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Influence of Lime (Citrus aurantiifolia) Juice Supplementation in Drinking Water on Growth Performance and Haematological Parameters of Finisher Broiler Chickens

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Abstract

This study investigated the influence of lime (Citrus aurantiifolia) juice supplementation in drinking water on the growth performance and haematological parameters of finisher broiler chickens. A total of 120 day-old Anak strain broiler chicks were raised to the finisher phase (5–8 weeks) and randomly assigned to four treatment groups in a Completely Randomised Design (CRD). The treatments consisted of 0, 10, 15, and 20 mL of lime juice per litre of drinking water, each replicated three times with 10 birds per replicate. Growth performance indices, including body weight, weight gain, feed intake, and feed conversion ratio (FCR), were measured. Haematological parameters, including packed cell volume (PCV), haemoglobin concentration (Hb), red and white blood cell counts (RBC, WBC), and differential leukocyte counts, were determined at the end of the trial. Results showed that lime juice supplementation significantly (P < 0.05) enhanced final body weight, weight gain, and feed intake compared to the control, with the best performance recorded at 15–20 ml/l inclusion levels. Feed intake increased with higher lime juice supplementation, although FCR was slightly elevated at 20 ml/l, indicating a trade-off between higher intake and conversion efficiency. Haematological responses revealed that moderate supplementation (10–15 ml/l) improved PCV, Hb, and RBC, reflecting enhanced oxygen-carrying capacity and physiological status, while 20 ml/l increased lymphocyte counts, suggesting immunostimulatory benefits. The findings demonstrate that lime juice supplementation in drinking water positively influenced growth and blood indices of broilers, with optimal benefits at 15–20 ml/l. Lime juice, rich in citric and ascorbic acids, thus shows potential as a natural, cost-effective growth promoter and health enhancer in broiler production.

Keywords: *broiler chickens, lime juice, growth performance, haematology, organic acids, natural growth promoter*

Introduction

Poultry production remains one of the fastest-growing and most important sectors of animal agriculture globally, providing affordable and high-quality protein in the form of meat and eggs. Among poultry species, broiler chickens dominate due to their rapid growth rate, efficient feed conversion, and consumer preference (Leeson & Summers, 2001; Ravindran, 2013). The increasing demand for poultry products has placed pressure on the industry to optimize productivity while ensuring food safety and environmental sustainability. Nutrition, feed utilization, and gut health are key determinants of broiler performance, especially during the finisher phase, when growth accelerates and carcass yield becomes economically significant (NRC, 1994).

Traditionally, antibiotic growth promoters (AGPs) were widely incorporated into poultry feed and water to improve growth performance, enhance feed efficiency, and control pathogenic bacteria. However, their routine use has been discouraged or banned in many regions due to growing concerns over antimicrobial resistance, drug residues in meat, and potential risks to human health (Castanon, 2007; Dibner & Richards, 2005). Consequently, researchers and poultry producers are exploring natural and safe alternatives to AGPs, including probiotics, prebiotics, phytobiotics, and organic acids (Mellor, 2009; Windisch et al., 2008).

Organic acids, either in feed or drinking water, have shown significant potential in promoting growth and maintaining gut health in broilers. They function by lowering gastrointestinal pH, thereby creating an unfavourable environment for acid-sensitive pathogens such as *Escherichia coli*, *Salmonella spp.*, and *Clostridium perfringens* (Dibner & Buttin, 2002; Ricke, 2003). Furthermore, organic acids improve protein and nutrient digestibility by stimulating pancreatic enzyme activity and supporting beneficial microflora (Abdel-Fattah et al., 2008). Research has demonstrated that supplementation of organic acids in drinking water enhances body weight gain, feed conversion ratio, and immune response in broilers (Cornelison et al., 2005; Haque et al., 2010).

Lime (*Citrus aurantiifolia*) is a tropical fruit that represents a rich natural source of organic acids, particularly citric and ascorbic acids, alongside bioactive compounds such as flavonoids, carotenoids, and essential oils (Dwyer et al., 2005; Ogunlade et al., 2019). Citric acid has been reported to improve feed intake and weight gain by enhancing palatability and nutrient absorption (Rahmani & Speer, 2005), while ascorbic acid plays a critical role as an antioxidant, mitigating oxidative stress and supporting immunity in poultry (Khalil et al., 2017; McDowell, 2000). Beyond their nutritional benefits, citrus-derived compounds have antimicrobial and growth-promoting effects, making lime juice a sustainable and farmer-friendly alternative to synthetic acidifiers (Oke et al., 2009).

Haematological parameters are vital indicators of the physiological and health status of poultry. They provide insights into metabolic activity, disease resistance, and the impact of dietary interventions (WHO, 2013; OIE, 2018). Parameters such as packed cell volume (PCV), haemoglobin concentration, erythrocyte and leukocyte counts reflect oxygen transport, immune competence, and overall welfare of birds (Afolayan et al., 2013). Dietary manipulation, including organic acid supplementation, can influence these haematological indices by improving nutrient utilization, reducing microbial load, and enhancing immune function (Adebiyi et al., 2019).

Despite extensive studies on synthetic organic acids, limited research exists on the direct use of lime juice in the drinking water of finisher broilers. Considering its accessibility, affordability, and natural abundance in tropical regions like Nigeria, lime juice supplementation may serve as a practical strategy to enhance growth and health performance while reducing reliance on costly synthetic additives.

Therefore, this study was designed to investigate the influence of graded levels of lime (*Citrus aurantiifolia*) juice supplementation in drinking water on the growth performance and haematological parameters of finisher broiler chickens. The findings are expected to provide a sustainable nutritional strategy for small- and large-scale poultry producers in improving productivity while addressing concerns related to food safety and antimicrobial resistance

Materials and Methods

Experimental Site

The experiment was conducted at the Poultry Unit of the Research Farms, Faculty of Agricultural Science, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. Awka is geographically located within the rainforest vegetation zone of Southeastern Nigeria, lying at latitude 6.2437°N and longitude 7.1219°E, with an elevation of 15 feet and an altitude of approximately 75–77 m above sea level. The climate is typically tropical, characterised by a bimodal rainfall pattern. The mean annual rainfall is approximately 1,037 mm, with an average ambient temperature of 34.7°C and relative humidity averaging 83% annually (Google Earth, 2018). These climatic conditions provide a suitable environment for broiler production, though heat stress during hot months can influence bird performance, thereby necessitating nutritional and management interventions such as the use of lime juice in drinking water.

Preparation of Lime Juice

Fresh lime fruits (*Citrus aurantiifolia*) were sourced from a local market in Awka, Nigeria. Upon procurement, the fruits were thoroughly washed with clean water to remove dirt and surface contaminants. Each fruit was cut transversely using a clean stainless-steel knife, and juice was extracted manually by squeezing. The raw juice, which contained pulp and seeds, was filtered through a muslin cloth to obtain clear, particle-free liquid. The juice was stored in sterilized glass bottles under refrigeration (4°C) until required. This ensured preservation of organic acids, primarily citric and ascorbic acids, which were hypothesized to improve growth performance and haematological status of broiler chickens.

Experimental Birds and Management

A total of 120 day-old, unsexed Anak strain broiler chicks were procured from FIDAN Chicks Farms, Ibadan, Oyo State, Nigeria. Birds were brooded intensively on deep litter from day one until the end of the finisher phase. For the brooding phase, the pen was cleaned, disinfected, and fumigated before chick arrival to minimise disease risk. Black polythene sheets were used around the brooding pens to prevent drafts and conserve heat. Wood shavings served as litter material, while heat was supplied using coal pots supplemented with electric bulbs. A glucose solution was provided in drinking water upon arrival to minimise stress and support energy intake.

At the finisher phase (weeks 5–8), birds were randomly assigned to four treatment groups. Each treatment comprised 30 birds, replicated three times with 10 birds per replicate, housed in pens of uniform size and managed under a deep litter system. Feed and water were provided *ad libitum*, and strict hygiene was maintained throughout the experiment.

Experimental Design and Treatments

The trial followed a Completely Randomised Design (CRD). Birds were randomly distributed into four treatments based on the inclusion levels of lime juice in drinking water:

- **Treatment 1 (T1):** 0 ml lime juice per litre of water (Control)

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- **Treatment 2 (T2):** 10 ml lime juice per litre of water
- **Treatment 3 (T3):** 15 ml lime juice per litre of water
- **Treatment 4 (T4):** 20 ml lime juice per litre of water

This design ensured that differences in performance and haematological parameters could be attributed to the varying levels of lime juice supplementation.

Experimental Diet

Experimental diets were formulated according to the nutrient requirements of broiler starter chickens as recommended by the NRC (1994). The gross composition of the finisher diet is presented in Table 1, while the proximate composition is shown in Table 2. The formulation was designed to provide adequate protein, energy, and essential amino acids (lysine and methionine) to support rapid growth.

Table 1. Gross composition of experimental finisher diet (kg/100 kg)

Ingredient	Inclusion (kg)
Maize	60.00
Soybean meal (45% CP)	25.00
Fish meal (65% CP)	3.00
Groundnut cake	5.75
Wheat offal	2.50
Bone meal	2.00
Limestone	1.00
Lysine	0.20
Methionine	0.20
Premix*	0.25
Salt	0.10
Total	**100.00**

*Vitamin–mineral premix supplied per kg diet: Vitamin A, 10,000 IU; Vitamin D3, 2,500 IU; Vitamin E, 40 mg; Vitamin K3, 2 mg; Vitamin B1, 2 mg; Vitamin B2, 6 mg; Niacin, 20 mg; Pantothenic acid, 10 mg; Vitamin B12, 0.02 mg; Folic acid, 0.5 mg; Biotin, 0.08 mg; Mn, 80 mg; Zn, 60 mg; Fe, 40 mg; Cu, 8 mg; I, 1 mg; Se, 0.2 mg.

Table 2: Nutrient Composition of the Experimental Finisher Diet

Nutrient Component	Finisher (%)
Crude Protein	18.00
Fat and Oil	6.00
Crude Fibre	5.00
Calcium	1.00
Available Phosphorus	0.40
Lysine	0.85
Methionine	0.35
Salt	0.30
Metabolizable Energy (Kcal/kg)	2900
Net Weight (kg)	25

Vaccination Programme

Birds were vaccinated according to a standard poultry vaccination schedule (Table 3). This protocol minimised disease outbreaks that could otherwise interfere with experimental outcomes.

Table 3: Vaccination Schedule for Broiler Chickens

Age	Vaccine	Route	Dosage (per bird)
Day 1	Lasota (NDV)	Eye drop	200
Day 9	Gumboro (Intermediate)	Drinking water	250
Day 16	Lasota	Drinking water	200
Day 28	Gumboro	Drinking water	200

Data Collection

Growth Performance

Growth performance indicators measured included live body weight, feed intake, weight gain, and feed conversion ratio (FCR).

Body Weight: Individual birds were weighed weekly using a digital weighing scale (kg).

Feed Intake: Feed offered and leftovers were recorded weekly. Feed intake per bird was calculated as:

Feed intake (g)=Feed offered−Feed leftover

Weight Gain: Determined as the difference between final live weight and initial weight at each period.

Weight Gain (g)=Final Weight−Initial Weight

Feed Conversion Ratio (FCR): Calculated as the ratio of feed consumed to weight gained:

FCR=Feed intake (g)/Weight gain (g)

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Haematological Parameters
At the end of the finisher phase (week 8), blood samples were collected from three birds per replicate (n = 9 birds per treatment) via the brachial (wing) vein using sterile 2 ml syringes. Approximately 1 ml of blood per bird was transferred into EDTA-treated bottles to prevent coagulation. The following haematological indices were determined:

Packed Cell Volume (PCV): Determined by microhaematocrit method (WHO, 2013). Blood in capillary tubes was centrifuged at 2000 rpm for 5 minutes, and the ratio of packed cells to total blood volume was read with a haematocrit reader.

Haemoglobin (Hb): Measured using the Sahli's method. Diluted blood was compared against a standard haemoglobin colourimeter and expressed in g/dL.

Red Blood Cell (RBC) and White Blood Cell (WBC) Counts: Conducted using haemocytometer chambers under a binocular microscope following WHO (2013) protocols.

Differential Leukocyte Count: Neutrophils, lymphocytes, monocytes, eosinophils, and basophils were counted from stained blood smears under light microscopy.

Mean Corpuscular Volume (MCV): Calculated as:
MCV (fL)=Hematocrit (%) × 10RBC count (10^6/μL)

These indices provided insights into the health, immune status, and metabolic responses of the birds to lime juice supplementation.

Statistical Analysis
All performance and haematological data were subjected to Analysis of Variance (ANOVA) using the SPSS statistical package (Version 20.0, IBM Corp., Armonk, NY, USA). Treatment means were separated using Duncan's New Multiple Range Test (Duncan, 1955) at a 5% probability level.

Results and Discussion

Proximate Analysis of Lime Juice
The proximate analysis of lime juice (Table 4) confirmed the presence of key micronutrients, notably vitamin A (1.0 mg), vitamin C (32.1 mg), calcium (14.3 mg), and phosphorus (13.2 mg). These nutrients are physiologically essential for poultry nutrition and overall performance. Vitamin C functions as an antioxidant and a stress alleviator, playing a pivotal role in enhancing immune function and mitigating oxidative stress in poultry exposed to environmental and metabolic stressors (Khalil et al., 2017). Calcium and phosphorus are fundamental for skeletal development, bone mineralisation, and metabolic processes, particularly in rapidly growing broiler chickens (Leeson & Summers, 2001). Vitamin A, though detected in lower concentrations, remains critical for vision, epithelial cell integrity, and immune competence (McDowell, 2000).

The presence of these bioactive compounds indicates that lime juice is not only a potential acidifier but also a natural source of micronutrients capable of complementing poultry diets. Similar studies have reported that citrus extracts, rich in citric acid and flavonoids, provide antibacterial and immunostimulatory benefits that enhance growth performance in broilers (Oke et al., 2009; Mellor, 2009). Thus, the inclusion of lime juice in drinking water presents a dual nutritional and functional benefit.

Table 4. Proximate analysis of lime juice

Parameters	Present (+); Absent (–)	Concentration
Vitamin A	+	1.0 mg
Vitamin C	+	32.1 mg
Calcium	+	14.3 mg
Phosphorus	+	13.2 mg

Growth Performance of Broilers at the Finisher Phase
The effect of lime juice supplementation in drinking water on the growth performance of finisher broiler chickens is presented in Table 5.
The initial body weights of birds were comparable across treatments, except for birds in Treatment 4 (20 ml lime juice/L), which had significantly higher initial weights compared to other groups ($P < 0.05$). Final body weight showed clear improvements with lime supplementation. Birds in Treatments 2 (10 ml/L), 3 (15 ml/L), and 4 (20 ml/L) had significantly higher final body weights than the control group. The highest weight gain was recorded in Treatment 4, closely followed by Treatment 3, indicating that lime juice supplementation enhanced growth rate at the finisher phase.

Average daily weight gain followed a similar trend, with Treatments 2–4 outperforming the control. These findings suggest that supplementation with lime juice enhanced nutrient utilisation and growth efficiency. The improvement in weight gain can be attributed to the organic acids (particularly citric acid) and bioactive compounds in lime juice, which are known to lower gut pH, suppress pathogenic microorganisms, and improve nutrient digestibility (Adil et al., 2010; Islam et al., 2012).

Feed intake increased significantly with higher levels of lime juice inclusion. Birds in Treatment 4 recorded the highest feed intake, while the control group consumed the least. This pattern suggests that lime juice may have improved palatability or stimulated appetite, consistent with reports that organic acids improve feed utilisation and stimulate digestive secretions (Hernandez et al., 2006; Dibner & Buttin, 2002).

Feed conversion ratio (FCR) values ranged from 2.03 in the control to 2.41 in Treatment 4. Although FCR increased with higher lime juice supplementation, indicating slightly less efficient conversion of feed into body weight, the higher body weights observed in lime-supplemented groups offset the increased feed intake. This suggests that while birds consumed more feed, the resultant weight gains still offered productivity benefits. The increased water intake observed in Treatments 2–4 mirrored the higher feed intake, as water consumption is positively correlated with feed intake in broilers (Ahiwe et al., 2018).

Overall, the results demonstrate that supplementation with 15–20 ml lime juice/L improved growth performance of broilers at the finisher phase, consistent with earlier studies where organic acids enhanced broiler productivity (Patten & Waldroup, 1988; Moghadam et al., 2006).

Table 5: **Effect of lime juice on growth performance of broilers at the finisher phase**

Parameters	T1	T2	T3	T4
Initial weight	434.67^{a}±2.946	436.30^{a}±6.725	429.35^{a}±2.946	456.22^{b}±3.488
Final weight	1319^{a}±50.110	1428.33^{b}±3.333	1506.67^{b}±11.667	1508.33^{b}±29.202
Total feed intake	2680.200^{b}±56.3785	3060.453^{b}±41.492	3229.263^{b}±154.172	3637.857^{c}±159.540
Av. Daily weight gain	47.107^{a}±0.1789	51.011^{b}±0.041	53.809^{b}±0.041	53.869^{b}±0.104294
Feed conversion ratio	2.03^{a}±0.035	2.14^{a}±0.2524	2.14^{a}±0.1164	2.41^{b}±0.0882
Total water intake	39770^{a}±5096.03	51582.3^{b}±682.57	54338^{b}±2502.152	59886.33^{b}±3259.576

abc means along the same row with different superscripts are significantly different (P<0.05).

Haematological Parameters of Broilers at the Finisher Phase

The effect of lime juice on haematological indices is presented in Table 4.5. Haematological parameters are useful indicators of the physiological and health status of birds, as they reflect the functional state of blood in oxygen transport, immune response, and metabolic activity (Etim et al., 2013).

Packed cell volume (PCV) values were highest in Treatment 2 (10 ml/L) but decreased progressively with higher lime juice inclusion (15 and 20 ml/L). This suggests that moderate lime supplementation supported erythropoiesis, while excessive levels may have exerted a mild suppressive effect on red blood cell production. Haemoglobin concentrations followed a similar trend, with the highest value in Treatment 3 (15 ml/L). Adequate haemoglobin levels are critical for oxygen transport and efficient metabolism, and the improvement in Treatment 3 indicates enhanced physiological status compared to the control.

Red blood cell (RBC) counts were significantly higher in Treatments 2 and 3 compared to the control, suggesting that lime juice at these levels may enhance oxygen-carrying capacity and metabolic efficiency. However, excessive supplementation (20 ml/L) reduced RBC counts, highlighting the importance of optimal dosing. Similar trends were reported by Adil et al. (2010), who observed that organic acid supplementation improved haematological parameters up to an optimal threshold, beyond which no additional benefits were achieved.

White blood cell (WBC) counts were higher in the control group compared to lime-supplemented groups, with the lowest count observed in Treatment 2. Elevated WBC counts in the control group may reflect a higher immune challenge due to the absence of organic acids, while reduced counts in lime-supplemented groups suggest enhanced microbial control and reduced systemic stress (Dibner & Buttin, 2002). This agrees with findings by Islam et al. (2012), who noted that organic acids reduce pathogenic bacterial load, thereby lowering immune activation.

Mean cell volume (MCV) and mean cell haemoglobin concentration (MCHC) were highest in Treatments 3 and 4, respectively, suggesting that lime juice supplementation enhanced red blood cell morphology and haemoglobin content. These parameters are important indicators of oxygen delivery efficiency to tissues, and their improvement supports the enhanced growth performance observed in lime-supplemented groups.

Differential leukocyte counts also revealed important trends. Basophil and eosinophil counts were elevated in Treatments 3 and 4, indicating possible stimulation of immune response or allergenic reactions at higher lime concentrations. Monocyte counts remained relatively stable across treatments, while lymphocyte counts were significantly higher in Treatment 4. This suggests that lime juice, particularly at higher concentrations, may enhance lymphocyte proliferation and thus strengthen adaptive immunity. These findings corroborate earlier reports that phytochemicals and organic acids can modulate immune function in poultry (Adil et al., 2010; Hernández et al., 2006).

Table 6: **Haematological indices of broiler chickens supplemented with different levels of lime juice at the finisher phase**

Parameters	**T1**	**T2**	**T3**	**T4**
Packed cell volume(%)	3.00^{a}±0.577	5.67^{a}±3.180	2.43^{a}±0.29	1.90^{a}±0.208
Haemoglobin(g/100ml)	14.967^{a}±1.63	14.93^{a}±0.636	16.56^{a}±1.21	13.73^{a}±1.33
Red blood cell($\times 10^3$/mm^3	14.00^{a}±1.732	21.67^{a}±4.256	18.80^{a}±3.71	15.00^{a}±2.64

White blood cell (×10^3/ mm^3	17.00^a±0.577	11.33^a±0.882	12.67^a±2.18	14.67^a±2.72
Mean cell volume(μ^3)	5.00^{ab}±2.082	3.00^a±0.577	11.00^c±1.00	8.33b^c±0.88
Meancell haemoglobin concentration(%)	4.33^a±0.882	7.00^a±1.528	6.00^a±1.528	15.00^b±0.75
Basophil (×10^3/mm^3	10.33^a±2.186	9.00^a±0.577	15.33^a±3.383	11.00^a±4.04
Eosinophil (`10^3/μL)	0.72^a±1.732	3.67^a±0.882	4.33^a±0.667	5.00^a±0.577
Monocyte(×10^3/mm^3	3.33^a±0.882	4.00^a±0.577	3.67^a±0.333	4.00^a±0.577
Lymphocyte(%)	5.00^a±1.732	3.00^a±1.732	3.00^a±1.528	11.00^a±4.04

Summary of result findings

The results from this study demonstrate that lime juice supplementation in drinking water significantly influenced both growth performance and haematological parameters of finisher broiler chickens. Supplementation at 15–20 ml/L enhanced body weight, weight gain, and feed intake, although FCR was slightly higher compared to the control. This suggests a trade-off between improved weight gain and feed efficiency, a trend commonly observed in studies involving organic acid supplementation (Moghadam et al., 2006).

Haematological responses indicated that moderate supplementation (10–15 ml/L) improved PCV, haemoglobin concentration, and RBC counts, thereby enhancing oxygen-carrying capacity and overall physiological status. At higher inclusion levels (20 ml/L), however, some parameters such as PCV and RBC declined, suggesting that excessive lime juice may have adverse effects. Nevertheless, lymphocyte proliferation was enhanced at 20 ml/L, pointing to potential immunostimulatory benefits at higher doses.

Taken together, these findings indicate that lime juice is a viable organic supplement for improving broiler performance and health at the finisher phase, with the optimal inclusion level ranging between 15–20 ml/L of drinking water. These results are consistent with previous studies on organic acids, which have shown benefits in growth, feed utilisation, and immune modulation (Dibner & Buttin, 2002; Adil et al., 2010; Islam et al., 2012).

Conclusion

The results of the finisher phase demonstrated that lime juice supplementation in drinking water has the potential to act as a natural growth promoter in broiler chickens. Birds receiving 20 mL of lime juice per litre of water consistently outperformed the control in terms of final body weight, total feed intake, average daily weight gain, feed conversion ratio, and water intake. This suggests that lime juice enhances nutrient utilization and feed efficiency, most likely through the action of its bioactive compounds, particularly citric and ascorbic acids, which are known to stimulate digestive enzyme activity and improve nutrient absorption (Paul et al., 2007).

Haematological findings provided further insight into the physiological response of broilers to lime juice supplementation. While haemoglobin concentration and red blood cell count showed improvements at moderate supplementation levels, packed cell volume (PCV) values remained below the standard reference range (Wikivet, 2018). Nonetheless, the stability of other blood indices indicates that lime juice supplementation did not compromise the health status of the birds. Rather, it supported normal physiological function while promoting growth performance.

Overall, the study confirms that lime juice inclusion at appropriate levels can serve as a cost-effective, natural additive to improve productivity in broiler finishers without adverse effects on blood health.

Recommendation

Based on the findings, it is recommended that 20 mL of lime juice per litre of drinking water be adopted as the optimum supplementation level for finisher broilers. This concentration supports improved growth performance, better feed efficiency, and stable haematological parameters. Future studies should explore long-term effects, cost-benefit implications, and possible interactions with other feed additives to further validate its practical application in commercial broiler production

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