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Effect of Madagascar Almond (*Terminalia mantaly*) Leaf Extracts on Growth Performance, Carcass Characteristics, and Blood Profile of Broiler Chickens

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Abstract: The study examined the effect of *Terminalia mantaly* leaf extracts on the growth performance, carcass characteristics, and blood profile of broiler chickens. A total of 105 day-old Ross 308 chicks were randomly assigned to five treatments, with 21 birds per treatment in three replicates of seven birds each. The treatments consisted of 0% (control), 0.5%, 1.0%, 1.5%, and 2.0% *T. mantaly* leaf extracts mixed in drinking water and administered to the birds for 56 days. The measured parameters comprised initial and final weights, total and average daily weight gain, total and average daily feed intake, feed conversion ratio, carcass traits, as well as haematological and serum biochemical indices of the broilers. Data were analyzed using ANOVA. The results showed that birds receiving 0.5% *T. mantaly* extract had significantly higher total weight gain and average daily weight gain compared to other treatments ($p < 0.05$). The feed conversion ratio was highest in the 0.5% treatment group. Carcass evaluation indicated significant differences in liver and small intestine weights among the treatment groups ($p < 0.05$). The haematological profile showed significant treatment-related effects ($p < 0.05$). Specifically, red blood cell count, haemoglobin, packed cell volume, mean corpuscular volume, and mean corpuscular haemoglobin concentration varied significantly among groups. Analysis of serum biochemistry identified significant differences ($p < 0.05$) among treatments for globulin, triglycerides, and low-density lipoprotein. The study concludes that *T. mantaly* leaf extract, administered at a 0.5% inclusion level, improved growth performance without adverse effects on organ health, suggesting its potential as an alternative to synthetic antibiotics in broiler production.

Keywords: *Terminalia mantaly*, broiler chickens, growth performance, phytobiotic, natural antibiotics

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1. Introduction

Global broiler meat production reached approximately 104.2 million metric tons in 2025 and is projected to continue its upward trajectory, with poultry production expected to increase by approximately 17–18% by 2030, exceeding 115 million metric tons. Poultry is anticipated to account for more than half of the growth in global meat production, driven by its efficiency and strong consumer demand [1]. This substantial growth in production has been accompanied by an increased reliance on synthetic antibiotics in broiler feeds, raising significant health concerns among consumers regarding meat quality and the development of pathogen resistance to common human antibiotics [2,3]. The continuous and often excessive use of antibiotics in broiler production, coupled with their financial implications, has necessitated the search for viable alternatives.

In response to the global antibiotic resistance and increasing treatment failures in humans, the European Union implemented a ban on antimicrobials in animal feeds in 2009 [4]. This regulatory action has stimulated extensive research into potential alternatives to synthetic antibiotics, with phytobiotic extracts emerging as promising candidates

[5]. These plant-derived compounds possess multiple beneficial properties, including antioxidant, antibacterial, antifungal, antiviral, hepatoprotective, and immune-stimulatory activities [6,7].

Phytobiotic extracts have demonstrated beneficial effects on broiler meat texture and the ability to inhibit pathogenic microbial growth in the digestive tract, thereby improving overall chicken health [8]. However, the utilization of these extracts requires careful consideration of inclusion levels, as excessive amounts may exert antinutritional or deleterious effects on animals [9]. Previous studies have reported beneficial effects of plant leaf extracts on carcass quality, including increased breast muscle development and reduced abdominal fat deposition [10].

Terminalia mantaly, commonly called Madagascar Almond, Umbrella Tree, Satellite Tree or Amandier de Madagascar, is a large tropical tree native to Asia and Madagascar. It is an underutilized resource with potential applications in livestock production. While this tree is widely distributed in tropical regions and serves as an excellent shading tree, its utilization as a natural feed additive alternative to antibiotics remains limited. Preliminary studies on the medicinal properties of *T. mantaly* bark and wood have been reported [11], demonstrating strong inhibitory effects of *T. mantaly* extracts against *Staphylococcus aureus* and *Escherichiacoli* strains.

Despite these promising findings, there remains a paucity of information on the utilization of *T. mantaly* leaf extracts in broiler production. The hematobiochemical parameters of broilers serve as crucial indicators of health status and metabolic functions, providing insights into the physiological effects of dietary interventions. Understanding these parameters is essential for evaluating the safety and efficacy of alternative feed additives.

This study contributes to the scientific literature by evaluating how T. mantaly leaf extracts influence broiler performance and health-related parameters. The novelty of this work lies in its comprehensive evaluation of growth performance, carcass characteristics, and blood profile of broilers administered varying levels of *T. mantaly* leaf extracts. This study contributes valuable information to the growing body of knowledge on natural alternatives to synthetic antibiotics in poultry production, with potential implications for sustainable and health-conscious broiler farming practices.

2. Materials and Methods

2.1. Experimental Location

The study was conducted at the poultry facility of the Department of Animal Science, Nnamdi Azikiwe University (Awka, Anambra State, Nigeria). This facility is in southeastern Nigeria, with coordinates ranging from latitude 6.24° to 6.28° and longitude 7.00° to 7.08°. The area has a tropical wet and dry climate with clear seasonal variations. Throughout the year, the average daily maximum temperature stays around 27°C, peaking at 34°C in March, and dropping to its lowest levels during the harmattan months of December to January [12].

2.2. Preparation of Test Ingredients

Fresh *T. mantaly* leaves were obtained from two locations within Anambra State. These were the campus of Nnamdi Azikiwe University in Awka and stretches along the Onitsha–Enugu Expressway in Awka South Local Government Area. The aqueous extraction was carried out following the procedure described by Obadoni and Ochuko [13]. Fresh leaves were washed under running water and allowed to air-dry. Once dried, the leaves were separated from the stems and milled into a flour. The powdered leaves were subsequently immersed in water at a 1:5 (leaf:water) ratio and left to soak for 72 hours, with intermittent stirring [14]. The resultant extract was filtered and stored for use in the experiment.

2.3. Feed Formulation

The experimental birds received standard broiler starter and finisher diets formulated (Table 1) in accordance with breed specifications [15].

Table 1. Ingredients and nutrient composition of the experimental feed.

Age Category (Years)	Percentage composition (%)	
	Starter	Finisher
Maize	43	48
Soybean meal (SBM)	30	25
Fishmeal	4	4
PKC	2	2
Bone meal	3	3
Rice bran	7	6
Wheat offal	9	10
Toxin binder	1	1
Salt	0.3	0.3
Methionine	0.25	0.25
Lysine	0.25	0.25
Vitamin premix	0.2	0.2
Total	100	100
Calculated Composition		
Crude Protein, %	22.21	20.49
Crude Fiber, %	4.73	4.47
Metabolizable, Kcal/kg	2728	2769

2.4. Experimental Birds and Rearing Management

The study used 105 day-old Ross 308 broiler chicks. The birds were managed in a deep litter system with strict adherence to good management practices throughout the starter (1–28 days) and finisher (28–56 days) phases of the experimental period. Initially, the brooding house was properly prepared and covered with black nylon sheets. A gas brooder was used as the heat source to ensure effective temperature control and regulation during the first week (0–7 days).

Birds were weighed at the commencement of the experiment to determine their initial body weight and subsequently weighed weekly until the end of the experiment to calculate average daily weight gain. Measurements were taken using a Camry (20 kg) general-purpose scale and a Camry (5 kg) high-precision electronic scale, with sensitivities of 50 g and 1 g, respectively. Feed was weighed before offering, and refusals were collected and weighed daily during both the starter and finisher phases.

2.5. Experimental Design

The experimental layout followed a completely randomized design (CRD), incorporating five treatment levels. A total of 105 birds were randomly allocated to the treatments, with 21 birds per treatment. Each treatment was replicated three times, with seven birds per replicate. Treatment groups consisted of a control (T_1) receiving drinking water without extract, and four supplemented groups: T_2 (0.5% or 5 mL/L), T_3 (1.0% or 10 mL/L), T_4 (1.5% or 15 mL/L), and T_5 (2.0% or 20 mL/L) of *T. mantaly* leaf extract.

2.6. Data Collection

2.6.1. Growth Parameters

All chicks were weighed at the beginning of the experiment to obtain their initial body weight (kg). Final body weight (kg) was measured at 56 days as the weight of the bird at the end of the trial. Daily feed intake (kg/bird/day) was determined by subtracting the amount of feed leftover on a given day from the feed offered on the previous day. Average daily weight gain (kg/bird/day) was computed from weekly weight measurements. Feed conversion ratio (FCR) was calculated as: FCR = Total feed intake / Total weight gain. Bird mortality was monitored over the entire duration of the experiment.

2.6.2. Carcass Characteristics

At the end of the experiment, one bird per replicate (15 birds total) was randomly selected for carcass evaluation. Birds were fasted for 12 hours prior to slaughter and processed following standard procedures. Major cuts (thigh, drumstick, breast, back, head, neck, wings, and shank) and internal organs (liver, heart, full gizzard, empty gizzard, spleen, and pancreas) were carefully removed and weighed, as their sole weights using 5 kg Camry high-precision scale with 1 gram sensitivity.

2.6.3. Blood Profile Analysis

Three days before the end of the experiment, blood samples were collected from three birds (2 ml each) per treatment via wing vein puncture. One sample was collected in EDTA-treated tubes for haematological analysis and the second in the plain tubes for serum biochemical analysis. Haematological parameters included white blood cell count (WBC), red blood cell count (RBC), packed cell volume (PCV), haemoglobin concentration (Hb), mean corpuscular volume (MCV), and mean corpuscular haemoglobin concentration (MCHC) using hemocytometry and haematocrit methods [16].

Serum biochemical indices analyzed included total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), total protein, albumin, globulin, liver enzymes (AST, ALT), and kidney function markers (urea, creatinine) using spectrophotometric methods [16].

2.6.4. Proximate and Phytochemical Analysis

The proximate analysis was carried out in accordance to AOAC [17] while the phytochemical analysis was done according to Trease and Evans [18].

2.7. Statistical Analysis

One-way analysis of variance (ANOVA) using the General Linear Model of IBM SPSS Statistics (2017) was used to analyse data collected. Duncan's New Multiple Range Test was used to statistically separate significant treatment means [19]. The probability level of 0.05 or less was accepted as the statistical significance.

3. Results

3.1. Proximate and Phytochemical Analyses of T. mantaly

The proximate analysis of air-dried *T. mantaly* leaves (Table 2) revealed a high crude protein content of 31.93%, low moisture content of 5.60%, crude fiber of 17.97%, ash content of 12.5%, crude fat of 17.10%, total carbohydrate of 14.95, and metabolizable energy of 341.44 kcal/g.

Table 2. Proximate Analysis of Test ingredients.

Nutrients	Contents
Ash (%)	12.5
Moisture (%)	5.60
Crude fat (%)	17.10
Crude fibre (%)	17.97
Dry matter	94.50
Crude protein (%)	31. 93
Total carbohydrate (%)	14.95
Metabolizable energy (kcal/g)	341.44

Phytochemical analysis (Table 3) revealed the presence of various bioactive compounds including alkaloids (13%), oxalate (4.14%), phenol (2.51%), saponins (2.0%), terpenoids (3.1%), tannins (0.94%), phytate (0.29%), flavonoids (0.26%), and cardiac glycosides (0.24%).

Table 3. Phytochemical constituents of processed *T. mantaly*.

Constituents	(%)
Tannin	0.94
Flavonoids	0.26
Phenol	2.51
Oxalate	4.14
Alkaloids	13
Phytate	0.29
Saponins	2
Terpenoids	3.1
Cardiac Glycoside	0.24

3.2. Growth Performance

Table 4 and Table 5 show the effect of T. mantaly leaf extracts on broiler growth parameters at starter stage and finisher stage, respectively. In both instances, there was no significant difference ($p < 0.05$) in initial body weight, final body weight, total feed intake, average daily feed intake, or mortality amongst the treatments. In Table 4, however, there were significant differences ($p < 0.05$) between total weight gain, average daily weight gain, and feed conversion ratio.

Table 4. Effect of *Terminalia mantaly* leaf extracts on growth parameters of broiler chickens at starter phase.

Parameter	T_1 (0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	T_5 (2.0%)	*p Value*	SEM
IBWT, kg	0.042	0.042	0.042	0.042	0.042	0.204	0.014
FBWT, kg	0.409	0.433	0.393	0.380	0.389	0.160	0.015
TWTG, kg	0.367 ^{b}	0.391 ^{a}	0.351 ^{b}	0.338 ^{b}	0.347 ^{b}	0.015	0.027
ADWTG, kg	0.050 ^{b}	0.071 ^{a}	0.055 ^{b}	0.055 ^{b}	0.048 ^{b}	0.016	0.004
TFI, kg	0.848	0.855	0.830	0.811	0.808	0.784	0.032
ADFI, kg	0.121	0.122	0.118	0.116	0.116	0.810	0.005
FCR	2.455 ^{a}	1.728 ^{b}	2.167 ^{a}	2.101 ^{a}	2.406 ^{a}	0.007	0.112

$^{a, b}$ Means on the same row with different superscripts are significantly ($p < 0.05$) different
IBWT = Initial body weight; FBWT = Final body weight; TWTG = Total weight gain; ADWTG = Average daily weight gain; TFI = Total feed intake; ADFI = Average daily feed intake; FCR = Feed conversion ratio

Table 5. Effect of *Terminalia mantaly* leaf extracts on growth parameters of broiler chickens at finisher phase.

Parameter	T_1 (0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	T_5 (2.0%)	*p Value*	SEM
IBWT, kg	0.425	0.451	0.407	0.403	0.427	0.204	0.014
FBWT, kg	2.317	2.500	2.350	2.367	2.383	0.399	0.066
TWTG, kg	1.891	2.049	1.943	1.963	1.956	0.618	0.069
ADWTG, kg	0.270	0.293	0.278	0.280	0.279	0.618	0.010
TFI, kg	3.825	3.451	3.773	3.981	3.477	0.208	0.172
ADFI, kg	0.682	0.493	0.651	0.711	0.552	0.209	0.069
FCR	2.031	1.691	1.936	2.034	1.777	0.107	0.097
Mortality, %	1.33	0.33	1.00	1.67	1.00	0.361	0.450

$^{a, b}$ Means on the same row with different superscripts are significantly ($p < 0.05$) different.

IBWT = Initial body weight; FBWT = Final body weight; TWTG = Total weight gain; ADWTG = Average daily weight gain; TFI = Total feed intake; ADFI = Average daily feed intake; FCR = Feed conversion ratio.

3.3. Carcass Parameters

The effect of T. mantaly leaf extracts on carcass parameters are shown in Table 6. The liver weight and small intestine weight had significant differences ($p < 0.05$) between treatments and other carcass parameters did not exhibit significant differences.

Table 6. Effect of *Terminalia mantaly* leaf extracts on carcass characteristics of broiler chickens.

Parameter (kg)	T_1 (0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	T_5 (2.0%)	*p* Value	SEM
Heart	0.011	0.012	0.011	0.012	0.012	0.976	0.001
Liver	0.04 ^{b}	0.052 ^{a}	0.042 ^{b}	0.054 ^{a}	0.048 ^{ab}	0.010	0.003
Small intestine	0.07 ^{a}	0.05 ^{c}	0.05 ^{bc}	0.06 ^{abc}	0.063 ^{ab}	0.041	0.003
Spleen	0.003	0.004	0.004	0.005	0.004	0.574	0.001
Breast	0.540	0.601	0.564	0.585	0.580	0.910	0.05
Thigh	0.277	0.294	0.249	0.247	0.262	0.191	0.02
Drumstick	0.238	0.262	0.227	0.216	0.231	0.335	0.02

$^{a, b, c}$ Means on the same row with different superscripts are significantly different ($p < 0.05$).

3.4. Haematological Parameters

Table 7 shows the haematological parameters of broiler chickens that were administered with T. mantaly leaf extracts. There were significant differences ($p < 0.05$) between the red blood cell count, haemoglobin concentration, packed cell volume, mean corpuscular volume, mean corpuscular haemoglobin concentration, and basophil count.

Table 7. Effect of *Terminalia mantaly* leaf extracts on haematological parameters of broiler chickens.

Parameter	T_1 (0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	T_5 (2.0%)	*p* Value	SEM
RBC ($\times 10^{12}$/L)	7.53^{a}	5.42^{c}	6.35^{bc}	7.82^{a}	7.09^{ab}	0.004	0.35
WBC ($\times 10^{9}$/L)	41.67	35.67	43.33	39.67	40.67	0.528	3.13
Hb (g/dl)	18.50^{a}	14.20^{c}	16.10^{bc}	19.10^{a}	17.60^{ab}	0.004	0.71
PCV (%)	51.67^{a}	37.33^{c}	43.67^{bc}	53.67^{a}	48.67^{ab}	0.004	2.36
MCV (fl)	68.61^{b}	68.85^{a}	68.72^{b}	68.59^{b}	68.65^{b}	0.007	0.04
MCHC (g/dl)	35.83^{bc}	38.13^{a}	36.93^{ab}	35.60^{c}	36.20^{bc}	0.007	0.40
Platelets ($\times 10^{9}$/L)	639.00	521.33	711.67	599.33	693.33	0.108	48.28

$^{a, b, c}$ Means on the same row with different superscripts are significantly ($p < 0.05$) different.
RBC = Red blood cell count; WBC = White blood cell count; Hb = Haemoglobin; PCV = Packed cell volume; MCV = Mean corpuscular volume; MCHC = Mean corpuscular haemoglobin concentration

3.5. Serum Biochemical Parameters

The serum biochemical parameters are presented in Table 8. Significant differences ($p < 0.05$) were observed in globulin, triglycerides, high-density lipoprotein, and low-density lipoprotein levels among the treatments.

Table 8. Effect of *Terminalia mantaly* leaf extracts on serum biochemical parameters of broiler chickens.

Parameter	T_1 (0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	T_5 (2.0%)	*p* Value	SEM
ALT, U/L	33.47	19.20	24.93	33.93	16.40	0.584	9.30
AST, U/L	111.00	121.33	121.67	140.50	118.67	0.805	17.20
Urea, mg/dl	87.99	52.16	104.13	136.48	58.17	0.861	61.49
Creatinine, mg/dl	0.367	0.184	0.173	0.216	0.237	0.813	0.125
Total protein, g/dl	4.13	4.09	3.98	4.76	3.87	0.148	0.24
Albumin, g/dl	2.33	2.76	2.29	2.15	2.35	0.254	0.18
Globulin, g/dl	1.80 ^{b}	1.33 ^{b}	1.69 ^{b}	2.61 ^{a}	1.52 ^{b}	0.005	0.18
Total cholesterol, mg/dl	161.04	164.88	134.43	138.09	184.09	0.858	36.12
Triglycerides, mg/dl	273.81 ^{c}	375.24 ^{bc}	487.14 ^{ab}	331.43 ^{bc}	567.62 ^{a}	0.014	5.14
HDL, mg/dl	33.33	26.87	25.94	29.59	26.96	0.099	1.86
LDL, mg/dl	72.94 ^{b}	146.88 ^{a}	30.33 ^{c}	66.98 ^{b}	63.59 ^{b}	0.046	22.10

$^{a, b, c}$ Means on the same row with different superscripts are significantly ($p < 0.05$) different.
ALT = Alanine aminotransferase; AST = Aspartate aminotransferase; HDL = High-density lipoprotein; LDL = Low-density lipoprotein

4. Discussion

The proximate analysis of *T. mantaly* leaves revealed a high crude protein content (31.93%), which differs from previous reports by [20], who found 12%. This variation may be attributed to differences in drying duration, harvesting time, or environmental conditions. The low moisture content (5.6%) indicates good preservation quality, while the presence of various phytochemical compounds confirms the bioactive potential of *T. mantaly* extracts.

The results of growth performance indicate that the leaf extract, T.mantaly at 0.5% inclusion level significantly increased the total weight gain and average weight gain per day as compared to the other treatment levels. This improved performance can be attributed to the presence of antimicrobial and growth-promoting compounds like alkaloids (13%), phenolic compounds (2.51%), and terpenoids (3.1%), in the extract. The better growth performance is in agreement with the results obtained by [21] and [22], who found that phytobiotic extracts reduced the number of pathogenic flora in the intestine, which led to better gut health and improved growth performance.

The treatment group with the highest numerically was the 0.5% treatment group (1.90), which indicated a better feed utilization efficiency. This effect could be given by the antioxidant properties of the extract, which alleviate oxidative stress and improves the metabolic processes. The fact that there were no significant changes in feed intake means that the extract did not have any negative impact on palatability or appetite.

Carcass evaluation revealed significant improvements in liver weight with *T. mantaly* supplementation, particularly at 0.5% and 1.5% inclusion levels. This finding suggests enhanced hepatic function and metabolic activity. The variation in small intestine weight may indicate improved gut development and digestive capacity. These results are consistent with others [23], who reported improved carcass characteristics in chickens fed phytogenic extracts.

The haematological analysis revealed significant variations in red blood cell parameters, with the 1.5% treatment showing the highest values for RBC count, haemoglobin, and PCV. These findings suggest improved oxygen-carrying capacity and overall health status [5]. The variations in MCV and MCHC values remain within normal physiological ranges, indicating no adverse effects on red blood cell morphology [24]. Similar results were reported by [25] in broilers administered *Polyalthia longifolia* leaf extract.

The significant differences obtained in lipid profile parameters, with notable increases in triglycerides at higher inclusion levels (2%), indicate altered lipid metabolism,

which could affect meat quality. The variations in globulin levels suggest potential immunomodulatory effects of the extract. The liver enzyme levels (ALT and AST) remained within normal ranges across all treatments, indicating no hepatotoxic effects [24].

The result of the kidney function parameters (urea and creatinine), which showed no significant difference suggests that *T. mantaly* extract at the tested levels does not adversely affect renal function. This is crucial for establishing the safety profile of the extract as a feed additive.

The bioactive compounds identified in *T. mantaly* extract, particularly flavonoids, alkaloids, and phenolic compounds, are known to possess antimicrobial, antioxidant, and anti-inflammatory properties [26]. These compounds likely contribute to the observed improvements in growth performance and health parameters by enhancing immune function and reducing oxidative stress.

5. Conclusions

Based on the significant parameters evaluated in this study, the 0.5% (5 ml/L) inclusion levels of *Terminalia mantaly* leaf extract in drinking water represents the optimal treatment for broiler chicken production. This treatment demonstrated the best growth performance with significantly higher total weight gain and average daily weight gain compared to other treatments, while maintaining the most favorable feed conversion ratio.

The study concludes that *T. mantaly* leaf extract can serve as an effective natural alternative to synthetic antibiotics in broiler production, promoting growth performance without adverse effects on organ health. The extract's bioactive compounds contribute to improved metabolic function and overall bird health, as evidenced by the haematological and biochemical parameters.

Further research should be conducted to evaluate the effects of T. mantaly extract on meat quality parameters, shelf life, and consumer acceptability. Additionally, long-term feeding trials should be undertaken to assess the cumulative effects of T. mantaly supplementation on broiler health and productivity across multiple production cycles. Investigation into the optimal processing methods and storage conditions for T. mantaly extract should be conducted to maximize its bioactive compound retention and efficacy.

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