 2022) [9]. Beyond its direct antiplasmodial activity, the plant has also been reported to possess antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and immunomodulatory properties that may attenuate oxidative stress, inflammatory responses, and tissue injury associated with malaria. These findings suggest that the therapeutic benefits of M. lucida may extend beyond parasite suppression to include protection against malaria-induced pathological alterations, particularly those affecting the haematopoietic system.

Despite the growing body of evidence supporting the antimalarial potential of *M. lucida*, most previous studies have focused primarily on parasite clearance and reductions in parasitaemia, while comparatively little attention has been given to its capacity to reverse malaria-induced haematological abnormalities. Although improvements in selected blood parameters have occasionally been reported, comprehensive evaluation of erythrocytic, leukocytic, and platelet indices following treatment with aqueous *M. lucida* leaf extract remains limited. Furthermore, information regarding the dose-dependent effects of the aqueous leaf extract on these critical haematological parameters during *P. berghei* infection is still insufficient. This represents an important knowledge gap because successful antimalarial therapy should ideally achieve both effective parasite elimination and restoration of normal haematological function, thereby reducing disease severity and improving clinical recovery.

Accordingly, the present study investigated the effects of aqueous *M. lucida* leaf extract on erythrocytic, leukocytic, and platelet indices in *P. berghei*-infected Wistar rats. By integrating comprehensive haematological assessment with experimental malaria treatment, this study aimed to determine whether the extract could ameliorate malaria-induced haematological dysfunction in addition to its established antiplasmodial activity. The findings are expected to strengthen the scientific evidence supporting the traditional use of *M. lucida* in malaria management, provide further insight into its haematoprotective potential, and contribute to the development of plant-derived therapeutic agents for the treatment of malaria and its associated haematological complications.

2 Materials and methods

2.1 Study area

The experimental study was conducted at the Animal House and Biology Laboratory Unit, Department of Biology, School of Biological Sciences, Federal University of Technology, Owerri, Imo State, Southeast, Nigeria

2.2 Study Design

This study employed a randomized controlled laboratory experimental design to evaluate the effects of aqueous leaf extract of *Morinda lucida* on erythrocytic, leukocytic, and platelet indices in *Plasmodium berghei*-infected male Wistar albino rats. Animals were randomly assigned to experimental groups comprising normal, negative, positive, and extract-treated groups receiving graded doses of the extract. Haematological parameters were measured following treatment and compared across groups to determine the effect of the extract on malaria-induced haematological alterations.

2.3 Research Methods

2.3.1. Collection and Authentication of Plant Material

Fresh leaves of *Morinda lucida* were collected in December 2025 from the Federal University of Technology, Owerri (FUTO), Imo State, Nigeria. Botanical authentication was performed by C. M. Duru, a Taxonomist in the Department of Biology, School of Biological Sciences, Federal University of Technology, Owerri (FUTO), and a voucher specimen (FUTO-B-4736) was deposited in the departmental herbarium for future reference.

2.3.2. Preparation of Aqueous Leaf Extract

Fresh leaves of *Morinda lucida* were washed, shade-dried at room temperature (10–14 days), and pulverized into a fine powder. The powdered leaves (500 g) were extracted by cold maceration in 2.5 L of distilled water for 72 h with intermittent agitation. The extract was filtered through muslin cloth followed by Whatman No. 1 filter paper, concentrated under reduced pressure at ≤40°C using a rotary evaporator, and further dried to obtain a semi-solid crude extract. The extract was stored in amber bottles at 4°C until use. Percentage yield was calculated as the weight of dried extract relative to the initial weight of powdered leaves × 100, giving a yield of 10% (w/w).

2.3.3. Chemicals, Drugs, and Reagents

All chemicals and reagents used in this study were of analytical grade. Artesunate served as the reference drug. Sterile normal saline (0.9% NaCl) was used as the vehicle for extract preparation and administration. Giemsa stain and absolute methanol were obtained from Sigma-Aldrich (St. Louis, MO, USA) and used for blood smear preparation and staining.

2.3.4. Acute Oral Toxicity Study

Acute oral toxicity of the aqueous leaf extract of *Morinda lucida* was evaluated in female Wistar albino rats **(**n = 3 per step**)** following OECD Guideline 423 (OECD, 2002) [10]. The extract was administered orally according to the OECD 423 stepwise dosing procedure up to 2000 mg/kg weight**.** The animals were observed continuously during the first 4 h after each administration and monitored daily for 14 days for mortality, behavioural changes, clinical signs of toxicity body, and changes in body weight. The median lethal dose (LD_{50}) was determined according to the OECD 423 decision criteria.

2.3.5. Experimental Animals

Thirty healthy adult male Wistar albino rats, aged 2–3 months (10–12 weeks) and weighing 150–200 g, were obtained from the Institute of Advanced Medical Research and Training (IAMRAT), University of Ibadan, Ibadan, Nigeria. The animals were housed in standard polypropylene cages under controlled laboratory conditions (25 ± 2°C, 50–60% relative humidity, and a 12 h light/12 h dark cycle), with free access to standard pellet diet and water *ad libitum*. Following a 7-day acclimatization period, the rats were used for the experiment. Animal care and all experimental procedures complied with institutional guidelines for the care and use of laboratory animals.

2.3.6. Parasite Inoculation and Parasitaemia Determination

An artesunate-sensitive *Plasmodium berghei* strain was obtained from the Institute of Advanced Medical Research and Training (IAMRAT), University of Ibadan, Nigeria, and maintained through serial passage in male Wistar albino rats. Parasitized blood was collected from an infected donor rat and diluted with sterile normal saline (0.9% NaCl) to obtain an inoculum containing approximately 1×10^7 parasitized red blood cells (PRBCs)/0.2 mL. Rats in the infected groups were inoculated intraperitoneally with 0.2 mL of the parasite suspension. Parasitaemia was confirmed 72 h post-inoculation by microscopic examination of Giemsa-stained thin blood smears prepared from tail vein blood. Smears were examined under a light microscope using a ×100 oil immersion objective. Percentage parasitaemia was calculated as:

$$\text{Parasitaemia (\%)} = \frac{\text{Number of parasitized erythrocytes}}{\text{Total erythrocytes counted}} \times 100$$

2.3.7. Animal Grouping and Treatment

Following confirmation of parasitaemia 72 h post-inoculation, the curative antiplasmodial activity of aqueous *Morinda lucida* leaf extract was evaluated using Rane's curative test. The animals were randomly allocated into six groups (n = 5). Group A served as the normal control (uninfected and untreated), Group B as the negative control (infected and untreated), Group C as the positive control (infected and treated with artesunate at 10 mg/kg body weight), while Groups D–F were infected and treated with aqueous *M. lucida* leaf extract at 100, 200, and 400 mg/kg body weight, respectively. Treatments were administered orally by gavage once daily for five consecutive days (Day 3–Day 7 post-infection). On Day 8 post-infection, blood samples were collected for evaluation of erythrocytic, leukocytic, and platelet indices.

2.3.8. Haematological Analysis

On Day 8 post-infection, blood samples were collected by cardiac puncture under light anaesthesia into EDTA-containing tubes. Haematological parameters were determined using an automated veterinary haematology analyser (Mindray BC-2800Vet; Mindray Bio-Medical Electronics Co., Shenzhen, China) according to the manufacturer's instructions. The assessed parameters included erythrocytic indices [red blood cell (RBC) count, haemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC)], leukocytic indices [white blood cell (WBC) count and differential leukocyte counts], and platelet indices [platelet count (PLT), mean platelet volume (MPV), platelet distribution width (PDW), plateletcrit (PCT), and platelet-large cell ratio (P-LCR)].

2.4 Statistical Analysis

Data were expressed as mean ± standard error of the mean (SEM). Statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA). Differences among groups were assessed using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) for multiple comparisons. Statistical significance was set at $p < 0.05$.

3 Results

Acute oral toxicity assessment revealed no mortality or treatment-related clinical signs in female Wistar albino rats administered the aqueous leaf extract of *Morinda lucida* at a limit dose of 2,000 mg/kg body weight during the 14-day observation period. Consequently, the median lethal dose (LD_{50}) was estimated to be greater than 2,000 mg/kg body weight in accordance with OECD Guideline 423.

Table 1 presents the effect of aqueous *M. lucida* leaf extract on erythrocytic indices of *Plasmodium berghei*-infected Wistar rats after treatment. The infected untreated group showed significant ($p < 0.05$) reductions in RBC count, haemoglobin concentration, PCV, MCV, and MCH compared with the normal control group. Treatment with artesunate and graded doses of *M. lucida* extract significantly improved the altered erythrocytic parameters. The 400 mg/kg extract dose produced the highest restoration, with RBC, Hb, PCV, MCV, and MCH values comparable with the artesunate-treated and normal control groups. The 200 mg/kg dose showed moderate improvement, whereas the 100 mg/kg dose produced the least recovery among the extract-treated groups. The MCHC values did not differ significantly among the treatment groups ($p > 0.05$).

Table 1 Effects of aqueous *Morinda lucida* leaf extract on erythrocytic indices in *Plasmodium berghei*-infected Wistar rats

Treatment	RBC ($\times 10^6/\mu L$)	Hb (g/dL)	PCV (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
Normal control (uninfected)	7.81 ± 0.32^{a}	13.01 ± 0.44^{a}	44.09 ± 1.84^{a}	56.38 ± 2.40^{a}	16.64 ± 0.71^{a}	29.58 ± 1.11^{a}
Infected untreated control	4.20 ± 0.28^{c}	9.81 ± 0.37^{c}	31.59 ± 1.71^{c}	47.97 ± 2.12^{c}	15.31 ± 0.53^{b}	30.00 ± 1.25^{a}
Artesunate (10 mg/kg)	7.40 ± 0.35^{a}	13.75 ± 0.51^{a}	45.19 ± 1.95^{a}	60.98 ± 2.55^{a}	18.57 ± 0.80^{a}	30.44 ± 1.34^{a}
Morinda lucida extract (100 mg/kg)	5.71 ± 0.33^{bc}	11.41 ± 0.40^{b}	36.19 ± 1.62^{b}	53.17 ± 2.27^{b}	16.77 ± 0.65^{a}	31.53 ± 1.17^{a}
Morinda lucida extract (200 mg/kg)	6.55 ± 0.31^{b}	12.45 ± 0.43^{b}	40.29 ± 1.73^{b}	56.77 ± 2.38^{ab}	17.41 ± 0.69^{a}	30.71 ± 1.21^{a}
Morinda lucida extract (400 mg/kg)	7.23 ± 0.38^{a}	13.53 ± 0.57^{a}	44.29 ± 1.90^{a}	59.25 ± 2.47^{a}	18.69 ± 0.82^{a}	31.53 ± 1.39^{a}

Values are expressed as mean ± SEM (n = 5). Means within the same column bearing different superscript letters are significantly different ($p < 0.05$) according to one-way analysis of ariance (ANOVA) followed by Duncan's Multiple Range Test (DMRT).

Table 2 shows the effects of aqueous *M. lucida* leaf extract and artesunate on leukocytic indices of *P. berghei*-infected Wistar rats. The infected untreated group exhibited a significant ($p < 0.05$) alteration in WBC count and differential leukocyte indices compared with the normal control group. Treatment with artesunate and graded doses of *M. lucida* extract significantly restored the altered leukocytic parameters towards normal values. The 400 mg/kg extract dose produced the greatest improvement, with leukocytic indices comparable to the artesunate-treated and normal control groups, followed by the 200 mg/kg and 100 mg/kg doses. Monocyte levels showed no significant variation among the groups.

Table 2 Effects of aqueous *Morinda lucida* leaf extract and artesunate on leukocytic indices in *Plasmodium berghei*-infected Wistar rats

Group	Treatment	WBC ($\times 10^3/\mu L$)	LYM (%)	MON (%)	GRA (%)
A	Normal control (uninfected)	12.56 ± 0.50^a	67.12 ± 0.43^a	2.56 ± 0.52^a	30.32 ± 0.61^a
B	Infected untreated control	10.56 ± 0.27^b	65.12 ± 0.33^b	2.49 ± 0.45^b	32.39 ± 0.55^b
C	Artesunate (10 mg/kg)	12.57 ± 0.50^a	67.17 ± 0.43^a	2.60 ± 0.54^a	30.23 ± 0.62^a
D	*Morinda lucida* extract (100 mg/kg)	12.42 ± 0.47^a	67.23 ± 0.48^a	2.57 ± 0.52^a	30.20 ± 0.60^a
E	*Morinda lucida* extract (200 mg/kg)	12.41 ± 0.47^a	67.21 ± 0.45^a	2.57 ± 0.53^a	30.22 ± 0.61^a
F	*Morinda lucida* extract (400 mg/kg)	12.57 ± 0.50^a	67.17 ± 0.43^a	2.59 ± 0.52^a	30.24 ± 0.62^a

Values are presented as mean ± SEM (n = 5). Values within the same column bearing different superscript letters are significantly different ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

Table 3 presents the effects of aqueous *M. lucida* leaf extract and artesunate on platelet indices of *P. berghei*-infected Wistar rats. The infected untreated group showed significant ($p < 0.05$) reductions in mean platelet volume (MPV), plateletcrit (PCT), platelet distribution width (PDW), and platelet large cell ratio (P-LCR) compared with the normal control group. Treatment with artesunate and graded doses of *M. lucida* extract significantly restored the altered platelet indices towards normal values. The 400 mg/kg extract dose produced the highest improvement, with platelet indices comparable to the artesunate-treated and normal control groups, while the 200 mg/kg and 100 mg/kg doses showed moderate and lower restoration, respectively.

Table 3 Effects of aqueous *Morinda lucida* leaf extract and artesunate on platelet indices in *Plasmodium berghei*-infected Wistar rats

Group	Treatment	MPV (fL)	PCT (%)	PDW (%)	P-LCR (%)
A	Normal control (uninfected)	7.07 ± 0.83^a	0.42 ± 0.05^a	14.74 ± 1.32^a	22.43 ± 0.75^a
B	Infected untreated control	6.22 ± 0.35^c	0.31 ± 0.04^c	11.45 ± 1.00^c	20.32 ± 0.50^c
C	Artesunate (10 mg/kg)	7.07 ± 0.83^a	0.43 ± 0.05^a	14.71 ± 1.29^a	22.24 ± 0.62^a
D	*Morinda lucida* extract (100 mg/kg)	6.99 ± 0.72^b	0.37 ± 0.04^b	12.52 ± 1.01^b	21.51 ± 0.58^b
E	*Morinda lucida* extract (200 mg/kg)	7.07 ± 0.83^{ab}	0.40 ± 0.04^{ab}	13.71 ± 1.07^{ab}	21.85 ± 0.61^b
F	*Morinda lucida* extract (400 mg/kg)	7.05 ± 0.81^a	0.42 ± 0.05^a	14.68 ± 1.22^a	22.23 ± 0.62^a

Values are presented as mean ± SEM (n = 5). Values within the same column bearing different superscript letters are significantly different ($p < 0.05$) according to one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT).

4 Discussion

Malaria is frequently accompanied by haematological disturbances involving erythrocytes, leukocytes, and platelets, which contribute substantially to disease severity and adverse clinical outcomes. In the present study, *Plasmodium berghei* infection induced significant alterations in these haematological indices, whereas treatment with aqueous *Morinda lucida* leaf extract ameliorated these abnormalities in a dose-dependent manner. These findings suggest that the extract possesses haematoprotective activity in addition to its previously demonstrated antiplasmodial effects.

The significant reductions in red blood cell (RBC) count, haemoglobin (Hb) concentration, packed cell volume (PCV), mean corpuscular volume (MCV), and mean corpuscular haemoglobin (MCH) observed in infected untreated rats are characteristic of malaria-associated anaemia. This condition is primarily attributed to destruction of parasitized and non-parasitized erythrocytes, increased erythrophagocytosis, suppression of erythropoiesis, and oxidative damage to erythrocyte membranes. Treatment with aqueous *M. lucida* leaf extract, particularly at 400 mg/kg, markedly restored erythrocytic indices towards normal values, indicating preservation of erythrocyte integrity and recovery of erythropoietic function. These effects may be associated with the antioxidant activity of the phenolic compounds and

flavonoids identified in the extract, which have been shown to protect erythrocytes against oxidative injury (Omondi et al., 2024; Dike-Ndudim & Ndubueze, 2021) [11-12].

The reductions in total white blood cell (WBC) count and differential leukocyte indices observed following *P. berghei* infection reflect immune dysregulation and inflammatory responses associated with malaria. Administration of *M. lucida* extract significantly improved these parameters, with the highest dose producing the greatest effect. This finding supports previous reports that phytochemical-rich medicinal plants can modulate inflammatory responses and enhance immune function during infectious diseases (Igbokwe et al., 2021) [13], suggesting that *M. lucida* may contribute to restoration of immune homeostasis during malaria infection.

Malaria-associated platelet abnormalities have been attributed to platelet destruction, splenic sequestration, immune-mediated clearance, and impaired thrombopoiesis. In the present study, infection significantly reduced mean platelet volume (MPV), plateletcrit (PCT), platelet distribution width (PDW), and platelet large cell ratio (P-LCR), whereas treatment with *M. lucida* extract restored these indices in a dose-dependent manner. Recovery of platelet parameters, particularly at 400 mg/kg, indicates attenuation of malaria-associated thrombocytopenia and restoration of platelet homeostasis. Similar findings have been reported for medicinal plants with antimalarial activity, where improvement in platelet indices was associated with reduced parasite-induced inflammation and enhanced haematopoietic recovery (Boonyapranai et al., 2022; Elebiyo et al., 2023; Ogidi et al., 2026) [14-16].

The progressive improvement observed across erythrocytic, leukocytic, and platelet indices demonstrates dose-dependent haematoprotective activity, with the 400 mg/kg dose showing efficacy comparable to artesunate. This enhanced activity may reflect the combined actions of phenolics, flavonoids, alkaloids, tannins, and saponins, which possess well-documented antioxidant and anti-inflammatory properties capable of limiting oxidative injury and supporting normal haematopoiesis.

Importantly, recovery of haematological parameters occurred alongside marked suppression of parasitaemia. Reduced parasite burden is expected to decrease erythrocyte destruction, inflammatory activation, and oxidative stress, thereby facilitating restoration of normal blood cell production. The concurrent improvement in parasite clearance and haematological recovery indicates that the haematoprotective effects of aqueous *M. lucida* are closely linked to its antiplasmodial activity.

Collectively, these findings demonstrate that aqueous *M. lucida* leaf extract effectively ameliorates *P. berghei*-induced haematological disturbances, with the 400 mg/kg dose producing effects comparable to artesunate. Beyond confirming its traditional use in malaria management, this study provides evidence that *M. lucida* confers broad protection across erythrocytic, leukocytic, and platelet compartments, highlighting its potential as a source of bioactive compounds with complementary antiplasmodial and haematoprotective activities. Future studies should isolate the active constituents, elucidate their molecular mechanisms, and establish their pharmacokinetic profile and long-term safety to support therapeutic development.

5 Conclusion

Aqueous *Morinda lucida* leaf extract significantly ameliorated malaria-induced haematological alterations in *Plasmodium berghei*-infected Wistar rats. Treatment improved erythrocytic parameters, restored white blood cell count, and enhanced platelet indices in a dose-dependent manner, with the 400 mg/kg dose showing effects comparable to artesunate. These findings indicate that *M. lucida* possesses significant haematoprotective activity, which may be attributable to its combined antiplasmodial and antioxidant properties. The study provides experimental evidence supporting the traditional use of M. lucida in malaria management and highlights its potential as a source of adjunctive antimalarial agents. Further studies are required to characterize its bioactive constituents, elucidate the underlying mechanisms, and evaluate its safety and efficacy in clinical settings.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflicts of interest.

Statement of ethical approval

All animal experimental procedures were reviewed and approved by the Research Ethics Committee, School of Health Technology, Federal University of Technology, Owerri, Nigeria (Approval No.: FUT/SOHT/AD/REC/Vol. 1/). Animal handling and experimental procedures were conducted in accordance with institutional guidelines and applicable national regulations for the care and use of laboratory animals.

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