p-ISSN 2615-787X e-ISSN 2615-790X
Accredited by Directorate General of Higher Education, Research, and Technology, Republic of Indonesia, No. 225/E/KPT/2022

Tropical Animal Science Journal, July 2026, 49(4):364-371
DOI: https://doi.org/10.5398/tasj.2026.49.4.364
Available online at https://journal.ipb.ac.id/index.php/tasj

Free-Range Rearing as a Welfare-Oriented System: Enhances Growth, Digestibility, and Lipid Traits of Cobb500 Broilers in Tropical Conditions

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(Received 20-03-2026; Revised 30-04-2026; Accepted 05-05-2026)

ABSTRACT

Free-range poultry production has gained increasing attention due to growing consumer demand for systems that promote animal welfare and sustainable meat production. However, information on the suitability of free-range systems for fast-growing broiler strains under tropical conditions remains limited and warrants further investigation. The current study aimed to evaluate the growth performance, behavior, apparent nutrient digestibility, serum lipid profile, and carcass characteristics of broilers reared under the free-range system. A total of 120 Cobb500 broiler chicks (14 days old) were randomly allocated to either a conventional indoor system or a free-range system with outdoor paddock access. Each treatment included 10 replicates of 6 birds reared in 1 × 1 m pens; free-range pens were provided with additional 1 × 6 m outdoor paddocks. Results revealed that free-range birds exhibited higher levels of foraging and locomotion. In contrast, indoor birds spent more time eating and resting throughout their growth period, especially at five weeks of age ($p<0.05$). No significant difference ($p>0.05$) was observed between the two treatments regarding growth performance traits. Meanwhile, broilers reared under a free-range system had significantly higher apparent digestibility of dry matter ($p=0.017$) and ether extract ($p=0.043$). In addition, free-range birds exhibited significantly lower serum triglycerides (−16.95%; $p=0.001$), LDL (−17.20%; $p=0.002$), VLDL (−14.07%; $p=0.023$), and LDL/HDL ratio (−20.00%; $p=0.002$) compared to conventionally reared birds. Abdominal fat content was also significantly reduced (−30%; $p=0.003$) in the free-range group, while other carcass traits remained unaffected ($p>0.05$). In conclusion, although the rearing system did not influence growth performance, free-range conditions improved behavioral expression, nutrient digestibility, and lipid metabolism by reducing serum lipid levels and carcass fatness.

Keywords: behavior; broilers; conventional system; free-range system; lipid profile

INTRODUCTION

Global poultry production faces conflicting challenges; most efforts have focused on increasing poultry productivity to address animal protein deficiency in the human diet (Mir *et al*., 2017). Poultry meat at an affordable price for the average consumer can generally be achieved through intensive production under conventional rearing systems (e.g., deep litter or multilayer cage). In many Western markets, particularly in the EU and the USA, a category of consumers pays close attention to poultry rearing conditions and is willing to pay a premium for products they perceive as safer, more authentic, and produced under higher welfare standards (Mulder & Zomer, 2017; Jin *et al*., 2019; Marchewka *et al*., 2023). In line with these preferences, broiler meat consumption patterns have increasingly shifted toward products from environmentally sustainable, welfare-oriented production systems, although the magnitude of this shift varies across regions and market segments (Amato *et al*., 2022; Campbell *et al*., 2025). Consequently, free-range and organic chicken meat have gained popularity, as they are commonly regarded as healthier and associated with improved animal welfare and management practices compared with conventional confined systems (Rehman *et al*., 2017; Hautefeuille *et al*., 2026).

Growing consumer awareness of broiler welfare, along with varying willingness to pay, has driven the development of diverse husbandry systems that balance animal welfare, environmental sustainability, and product affordability (Papageorgiou *et al*., 2025). At the same time, farm animal welfare has become a major concern for policymakers, consumers, and stakeholders throughout the food supply chain (Sánchez-Casanova *et al*., 2020). Furthermore, research has highlighted that free-range management is a fundamental component of organic farming, as it aligns closely with the natural behaviors and biological needs of animals (Pettersson *et al*., 2016; Jin *et al*., 2019).

Broiler production is increasingly shifting toward higher-welfare systems that incorporate slower-growing strains, lower stocking densities, and enhanced environmental enrichment. In this context, semi-intensive production systems (e.g., free-range, pasture, or organic) with outdoor access are associated with higher animal welfare standards, resulting in improved sensory quality and greater product security (Tong *et al*., 2015; de Jong *et al*., 2022). Recently, consumer preferences have shifted, driven by tremendous advances in human living standards, toward products from hens raised in free-range settings with pasture access (Zheng *et al*., 2021). Conversely, the intensification of broiler chicken farming has been widely associated with compromised broiler welfare. Under intensive conditions, broilers are frequently subjected to high stocking densities, suboptimal ventilation, and musculoskeletal and cardiovascular disorders arising from accelerated growth rates (Nielsen *et al*., 2023; Papageorgiou *et al*., 2025).

An outdoor rearing system requires a moderate climate and abundant vegetation to promote broiler pasture, which is available in tropical and subtropical regions where most developing countries are located. Although these developing countries are more concerned about animal protein shortages than meat quality, they can expand this type of production for export, given the limited local consumption of such expensive natural products, which could be highly profitable (Sánchez-Casanova *et al*., 2020). Some studies have shown that free-range production systems enable birds to display natural behaviors by providing greater space and environmental enrichment, thereby improving living conditions, reducing stress levels, and enhancing health and performance (Martínez-Pérez *et al*., 2023; Safwat *et al*., 2026). There is some research comparing broilers raised in free-range systems with those kept indoors that shows inconsistent results, largely influenced by differences in breed, environmental conditions, and management practices. (Tellis *et al*., 2024; Campbell *et al*., 2025; Hautefeuille *et al*., 2026). Although several studies have investigated free-range systems, most have focused on slower-growing genotypes or temperate environments, with limited integration of behavioral, productive, physiological, and metabolic responses. Consequently, the adaptability and performance of fast-growing commercial broiler strains, such as Cobb500, widely used in intensive production systems, under free-range management in tropical environments, remain poorly understood. Therefore, the present study aimed to provide a comprehensive evaluation of free-range rearing in a tropical production system using a fast-growing commercial genotype, focusing on behavior, growth performance, nutrient digestibility, serum lipid profile, and carcass characteristics of Cobb500 broilers compared with a conventional indoor system. It was hypothesized that free-range rearing would improve bird welfare and physiological status without compromising growth performance.

MATERIAL AND METHODS

Ethics Approval Statement

All experimental procedures involving animals were reviewed and approved by the Bioethical Committee of the Campus de Ciencias Biológicas y Agropecuarias, Universidad Autónoma de Yucatán; approval code: CB-CCBA-PD-2022-001.

Study Site

The experiment was conducted at the poultry research facilities of the Faculty of Veterinary Medicine and Animal Science at the University of Yucatán, in Mérida, Mexico. It took place during winter (December to February) under a tropical sub-humid climate characterized by an annual rainfall of approximately 999 mm and a dry season lasting 6–7 months. During this period, the average daily temperature was 23 °C (ranging from 15 to 32 °C), with a natural photoperiod of 11–13 hours (Sánchez-Casanova *et al*., 2022).

Birds, Treatments, and Experimental Layout

A total of 120 male Cobb500 broiler chicks, 14 days old with an average body weight (BW) of 487.63 ± 28.52 g, were randomly allocated to two treatments: a conventional indoor system (control) and a free-range system with outdoor access, each consisting of ten replicates with six birds per replicate. Birds of each replicate were allocated in a deep litter of wood shavings floor pen (1 × 1 m) under natural ventilation, with standard management practices for commercial broilers. Additionally, a fixed outdoor range area (1 × 6 m) was provided for each free-range treatment pen. The outdoor area lacked grass or herbaceous cover but featured small shrubs that provided partial shade and encouraged natural behaviors and activity. Birds in the free-range group were allowed access to the paddock daily from 08:00 to 17:00.

Throughout the entire experimental period, spanning 14 to 49 days of age, birds in both groups had unrestricted access to feed and water. Feeders and drinkers were located indoors only, ensuring consistent measurement of feed intake. The experimental diet was formulated to satisfy the nutritional requirements according to the guidelines for the strain (Table 1). Individual BW and the feed intake (FI) were recorded weekly, while body weight gain (BWG) and feed conversion ratio (FCR) were determined accordingly.

Behavioral Assessment

On a fixed observation day during weeks 3, 5, and 7 of age, birds were monitored for behavioral activity during two daily sessions (morning and afternoon), each lasting three hours. A 5-minute adaptation period was allowed before observations to minimize disturbance. Behavioral observations were conducted using instantaneous scan sampling at 5-minute intervals. During each scan, all birds within each replicate pen were observed,

Table 1. Composition and chemical analyses (%) of the experimental diet

Ingredients	Composition (%)
Yellow corn	64.65
Soybean meal	30.02
Soybean oil	2.4
Dicalcium phosphate	0.86
Calcium carbonate	1.50
Sodium chloride	0.28
Choline chloride	0.05
Anti-coccidial compound	0.05
Mycotoxin adsorbent	0.10
Antioxidant	0.01
Vitamins premix[1]	0.03
Minerals premix[2]	0.05
Total	100
Chemical analysis (% on DM basis)	
Dry Matter[3]	91.92
Metabolizable Energy (kcal/kg)[3]	3050
Crude protein[3]	18.03
Ether extract[3]	4.27
Crude fiber[3]	2.03
Calcium[4]	0.83
Available phosphorus[4]	0.35
Lysine[4]	0.90
Methionine[4]	0.35
Methionine + Cystine[4]	0.79

Note: [1]Content kg^{-1} of diet: vitamin A, 8000 IU; vitamin D, 2500 IU; vitamin E, 8 IU; vitamin K, 2 mg; thiamine, 1 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; vitamin B12, 0.002 mg; choline, 500 mg; folic acid, 0.5 mg; pyridoxine, 2.2 mg; and biotin, 0.05 mg. [2]Content kg^{-1}: Manganese, 65 mg; iron, 55 mg; copper, 6 mg; iodine, 1 mg; zinc, 55 mg; selenium, 0.3 mg. [3]Analyzed. [4]Calculated.

and the number of individuals performing each behavior was recorded. Observations were carried out in both indoor and outdoor areas for the free-range group, and within the indoor pens for the conventional group. Behaviors were categorized following Castellini *et al.* (2016) into feeding (eating, drinking, pecking, or foraging), movement (locomotion), comfort (dust bathing), and resting (standing idle or lying on the sternum). The observer maintained a consistent observation procedure throughout the study; however, blinding to treatment was not feasible due to the visible differences between rearing systems. Behavioral data were expressed as percentages by dividing the frequency of each behavior by the total number of observations per pen and multiplying by 100.

Apparent Ileal Digestibility

Two days before the end of the experiment, a digestibility trial was conducted to determine the nutrient digestibility of the experimental diet using the indigestible marker technique with 4 g titanium dioxide (TiO_2)/kg of diet. For the trial, 10 broiler chickens per treatment (one bird per replicate) were selected. The digestibility trial lasted for 48 h of diet ingestion to ensure marker dispersion throughout the digestive tract, and then the assigned birds were euthanized by electrical stunning for digesta collection. Ileal digesta were obtained from the segment extending from Meckel's diverticulum to approximately 2 cm proximal to the ileocecal junction, in accordance with Anwar *et al*. (2023). The individual collected ileal digesta samples were freeze-dried, milled to pass through a 0.5 mm screen, and then subjected to chemical analysis. Analyses of dry matter (DM; 934.01), crude protein (CP; 986.06), and ether extract (EE; 920.39) in both diet and digesta samples were performed according to AOAC (2000) methods. Titanium dioxide concentrations were determined using UV absorption spectrophotometry (UV-1700; Shimadzu, Kyoto, Japan). Gross energy (GE) determination was performed using a Parr adiabatic bomb calorimeter (Parr 1261; Parr 94 Instrument Co., Moline, IL, USA). Apparent nutrient digestibility was estimated as the ratio of nutrient to marker in both the diet and ileal digesta, using the equation proposed by Ravindran *et al.* (1999).

Apparent nutrient digestibility (%)=
$$100 \times \{[(N/TiO_2)_d - (N/TiO_2)_{ie}] / ((N/TiO_2)_d\}$$

Where $(N/TiO_2)_d$ = nutrient-to-marker ratio in the diet, and $(N/TiO_2)_{ie}$ = nutrient-to-marker ratio in the ileal digesta.

Blood Collection and Lipid Profile Analyses

At 49 days of age, blood samples were collected from ten randomly selected fasted chickens in each treatment (one bird per replicate). Blood samples (approximately 3 ml) were collected from the wing vein of the assigned birds for the serum lipid profile determination. Serum was prepared by collecting blood samples without anticoagulant, then centrifuging at 3000 rpm for 20 minutes; the serum was stored at –20 °C for subsequent analyses. Serum triglycerides, total cholesterol, and the lipoprotein fractions including high density (HDL), low density (LDL) and very low density (VLDL) were measured using commercial diagnostic kits obtained from sentinel CH Milano, Italy, CALTECH Diagnostics, Inc., Chino, CA, USA and quantified using spectrophotometer (Beckman DU-530, Germany), Diagnostic Products Corporation, Los Angeles, USA according to kits manufacturers recommendations.

Carcass Characteristics and Slaughter Yield

At the end of the experiment (49 d), 20 broilers (10 per treatment, one bird per replicate) with BW near the average to reduce extreme variability in carcass evaluation were selected for slaughter measurements. After cutting the jugular vein, birds were exsanguinated, then mechanically defeathered. The carcass was cut open and eviscerated, after which the empty carcass, gizzard, liver, heart, spleen, small intestine, and abdominal fat were separately weighed and proportioned to the live pre-slaughter body weight to calculate the relative weight of each organ. Weights of the front halves, back halves, breast, and wings were determined and calculated relative to the carcass weight.

Statistical Analysis

A completely randomized design was implemented to evaluate the effects of the two treatments, and data were analyzed using the ANOVA procedure of SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). In this study, the "pen" was defined as the experimental unit; therefore, each treatment comprised 10 experimental units, and no repeated observations were taken for any of the studied traits. Percentage data of behavior traits were subjected to a square root transformation to ensure normality and homogeneity of variance before analysis. Normality of the data was checked using the Shapiro–Wilk test in the SAS UNIVARIATE procedure. All datasets were found to be normally distributed, with Shapiro–Wilk values (W) of 0.90 or higher. The statistical model used for all measurements was as follows:

$$Y_{ij} = \mu + T_i + E_{ij}$$

Where Y_{ij} was an observation, μ was the overall mean, T_i was the effect of treatment, and E_{ij} was the experimental random error.

RESULTS

Behavioral Performance

The behavioral patterns observed across ages demonstrated a clear influence of the rearing system on broiler activity and welfare (Table 2). At 3 weeks of age, no significant differences (p>0.05) were detected between indoor and free-range systems for any behavioral trait; however, numerical trends already indicated higher pecking/foraging and locomotion in free-range birds. By 5 weeks of age, these differences became more pronounced and statistically significant, with free-range broilers exhibiting markedly higher pecking/foraging and locomotion (p=0.018 and 0.045, respectively), accompanied by a reduction in resting behavior (p=0.017) compared to indoor birds. At 7 weeks, although the differences were no longer statistically significant (p>0.05), similar behavioral patterns persisted.

Growth Performance

Table 3 presents the growth performance data of broilers raised in conventional indoor and free-range systems from 14 to 49 days. Both groups had similar initial BW (p=0.258). It was observed that rearing system conditions (conventional or free-range) had no significant effect on final BW, BWG, FI, or FCR.

Apparent Ileal Digestibility

The impact of conventional and free-range rearing systems on apparent nutrient digestibility of broilers is shown in Table 4. It could be observed that the free-range system significantly improved both DM and EE digestibility compared to broilers reared in the conventional system (p=0.017 and 0.043, respectively). However, the rearing system did not influence (p>0.05) the digestibility of either GE or CP.

Serum Lipid Profile

Serum lipid parameters for broilers reared in conventional indoor and free-range systems are presented in Table 5. Compared to birds reared in the traditional indoor system, broilers reared under the free-range system exhibited significantly lower concentrations of serum triglycerides, LDL, and VLDL, as well as LDL-to-HDL ratio (−16.95%, −17.20%, −14.07%, and −20.00%, respectively) compared to indoor birds. Although total cholesterol, HDL levels, and the cholesterol-to-HDL ratio remained statistically unaffected (p>0.05) by the different rearing systems, free-range birds showed a numerical increase in HDL concentrations.

Table 2. Behavioral performance (%) of broilers reared in conventional indoor and free-range rearing systems

Activities (%)	Feeding			Movement	Comfort	Resting
	Eating	Drinking	Pecking/Foraging	Locomotion	Dust bathing	
3 Weeks						
Indoor	16.85	6.02	1.66	3.54	2.36	69.57
Free-range	13.54	6.47	6.13	6.29	3.48	64.09
SEM	2.39	1.87	1.66	1.75	1.37	3.63
p–value	0.500	0.984	0.135	0.355	0.556	0.372
5 Weeks						
Indoor	17.74	5.36	1.37[b]	2.21[b]	1.83	71.49[a]
Free-range	11.89	7.54	9.77[a]	7.63[a]	4.11	59.06[b]
SEM	2.39	1.87	1.82	1.75	1.53	3.26
p–value	0.169	0.388	0.018	0.045	0.288	0.017
7 Weeks						
Indoor	18.18	4.91	0.96	1.06	1.26	73.63
Free-range	12.32	6.83	6.69	5.04	2.89	66.23
SEM	2.25	1.82	1.66	1.53	1.37	3.18
p–value	0.279	0.660	0.135	0.288	0.556	0.307

Note: Values in the same row with different letters are significantly different (p<0.05). SEM: standard error of the mean, p: probability. n=10 for each mean.

Table 3. Performance traits of broilers reared under conventional indoor or free-range systems

Variables	Treatments		SEM	p–value
	Indoor	Free-range		
Initial weight (g)	495.26	494.73	0.689	0.258
Final weight (g)	3413.50	3519.88	52.62	0.175
Body weight gain (g/bird/day)	83.47	86.52	1.51	0.174
Feed intake (g/bird/day)	156.98	160.14	2.43	0.372
Feed conversion ratio (g feed: g gain)	1.88	1.86	0.04	0.616

Note: Values in the same row with different letters are significantly different (p<0.05). SEM: standard error of the mean, p: probability. n=10 for each mean.

Table 4. Apparent nutrient digestibility (%) of broilers in either conventional indoor or free-range rearing systems

Nutrients	Treatments		SEM	p–value
	Indoor	Free-range		
Dry matter	70.13^{b}	72.39^{a}	0.61	0.017
Gross energy	69.86	70.75	0.72	0.396
Crude protein	75.70	74.96	0.57	0.372
Ether extract	74.16^{b}	76.27^{a}	0.71	0.043

Note: Values in the same row with different letters are significantly different (p<0.05). SEM: standard error of the mean, p: probability. n=10 for each mean.

Table 5. Lipid profile of broilers reared under conventional indoor or free-range systems

Variables	Treatments		SEM	p–value
	Indoor	Free-range		
Triglycerides (mg/dl)	32.04^{a}	26.61^{b}	0.99	0.001
Total cholesterol (mg/dl)	114.16	110.92	2.67	0.402
HDL (mg/dl)[1]	83.98	88.48	1.94	0.118
LDL (mg/dl)[2]	29.47^{a}	24.40^{b}	0.78	0.002
VLDL (mg/dl)[3]	6.61^{a}	5.68^{b}	0.26	0.023
Total cholesterol/HDL	1.35	1.39	0.02	0.306
LDL/HDL	0.35^{a}	0.28^{b}	0.01	0.002

Note: Values in the same row with different letters are significantly different (p<0.05). [1]HDL: high-density lipoprotein; [2]LDL: low-density lipoprotein; [3]VLDL: very low-density lipoprotein; SEM: standard error of the mean, p: probability. n=10 for each mean.

Table 6. Carcass characteristics of broilers reared under conventional indoor or free-range systems

Variables	Treatments		SEM	p–value
	Indoor	Free-range		
Slaughter weight (g)	3390	3401	31.27	0.801
Carcass weight (%)	74.96	74.63	0.52	0.658
Liver (%)	1.86	1.90	0.06	0.655
Gizzard (%)	1.14	1.09	0.06	0.587
Heart (%)	0.50	0.45	0.03	0.205
Spleen (%)	0.09	0.12	0.01	0.121
Intestine (%)	4.15	4.39	0.14	0.228
Abdominal fat (%)	0.47^{a}	0.33^{b}	0.03	0.003
Fore half (%)*	61.36	60.79	0.53	0.457
Back half (%)*	38.64	39.21	0.53	0.457
Breast yield (%)*	50.37	50.00	0.52	0.615
Wings (%)*	10.98	10.79	0.30	0.651

Note: Values in the same row with different letters are significantly different (p<0.05). SEM: standard error of the mean, p: probability. *: Proportioned to carcass weight. n=10 for each mean.

Carcass Characteristics

As shown in Table 6, the carcass traits data indicate that the rearing system had minimal effects on the carcass yield of broilers. Relative weights of the carcass or internal organs were not significantly influenced (p>0.05) by the production system. However, a notable exception was observed in abdominal fat deposition, which was significantly lower in free-range birds (p=0.003). Furthermore, carcass cut-out percentages did not differ significantly between the two groups.

DISCUSSION

Free-range birds engaged in a wider variety of activities, particularly foraging, locomotion, and dust bathing. These behaviors are associated with improved welfare because they align with chickens' natural behavior (Baxter *et al*., 2019). Indoor housing, by contrast, restricted opportunities for such behaviors, leading to more feeding and resting. In both systems, foraging and locomotion tended to decline slightly with age, while resting increased. In this respect, broiler chickens maintain a tightly regulated overall energy budget, with resting metabolic demands accounting for an increasingly larger proportion of total energy expenditure as birds mature. This shift limits the energy available for other functions, particularly physical activity, and likely contributes to the progressive decline in locomotor capacity with age (Tickle *et al*., 2018; Bonnefous *et al*., 2024). Consistent with previous behavioral studies, the proportion of time spent in active movement decreases markedly during development, declining from approximately 12% in two-week-old chicks to less than 5% in birds at market weight (Van der Eijk *et al*., 2022; Whittle *et al*., 2025). In parallel, walking speed decreases with increasing body mass, following a pattern similar to that observed for activity levels, with a steep reduction until a critical body weight is reached, after which further changes are minimal. Notably, both mean and peak walking speeds decline substantially as body mass increases, a response that may be attributed to higher body weight and reduced agility in older broilers (Tickle *et al*., 2018; Sánchez-Casanova *et al*., 2022).

The absence of significant differences in growth performance between the conventional indoor and free-range systems suggests that broilers reared outdoors maintained comparable productive efficiency despite increased locomotor activity. This may be explained by a compensatory mechanism in which the higher energy expenditure associated with movement is offset by improved welfare status, reduced chronic stress, and better physiological adaptation. Previous studies have similarly reported no significant differences in growth performance traits between rearing systems (Jin *et al*., 2019; Zheng *et al*., 2021; Safwat *et al*., 2026), indicating that environmental and management conditions may moderate system-related effects. Conversely, some studies have reported either improved or reduced performance under free-range conditions, which may be attributed to differences in environmental variability, including temperature fluctuations, as well as bird-related factors such as genotype and activity level (Haruna *et al*., 2018; Bonnefous *et al*., 2024).

Furthermore, fast-growing broilers often exhibit low sustained activity in free-range environments, spending much of their time resting or near shelters, thereby minimizing additional energy expenditure (Horna *et al*., 2023). Consequently, genetic efficiency, restricted outdoor activity, and compensatory feed intake together may help explain why growth performance often does not differ significantly between free-range and conventional systems. It should be noted that, to reduce the impact of temperature variation, birds in both treatment groups were kept indoors overnight in the present study. Moreover, the commercial broiler breed (used in our study) did not exhibit excessive free-range activity, like local chicken breeds, and this activity decreased as birds aged (Sánchez-Casanova *et al*., 2022).

The improvement in apparent DM and EE digestibility observed in broilers reared under the free-range system could be attributed to the stimulatory effect of free-range activity on digestive enzyme secretion. This may be associated with greater physical activity and the possible ingestion of fibrous material or grit from the available outdoor area. However, this was not directly measured in the present study. Such factors could increase digesta retention time, thereby improving nutrient digestibility and absorption by increasing the digesta exposure period to digestive enzymes and absorptive cells (Wang *et al*., 2015; Kheravii *et al*., 2017). The positive effect of free-range treatment on the digestibility of DM and EE may partially explain how these birds could maintain their growth performance as the indoor birds without increasing FI, despite the excessive energetic demand during free-range activities, which suggests higher efficiency of feed utilization for broilers in a free-range rearing system.

Generally, blood biochemical parameters provide good insight into the physiological and metabolic state of the bird (Jin *et al*., 2019). Determination of these parameters can be used to evaluate stress induced by environmental, housing, managerial, or nutritional conditions in farm animals (Dong *et al*., 2017; Tellis *et al*., 2024). The concentration of lipid parameters in blood serum (including triglyceride, cholesterol, HDL, LDL, and VLDL) is strongly related to lipid metabolism and fat deposition (Ma *et al*., 2014). In this study, the reduced serum triglyceride concentration in the free-range group might be attributed to the excessive physical activity of birds in the range area, leading to decreased fat deposition in adipose tissue. Consistent with this finding, Jin *et al*. (2019) observed a significant decrease in fat deposition in Wannan Yellow chickens as the duration of free-range rearing increased. The observed reduction in serum LDL and VLDL concentrations (the harmful cholesterol fractions) could reflect a better health status of broilers reared under this alternative system. In this regard, previous studies have revealed that the free-range rearing system not only improves the comfort and welfare of birds but also enhances their physiological and health status (Jin *et al*., 2019; Martínez-Pérez *et al*., 2023).

The lack of significant differences in carcass traits between rearing systems indicates that overall tissue accretion was not substantially affected, likely because net energy availability for growth was similar under both conditions (Tong *et al*., 2015). This outcome may be explained by a compensatory energy allocation mechanism, whereby increased energy expenditure from locomotor activity in free-range birds is offset by physiological adaptations that sustain muscle deposition. In contrast, the reduced abdominal fat observed in free-range birds can be attributed to altered energy partitioning, with more metabolizable energy directed toward maintenance and activity rather than lipogenesis (Li *et al*., 2016; Mutibvu *et al*., 2019; Safwat *et al*., 2026). Increased physical activity enhances lipid mobilization and oxidation, thereby limiting fat accumulation while preserving lean tissue growth (Jin *et al*., 2019). Furthermore, improved protein deposition efficiency in free-range birds may be linked to enhanced metabolic efficiency and reduced chronic stress, promoting anabolic processes over fat storage (Połtowicz & Doktor, 2011; Evaris *et al*., 2021). These metabolic responses align with the observed serum lipid profile, indicating reduced lipogenesis and improved nutrient utilization. However, variations reported in the literature, including improved carcass yield under outdoor access (Schreiter *et al*., 2025), likely reflect differences in genotype, management, and environmental conditions.

CONCLUSION

Under the conditions of the present study, free-range rearing did not negatively affect the growth performance of Cobb-500 broilers compared with the conventional indoor system. However, it reduced abdominal fat deposition and improved selected lipid-related serum markers, indicating a favorable shift in body fat metabolism. These findings suggest that free-range production enhances nutrient utilization and carcass composition. Therefore, within the limits of this experiment, free-range rearing can be considered a viable and sustainable production system for welfare-oriented broiler production in tropical environments.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) did not use AI-assisted technologies in the writing process.

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