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Coccidial Experimental Infection of Broiler Chickens and Effects of Treatment with *Conyza aegyptiaca* Ethanolic Extract on Haematological and Carcass Parameters

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Abstract

Background and objective: Coccidiosis is caused by a protozoan parasite of the genus *Eimeria* and affects poultry industries worldwide. This study was conducted to evaluate the impact of *C. aegyptiaca* ethanolic extract on broiler chicken coccidiosis.

Methods: Six groups of chicks in a complete randomized design were used for the study. Each chick among five groups was orally challenged with 2×10^4 *Eimeria tenella* sporulated oocysts. The first three groups received the decoction of *C. aegyptiaca* orally at 400, 200 and 100 mg/kg respectively, while the fourth group received anticox. The fifth group was the negative control. Chickens were sacrificed at the end of the treatment and haematological parameters such as white blood cell count, lympocytes, red blood cell count, hemoglobin, hematocrit and platelet count were determined using an automatic counter. For carcass performance, the chickens were weighed after de-feathered with and without internal organs (non-conventional and conventional yields respectively). Meat samples were collected from the thigh muscles and chest for the evaluation of chemical and technological properties.

Results: There was a significant improvement on the haematological (red blood cells, platelets, white blood cells and differential counts, haemoglobin, hematocrit and mean corpsular volume) and carcass (chemical and technological) parameters, especially in the IME400 mg/kg, positive and the normal control compared to the negative control.

Conclusion: Results from this study could be used for developing phytoelements that can serve as an alternative to synthetic anti-coccidial drugs.

Keywords

Conyza aegyptiaca • Phytobiotics • Anticoccidial • Cecalcoccidiosis • Carcass • Haematological parameters

Introduction

Throughout the world, poultry meat consumption continues to grow, both in the developed and developing countries [1]. In 1999, global production of chickens reached 40 billion, and by 2020 this trend was expected to continue to grow, so that poultry meat would become the consumers' first choice [2]. Poultry meat consumption takes one of the leading places compared to other meat in both developed and undeveloped countries [3]. High mortality rates due to coccidiosis outbreak constitute the greatest constraint on chicken development, especially broilers and village chickens that provide quality proteins and income to resource-poor smallholder farmers around the world.

Coccidiosisis a major parasitic poultry disease caused by protozoan parasites belongs to the genus *Eimeria* [4]. Chickens ingest sporulated oocysts orally and the infection can lead to clinical coccidiosis primarily in young birds [5]. Seven distinct *Eimeria* species have been identified in chickens, with 6 species colonizing the intestinal tract (intestinal coccidiosis) and one species (*Eimeria tenella*) infecting the ceca (cecal coccidiosis) [6,7]. *Eimeria tenella* is most responsible for severe coccidiosis and increased mortality in domestic chickens [8]. Most of these *Eimeria* species affect chicken production as a result of poor feed conversion, reduced growth rate and increased mortality impacting a huge economic loss to the poultry industry [9]. The widespread and uncontrolled use of many anti-coccidial drugs has led to the development of resistance in *Eimeria* species [10]. Parasite resistance and the side effects of some of the anti-coccidial drugs have serious consequences on disease control. Toxic effects of these products represent a danger to the users and health of animals and therefore their use has been restricted [11]. The increased occurrence of resistance against all anti-coccidial drugs has left the poultry industry with a renewed challenge for coccidiosis prevention and control and has propelled the search for other strategies [10]. With the currently increasing problems of drug-resistance and pressures from consumers to ban chemical drugs from animal feeds, phytobiotics (plant based materials) are now mostly considered as alternatives over chemicals for coccidia control in poultry farming [12].

Conyza aegyptiaca is an annual medicinal plant belonging to the family Asteraceae. This herb is mainly distributed in Africa, tropical Asia and Australia. The plant has multiple erect stems, which branch extensively at the base and are covered with stiff hairs. These stems decrease upwards and can be up to 1 m in height [13]. Phytochemical studies of *Conyza aegyptiaca* have led to the identification of bioactive elements in the areal parts of the plant which possess antioxidant activity [14]. The plant is used in folk medicine as an anthelmintic and soothing for skin diseases. Previous pharmacological studies have shown that its polar extracts possess antiviral and antimicrobial activities. *C. aegyptiaca* is used in West Africa to treat malaria, sickle cell disease, sore throat, diabetes. Traditional practitioners in the Western Highlands of Cameroon use the leaves of *C. aegyptiaca*

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to treat vomiting, dysentery, typhoid, protozoan diseases, gastrointestinal disorders and malaria. The anti-coccidial and antioxidant efficacy of this plant might be due to the presence of the various bioactive components [13].

Ethno medicinal practices could be recognized and encouraged as alternatives to chemical drugs and empower farmers to use the available resources for the prevention and control of livestock diseases. According to Habibi et al., and Song et al., several experiments have recently proven remarkable anti-coccidial effects of different herbal extracts and essential oils on coccidian infections [8,15]. The use of *C. aegyptiaca* extracts as the anti-coccidial substance has not yet been developed and no studies have been handed down in this regard. This study was therefore designed to develop a scientific basis of C. aegyptiaca which could be useful as an anti-coccidial remedy.

Materials and Methods

Study area

The study was carried out in the Research Unit of Biology and Applied Ecology laboratory, Department of Animal Biology, Faculty of Science, University of Dschang from June 2019 to November 2020.

Plant identification

Conyza aegyptiaca plant was primarily and locally identified due to its medicinal properties by indigenes of Mbessa village in Belo Sub division, North West Region of Cameroon. The plant was later harvested and identified at the National Herbarium Yaounde, where a scientific classification was assigned under a voucher specimen registered under the reference number: 5604/SRFCam.

Management and acclimatization of experimental chicks

One hundred broiler chicks (one day old) of both sexes were grown under standard management practices in the animal house of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang. All chicks were offered broiler starter ration for the first three weeks, followed by broilers finisher ration till the end of the experiment. Feed and water were provided ad libitum. Chicks were vaccinated against infectious diseases according to the programs applied in the F.A.R (Fermed' Applicationet de Recherche) of the University of Dschang. At 22 days, chicks were transferred into suspended wire meshed (battery system) cages under sanitary conditions and acclimatized till 28 days of age.

Eimeria tenella parasite

The coccidian parasite (*Eimeria tenella*) was kindly provided by the Department of Veterinary Parasitology and Entomology, Faculty of Veterinary Medicine, Ahmadu Bello University of Zaria, Nigeria.

Preparation of ethanolic extract

One hundred grams of the plant powder were macerated in 1.5 L of ethanol. The mixture was stirred three times daily and 72 hours later, the resulting solution was filtered using a sieve and Whatman Paper No 2 (Merck KGaA, Darmstadt, Germany). The filtrate was then distributed in three large plates and was concentrated by evaporating the solvent at 50°C in an oven for two days.

Phytochemical analysis of plant extract

The ethanolic extract was tested for the presence of phenolic compounds, alkaloids, flavonoids, polyphenols, tannins, saponin, triterpenes and steroids as described by Builders et al., in the Laboratory of Microbiology and Antimicrobial Substances [16].

Designation of chicks and induction of coccidiosis

Seventy-two broiler chicks (twenty-eight days old) of similar body weight and free from coccidiosis were randomly assigned in to 6 dietary treatment groups containing twelve chicks of four replicates and kept in battery cages under coccidia-free conditions. All groups except the normal control group were orally infected with a suspension of 2×10^4 *E. tenella* sporulated oocyst in a volume of 2 ml per chick. At day 35 (day 7 post-infection) after the establishment of the infection, they were treated with ethanolic extracts of *Conyza aegyptiaca* at various doses in the following design: Groups 1: infected and medicated with 400 mg/kg of the extract, Group 2: Infected and medicated with 200 mg/kg of the extract, Group 3: Infected and medicated with 100 mg/kg of the extract, Group 4: Infected and medicated with 20 mg/kg of anticox (positive control), Group 5: Infected and non-medicated (negative control), Group 6: Non-infected and non-medicated (normal control).

Anti-coccidial assessment of *C. aegyptiaca* ethanolic extract

Evaluation of haematological parameters: At the end of the treatment which lasted for seven days, chickens were subjected to a 12-hour food fasting after which they were sacrificed and blood samples collected in EDTA coated tubes. Hematological parameters such as White Blood Cells (WBC) count, Granulocytes, Lympocytes (Lym), Monocytes, Red Blood Cells (RBC) count, Hemoglobin (HGB), Hematocrit (HCT), Mean Corpsular Volume (MCV), Mean Corpsular Hemoglobin (MCH), Mean Corpsular Hemoglobin Concentration (MCHC), Mean Platelets Volume (MPV) and platelet count were determined using an automatic counter.

Evaluation of carcass parameters: The chickens were de-feathered after slaughter. For the non-conventional carcass yields, chickens were weighed with internal organs like the liver, heart, intestine, pancreas and gizzard and body parts such as the head and the legs using an electronic balance, while the conventional carcass yield was determined by weighing the chickens without the above mentioned organs and body parts. The internal organs, head and the legs were also weighed separately. Meat samples were collected from the thigh muscles and chest for the evaluation of chemical (carcass moisture, ash, mineral, fat and protein contents) and technological (carcass ultimate pH and water holding capacity, such as drip loss, cooking loss and freezing loss) properties [17].

Statistical analysis

The data obtained were analyzed using the Statistical Package for Social Sciences (SPSS) software version 20.0. Analysis of Variance (ANOVA) was performed in one way and Duncan's multiple range tests were used for statistical comparisons between groups, considering the probability level of $p<0.05$ as significant. Values were expressed as the mean ± SD.

Ethical approval and consents to participate: All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

Results

Phytochemical analysis of plant extracts

C. aegyptiaca ethanolic and aqueous extracts were tested for the presence of phenolic compounds, alkaloids, flavonoids, polyphenols, tannins, saponin, triterpenes and steroids. The ethanolic extract was found to contain all these phytochemical elements under investigation in the plant (Table 1).

Table 1. Phytochemical elements of *C. aegyptiaca* ethanolic and aqueous extracts.

Extracts	Phytochemical elements						
	Alkaloids	Polyphenols	Flavonoids	Tannins	Saponin	Steroids	Triterpenes
Aqueous	+	-	+	+	+	-	-
Ethanolic	+	+	+	+	+	+	+

Effects of treatment with *C. aegyptiaca* ethanolic extract on haematological parameters

Red blood cell counts of experimental chickens: Table 2 revealed that red blood cells counts were significantly higher in the positive and normal controls groups followed by the IME400 mg/kg and the lowest in the negative control. Haemoglobin contents were significantly higher in the IME400 mg/kg, positive and normal controls with no significant differences among the groups and lower in the IME100 and IME200 mg/kg and the negative control. Hematocrit values were significantly higher in the IME400 mg/kg, positive and normal controls groups, followed by the IME100 and IME200 mg/kg chickens and the lowest in the negative control. The positive and normal controls had significant higher Mean Corpsular Volume (MCV) values, followed by the IME400 mg/kg, IME200 mg/kg and the negative control with no significant differences. There were no significant differences in the Mean Corpsular Haemoglobin Concentration (MCHC) altogether.

White blood cells counts and differentials of experimental chickens: White blood cells had significant lower counts in the IME400 mg/kg followed by the IME200 mg/kg, positive and the normal control groups, while the negative control showed the highest value. Granulocytes had significant lower counts in the IME400 mg/kg followed by the normal control groups, while the negative control showed the highest value. Lymphocytes, monocytes and MPV showed significantly lower counts with no significant differences among the IME400 mg/kg, IME200 mg/kg, IME100 mg/kg, positive and the normal control, except for the IME100 mg/kg, which had a significantly lower Mean Platelet Volume (MPV) values. Platelets counts were also significantly lower in the IME400 mg/kg and the positive control. In each of these parameters examined, the negative control had highest counts (Table 3).

Effects of treatment on carcass parameters

Nutrient contents of experimental chickens: Table 4 presents nutritional contents of chicken meat and these revealed that the ash, lipids and protein contents were significantly higher in the extract medicated higher doses, positive and the normal control groups and lower in the IME100 and negative control groups, whereas the reverse was observed for moisture content. Calcium content of the normal control was significantly higher followed by the IME400 group. Magnesium content was significantly higher in the positive and the normal controls followed by all the extract medicated groups. All medicated groups showed no significant differences in the iron content, meanwhile that of the normal control was significantly higher. Phosphorus content was also significantly higher in the normal control followed by the IME200 group and the positive control. It was generally observed that the infected non-medicated control group revealed lowest significant mineral contents except for calcium content that did not have significant difference with the IME100 group.

Table 2. Red blood cells count of treated chickens.

Treatments	Red Blood Cells (RBC) and concentrations					
(mg/kg)	RBC (x 10^{12}/L)	HGB (g/dl)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dl)
IME100	2.31 ± 0.11^{b}	10.37 ± 0.32^{b}	27.93 ± 3.81^{b}	127.43 ± 4.78^{b}	42.80 ± 2.00^{b}	31.17 ± 0.40^{a}
IME200	2.33 ± 0.10^{b}	10.34 ± 0.60^{b}	28.87 ± 1.48^{b}	134.97 ± 6.47^{ab}	45.33 ± 2.61^{a}	31.40 ± 0.78^{a}
IME400	2.59 ± 0.03^{a}	11.83 ± 0.40^{a}	32.93 ± 1.74^{a}	137.23 ± 3.31^{ab}	46.80 ± 1.91^{a}	31.80 ± 0.95^{a}
1MAC	2.56 ± 0.06^{a}	11.52 ± 0.57^{a}	32.60 ± 1.73^{a}	140.60 ± 5.20^{a}	46.03 ± 3.97^{a}	32.27 ± 0.95^{a}
INMC	2.10 ± 0.18^{c}	9.92 ± 0.32^{b}	25.83 ± 2.93^{c}	133.53 ± 7.04^{ab}	45.87 ± 3.16^{a}	31.97 ± 1.00^{a}
NINM	2.66 ± 0.22^{a}	12.10 ± 0.50^{a}	33.37 ± 1.67^{a}	139.40 ± 4.42^{a}	45.33 ± 2.61^{a}	31.37 ± 0.65^{a}
NR	2.5-3.5	11-17.5	26-35	90-140	37-47	26-35

IME: Infected and Medicated with Extract; IMAC: Infected and Medicated with Anticox Control; INMC: Infected Non-Medicated Control; NINM: Non-Infected Non Medicated; NR: Normal Range; HGB: Hemoglobin; HCT: Hematocrit; MCV: Mean Corpuscular Volume; MCHC: Mean Corpuscular Hemoglobin Concentration. For the same column, values carrying the same superscript letter (a, b c….) are not significantly different at p ≥ 0.05. Results are expressed as Mean ± SD.

Table 3. White blood cells counts and differentials of treated chickens.

Treatments	White Blood Cells (WBC) and differentials					
(mg/kg)	WBC (x 10^{9}/L) 10^{-1}	Granulocytes (%)	Lymphocytes (%)	Monocytes (%)	MPV (fL)	Platelets (x 10^{9}/L)
IME100	14.12 ± 1.95^{b}	2.51 ± 0.02b^{c}	83.3 ± 1.22^{b}	16.87 ± 6.1^{b}	7.5 ± 0.81^{ab}	141.67 ± 4.51^{b}
IME200	13.56 ± 0.3^{bc}	2.78 ± 0.25^{b}	80.9 ± 0.39^{b}	16.7 ± 4.06^{b}	7.90 ± 0.3^{ab}	127.33 ± 5.7^{7c}
IME400	12.19 ± 0.50^{c}	1.79 ± 0.25^{e}	71.2 ± 0.42^{b}	12.0 ± 4.49^{b}	6.97 ± 0.2^{b}	106.00 ± 2.00^{d}
1MAC	13.2 ± 0.58^{bc}	2.31 ± 0.09^{cd}	73.1 ± 0.83^{b}	15.7 ± 1.90^{b}	6.7 ± 0.15^{b}	123.67 ± 6.66^{c}
INMC	17.66 ± 0.73^{a}	3.91 ± 0.21^{a}	97.6 ± 0.14^{a}	30.36 ± 4.16^{a}	11.2 ± 0.21^{a}	176.3 ± 11.24^{a}
NINM	13.17 ± 0.31^{bc}	2.56 ± 0.06^{de}	72.6 ± 0.25^{b}	14.11 ± 1.78^{b}	6.80 ± 0.62^{b}	101.33 ± 11.0^{d}
NR	2.95-4.15	50-70	54.3-73.04	1.0-15.0	6.5-12	100-350

IME: Infected and Medicated with Extract; IMAC: Infected and Medicated with Anticox Control (Positive control); INMC: Infected Non-medicated Control (Negative control); NINM: Non-infected Non Medicated; NR: Nomal Range, MPV: Mean Platelet Volume.

Table 4. White blood cells counts and differentials of treated chickens.

Nutrients	Treatments (mg/kg)					
Content	**IME100**	**IME200**	**IME400**	**IMAC**	**INMC**	**NINM**
Moisture	74.92 ± 1.00[a]	75.51 ± 0.97[a]	73.96 ± 1.63[b]	74.23 ± 0.57[b]	75.64 ± 1.84[a]	72.04 ± 0.66[ab]
Ash	1.15 ± 0.07[b]	1.23 ± 0.05[b]	1.26 ± 0.05[ab]	1.26 ± 0.04[ab]	1.14 ± 0.06[b]	1.39 ± 0.13[a]
Lipids	2.41 ± 0.12[a]	3.42 ± 0.14[ab]	3.82 ± 0.23[a]	3.80 ± 0.22[a]	2.02 ± 0.04[a]	3.84 ± 0.42[a]
Proteins	17.54 ± 0.60[c]	18.50 ± 0.35[b]	17.92 ± 0.21[bc]	17.34 ± 0.38[c]	13.12 ± 0.44[d]	19.60 ± 0.44[a]
Calcium	35.73 ± 9.24[d]	59.73 ± 9.24[d]	98.40 ± 12.58[b]	67.73 ± 16.17[c]	38.30 ± 8.00[d]	121.7 ± 12.05[a]
Magnesium	55.89 ± 5.61[bc]	60.51 ± 1.43[bc]	66.91 ± 9.83[bc]	71.95 ± 7.61[a]	51.19 ± 7.47[c]	64.17 ± 4.00[a]
Iron	52.49 ± 2.49[bc]	55.61 ± 2.06[bc]	59.03 ± 4.89[bc]	53.52 ± 11.01[bc]	46.87 ± 9.79[b]	64.17 ± 4.00[a]
Phosphorus	47.35 ± 0.81[d]	49.82 ± 0.78[ab]	48.47 ± 1.32[bc]	49.48 ± 1.39[ab]	47.41 ± 1.15[c]	50.50 ± 0.58[a]

IME: Infected and Medicated with Extract; IMAC: Infected and Medicated with Anticox Control; INMC: Infected Non-medicated Control; NINM: Non-infected Non Medicated. Results are expressed as Mean ± SD. For the same column, values carrying the same superscript letter (a, b,c….) are not significantly different at p ≥ 0.05.

Ultimate pH and water holding capacity of experimental chickens: Table 5 showed that pH24 and drip loss was not significantly different in all experimental groups. Cooking loss was significantly higher in the IME400 mg/kg chickens, the positive and the normal controls groups, followed by the IME100 and the IME200 mg/kg groups, while the negative control had significantly lower cooking loss values. The IME400 mg/kg chickens and the normal control also had high significant difference of freezing loss followed by the IME100 mg/kg, while the IME200 mg/kg chickens, positive and negative control groups had lower values with no significantly difference between the groups.

Organs weight of experimental chickens: Results from Table 6 showed that both internal and external organ weights were significantly higher p<0.05) in the IME400 mg/kg. The liver and the heart weights were higher in the IME400 mg/kg treated chickens followed by the positive and the normal controls, while the negative control showed the least significant weights in both cases. Gizzard weights showed significant higher differences in the IME400 mg/kg, IME100 mg/kg treated chickens and the normal control chickens followed by the positive control, while the IME200 mg/kg group and the negative control revealed lower values. The head and legs had higher significant differences in the IME400 mg/kg, the positive and normal control followed by the IME100 and the IME200 mg/kg chickens, and whereas it was observed that the negative control chickens had lowest significant head and legs weights.

Carcass yields of experimental chickens: Figure 1 presents conventional and non-conventional carcass yields of treated chickens and this reveals that the IME400 mg/kg and the positive control showed significant higher yields for conventional carcass followed by the normal control, meanwhile the non- conventional carcass yield was significantly higher in the IME400 mg/kg and the normal control followed by the positive control. In each case, the negative control had the lowest yield.

Table 5. Ultimate pH and water holding capacity of treated chickens.

Treatments (mg/kg)	Ultimate pH (pH24)	Water holding capacity (%)		
		Drip loss	Cooking loss	Freezing loss
IME100	6.47 ± 0.12[a]	9.43 ± 3.83[a]	4.93 ± 0.64[ab]	2.98 ± 0.48[ab]
IME200	6.47 ± 0.06[a]	11.2 ± 1.67[a]	5.02 ± 0.80[ab]	2.53 ± 0.12[b]
IME400	6.47 ± 0.06[a]	10.7 ± 2.12[a]	5.33 ± 0.50[a]	3.54 ± 0.41[a]
1MAC	6.53 ± 0.06[a]	10.30 ± 3.2[a]	5.56 ± 0.30[a]	2.50 ± 0.12[b]
INMC	6.53 ± 0.15[a]	9.00 ± 4.11[a]	4.23 ± 0.30[c]	2.51 ± 0.03[b]
NINM	6.47 ± 0.06[a]	11.82 ± 2.73[a]	5.47 ± 0.28[a]	3.49 ± 0.36[a]

IME: Infected and Medicated With Extract; IMAC: Infected and Medicated with Anticox Control; INMC: Infected Non-medicated Control; NINM: Non-infected Non Medicated. Results are expressed as Mean ± SD. For the same column, values carrying the same superscript letter (a, b, c…) are not significantly different at p ≥ 0.05.

Table 6. Weights of internal and external organs of treated chickens.

Treatments	Internal organs			External organs	
(mg/kg)	**Liver (g)**	**Heart (g)**	**Gizzard (g)**	**Head (g)**	**Legs (g)**
IME400	34.00 ± 2.61[a]	9.67 ± 1.16[a]	37.33 ± 4.93[a]	44.33 ± 1.59[a]	62.00 ± 1.73[a]
IME200	26.67 ± 0.58[b]	6.67 ± 1.16[bc]	32.33 ± 4.04[b]	40.00 ± 3.46[b]	52.67 ± 4.62[b]
IME100	28.67 ± 1.53[b]	7.67 ± 1.16[bc]	35.33 ± 5.51[a]	37.00 ± 0.00[bc]	53.67 ± 3.23[b]
1MAC	27.67 ± 1.53[b]	8.00 ± 1.00[ab]	33.00 ± 2.65[ab]	45.33 ± 2.89[a]	68.33 ± 2.31[a]
INMC	21.67 ± 2.08[c]	6.00 ± 0.00[c]	26.33 ± 4.73[b]	33.33 ± 2.31[c]	42.00 ± 2.64[c]
NINM	30.00 ± 2.00[b]	8.33 ± 1.16[ab]	41.10 ± 4.36[a]	47.00 ± 1.73[a]	68.67 ± 6.81[a]

IME: Infected and Medicated with Extract; IMAC: Infected and Medicated with Anticox Control (Positive control); INMC: Infected Non-medicated Control (Negative control); NINM: Non-infected Non Medicated (Normal control); SOD: Superoxide Dismutase. Results are expressed as Mean ± SDFor the same column, values carrying the same superscript letter (a, b, c…) are not significantly different at p ≥ 0.05.

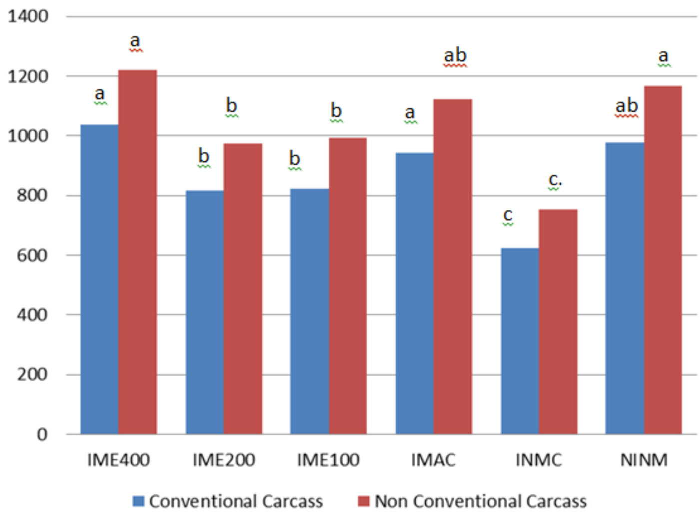

Figure 1. Conventional and non-conventional carcass yields.

Discussion

Chicken coccidiosis leads to huge economic losses in poultry production, because of pathogenic effects of *Eimeria* species in the intestinal tract, resulting in malabsorption of nutrients and subsequent adverse effects on the growth parameters [18,19]. The influence of medication of chickens experimentally infected by *E. tenella* with *C. aegyptiaca* ethanolic extract compared with the reference anticox drug in our study was evaluated based on haematological and carcass parameters. This provided a new herbal drug known as *C. aegyptiaca* for treating coccidiosis in chickens and the potency is similar to that of anticox.

Eimeria species mainly damage intestine at the site of infection of parasites at the primary stages, especially merozoites, breaking out of gut cells and invading other cells of the gut. This may lead to reduction in blood components as a result of severe bleeding and tissue damage in the mucosa following invasion by *Eimeria tenella* [20]. In the current study, *C. aegyptiaca* medicated groups showed remarkable and comparable anti-coccidial improvement on the hematological profile, when compared with the reference anticoxdrug (positive control) and the normal control. Gotep et al., reported that an increase in Red Blood Cell (RBC) count and Haemoglobin (Hb) concentrations in the medicated groups is indicative of the erythropoietic ability of extracts, which is beneficial, since the *Eimeria* parasite in the epithelia of the intestines causes bloody diarrhea and consequently anaemia [18]. This could invariably results in reduced red blood cell, haemoglobin and hematocrit blood counts in the infected non-medicated control chickens in this study. Our results were in conformity with the findings of Gotep et al., which also agreed with the observations of Zhang et al. This was consistent in another study conducted by Nghonjuyi et al., whose results obtained also showed that *C. papaya* leaf ethanolic extract had significant effects on the red blood cell count and haemoglobin concentrations of the extract treated chickens [18,20-22]. Moreover, Muraina et al., reported that an increase in the RBC count, Hb and Pack Cell Volume (PCV) across the treatment groups showed anti-anaemic property of the extracts, suggesting that the extracts have an erythropoietic inducing ability and a decreased levels of PCV, Hb and RBC counts in the infected untreated group (negative control) might be correlated with loss of blood (haemorrhage) in the caeca [23]. However, this was not consonant with the findings of Aljedaie and Al-Malki, who observed that *Z. officinale* and *C. longa* treated groups showed a significant reduction of RBCs, Hb% and PCV, holding to their previous assertion.

White Blood Cell (WBC) counts measure the number of white blood cells in the body, while white blood differential counts determine the percentage of each type (neutrophils, lymphocytes, monocytes, eosinophils and basophils) of white blood cells presents in the blood. These types of white blood cells can be affected in different ways during a particular condition or disease (homeo-dynamics). For example, neutrophils and monocytes are capable of the process of phagocytosis of various pathogens [24]. These authors reported that chronic systemic inflammation and subclinical diseases can manifest themselves in elevated leukocyte counts that are within the normal range but may signal health problems. White blood cell counts and differentials address suspected conditions in the body including anemia, infections and leukemia [25]. Coccidia infected non-medicated chickens in this study showed a significant increase in WBCs and differentials compared to the medicated groups and the normal control. The dose dependent decrease in white blood cells count, granulocytes, lymphocytes, monocytes, MPV and platelets observed is suggestive of decreased inflammation in the medicated groups. According to Gotep et al., it can be extrapolated that the decrease in parasitic load down regulates the activity of the immune system leading to decrease in inflammation and consequently a decrease in the various parameters, tending towards the normal blood picture of a greater ratio in avian species [18]. Our results were similar to the findings of Nghonjuyi et al., whose results obtained showed that *C. papaya* leaf ethanolic extract had significant effects on the WBC counts of the extract treated chickens [22]. Muraina et al., reported that the increase in the lymphocyte and monocyte count as compared to the negative control suggests the cellular immuno-modulatory effect of the extract, since it has a direct activity on the parasitic load [23].

Coccidiosis poses a significant economic burden in poultry production systems with the implications in animal health, growth and quality [18,19]. According to Kralik et al., good ratings of poultry meat such as: short fattening duration, high reproductive ability of poultry, excellent feed conversionare compromised in a disease state. Most researchers have showed that the disposition of fats, proteins and minerals in the infected chicken meat is significantly lower than in uninfected chickens, indicating that chicken meat quality as well as quantity may be affected adversely by coccidiosis. Gotep et al., and Włosek et al., reported earlier that weight gain is the more sensitive variable to coccidial and anticoccidial treatments and this is directly linked to the uptake of nutrients in the intestine [18,19]. Yamssi et al., suggested that the effect of infection on growth performance may be related to the degree of infection and weight gain is generally reduced under conditions of more severe infection with *Eimeria* [11]. In our study, results showed improvements in the contents of minerals, ash, fats, proteins, organ weights and the overall carcass performance in the medicated groups especially the IME400 mg/kg, while the infected non-medicated control showed less significant contents. This suggested that treatment of coccidia infections in broiler chickens with *C. aegyptiaca* could revert the histopathological changes of the cecum therefore; the relative uptake rates of nutrients in the *C. aegyptiaca* extract treated groups were also improved. These results of nutrient content and organ weights improvement as well as the overall carcass yield as reflected to the results obtained with the growth performances in the medicated groups are in consonance with the findings of Habibi et al., Adulugba et al., and Qaidet al. [5,12,15]. However, results for organ weights and overall carcass yield opposed those obtained by Nghonjuyi et al., except for the heart weight [22].

Water holding capacity in fresh poultry meat is a complex trait that is controlled by the chemical and structural attributes of the muscle tissue as they are influenced by the transformation of muscle to meat. This biochemical process serves an important function in establishing acidity in the meat [26]. Glycogen the main energy supplier to the muscle is used in stress situations like coccidiosis before slaughter. Meat of animals, which had depleted their glycogen reserves before slaughtering due to stressful activities, will not have a sufficient amount of lactic acid production (high pH). The muscle pH does not fall and this produces Dark Firm Dry (DFD) meat. The high pH causes the muscle proteins to retain most of their bound water [26]. Researchers have supported the fact that pH values of meat is linked to water-holding capacity and that a decrease in pH value is accompanied by a decreasing water-binding ability, whereas along with pH value increase, the water-holding capacity of muscle proteins increases as well [27]. A reverse phenomenon may arise in animals which have not been stressed for a period before slaughter, thus the pH may decline very quickly, while the meat is still warm and a very wet surface (pale, soft, exudative=PSE meat) condition develops. PSE meat has lower binding properties and loses weight (water) rapidly during cooking. During this study; there was a slight increase in pH of meat in the infected non-medicated group, though there were no significant differences among all the experimental groups. Compared to the observations of Łukasiewicz et al., no significant differences were demonstrated in the pH value of the muscles of chickens administered feed mixture with the addition of plant coccidiostat [27]. Our results showed that drip loss was not significantly different, whereas cooking and freezing loss were significantly higher in the medicated groups than the negative control. In the findings of Łukasiewicz et al., water holding capacity in terms of drip loss and cooking loss were significantly lower inthe medicated groups of chicken muscles [27]. Wan et al., also revealed that broilers in 1.0 g/kg and 1.5 g/kg enzymatically treated Artemisia annual [28]. (EA) groups exhibited better water-holding capacity and tenderness than the 0.5 g/kg EA group numerically. Nevertheless, Rajput et al., disagreed by reporting that coccidiosis reduced the meat's water holding capacity in non-supplemented chicken meat and was improved by natural carotenoids [29].

Conclusion

Results from our study confirmed that treatment of coccidiosis (*Eimeria tenella*) with *C. aegyptiaca* ethanolic extract showed excellent anti-coccidial effects in broiler chickens and improved nutritional and haematological parameters as well as carcass performance. It was therefore concluded that *C. aegyptiaca* can serve as an alternative to synthetic anti-coccidal drugs and the advantage of using natural plants-based nutrientsis to minimize the risk of synthetic drug resistance. Moreover, natural products have no residual effects on poultry meat and eggs, thus beneficial for human consumption with no adverse effects on their health. Again, the contents of the formulation are commonly available, cheap, and easy to use as a decoction particularly for the resource-poor farmers. Incorporation of this herb in integrated coccidiosis management practices will add to the sustainability and thus, the income of the farmers. Large-scale controlled studies are, however, recommended for standardization of the doses and applications of the product.

Availability of Data and Materials

Data and material are available to other researchers upon request.

Author's Contribution

Toah ET, Yamssi C, Noumedem ACN and PayneVK proposed the research domain, designed the hypotheses, performed the field and laboratory activities and wrote the manuscript. Sop Foka EI assisted in the field and laboratory activities. All authors contributed in statistical and data analysis read and approved the final manuscript.

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Competing Interest

The authors declared that they have no competing interest.

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