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# Effects of Aqueous Extracts of Neem Leaf and Ginger Rhizome on Growth Performance and Haematological Parameters of Pure and Crossbred Chickens

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## ABSTRACT

Neem leaf and ginger rhizome contain numerous chemical components that are biologically active and are widely utilized in medications to treat various illnesses. The purpose of the current study was to assess the effect of aqueous neem leaf and ginger rhizome extracts on the growth performance and hematological parameters in the three breeds of chicken. A total of 360 one-day-old chicks from 3 genetic groups consisting of 120 Noiler chicks, 120 Heavy Ecotype chicks, and 120 main cross chicks were considered for this study. Each breed of chickens was randomly distributed into four groups, with three replications per group. Each replication consisted of eight females and two males, raised in a deep litter system. A 3×4 factorial arrangement was employed, involving four levels of plant extracts: a control group receiving the basal diet without any extract, a group receiving 200 ml of neem extract (NE200), a group receiving 200 ml of ginger extract (GE200), and a group receiving 100 ml of neem + 100 ml of ginger extract (NE100+GE100). The chickens were evaluated for growth parameters such as initial weight (IW), final weight (FW), average daily gain (ADG), average feed intake (AFI), feed conversion ratio (FCR) as well as some haematological parameters such as haemoglobin (Hb), packed cell volume (PCV), white blood cell (WBC), red blood cell (RBC), platelet (P), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC). Noiler chickens receiving NE100+GE100 and GE200 showed the highest final body weight and daily weight gain. The results of the haematological indices revealed that the interaction effect of genotype and plant extracts on all the treatment groups were significantly different for haemoglobin (Hb), packed cell volume (PCV), white blood cell (WBC), and platelet (P). Some haematological indices such as Hb, PCV, WBC, and platelet were better for chickens receiving GE200 and NE100+GE100 compared to NE200 and control groups. In conclusion, the interaction of GE200 and NE100+GE100 with Noiler and main cross chickens was beneficial, with no adverse effects on the physiological traits and health status of the chickens 16 weeks of age.

**Keywords:** Haematology, Heavy ecotype, Heterosis, Noiler, Performance, Plant extracts

## INTRODUCTION

The significant increase in chicken production to meet the growing demand for poultry products in developing countries has led to a corresponding rise in the use of antibiotics as growth promoters. These synthetic and semi-synthetic antibiotics positively impact poultry by improving appetite, increasing feed conversion, stimulating the immune system, increasing vigor, and modulating intestinal microflora, all of which contribute to higher survival rates (Ayalew et al., 2022). However, their use comes with several drawbacks, such as high production costs, negative effects on bird health, long withdrawal times, risks of accumulation in tissues and eggs, and ensuing human cancer risks. In line with these findings, the European Union (2006) recommended alternatives categorized as natural growth promoters (NGPs). Nigerian researchers have used a wide variety of

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herbs and plant parts from seeds, fruits, and tree barks to leaf meals and extracts as replacements for conventional feeds, feedstuff, growth boosters, and antibiotics. Plant extracts from therapeutic plants, including neem and ginger, are safe, affordable, and full of various bioactive compounds, or secondary metabolites, and are, therefore, among the possible substitutes (Oluwafemi et al., 2020; Mukherjee et al., 2024).

Dogonyaro, also known as neem (*Azadirachta indica*), is a fast-growing native tropical tree that grows well throughout Nigeria, especially in poor, shallow, stony, or sandy soils where agricultural crops yield little (Ogbuewu et al., 2011). Due to its extensive therapeutic potential, including its antibacterial, antiviral, antifungal, antiprotozoal, hepatoprotective, and anticoccidal effects in poultry and other animals (monogastric and ruminant species), neem trees have drawn attention from all over the world. Since the meal from neem leaf contains some bioactive components (limonoids, tannin, and azadirachtin) that negatively impact nutrient consumption, its application is restricted (Islas et al., 2020). Furthermore, the high fiber content of neem leaf meal presents challenges for digestion and consumption in chicken diets (Oloruntola et al., 2019).

To overcome these limitations, the use of neem leaf extracts offers a promising solution, allowing the nutritional and therapeutic benefits of neem leaf meal to be fully utilized without the associated drawbacks (Tibebu et al., 2017). Neem leaf extract contains several bioactive compounds, including nimbin, nimbinene, 6-desacetylnimbiene, nimbadole, nimbolide, and quercetin (Miltra et al., 2000). Studies have shown that neem leaf infusion stimulates growth and enhances haematological parameters, immunological response, and growth performance in chickens (Egbeyale et al., 2021). Furthermore, Egbeyale et al. (2021) reported that administering aqueous neem leaf infusions at concentrations of up to 0.3% in drinking water did not adversely affect the growth performance, carcass traits, or meat quality of broiler chickens, making it a viable alternative to antibiotics.

*Zingiber officinale*, a perennial blooming plant, is utilized extensively in both culinary and medicinal applications. It facilitates faster digestion and has antibacterial, anti-inflammatory, and therapeutic qualities. In many households, ginger serves as a preservative, spice, condiment, while also being employed for a variety of additional therapeutic uses (Sachan et al., 2018). The primary bioactive constituents responsible for ginger's distinctive flavor and pharmacological effects are gingerols, including 6-, 8-, and 10-gingerol (Alsherbiny et al., 2019). These gingerols, a class of phenolic compounds present as a yellow oil at room temperature, exhibit a wide range of biological activities, such as anti-inflammatory, anti-allergic, antioxidant, anti-cancer, and antimicrobial properties. They are also used in treating different disorders of the central nervous system (Semwal et al., 2015). It has been demonstrated that gingerols can reduce animal oxidative stress brought on by heavy metals, mycotoxins, age, etc (Li et al., 2019). Ginger's immunostimulant properties enhance the body's ability to respond to future challenges from pathogenic organisms by activating cell-mediated immune responses. In vitro studies further suggest that ginger extract may have anti-diabetic effects and regulate the amount of free radicals and lipid peroxidation (Morakinyo et al., 2011). When immuno-suppressed birds are fed neem leaves and ginger extracts, their humoral and cell-mediated immune responses are boosted (Sadekar et al., 1998).

There has been research on the use of several medicinal plant extracts as growth promoters for antibiotics (Lukanov et al., 2018). Still, no published studies have specifically examined the effects of neem leaf and ginger extracts on Noiler chickens, Nigerian Heavy Ecotype chickens, and their crossbreeds. If the biological properties of ginger and neem leaf extracts are demonstrated to improve the growth and hematological parameters in these chickens without adversely affecting their physiological traits and health, these extracts could serve as promising growth-promoting supplements in poultry diets, contributing positively to animal production. Therefore, this study aims to evaluate the effects of neem leaf and ginger extracts on the growth performance and haematology of Noiler chickens, Nigerian Heavy Ecotype chickens, and their crossbreeds.

## MATERIAL AND METHODS

### Ethical approval

This research was carried out in accordance with the recommendations of research ethics for scientific researchers involving animal subjects. The animals were handled in line with the principles set forth by the Animal Experimentation Ethics Committee of the University of Nigeria, Nsukka (No: UNN/C031ARO12.02.07.2023) following the Research Ethics Committee Recommendations (2013).

### Location and duration of the study

The study was conducted from August 5, 2023, to November 25, 2023, at the Poultry Unit of the Department

of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka, Nigeria. Nsukka lies within longitude 6° 45′E and 7° E and latitude 7° 12.5 ′N at an altitude of 447 m above sea level. The climate of the study area is typically tropical, with relative humidity ranging from 65% to 80% and a mean daily temperature of 26.8 °C (Okonkwo and Akubuo, 2007). The present experiment lasted for 16 weeks.

**Preparation of extracts**

Fresh neem leaves were picked from neem trees inside the premises of the university environment while ginger roots were purchased. They were repeatedly rinsed under running tap water to remove any remaining dirt. In order to lower the moisture level without destroying the chemical content, the ginger roots were peeled, chopped into chips, and oven dried at 50 $^{o}$C. The neem leaves were allowed to air dry for five to six days, during which time they crisped up and kept their greenish hue. After being dried and powdered to a 1 mm mesh size, the neem and ginger leaves were kept apart in airtight plastic containers. To prepare the aqueous extracts, 100 g of each fine powder was added to 1 liter of sterile distilled water in a 1:10 ratio. After allowing the mixtures to infuse for eight hours, shaking them, and letting them cool at room temperature, the aqueous extracts were obtained by filtering the infusion, which was subsequently stored at 4$^{o}$C (Khan et al., 2023).

**Experimental birds and management**

A total of 360 one-day-old chicks, with an average weight of 35.49±0.82 g, were used in this study. The chicks were from three genetic groups: 120 chickens from a cross between Noiler cocks × Noiler hens (NN), 120 chicks from a cross between Heavy Ecotype cocks × Heavy Ecotype hens (HH), and 120 chickens from a cross between Noiler cocks × Heavy Ecotype hens (MC). The birds were randomly assigned to four treatment groups, with 30 chickens per treatment (6 males and 24 females). Each treatment group was divided into three replicates, with 10 chickens (8 females and 2 males) per replicate. The chicks were raised on deep litter in pens measuring 2.6 m wide by 3 m long. The temperature was kept at 22 $^{o}$C until the end of the study. The humidity ranged from 70%–75% in the first week and 55%–65% in the second week. They were provided with unlimited access to feed and water. All groups were managed under the same environmental conditions, including temperature, light, and vaccination programs. All chicks were vaccinated with the Newcastle disease vaccine (Lasota) on day 7 of hatching. Their vaccination program also included the infectious bursal vaccine (Gumboro) on day 14, the infectious bursal (Gumboro booster) vaccine on day 21, and the Newcastle disease (Lasota booster) vaccine on day 28. The third Newcastle disease vaccine (Komarov strain) was administered at week 10, followed by the Fowl pox vaccine at week 12. A 3×4 factorial design was used to administer four dietary treatments based on aqueous plant extracts, which were allocated as follows.

Control = Chickens received the basal diet without any extract.
NE200 = Chickens received 200 ml of neem extract per liter of water.
GE200 = Chickens received 200 ml of ginger extract per liter of water.
NE100+GE100 = Chickens received 100 ml of neem + 100 ml of ginger extract per liter of water.

**Feed ingredients and chemical analysis**

Chemical analyses of the feeds were done at the Department of Animal Science Biochemistry and Nutrition Teaching Laboratory, University of Nigeria, Nsukka. Samples were randomly selected from each feed ingredient (maize grain, soybean meal, fish meal, and wheat) and their chemical composition was assessed following the Association of Official Analytical Chemists (AOAC) protocol (method 930.15; AOAC, 2016). Based on the results, an experimental ration was formulated.

Benzoic acid was used as a calibration reference in an adiabatic bomb calorimeter (Gallenkamp Autobomb, Weiss Gallenkamp Ltd., UK) to calculate total metabolizable energy. Nitrogen (N) content was determined using the Kjeldahl technique, and crude protein was calculated as N × 6.25. The ether extract was examined using the AOAC protocol (method 920.39; AOAC, 2016). The standard approach (method 2002.04; AOAC, 2016) was followed for the analysis of crude fiber.

For mineral analysis, samples were first ashed and digested with HCl. Then, using Thermos Jarrell equipment (method 968.08D; AOAC, 2005), the concentrations of calcium and phosphorus were measured using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES). The WinFeed program (Cambridge, UK) was utilized to formulate the experimental diet. The diets were prepared in accordance with NRC guidelines to ensure that the chickens' nutritional needs were met for the starter phase (0 to 8 weeks) and the grower phase (9 to 16 weeks) (NRC, 1994; Table 1). Feed and water were provided *ad libitum* throughout the study.

**Table 1.** Ingredient composition and chemical composition of experimental diet

| Ingredient (kg/1000 kg) | Starter diet (0-8 weeks) | Grower diet(9-16 weeks) |
|---|---|---|
| Maize | 539.7 | 523.5 |
| Soybean meal | 140.6 | 62.8 |
| Fish meal | 35.1 | 15.7 |
| Wheat | 231.3 | 348.9 |
| Dicalcium phosphate | 18.8 | 14.6 |
| Calcium carbonate | 26.5 | 26.5 |
| Mineral and vitamin premix | 2.5 | 2.5 |
| NaCl | 2.5 | 2.5 |
| L-lysine | 1 | 1 |
| DL-methionine | 1 | 1 |
| L-threonine | 1 | 1 |
| Total | 1000 | 1000 |
| **Calculated nutrient content** | | |
| Metabolizable energy, Kcal/kg | 3005.87 | 2864.26 |
| Crude protein, % | 18.24 | 15.31 |
| Ether extract, % | 3.55 | 3.57 |
| Crude fibre, % | 3.96 | 4.43 |
| Lysine, % | 1.47 | 1.62 |
| Methionine, % | 0.77 | 0.55 |
| Calcium, % | 1.46 | 1.36 |
| Phosphorus, % | 0.45 | 0.35 |

**Growth performance**

***Live weight (g)***

Initial weight (IW) and final body (FW) weights were obtained by weighing chickens at the beginning and at the end of the experimental period.

***Weight gain (g)***

The birds were weighed at the beginning of the experiment and weekly thereafter in order to determine the body weight gain (BWG) that corresponded to each treatment group. During the experiment, BWG was calculated by subtracting the initial weight from the final weight (BWG = FW – IW). Additionally, daily weight gain (DWG) was determined by dividing the BWG by the number of days in the experimental period.

***Feed intake (g/chicken)***

Each replicate received a known quantity of feed (X) in the morning and evening. The amount consumed was calculated by weighing the leftover feed (Y) in the following morning. The difference between X and Y (X-Y) was recorded as the quantity of feed consumed by each replicate.

***Feed conversion ratio***

The ratio between the amount of feed consumed and the weight gained during the same period was used to calculate the feed conversion ratio: FCR = feed intake (g) / total weight gain (g).

**Haematological analysis**

At the end of the study, three chickens from each genotype group within each treatment were randomly selected for blood analysis. Using a syringe and needle, approximately 3 ml of blood was drawn from the chickens' wing veins and immediately poured into ethylene diamine tetra-acetate (EDTA) sample vials for the analysis of haematological indices. Haemoglobin concentration (g/dl) was measured using a hemoglobinometer (Patil et al., 2013). To calculate the total amount of red blood cells ($x10^9$/L) and white blood cells ($x10^9$/L), a Neubauer hemocytometer was utilized (Abuoghaba, 2018). Packed cell volume (PCV) (%) was measured with a Microhematocrit Capillary Tube and subsequently centrifuged at 10,000 RPM for five minutes (Duah et al., 2020). Compound microscopes were used to count platelets ($x10^9$/L) (Mayengbam et al., 2020). Mean cell volume (MCV, $\mu m^3$), mean cell hemoglobin (MCH, pg), and mean cell hemoglobin concentration (MCHC, g/dl) were calculated using formulas provided by Odunitan-Wayas et al. (2018).

**Statistical analysis**

All data were subjected to a 3 × 4 factorial analysis with the following model in a completely randomized design using SAS (2013) software.

$Yijk=\mu+ai+\beta j+(\alpha\beta)ij+\varepsilon ijk$

where Yijk is the response variable, μ is the overall mean, and ai is the effect of the ith genotype (i= NN, HH, and MC). βj represents the effect of the jth level of plant extracts (j= 0, NE200, GE200, and NE100+GE100), (αβ)ij is the effect of the interaction between the level of plant extracts and the genotype, and εijk is the random error due to experimentation. Where necessary, mean separation was performed using Duncan's New Multiple Range Test in the same statistical package with significance accepted at the 5% level. Data are presented as mean ± standard deviation (SD).

## RESULTS AND DISCUSSION

**Growth performance**

The results of the effects of aqueous neem leaf and ginger extracts on the growth performance of pure and crossbred chickens are presented in Table 2. The interaction between genotype and plant extracts levels showed no significant differences ($p > 0.05$) in initial weight (IW), average feed intake (AFI), and feed

conversion ratio (FCR). However, final weight (FW) and average daily gain (ADG) were significantly affected ($p < 0.05$) by the treatments. As shown in Table 2, Noiler chickens (NN) fed GE200 and NE100+GE100 had the highest ($p < 0.05$) FW (2253.78 g and 2205.07 g, respectively) and ADG (19.80 g and 19.37 g, respectively), followed by the main cross (MC), while the Heavy Ecotype (HH) recorded the lowest values.

The highest body weight in NN may be attributed to the genetic potential of this breed as a commercial chicken, which tends to outperform others in terms of growth. The average body weight of MC was higher than HH indicating that the genetic potential of NN might be responsible for the higher body weight of the MC observed. Additionally, the therapeutic properties of ginger might also be the reason for the improved FW observed in NN chickens receiving GE200 and NE100+GE100. Ginger contains zingibain, a proteolytic enzyme known to aid digestion, which might have enhanced nutrient utilization and growth in these chickens. These findings corroborate those of Arkan et al. (2012), who found that adding ginger to chicken diets significantly improved body weight. From the result, it is evident that the interaction between genotype and plant extracts levels contributed to the variations in body weight observed in different breeds. This finding indicates that, alongside inherent breed differences, environmental factors such as feeding and management conditions play a crucial role in determining the body weight of chickens (Muller, 2018). The sole administration of ginger extract (GE200) and the combined use of neem and ginger extracts (NE100+GE100) significantly ($p < 0.05$) improved ADG compared to other treatments. The enhanced ADG in NN chickens treated with NE100+GE100 and GE200 may be explained by genetic selection aimed at enhancing the breed's growth rate. Also, it may be attributed to the stimulatory effects of ginger extract on the microbiota, digestive secretions, and nutrient absorption in the digestive tract (Sa'aci et al., 2018). This could be explained by ginger's ability to improve feed palatability and promote faster digestion, leading to earlier emptying of the digestive tract and stimulating additional feed intake. Ginger has been shown to enhance the release of digestive enzymes such as lipase, disaccharidase, and maltase (Zhang et al., 2009). Furthermore, Herawati (2010) reported that the enhanced performance in chickens may be attributed to the two digestive enzyme types found in ginger, lipase and protease, which are part of the plant's natural defense mechanisms.

According to Zhao et al. (2011), ginger enhances gastric secretion, enterokinesia, and digestive enzyme activity, leading to improved nutrient digestion and absorption in animals. Similarly, bioactive compounds such as flavonoids, alkaloids, and saponins found in neem leaves may aid in improved nutrient utilization, thereby improving the growth performance of birds on the NE100+GE100 treatment. On the other hand, Nidaullah et al. (2010) observed that weight gain varied insignificantly across broiler groups fed aqueous infusions of therapeutic herbs such as neem leaves, ginger rhizomes, and garlic bulbs. In the present study, the interaction between neem and ginger extract had no significant effect on FI and FCR. The findings also demonstrated that the plant extracts did not impede the availability, digestion, absorption, or utilization of nutrients. The obtained result was consistent with Landy et al. (2011) study, which indicated that feed intake was not significantly affected by adding neem leaf powder to broiler diets at a rate of 7 or 12 grams/kg at 42 days of age.

**Table 2.** Effect of aqueous neem leaf and ginger extracts on growth performance of pure and crossbred chickens aged 16 weeks

| Parameters | IW (g) | FW (g) | ADG (g) | AFI (g) | FCR |
|---|---|---|---|---|---|
| NN × Control | 36.66±0.65 | 1729.15±38.4$^{c}$ | 15.11±1.96$^{c}$ | 45.41±1.37 | 2.95±0.63 |
| NN × NE200 | 35.36±0.08 | 2035.23±57.6$^{b}$ | 17.84±1.03$^{b}$ | 51.00±3.36 | 2.62±0.09 |
| NN × GE200 | 35.80±0.48 | 2253.78±42.1$^{a}$ | 19.80±0.36$^{a}$ | 51.53±5.78 | 2.61±0.34 |
| NN × NE100+GE100 | 36.14±0.57 | 2205.07±62.2$^{a}$ | 19.37±0.55$^{a}$ | 41.66±2.01 | 2.33±0.01 |
| HH × Control | 34.15±0.60 | 730.33±46.6$^{g}$ | 6.06±0.65$^{g}$ | 30.42±0.91 | 5.05±0.39 |
| HH × NE200 | 35.02±0.56 | 913.99±20.1$^{f}$ | 7.84±0.17$^{f}$ | 33.55±1.34 | 4.27±0.07 |
| HH × GE200 | 35.50±0.70 | 942.14±42.2$^{f}$ | 8.24±0.56$^{f}$ | 34.28±1.22 | 4.18±0.42 |
| HH × NE100+GE100 | 35.14±1.47 | 1007.92±37.3$^{f}$ | 8.69±0.32$^{f}$ | 32.96±1.21 | 3.79±0.14 |
| MC × Control | 34.62±1.50 | 1265.06±4.74$^{e}$ | 10.99±0.02$^{e}$ | 34.23±7.94 | 3.11±0.71 |
| MC × NE200 | 35.83±2.00 | 1209.03±19.4$^{e}$ | 10.47±0.15$^{e}$ | 33.08±3.03 | 3.15±0.34 |
| MC × GE200 | 35.44±0.47 | 1417.75±49.5$^{d}$ | 12.28±0.88$^{d}$ | 30.28±1.18 | 2.46±0.80 |
| MC × NE100+GE100 | 36.23±1.03 | 1411.73±50.9$^{d}$ | 12.33±0.43$^{d}$ | 30.30±3.22 | 2.47±0.15 |
| P-value | 0.112 | 0.000 | 0.000 | 0.284 | 0.181 |

$^{a,b,c,d,e,f \text{ and } g;}$ Means with different letters in the column represent significant differences at $p < 0.05$. Control: Chickens on 0 ml of extract; NE200: Chickens on 200 ml neem extract; GE200: Chickens on 200 ml ginger extract and NE100+GE100: Chickens on 100 ml of neem + 100 ml ginger extract. IW: Initial weight, FW: Final weight, ADG: Average daily gain, AFI: Average feed intake, FCR: Feed conversion ratio

**Table 3.** Effect of aqueous neem leaf and ginger leaf extract on haematological indices of pure and crossbred chickens aged 16 weeks

| Parameters | Hb (g/dl) | PCV (%) | RBC ($x10^9$/L) | WBC ($x10^9$/L) | Platelet ($x10^9$/L) | MCV ( $\mu m^3$) | MCH (pg) | MCHC (g/dl) |
|---|---|---|---|---|---|---|---|---|
| NN×Control | 7.40±0.22$^{e}$ | 21.85±0.62$^{d}$ | 1.75±0.74 | 9.00±1.38$^{bc}$ | 85.50±8.08$^{a}$ | 146.19±33.1 | 49.95±11.1 | 33.86±0.06 |
| NN×NE200 | 8.85±0.50$^{cd}$ | 29.80±0.72$^{bc}$ | 2.45±0.16 | 7.95±0.62$^{c}$ | 70.95±3.06$^{b}$ | 148.65±1.54 | 41.71±1.52 | 28.05±0.72 |
| NN×GE200 | 8.00±0.22$^{d}$ | 31.93±5.12$^{b}$ | 2.35±0.17 | 8.10±0.68$^{c}$ | 58.35±2.82$^{c}$ | 154.95±16.3 | 48.51±0.12 | 31.56±3.22 |
| NN×NE100+GE100 | 9.00±0.92$^{c}$ | 27.50±5.19$^{cd}$ | 1.35±0.28 | 8.80±1.02$^{bc}$ | 45.20±3.34$^{d}$ | 198.15±34.6 | 40.17±1.65 | 37.71±8.81 |
| HH×Control | 7.05±0.50$^{e}$ | 28.81±2.34$^{c}$ | 3.00±0.46 | 8.65±0.04$^{bc}$ | 88.50±5.88$^{a}$ | 96.86±7.08 | 24.12±5.44 | 24.69±3.80 |
| HH×NE200 | 7.15±0.51$^{e}$ | 30.94±3.78$^{b}$ | 3.50±1.02 | 9.85±0.28$^{b}$ | 67.85±2.94$^{b}$ | 97.24±39.6 | 22.22±8.08 | 23.21±1.16 |
| HH×GE200 | 10.20±0.34$^{b}$ | 36.20±1.14$^{a}$ | 3.35±0.28 | 13.10±0.34$^{a}$ | 55.55±5.82$^{c}$ | 96.85±23.6 | 26.46±0.72 | 28.45±6.20 |
| HH×NE100+GE100 | 10.20±0.80$^{b}$ | 36.69±1.44$^{a}$ | 3.05±0.62 | 12.25±0.62$^{a}$ | 53.30±8.54$^{cd}$ | 123.56±20.8 | 34.75±8.36 | 27.85±2.04 |
| MC×Control | 7.20±0.81$^{e}$ | 28.78±4.26$^{c}$ | 2.85±0.40 | 7.55±0.04$^{c}$ | 85.65±5.70$^{a}$ | 104.14±29.6 | 25.34±0.76 | 25.74±6.62 |
| MC×NE200 | 8.65±0.86$^{cd}$ | 29.32±0.72$^{bc}$ | 3.45±0.98 | 10.00±2.18$^{b}$ | 63.05±8.70$^{bc}$ | 92.01±32.8 | 27.26±10.2 | 29.45±0.62 |
| MC×GE200 | 11.40±0.80$^{a}$ | 36.40±2.18$^{a}$ | 3.35±0.28 | 11.65±1.44$^{a}$ | 68.30±8.76$^{b}$ | 89.59±9.92 | 24.05±2.76 | 26.83±0.10 |
| MC×NE100+GE100 | 10.20±0.34$^{b}$ | 35.53±1.38$^{ab}$ | 3.10±0.46 | 12.20±0.68$^{a}$ | 55.65±6.06$^{c}$ | 116.04±12.7 | 33.16±2.32 | 28.67±1.14 |
| P-value | 0.000 | 0.001 | 0.81 | 0.000 | 0.000 | 0.90 | 0.50 | 0.55 |

$^{a,b,c,d \text{ and } e;}$ Means with different letters in the column represent significant differences at $p < 0.05$. Control: Chickens on 0 ml of extract; NE200: Chickens on 200 ml neem extract; GE200: Chickens on 200 ml ginger extract and NE100+GE100: Chickens on 100 ml of neem + 100 ml ginger extract. Hb: Haemoglobin, PCV: Packed cell volume, RBC: Red blood cell, WBC: White blood cell, MCV: Mean cell volume, MCH: Mean cell haemoglobin, MCHC: Mean cell haemoglobin concentration

**Haematological indices**

The results regarding the effects of aqueous neem leaf and ginger extracts on the haematological indices of pure and crossbred chickens are presented in Table 3. The study revealed no significant interaction effects ($p > 0.05$) on red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), or mean corpuscular hemoglobin concentration (MCHC). However, hemoglobin (Hb), packed cell volume (PCV), white blood cells (WBC), and platelets exhibited significant differences ($p < 0.05$) among treatments.

The highest hemoglobin levels were observed in the main cross (MC) on GE200 (11.40 g/dl), followed by the Heavy Ecotype chickens on GE200 (10.20 g/dl), NE100+GE100 (10.20 g/dl), and the main cross on NE100+GE100 (10.20 g/dl). In contrast, Noiler chickens recorded the lowest hemoglobin levels suggesting that the different genotypes had different Hb concentrations for oxygen consumption. Similarly, the highest PCV values were found in the main cross on GE200, the Heavy Ecotype on GE200 and NE100+GE100, which were comparable to the main cross on NE100+GE100, Heavy Ecotype on NE200, and Noiler on GE200. Moreover, both the main cross and the Heavy Ecotype chickens receiving GE200 and NE100+GE100 had significantly higher ($p < 0.05$) WBC counts than the other treatment groups. This might account for the "hardiness" or strength of the local chicken. The current study's findings are in line with those of Vivian et al. (2015), who hypothesized that increases in key haematological components such as PCV, Hb, RBC, and WBC in birds fed ginger-supplemented diets suggest enhanced oxygen-carrying capacity in cells, which, in turn, increases the availability of nutrients for the birds to use, ultimately contributing to overall better health and a stronger immune system in the chickens. The capacity of ginger to enhance immunity could be ascribed to its antioxidant properties as well as the presence of naturally fragrant active ingredients such as shogoals and gingerol in ginger (Khan et al., 2012). Additionally, according to Ali et al. (2008), ginger has specific anti-inflammatory and anti-oxidant properties that indirectly boost the immunity of the birds. Chickens given aqueous neem leaf and ginger extracts (NE200, GE200 and NE100+GE100) exhibited a significant ($p < 0.05$) decrease in blood platelet count compared to the control group. According to Muhammad and Lakshmi (2007), adding ginger to a fatty diet may help prevent the conversion of arachidonic acid to thromboxane and reduce platelet susceptibility to aggregating agents. This finding suggests that due to its inhibitory effects on platelet aggregation, ginger may help enhance blood circulation. The main haematological indices of the birds (RBC, MCV, MCH, and MCHC) showed a non-significant ($p > 0.05$) interaction effect among all the treatments studied, indicating that the plant extracts had no adverse effects on the formation of blood cells, their function, and their constituents. However, the values

obtained were within the reference ranges for clinically normal chickens (1.35-3.50 x$10^9$/L RBC; 89.59-154.94 µm$^3$ MCV; 24.05-34.75 pg MCH; 23.21-37.71 g/dl MCHC) (Abdulazeez et al., 2016). The significant decrease in haematological markers observed in all birds treated with higher levels of neem is likely due to the triterpenoid found in neem leaves, as noted by Singh et al. (2015). The results of the current study showed that all the haematological parameters investigated fall within the normal reference range for domestic chickens, as defined by Abdulazeez et al. (2016). The findings also indicate that the treatments administered did not have any adverse effect on the chickens.

## CONCLUSION

At 16 weeks of age, the aqueous plant extracts utilized in this study improved the growth performance and haematological parameters of the birds without causing any detrimental effects on their health. It can, therefore, be concluded that NN and MC chickens administered GE200 and NE100+GE100 performed well and that these treatments can serve as suitable alternatives to antibiotic growth promoters without having negative impacts on the physiological traits of the birds. This finding may aid in the selection of superior chickens for genetic improvement, better feed efficiency, promoted growth, and improved health. To achieve the best results, the inclusion of these levels of ginger or neem extracts in chickens' drinking water is recommended.

## DECLARATIONS

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### Authors' contribution

Anizoba Nnenna Winifred performed the experiments, collected data, and interpreted data, writing and editing. Ikeh Nnanna Ephraim and Machebe Ndubuisi Samuel participated in data collection, and data interpretation and they designed the research methodology. Ezenwosu Celestine and Onuorah Samuel Ifeanyichukwu reviewed the literature. Amaefule Bright Chigozie and Regina Damian-Ozoke drafted the article and participated in data collection. Ugwu Chekwube Maureen and Chukwudi Prosper collected the data and revised the manuscript. Ugwuoke Jervas Ikechukwu and Madu Patricia Onyemaechi participated in the data analysis. Udeh Fredrick Ugochukwu and Nwoga Cornelius Chijioke supervised the data collection and revised the manuscript. Ugwu Simeon Ogochukwu, Ndofor-Foleng Harriet Mbunwen, and Onyimonyi Anselm Ego conceptualized and supervised the study. All authors confirmed the final version of the manuscript.

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### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

### Competing interests

The authors have declared no conflict of interest.

### Ethical consideration

The current regulations regarding ethical concerns, such as plagiarism, consent to publication, misconduct, data fabrication and/or falsification, double posting and/or submission, and redundancy have been carefully considered and complied with by the authors to prevent any violations. They have taken necessary measures to ensure that none of these concerns have been overlooked or violated.

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