Vitamin E Supplementation and its Effects on Broiler Performance, Nutrient Absorption and Health Markers

Onaolapo A.A.[1*], Seidu S.[2], Bashir S. A[1], Olatunde A.O.[1]

[1]Department of Agricultural Technology, Federal Polytechnic Ayede, Nigeria

[2]Global Food System Quality and Sustainability, Sheffield Business School, Sheffield Hallam University, UK.

[*]Corresponding Author

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ABSTRACT

Vitamin E plays a critical role in antioxidant defense and immune function in poultry, yet optimal dietary inclusion levels remain poorly defined. This study investigated the dose-dependent effects of dietary vitamin E supplementation on growth performance, nutrient digestibility, and hematological indices in broiler chickens. Ninety-six day-old Marshall broiler chicks were distributed across four dietary treatments with graded vitamin E levels (n = 24 per treatment). Weight gain increased with increasing vitamin E supplementation, resulting in improved feed conversion ratio. Crude protein digestibility showed a positive dose-dependent response ($p<0.001$), while ether extract digestibility decreased with increasing vitamin E supplementation. Hematological parameters demonstrated variable responses to vitamin E levels. Serum biochemistry remained largely unaffected, except for low-density lipoprotein which showed a negative dose-dependent relationship. These findings indicate beneficial effects of vitamin E supplementation on growth performance and protein utilization in broilers. From a practical standpoint, the improved feed conversion ratio and enhanced protein digestibility associated with vitamin E supplementation offer favorable economic returns for commercial broiler production, making it a cost-effective nutritional strategy for poultry farmers.

INTRODUCTION

Protein malnutrition remains a persistent global health challenge, affecting over 820 million people worldwide and disproportionately impacting populations in low- and middle-income countries (UNICEF, 2023). Animalsource foods, particularly poultry products, represent strategically important interventions for addressing concurrent macronutrient and micronutrient deficiencies while promoting sustainable food production systems.

Poultry production has emerged as one of the fastest-growing food production sectors globally, with broiler meat production exceeding 137 million tonnes annually (Bist et al., 2024). This growth reflects several intrinsic advantages: superior feed conversion efficiency (1.7-2.0 kg feed per kg meat gain), rapid production cycles, and exceptional scalability across diverse production environments (Costa, 2009; Mottet & Tempio, 2017). Broiler chickens achieve market weight within six to eight weeks, facilitating rapid capital turnover (Mramba & Mapunda, 2024). Poultry meat exhibits favorable nutritional characteristics including high protein content (2022%), low intramuscular fat, and excellent digestibility (>95% for essential amino acids), making it suitable for diverse dietary requirements (Ajayi, 2010; Bordoni & Danesi, 2017).

Despite its strategic importance, commercial poultry production faces mounting challenges. Feed costs constitute 60-70% of total production expenses, exacerbated by volatile input markets and climate variability (Mengesha et al., 2008). These pressures necessitate integrated strategies for optimizing production efficiency and enhancing flock health resilience through nutritionally optimized diets that precisely meet the complex requirements of modern broiler genotypes.

Oxidative stress, characterized by an imbalance between reactive oxygen species (ROS) production and endogenous antioxidant capacity (Juan et al., 2021), has been identified as a fundamental physiological constraint on broiler productivity and health (Xiao et al., 2011). Under conditions of thermal stress, high stocking densities, or accelerated growth, broilers experience elevated metabolic rates and increased ROS generation, resulting in systemic oxidative damage to cellular lipids, proteins, and nucleic acids (Adebiyi, 2011). This oxidative insult manifests as reduced growth performance, impaired nutrient utilization, immune suppression, and compromised meat quality attributes including colour stability and shelf-life (Rahman, 2007; Simitzis et al., 2012). Consequently, exogenous antioxidant supplementation has become standard practice in commercial poultry nutrition.

Vitamin E comprises eight naturally occurring compounds, four tocopherols (α-, β-, γ-, δ-tocopherol) and four tocotrienols, collectively functioning as lipophilic antioxidants and cell signaling molecules (Szewczyk et al., 2021). α-Tocopherol, the most biologically active isoform in avian species, preferentially accumulates in cellular membranes where it neutralizes lipid peroxyl radicals and interrupts lipid peroxidation (Gao et al., 2010; Pompeu et al., 2018). Beyond antioxidant functions, vitamin E modulates nuclear factor-kappa B (NF-κB) signalling, enhances immune cell activation, amplifies antibody responses, and supports optimal physiological performance during critical developmental and stress periods (Selim et al., 2013). At the production level, adequate vitamin E status enhances lipid stability in meat products, extends shelf-life, and potentially increases economic returns through improved feed conversion efficiency (Buckley & Morrissey, 1992; Kennedy et al., 1992).

While the general importance of vitamin E in poultry nutrition is well-established, critical knowledge gaps persist regarding optimal dietary inclusion levels, dose-response relationships under varied environmental and genetic contexts, and potential interactions with other micronutrients. The dose-dependent effects of dietary vitamin E supplementation on broiler growth performance, apparent nutrient digestibility, hematological health markers, and serum biochemical profiles remain incompletely characterized, particularly within tropical and subtropical production environments characterized by chronically elevated ambient temperatures and corresponding metabolic stressors. Furthermore, the relative cost-effectiveness of varying supplementation strategies and the long-term health implications of different micronutrient fortification approaches warrant systematic investigation to support evidence-based recommendations for commercial poultry producers.

Research Objective

This study was designed to elucidate the dose-dependent effects of dietary vitamin E supplementation on growth performance, apparent nutrient digestibility, hematological parameters, and serum biochemical profiles in broiler chickens under standardized production conditions. The overarching objective was to establish evidence-based recommendations for optimal vitamin E fortification strategies in commercial poultry diets, particularly for tropical and subtropical production environments where oxidative stress challenges are pronounced. This research addresses critical knowledge gaps in vitamin E dose-response relationships and contributes to enhanced productivity, product quality, and flock health resilience in modern poultry production systems.

MATERIALS AND METHODS

Experimental Design and Housing

A Completely Randomized Design (CRD) with four dietary treatments and three replications per treatment was employed. Ninety-six unsexed, day-old Marshall broiler chicks (Gallus domesticus) were obtained from a commercial hatchery (Obasanjo Farms, Nigeria) and housed in twelve pens (3.0 m × 2.5 m each) with eight birds per replicate, providing a stocking density of approximately 10.7 birds per square meter. Wood shavings were used as bedding material and replaced weekly. Artificial heating was provided during brooding (weeks 1-2) using 100-watt incandescent bulbs to maintain pen temperatures at 32-34°C, with gradual temperature reduction in subsequent weeks. Natural ventilation was maintained throughout the trial.

Experimental Diets and Feeding Management

All birds received a common basal diet during a one-week brooding phase prior to treatment allocation. Four isocaloric and isonitrogenous experimental diets were formulated to meet NRC requirements with varying levels

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of vitamin E (α-tocopheryl acetate; Evonik Industries AG, Essen, Germany) supplementation: Treatment 1 (0.5 g/kg), Treatment 2 (1.0 g/kg), Treatment 3 (1.5 g/kg), and (Control, 0 g/kg additional vitamin E). Experimental diets were provided from week two throughout the eight-week trial. Birds were fed ad libitum using linear feeders, with fresh water provided continuously via bell drinkers.

Table 1. Composition of basal feed and feeding time line into plain tubes for serum collection.

Ingredients	Starter 0-4 Weeks	Finisher 4-8 Weeks
Maize (kg)	60	64
Fish Meal (kg)	2	0.3
Soya Bean Meal (kg)	23	19
GNC (kg)	8	7
Wheat bran (kg)	2	4
Bone meal (kg)	2.5	3
Oyster shell (kg)	1.5	1.5
Methionine (kg)	0.2	0.15
L-lysine (kg)	0.2	0.15
Micro mic broiler (kg)	0.3	0.3
Salt (kg)	0.3	0.3
Atox (kg)	0.3	0.3
ME (Kcal)	2793	3001
CP %	21.00	18.90
Fat %	2.10	4.50
Fibre %	3.00	3.25
Ca %	1.05	1.36

Hematological parameters assessed included packed cell volume (PCV; %), hemoglobin concentration (Hb; g/dL), red blood cell count (RBC; × 10^6/μL), and white blood cell count (WBC; × 10^3/μL), determined using an automated hematology analyzer (Sysmex KX-21, Kobe, Japan). Serum samples were obtained by centrifugation at 3,000 × g for 10 minutes and stored at −20°C pending analysis. Serum biochemical parameters analyzed included total protein (TP; g/dL), glucose (mg/dL), total cholesterol (TC; mg/dL), high-density lipoprotein cholesterol (HDL-C; mg/dL), and low-density lipoprotein cholesterol (LDL-C; mg/dL), determined using a semiautomated clinical chemistry analyzer (Cormay Liasys, Piaseczno, Poland).

Statistical Analysis

All data were subjected to one-way analysis of variance (ANOVA) using the General Linear Model procedure. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at $P < 0.05$. Homogeneity of variance was verified using Levene's test, and normality of residuals was assessed through Shapiro-Wilk testing.

Statistical analyses were conducted using SPSS software (version 25.0; IBM Corporation, Armonk, NY, USA). Results are presented as treatment means with standard deviation (SD).

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RESULTS AND DISCUSSIONS

Nutrient Digestibility

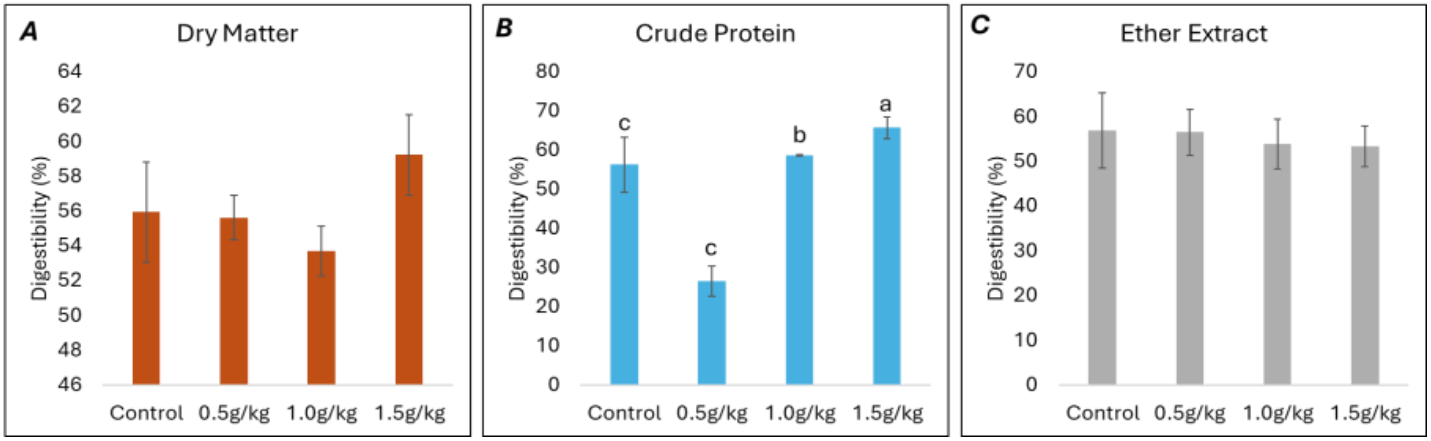

Fig. 1. Shows the means of nutrient digestibility of Dry matter (A), Crude protein (B) and Ether extract (C). Histograms with different annotation are significantly different ($p<0.05$).

Mean dry matter digestibility values ranged from 55% to 59% across treatments, indicating that vitamin E supplementation does not substantially impair overall dry matter digestibility in broiler chickens. The maintenance of dry matter digestibility across treatment groups suggests that the basal diet was formulated to support adequate nutrient availability regardless of vitamin E status.

Crude protein digestibility (CPD) demonstrated a significant positive dose-dependent relationship with dietary vitamin E supplementation (Fig. 1; $P < 0.001$). Birds receiving the control diet exhibited the lowest CPD (56.38%), with progressive increases at higher vitamin E levels, reaching the highest value in Treatment 3 (65.84%). This response suggests that vitamin E enhances intestinal proteolytic enzyme activity, amino acid transporter expression, or intestinal epithelial integrity, facilitating improved protein utilization. Vitamin E's role as a lipophilic antioxidant may stabilize the intestinal epithelium, enhance tight junction integrity, and promote beneficial microbiota populations that optimize protein fermentation and amino acid bioavailability (Reboul, 2017, 2018). Previous research by Selim et al. (2013) demonstrated that physiological vitamin E concentrations can positively influence intestinal permeability and tight junction protein expression, potentially enhancing selective amino acid transport. These findings indicate that adequate vitamin E status is essential for maximizing crude protein utilization efficiency in broiler production systems.

Ether extract digestibility (EED) showed an inverse trend with increasing vitamin E supplementation. Numerical values ranged from 53.43% in Treatment 3 (1.5 g/kg vitamin E) to 56.92% in the control diet. The inverse trend may reflect vitamin E's antioxidant activity altering lipid substrate properties and reducing enzymatic accessibility for pancreatic lipase-mediated hydrolysis. As documented by Loliger (1991), vitamin E functions as a lipophilic antioxidant by intercalating into cellular and lipoprotein membranes, where it effectively scavenges lipid peroxyl radicals. This antioxidant activity, while generally beneficial for preserving lipid nutritional quality, may inadvertently alter the structural and chemical properties of dietary lipids. Enhanced protection against lipid oxidation may modify the hydrophobic surface characteristics of lipid droplets and micelle formation, potentially reducing substrate availability for pancreatic lipase and colipase-mediated hydrolysis (Traber, 2013). Alternatively, suppression of reactive oxygen species signaling, which regulates intestinal tight junction permeability and lipid transport processes, may contribute to this pattern (Ebhohimen et al., 2021; Traber, 2013). These mechanistic insights underscore the complexity of micronutrient interactions in avian digestive physiology and suggest that vitamin E supplementation strategies should consider potential tradeoffs between antioxidant protection and lipid digestive efficiency.

These nutrient-specific responses reveal potential trade-offs in vitamin E supplementation. Enhanced protein digestibility likely reflects improved intestinal epithelial integrity and amino acid transporter function, while the numerical decline in fat digestibility may result from altered lipid substrate properties. Rather than simply

providing greater antioxidant protection, elevated vitamin E supplementation may impose subtle costs on lipid digestive processes. These findings indicate that optimization of vitamin E supplementation must account for macronutrient-specific effects and align with dietary composition and production objectives. Future investigations employing stable isotope tracer studies, intestinal tissue sampling, microbiota profiling, and targeted mechanistic analyses would advance understanding of these divergent digestibility responses and enable more precise optimization of vitamin E supplementation strategies in broiler production systems.

Performance Characteristics

Body weight gain demonstrated a numerical dose-dependent trend with increasing vitamin E supplementation (Fig. 2), with the lowest weight gain (653.36 g) observed in control birds and the highest (712.60 g) in birds receiving 1.5 g/kg vitamin E, representing approximately a 9% increase.

Feed intake differed significantly among treatments ($P < 0.001$). Birds receiving treatments 1 and 2, exhibited feed intake values of 15.30 kg, 15.33 kg, respectively, while treatment 3 and control both exhibited 15.34 kg and differ significantly from other treatments having demonstrated the highest feed intake.

Feed conversion ratios improved with vitamin E supplementation. Treatment 1 (0.5 g/kg vitamin E) exhibited an FCR of 0.0237 g/kg, while treatments 2 and 3 demonstrated numerically improved ratios of 0.0217 g/kg and 0.0216 g/kg, respectively. Control birds had an FCR of 0.0235 g/kg.

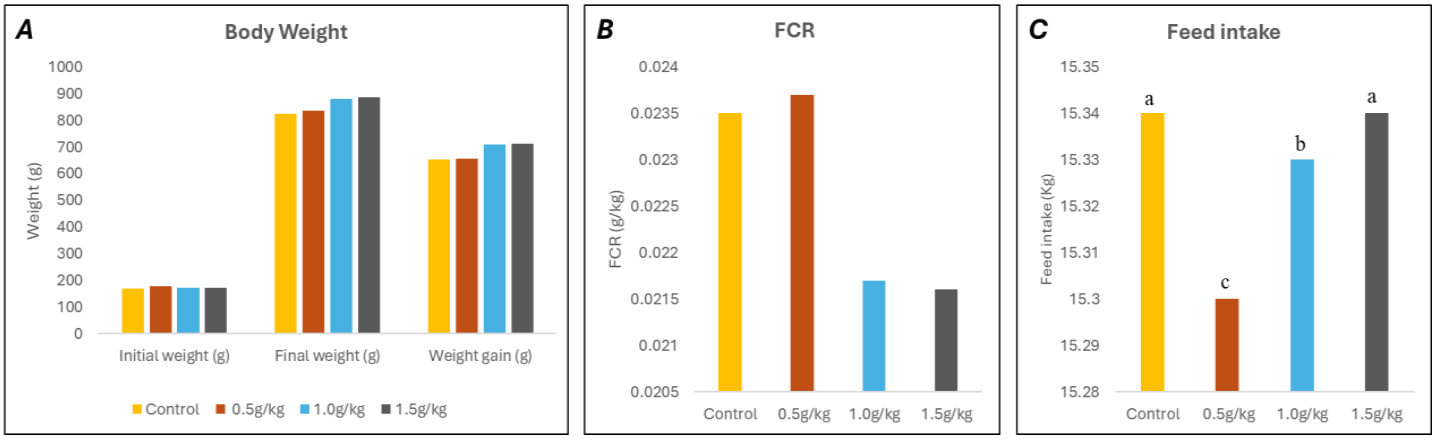

Fig. 2. Shows the broiler performance characteristics with body weight (A) Feed Conversion Ratio (FCR) (B) and Feed intake (C). Histograms with different annotation are significantly different ($p<0.05$).

The numerical dose-dependent improvements in body weight gain and feed conversion ratio align with the enhanced crude protein digestibility observed at higher vitamin E levels. Although growth parameters did not achieve statistical significance, the consistent numerical trends demonstrate potential practical relevance. This finding is consistent with Adebiyi (2011) and Sadiq et al. (2023), who reported no significant differences in final weight and weight gain but observed dose-dependent increases, particularly between control and high supplementation groups. Similarly, Asghar et al. (1991) found that high vitamin E dosages (100-200 mg/kg) significantly improved daily weight gain and feed conversion ratio in pigs. However, the present results is in, contrast with Dalia et al. (2018) and Swain et al. (2000), who reported significant enhancements. These divergent findings across studies underscore the influence of experimental conditions, dietary composition, and supplementation levels on vitamin E efficacy.

The improved crude protein digestibility at higher vitamin E levels, coupled with numerically improved feed conversion ratios, suggests that benefits to amino acid absorption outweigh the numerical reductions in fat digestibility. The enhanced protein digestibility may also support immune function and other physiological processes beyond growth (Coetzee & Hoffman, 2001; Guo et al., 2001).

From a cost-benefit perspective, the lack of significant difference in feed intake between treatment 3 and control is particularly noteworthy. Birds receiving the highest vitamin E supplementation consumed essentially the same

quantity of feed as control birds yet achieved approximately 9% higher weight gain and 8% improvement in FCR, translating to superior feed conversion efficiency. In commercial broiler production where feed costs constitute 60-70% of total expenses, this improved nutrient utilization without increased feed consumption represents a favorable economic proposition. The cost of vitamin E supplementation is minimal compared to the value generated from improved weight gain using the same feed input. This economic advantage becomes magnified at commercial scale, where marginal improvements in feed efficiency translate to substantial cost savings per kilogram of meat produced.

Serum Biochemistry

Total protein concentrations exhibited a dose-dependent increase with increasing vitamin E supplementation, ranging from 3.13 g/dL in control birds to 3.63 g/dL in treatment 3. This finding is consistent with Adebiyi (2011). Triglyceride concentrations also increased with increasing vitamin E supplementation while total cholesterol exhibited considerable variability.

Low-density lipoprotein (LDL) concentrations demonstrated significant treatment effects ($P < 0.001$), with treatments 3 and control exhibiting significantly different values compared to treatments 1 and 2. High-density lipoprotein (HDL) and very low-density lipoprotein (VLDL) concentrations remains variable across all treatments. Serum glucose concentrations remained consistent across all treatments.

Table 2. Illustrates the effect of vitamin E on serum characteristics. Means with different superscripts are significantly different ($p>0.05$)

Treatments				
	(Control)	T1 (0.5g/kg)	T2 (1.0g/kg)	T3 (1.5g/kg)
Triglyceride (mg/dl)	48.28	53.45	49.43	33.80
Glucose (mg/dl)	216.67	197.00	208.00	186.00
Total protein (g/dl)	3.13	3.59	3.33	3.63
Cholesterol (mg/dl)	112.42	105.56	109.57	113.07
High Density Lipoprotein (mg/dl)	118.3	109.38	97.03	109.82
Low Density Lipoprotein (mg/dl)	9.79^{b}	11.17^{a}	10.4^{a}	6.34^{ab}
Very Low Density Lipoprotein (mg/dl)	6.65	10.69	9.87	6.76

DISCUSSION

The numerical increase in total protein concentrations with increasing vitamin E supplementation aligns with the enhanced crude protein digestibility observed in this study. This relationship suggests that improved intestinal amino acid absorption translates to increased circulating protein availability. The approximately 16% increase from control to the highest supplementation level indicates potential biological relevance for protein utilization and tissue accretion, though larger sample sizes are needed to confirm statistical significance.

The reduction in triglyceride concentrations with increasing vitamin E supplementation represents a favorable metabolic outcome, suggesting enhanced lipid utilization or reduced hepatic lipogenesis. Vitamin E's antioxidant properties may protect circulating lipoproteins from oxidative modification, facilitating more efficient lipid metabolism (Pompeu et al., 2018).

The significant differences in LDL cholesterol concentrations across treatments align with findings of Bolukbasi et al. (2006), who reported similar vitamin E-mediated effects on LDL metabolism in poultry. The specific pattern, with treatments 3 and 4 differing significantly from treatments 1 and 2, suggests a complex, non-linear relationship involving vitamin E's antioxidant protection of LDL particles from oxidative modification (Gao et al., 2010) versus enhanced hepatic LDL receptor expression and clearance (Singh et al., 2014). The lack of significant differences in HDL and VLDL suggests vitamin E primarily influences LDL metabolism. The absence of significant effects on serum glucose indicates that vitamin E supplementation does not materially alter carbohydrate metabolism or insulin sensitivity. This stability in glucose homeostasis, coupled with reduced

triglycerides and modulated LDL concentrations, suggests that vitamin E supplementation at 1.0-1.5 g/kg supports favorable metabolic profiles without inducing adverse metabolic perturbations.

These serum biochemical findings complement the nutrient digestibility and performance data, indicating that vitamin E supplementation influences protein metabolism favourably while modulating lipid metabolism in ways that may reduce metabolic disease risk. These metabolic effects likely contribute to the observed improvements in feed conversion efficiency and growth performance.

Haematology

Haemoglobin concentrations exhibited a numerical dose-dependent decrease with increasing vitamin E supplementation levels. Red blood cell (RBC) counts, white blood cell (WBC) counts, and platelet s remained relatively consistent across all treatments.

Packed cell volume (PCV) demonstrated significant differences across treatments ($P < 0.001$). Among differential white blood cell counts, lymphocyte, heterophil, and monocyte percentages all exhibited statistical variation across treatments, while eosinophil counts remained relatively stable.

Table 3. shows the effect of vitamin E on haematological parameters. Means with different superscripts are significantly different ($p>0.05$)

Treatments				
	(Control)	T1 (0.5g/kg)	T2 (1.0g/kg)	T3 (1.5g/kg)
PCV	19.00^{b}	28.25^{a}	26.33^{ab}	24.50^{ab}
Haemoglobin	6.05	9.23	8.40	8.15
Red Blood Cell	1.88	3.18	2.39	2.92
White Blood Cell	12600	17550	16125	19137
Platelet	160.5	189.5	155.5	163.25
Lymphocyte	49.50^{b}	68.00^{a}	70.33^{a}	61.00^{ab}
Heterophil	44.50^{a}	26.00^{b}	24.33^{b}	30.75^{ab}
Monocyte	3.50^{a}	2.00^{b}	1.67^{a}	3.50^{a}
Eosinophil	2.50	3.50	3.67	4.50

DISCUSSION

The dose-dependent decrease in haemoglobin concentrations aligns with findings by Biu et al. (2009) and Akbari et al. (2008), who observed that higher dietary vitamin E levels reduced haemoglobin concentrations in broilers.

This may reflect vitamin E's antioxidant effects on iron metabolism and haemoglobin turnover, as elevated vitamin E may reduce oxidative stress-induced erythropoiesis stimulation (Niki, 2015). The maintained RBC counts despite reduced haemoglobin suggest that vitamin E influences haemoglobin content per erythrocyte rather than erythrocyte production itself.

The significant differences in packed cell volume (PCV) contrast with Akbari et al. (2008), who reported no vitamin E effects on PCV. The significant PCV differences observed, coupled with non-significant RBC count variations, suggest that vitamin E supplementation may modulate erythrocyte size or hydration status through its influence on erythrocyte membrane fluidity and integrity (Stephen et al., 2017).

The significant differences in lymphocyte, heterophil, and monocyte percentages indicate that vitamin E supplementation exerts immunomodulatory effects on circulating leukocyte populations. These findings contrast with Akbari et al. (2008), who reported no significant vitamin E effects on these parameters. The observed alterations suggest that vitamin E influences immune cell distribution, trafficking, or proliferation. Vitamin E regulates T-cell proliferation, cytokine production, and immune cell membrane composition (Lee & Han, 2018). The significant alterations in lymphocyte and monocyte percentages may indicate enhanced immune surveillance

and adaptive immune capacity, potentially contributing to improved disease resistance. The heterophil changes may reflect modulation of innate immune responsiveness.

The absence of significant differences in eosinophil counts aligns with Akbari et al. (2008) and suggests that vitamin E supplementation does not materially affect eosinophil-mediated immune responses. This selective effect underscores the complexity of vitamin E's immunomodulatory mechanisms.

These haematological findings indicate that vitamin E supplementation influences both erythrocyte characteristics and immune cell distribution without causing adverse haematological effects. The maintained RBC, WBC, and platelet counts within normal ranges indicate safe supplementation levels. The immunomodulatory effects on differential white blood cell populations may contribute to the observed improvements in nutrient utilization and growth performance, as optimal immune function supports efficient resource allocation toward productive processes.

CONCLUSION

This study demonstrates that dietary vitamin E supplementation exerts multifaceted, nutrient-specific effects on broiler chicken physiology. Crude protein digestibility showed a significant positive dose-dependent response, reaching optimal values at 1.5 g/kg vitamin E inclusion, while ether extract digestibility exhibited a numerical inverse relationship at higher supplementation levels. These opposing responses underscore that optimization must account for trade-offs in macronutrient utilization efficiency.

Performance parameters revealed favorable outcomes, with final body weight, weight gain, and feed conversion ratio demonstrating dose-dependent improvements. Notably, birds receiving 1.5 g/kg vitamin E consumed essentially the same quantity of feed as control birds yet achieved higher weight gain and FCR, demonstrating superior feed conversion efficiency. Serum biochemical findings showed numerical increases in total protein and reductions in triglycerides, with significant modulation of LDL cholesterol. Haematological parameters revealed significant alterations in packed cell volume and differential white blood cell populations ($P < 0.05$), demonstrating vitamin E's immunomodulatory properties.

From a practical and economic standpoint, these findings support vitamin E supplementation at 1.0 to 1.5 g/kg in commercial broiler diets. The improved feed conversion efficiency achieved without increased feed consumption represents a favorable cost-benefit ratio, as the minimal cost of vitamin E supplementation is outweighed by economic value from improved weight gain and feed efficiency. At commercial scale, the approximately 9% improvement in weight gain and 8% improvement in feed conversion ratio translate to substantial cost savings per kilogram of meat produced. While 1.5 g/kg produced the most favorable outcomes, 1.0 g/kg may represent an economically optimal balance between performance benefits and supplementation costs, depending on market conditions. The consistent improvements across multiple parameters indicate that vitamin E supplementation provides economically meaningful value that justifies its inclusion in commercial broiler feeding programs, particularly where marginal efficiency gains create competitive advantages.

RECOMMENDATIONS

1. Future research should employ larger sample sizes and extended production cycles to establish precise dose-response relationships and evaluate long-term effects on growth performance, carcass characteristics, meat quality, and economic returns across diverse production systems.
2. The immunomodulatory role of vitamin E should be investigated under stress conditions such as heat stress, disease challenges, or high stocking densities common in commercial broiler production.
3. Studies should examine synergistic or antagonistic interactions between vitamin E and other micronutrients, particularly selenium and vitamin C, to optimize comprehensive dietary fortification strategies.
4. Mechanistic studies employing intestinal tissue sampling, microbiota profiling, and molecular analyses of nutrient transporter expression would clarify the divergent effects of vitamin E on protein and fat digestibility observed in this study.

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