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Phytochemical Screening and Therapeutic Effect of *Solanum torvum* Root Extract on Some Clinical Signs of Malaria Induced in Wistar Rats

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Abstract

Background and Objectives: Malaria is very often characterized by fever, pain, and anemia. Its treatment in modern medicine always includes a medication for each symptom, which can sometimes be difficult for patients to take. The aim of this work is to assess the therapeutic potential of *Solanum torvum* roots aqueous extract for a single treatment of all three malarial symptoms in animal model. **Methods:** After inducing all the three malarial manifestations in healthy rats, they were treated with doses of *S. torvum* root extract in comparison to reference molecules for each symptom. The extract's therapeutic efficacy was indicated by hematological parameters to diagnose anemia, while temperature and number of writhings were used to indicate fever and pain, respectively. **Results:** The induction of symptoms was characterized by significant increase ($p < 0.05$) in number of white blood cells, rising from (7.25 ± 0.05) to (10.62 ± 0.03) $\times 10^6/mm^3$, and significant decrease ($p < 0.001$) for other hematological markers. Moreover, the pain induced in animals resulted in significant increase ($p < 0.05$) in writhing from 56 ± 2.35 to 108 ± 1.25 and an elevation of the rectal temperature from $35^\circ C \pm 0.02^\circ C$ to $39.45^\circ C \pm 0.09^\circ C$ for fever. Like reference molecules at dose of 10 mg/kg bw, therapeutic effect of extract was pronounced at 500 mg/kg bw, which normalized all indicators in comparison to control group. **Conclusion:** The therapeutic efficacy thus observed supports the use of *Solanum torvum* in the treatment of malaria symptoms and allows for the development of an effective single treatment for

these symptoms.

Keywords

Solanum torvum, Aqueous Extract, Treatment, Clinical Signs, Malaria

1. Introduction

Medicinal plants, due to their multiple pharmacological properties, are capable of preventing, alleviating, or curing numerous diseases [1]. These practices are situated within a specific sociocultural context, where the acquisition of knowledge, skills, and practices is passed down through generations over centuries. Even today, studies are being conducted [2] [3] to document the use of medicinal plants in the treatment of malaria. Among them, *Solanum torvum* is included [4]. The use of plants for therapeutic purposes is currently experiencing renewed interest on a global scale. In fact, 80% of the world's population, especially those in developing countries, use them to treat a number of pathologies [5], including malaria. Malaria is a parasitic disease caused by *Plasmodium falciparum*, a parasite that infects liver cells. Its symptoms include anemia, asthenia, fever, and chills [6] related to the massive lysis of red blood cells.

Plasmodium affects the global population at a prevalence rate of 263 million infected individuals and 597,000 annual deaths, according to [7]. Its prevalence remains very high on the African continent, with 94% of cases (or 246 million people) and 95% of deaths (corresponding to 569,000 deaths), of which 76% concern children under five years old [7].

In Côte d'Ivoire, the disease manifests in an endemic-epidemic mode, and its incidence is significantly influenced by the ecology of the vector. In 2022, the country reported 3.0% of malaria cases and deaths worldwide, 6% of cases and 1.8% of deaths in West Africa [8]. The Ministry of Health of Côte d'Ivoire assessed the hospital prevalence of the disease at 33% in 2023, based on the number of daily medical consultations. These data, which only concern reported cases, remain concerning.

In this context, the health authorities have implemented a set of strategies, among which we can mention the therapeutic combination of antimalarial, the distribution of impregnated mosquito nets, and the intermittent preventive treatment of pregnant women. These measures aim to improve the care of the populations. However, in the context of unfavorable socioeconomic conditions and the emergence of drug-resistant parasitic strains [9], there is an observed increase in malaria within families. Indeed, even a moderate deficit in access to treatment leads to a considerable number of deaths. Thus, a 10% disruption in access to antimalarials could lead to 19,000 additional cases in the affected region [7]. Therefore, in developing countries such as Côte d'Ivoire, malaria remains a real public health problem.

Thus, in order to address their health problem, the populations resort the use

of antimalarial medicinal plants. Such therapy requires scientific validation for the development of new drugs with high antiparasitic potential, able to treat all symptoms of malaria. Furthermore, the World Health Organization (WHO) has set a goal to reduce the prevalence of malaria and the mortality rate associated with this disease by 90% globally by 2030. The main objective of this study was to evaluate the curative effect of *Solanum torvum* roots aqueous extract on three symptoms associated with malaria in animal model.

2. Materials and Methods

2.1. Material

2.1.1. Plant Material

The plant material consists of *Solanum torvum* roots. These specimens were collected in their natural habitat in Bouaké, a city located approximately 347 kilometers north of Abidjan. The identification of the plant was carried out by the National Center for Floristics (CNF) of the Félix Houphouët-Boigny University. This identification was carried out by comparing it with the herbarium of *S. torvum* archived under the number CNF 8377.

2.1.2. Animal Material

In this study, white albino rats of the species *Rattus norvegicus*, belonging to the subfamily Muridae and more specifically to the Wistar strain, were used as experimental subjects. The average age of the subjects was 12 weeks, with an average weight of 225 ± 25 g. The animals were fed pellets (IVOGRAIN®) and had free access to water. Their acclimatization took place in a controlled environment, namely a laboratory, where the temperature was maintained at 22˚C and a 12-hour light cycle was established.

2.2. Methods

2.2.1. Preparation of the Aqueous Extract from the Roots of *Solanum torvum*

The roots of *Solanum torvum* were washed, cut into small pieces, and dried in the shade at room temperature for two weeks. The powder obtained by grinding this dry material was used for the preparation of the aqueous extract according to the method of [10]. Thus, 100 g of the powder were homogenized in one liter (1 L) of distilled water using a Blender-type mixer. This operation was repeated three times. The obtained homogenates were successively filtered, twice through hydrophilic cotton and once through Whatman 3 mm filter paper. The filtrates were dried in an oven at 50˚C for five days. The brown-colored evaporate obtained constituted the extract of *Solanum torvum* roots coded EX used for experimentation.

2.2.2. Phytochemical Screening

Qualitative phytochemical analysis is based on the one hand on the formation of insoluble complexes using precipitation reactions and on the other hand on the formation of colored complexes using staining reactions [11].

1) Test for polyphenols

The polyphenols in the extract were detected by the ferric chloride ($FeCl_3$) reaction. Indeed, 2% ferric chloride oxidizes in the presence of polyphenols and gives a blue-black coloration. For this test, 2 mL of the EX extract were taken in a test tube, and then a drop of alcoholic solution was added. The tube was homogenized and observed for the appearance of a blue-black or green coloration.

2) Test for flavonoids

Flavonoids were detected using the cyanohydrin reaction. In the presence of flavonoids, cyanidin changes from a red color to a pink-orange color. Thus, 2 mL of the EX extract were evaporated on a sand bath, and the residue was dissolved in 5 mL of hydrochloric acid diluted twice. To this solution, 3 magnesium chips were added, followed by three drops of isoamyl alcohol. The tube was observed for the release of heat and the appearance of a rose orange color.

3) Test for tannins

Catechin tannins were detected from the intense black in the presence of the Stiasny reagent. In this method, the tannins are characterized by a blue coloration. To do this, five (5) mL of the extract were evaporated in the oven. The obtained residue was dissolved in 15 mL of the Stiasny reagent. The mixture was maintained in a water bath at 80˚C for 30 minutes and the tube was observed for the appearance of a blue color.

4) Test for alkaloids

The alkaloids were characterized using Buchard's reagent (iodo-iodide reagent) and Dragendoff's reagent (potassium iodo-bismuthate reagent). Indeed, in the presence of alkaloids, Buchard and Dragendoff reagents produce a reddish-brown precipitate. For this test, 6 mL of the extract were evaporated to dryness. The residue was dissolved in 6 mL of alcohol at 60˚C, and 2 drops of Dragendorff's reagent were added to the alcoholic solution. The tubes are observed for the presence of a precipitate or an orange coloration.

2.2.3. Iron Dosage

Iron content of the extract was determined according [12]. To do this, 1 g of powdered *Solanum torvum* roots was taken in a crucible and then calcined in a muffle furnace for two hours. The obtained ash was dissolved in a test tube containing 4 mL of concentrated nitric acid, then the solution was homogenized for 1 minute. The homogenate was evaporated to dryness on a hot plate at 100˚C, then the evaporate was calcined at 550˚C in a muffle furnace for 1 hour. After cooling in a desiccator, the ash from the evaporate was taken up in 10 mL of hydrochloric acid, then filtered into a standard 50 mL dilution tube. The filtrate was homogenized for 2 minutes, then the homogenate was preserved for iron dosage. A calibration curve was established using a range of concentrations from 0 to 20 µg/mL, obtained from a stock solution of iron concentrated at 100 µg/mL. The reading of the samples was done using a Flame Atomic Absorption Spectrophotometer (AAS) (Pekin Elmer AAnalyst 400) at 248 nm, and the iron content was calculated using the expression below and then expressed in mg/100

g of extract:

$$\text{Iron content}\left(\text{mg}/100\ g\ \text{extract}\right)=\frac{C\times 50\times 100}{PE\times 1000}$$

C: concentration of the element to be measured in mg/l read at the AAS.

PE: Test run in g.

2.2.4. Induction Protocol and Treatment of Signs Associated with Malaria

1) Induction of malaria clinical signs in rats

In this study, three symptoms associated with malaria, namely anemia, pain, and fever, were induced in 25 healthy rats. Their temperature and contortion were recorded, and then the blood levels of anemia markers such as hemoglobin (Hb), red blood cells (RBC), and hematocrit (Hct) were measured. Subsequently, the 25 rats were divided into two distinct groups: a control group of five untreated sick individuals and a test group of 20 specimens.

Anemia was induced in the animals according to the method of [13], which involves administering 1 mL of phenylhydrazine (20 mg/kg) by gavage for 7 consecutive days to the test group, while the control group received only distilled water. At the end of this period, analgesia was induced in the anemic rodents by intraperitoneal injection of 1 mL of a 1% acetic acid solution [14].

To cause hyperthermia, the ill animals were starved for a whole day [15]. The rats were given a single subcutaneous injection of 1 mL of a 20% brewer's yeast (*Saccharomyces cerevisiae*) slurry as part of the experiment. Eighteen hours after induction, the temperature and the number of writhes were recorded.

2) Treatment of animals

The selected anemic animals were divided into 5 groups of 5 rats each. This number of rats is sufficient to observe significant pharmacological effects of the substances, takes into account ethical considerations and allow difference between the mean of two groups. The treatment lasted 7 days for all the animals. Lot 1 (healthy control) and 2 (sick no treated) receive no treatment, lot 3 (EX100) receives the extract at a dose of 100 mg/Kg.BW, lot 4 (EX500) receives the extract at a dose of 500 mg/Kg.BW, and lot 5 (FTP 10) receives the references molecules at a dose of 10 mg/Kg.bw (Folifer for anemia, Tramadol for pain, and Paracetamol for fever). At the end of the treatment, the animals' blood was collected for the determination of hematological parameters including red blood cell (RBC) count, hemoglobin (Hb) and hematocrit (HCT). Rectal temperatures are taken every hour for 4 hours after administration of the test substances, using an accurate electronic thermometer. Reference molecules dose is slightly lower than those found by the conversion equations proposed by [16] and adjusted according to the Institutional Animal Care & Use Committee's guidelines [17].

2.3. Statistical Analysis

The statistical analysis and graphs were performed using GraphPad Prism version 8.0 software. The values expressed are the means of at least three experi-

ments accompanied by the standard error of the mean (Mean ± SEM). The one-way analysis of variance (ANOVA) followed by Dunnett's non-parametric multiple comparisons test was used for comparing the means with a significance level of 5%.

3. Results

3.1. Phytochemical Screening

The results of the qualitative characterization of the secondary metabolites of the extract are recorded in Table 1. According to the data in this table, the observation of the tubes for polyphenols shows the appearance of a blue-black coloration, indicating a high polyphenol content in the extract. Also, the extract is very rich in flavonoids, identified in the tubes by a release of heat followed by the appearance of an intense pink-orange coloration. Regarding the tannins, the presence of a faint blue coloration indicates a medium content of the extract. Furthermore, the extract shows a high alkaloid content, indicated by the presence of a very dark brown-reddish coloration.

Moreover, the iron assay showed that the extract has an iron content of 44.07 mg/100g of extract.

3.2. Induction of Malaria Manifestations in Rats

Table 2 shows the variation of symptomatic markers of malaria between the control group and the test group. Indeed, the serum values of white blood cells

Table 1. The results of phytochemical screening of *Solanum torvum* root aqueous extract.

Metabolites	Observations	Content
Polyphenol	Bluish-black coloration darker in the tube	+++
Flavonoids	Heat release and appearance of intense orange-pink	+++
Tannins	Average presence of blue coloration in the tube	++
Alkaloids	Presence of a precipitate or an orange coloration	++

+: presence; +++: High content; ++: Average content.

Table 2. Variation of markers of anemia, pain, and pyrexia in sick rats.

	Evaluated markers					
	RBC (10^6/mm^3)	WBC (10^6/mm^3)	Hb (g/dl)	HCT (%)	Number of contortions	Temperature (˚C)
Control Lot	7.25 ± 0.05	9.05 ± 0.26	15.12 ± 0.03	39;25 ± 0.06	56 ± 2.35	35.98 ± 0.02
Test Lot	10.62 ± 0.03*	5.27 ± 0.03***	8.53 ± 0.2***	22.09 ± 0.55***	108 ± 1.25***	39.45 ± 0.09*
Percentage of variation (%)	46.48	41.17	43.58	43.71	92.85	12.27

Value = Mean ± SEM ($n \geq 5$); With asterisk (* or ***) in the column indicates a significant difference compared to the control batch value respectively with $p < 0.05$ and $p < 0.001$. RBC: Red Blood Cells; WBC: White blood cells; Hb: Hemoglobin; HCT: Hematocrit.

(WBC), red blood cells (RBC), hemoglobin (Hb), hematocrit (HCT), the number of writhings, and the rectal temperature in healthy control rats are respectively (7.25 ± 0.05) × 10^6/mm^3; (9.05 ± 0.26) × 10^6/mm^3; 15.12 ± 0.03 g/dl; 39.25% ± 0.06%; 56 ± 0.02 writhings; and 35.98˚C ± 0.02˚C.

Once anemia is established, a significant variation in the evaluated hematological markers is observed in the animals. Thus, a significant increase in the number of WBCs was observed in the study subjects, rising from (7.25 ± 0.05) to (10.62 ± 0.03) × 10^6/mm^3, which corresponds to a relative increase of 46.48%. In contrast, anemia, unlike white blood cells, induces a significant reduction ($p < 0.001$) in other hematological markers. Thus, a decrease in hemoglobin, hematocrit, and red blood cell count was observed. Indeed, the initial values, respectively 15.12 ± 0.05 g/dl, 39.25 ± 0.06, and 49.25% ± 0.06%, respectively decreased to 8.53 ± 0.2 g/dl, 22.09% ± 0.55%, and 43.71% ± 0.1%. These results suggest a significant decrease in hemoglobin and hematocrit, with respective variations of 41.76% ± 0.5% and 43.71% ± 0.1%.

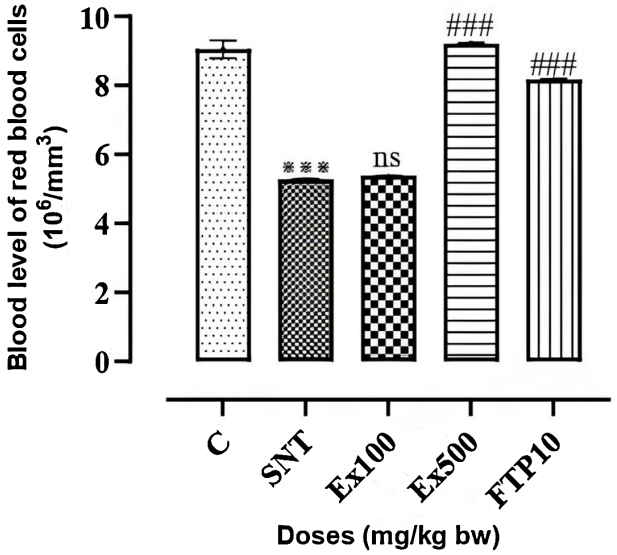
Moreover, the pain induced in the animals leads to a significant increase ($p < 0.05$) in writhing, from 56 ± 2.35 to 108 ± 1.25, which is an increase of 92.85%. As for the fever, it was characterized by an increase in rectal temperature from 35 ± 0.02 to 39.45 ± 0.09˚C, which is an increase of 12.27%.

3.3. Therapeutic Effects of *Solanum torvum* Roots Aqueous Extract on Sick Animals

The effect of the extract on the symptoms of malaria is represented by **Figures 1-6**. According to these results, the extract at a dose of 100 mg/kg pc leads to a modest non-significant increase ($p > 0.05$) in red blood cells from 5.27 ± 0.03 to 5.38 ± 0.01.106/mm^3 (**Figure 1**); hemoglobin from 8.53 ± 0.2 to 8.67 ± 0.01 g/dl (**Figure 2**); hematocrits from 22.09% ± 0.55% to 22.35% ± 0.37% (**Figure 3**) compared to the untreated sick batch, with respective percentage increases of 2.08%; 1.64%; 1.17%; 2.89%.

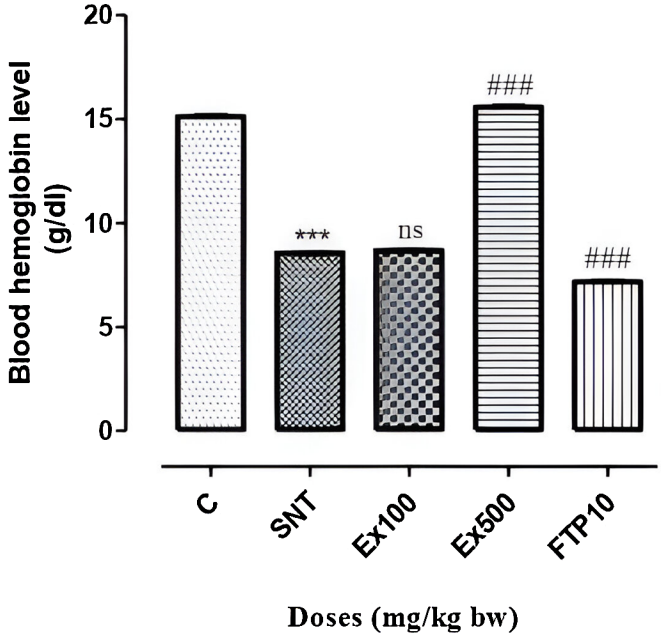
The same applies to white blood cells (**Figure 4**), contortions (**Figure 5**), and temperature (**Figure 6**), changing respectively from (10.62 ± 0.56) to (10.15 ± 0.02) × 10^6/mm^3, from 108 ± 1.55 to 100 ± 0.06, and from 39.45 ± 0.09 to 38 ± 0 when to compared to the untreated sick batch.

However, compared to the healthy control group, a significant variation ($p < 0.05$) of the different markers is observed at this same dose. Indeed, this dose causes a significant decrease in the number of white blood cells from 9.05 ± 0.26 (control value) to 5.38 ± 0.01 (value at 100 mg/kg pc), hemoglobin from 15.12 ± 0.03 (control value) to 8.67 ± 0.01 (value at 100 mg/kg pc), and hematocrit from 39.25 ± 0.65 (control value) to 22.35 ± 0.37 (value at 100 mg/kg pc), as well as a significant increase in the number of white blood cells from 7.25 ± 0.03 (control value) to 10.15 ± 0.01 (value at 100 mg/kg pc), contortions from 56 ± 2.25 (control value) to 100 ± 0.65 (value at 100 mg/kg pc), and temperature from 35 ± 1.25 (control value) to 38 ± 1.65 (value at 100 mg/kg pc).



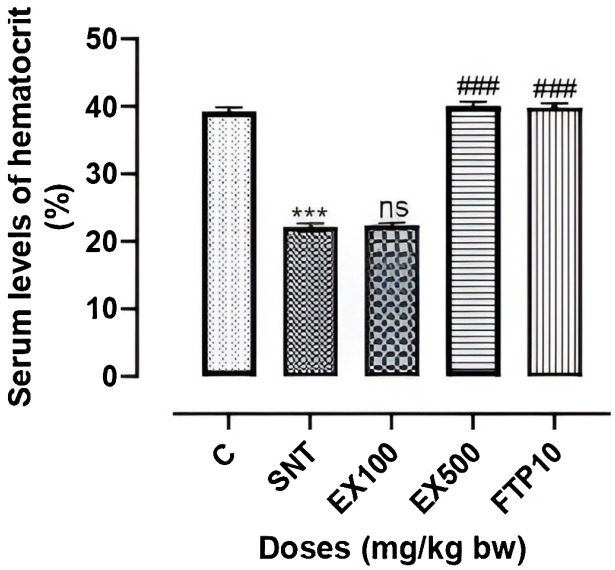
Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw; **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 1. Effect of EX on red blood cell.



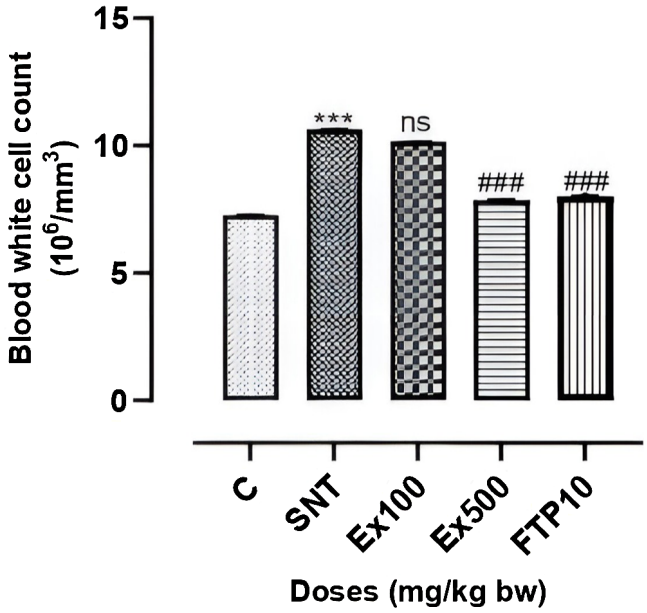
Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw; **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 2. Effect of EX on hemoglobin.



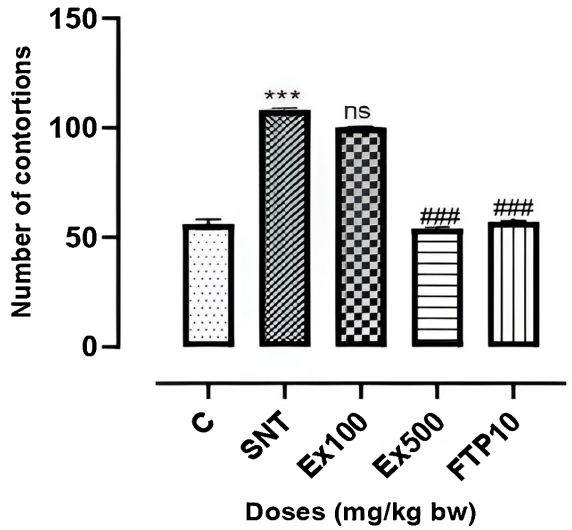
Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw, **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 3. Effect ofEX on hematocrit.



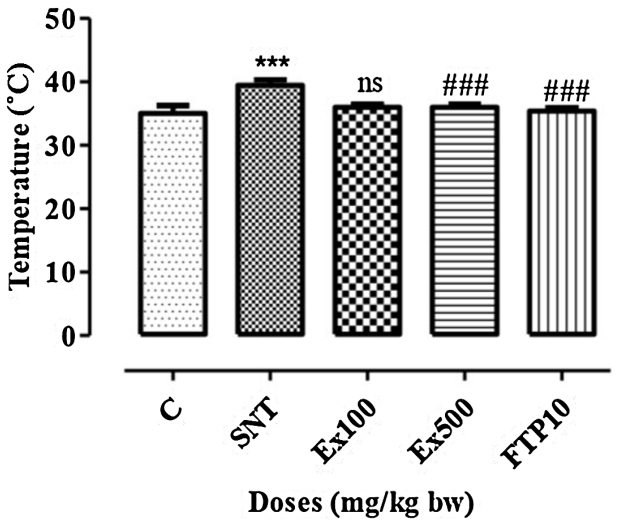
Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw; **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 4. Effect of EX on blood white cell.



Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw; **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 5. Effect of EX on contortions.



Value = Mean ± SEM (n ≥ 5); With asterisk (***) indicates a significant difference compared to the control batch value respectively with $p < 0.05$; With asterisk (###) indicates a significant difference compared to the sick untreated lot with $p < 0.05$; ns: no significant at $p < 0.05$. **C**: healthy control; **SNT**: sick no treated: **EX100**: sick treated with extract at a dose of 100 mg/Kg.bw; **EX500**: sick treated with extract at a dose of 500 mg/Kg.bw; **FTP 10**: sick receives the references molecules at a dose of 10 mg/Kg.bw; **EX**: extract.

Figure 6. Effect of EX on temperature.

Furthermore, the extract at a dose of 500 mg/kg bw significantly normalized ($p < 0.05$) the levels of the studied markers compared to the healthy control group. In the context of the analysis conducted, the red blood cell (RBC) count was de-

termined to be (09.21 ± 0.03) × 10^6/mm^3, hemoglobin (Hb) at 15.65 ± 0.045 g/dl, hematocrit (HCT) at 40.06% ± 0.01%, white blood cell (WBC) count at (7.85 ± 0.05) × 10^6/mm^3, contortions at 54, and body temperature at 36.05˚C.

The extract at a dose of 500 mg/kg pc significantly normalized ($p < 0.05$) the RBCs to (09.21 ± 0.03) × 10^6/mm^3, Hb to 15.65 ± 0.045; HCT to 40.06% ± 0.01%; white blood cells to (7.85 ± 0.05) × 10^6/mm^3; contortions to 54, and temperature to 36.05˚C compared to the healthy control lot.

The reference molecules (Folifer, Trémadol, and paracetamol) at doses of 10 mg/kg bw normalized the clinical signs associated with anemia, pain, and fever in the treated rats.

In untreated sick animals (SNT), the RBC, Hb, and HCT significantly decreased ($p < 0.05$) to (3.57 ± 0.03) × 10^6/mm^3; 16.26 ± 0.1 g/dl, and 16.26% ± 0.06%, respectively, while the white blood cell count, contortions, and temperature significantly ($p < 0.05$) increased to (15.32 ± 0.06) × 10^6/mm^3; 127 ± 2.47, and 39.86˚C ± 2.35˚C, respectively, compared to the healthy control group.

4. Discussion

In the context of this study, the therapeutic efficacy of the aqueous extract of *Solanum torvum* roots was evaluated on three clinical symptoms frequently associated with malaria in animal model. The observed symptoms include anemia, fever, and pain. The study was conducted in two phases. The first phase consisted of a phytochemical screening of the extract and the second phase focused on the treatment of symptoms above-mentioned.

The results of the phytochemical screening revealed that the aqueous extract of *Solanum torvum* roots contains polyphenols, flavonoids, alkaloids, and tannins. Indeed, several authors attribute antioxidant properties [18] and antimicrobial properties [19], anticancer properties [20], and anti-inflammatory properties [21] to phenolics compounds (phenols, flavonoids, and tannins). The analgesic, antioxidant, and antihypertensive properties are attributed to alkaloids [22]. Also, a significant iron content has also been highlighted. The role of iron has been mentioned in numerous vital processes of the body, including mitochondrial catabolic and anabolic reactions, oxygenation [23] and neurotransmitter synthesis [24].

These biomolecules, endowed with multiple therapeutic properties, could confer to the plant broad-spectrum therapeutic capabilities of biological activities.

The second phase of the study began with the induction of anemia. The results showed that once established in the animal, it leads to a significant decrease in red blood cells, hemoglobin, and hematocrit compared to the healthy control group. These results seem to confirm the presence of anemia in the rats. Such a hypothesis is corroborated by the work of [25]. According to these authors, hemolytic anemia is characterized by a decrease in the number of red blood cells due to the lysis of more than 30% of red blood cells, as well as a decrease in hemoglobin levels.

These results are similar to those of [26], who showed that the turkey berry (*Solanum torvum*)-fortified biscuit significantly reduced anemia prevalence the

biscuit enriched with turkey berry (*Solanum torvum*) significantly reduced the prevalence of anemia in adolescent girls.

For analgesic evaluation, the acetic acid-induced writhing test was employed. Results showed significantly increase the number of writhes. These results are comparable to those of [27]. Indeed, acetic acid stimulates the activity of cyclooxygenase-1, which results in an increase of pro-inflammatory mediators such as PGE2, TNF-α, bradykinin, histamine, serotonin, IL-6, and IL-8 [27]. The extract normalize writhing responses at dose of 500 mg/kg bw compared to control, suggesting inhibition of these mediators as demonstrated by [28] with leaves extract leaves of the same plant.

Furthermore, yeast induced pyrexia test was used. Results showed significantly increase in temperature. This injection act on the thermal equilibrium point at the hypothalamic center and cause an increase in temperature [29]. *S. torvum* root extract significantly suppressed temperature responses at dose of 500 mg/kg bw and normalized it.

The extract at this dose could inhibit the effects of these mediators at the hypothalamus, suppressing the fever.

The therapeutic efficacy of the extract was more pronounced at the dose of 500 mg/kg bw. At this dose, the extract completely normalized the white blood cells, red blood cells, hemoglobin, hematocrits, contortions, and pyrexia. Eradicating the all three symptoms of malaria by the extract could be attributed to its high content of secondary metabolites and iron. Indeed, the production of red blood cells in the bone marrow uses two-thirds of the iron present in the body as a substrate [30]. Thus, the iron provided by the extract could be used in the normalization of blood cells. Moreover, phenolics compounds with antioxidant properties due to their ability to capture and neutralize free radicals could impact hematopoietic function [31]. These metabolites, present in the extract, could therefore potentially confer an antiradical activity to it. The latter would, on the one hand, prevent the lysis of red blood cells and, on the other hand, stimulate their production and differentiation. Furthermore, it has been observed that these same phytomolecules could inhibit the activity of cyclooxygenase-1, leading to the complete elimination of pain and the normalization of body temperature in treated rodents [32].

The studied extract has the particularity of containing bioactive molecules. These confer upon it the ability to treat a range of symptoms. Therefore, it could be considered a potential remedy for the symptoms associated with malaria. Although the antiplasmodial activity of alkaloids was not demonstrated in the present study, several authors, including [33], attribute pronounced effects against *Plasmodium falciparum* to them. This approach could represent a substantial advantage for the therapeutic efficacy of malaria treatment. This diversity of action of *Solanum torvum* roots justifies their use in traditional settings as an antimalarial.

5. Conclusion

The results of this study show that the roots of *Solanum torvum* treat anemia,

fever, and pain, three symptoms associated with malaria. This triple pharmacological action thus highlighted supports the effectiveness of *Solanum torvum* roots in the treatment of malaria in traditional medicine. Further studies are planned for *in vivo* tests during an experimentally induced malaria in rats.

Ethical Approval

The Pasteur Institute of Côte d'Ivoire ethical policy on the rights of laboratory animals (Charter of Ethics of the Pasteur Institute, Text of September, 2012) was followed in the treatment of the animals utilized in this study.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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