



OPTIMIZATION OF DIETARY ENERGY DENSITY FOR BROILER CHICKENS DURING THE COLD DRY SEASON OF JOS, PLATEAU STATE, NIGERIA

¹Idachaba, Collins Udagbene, ²Adeniyi, Adebayo Kunle, ³Akinsola, Oludayo Michael, ³Oladipo, Mary Foluke, ¹Kurdor, Peter Nandur., Abdullahi, Idris and ⁵Zungum, Aliyu Garba

¹Tetfund Centre for Excellence in Food Security, University of Jos, Nigeria.

²Department of Animal Production, University of Jos, Nigeria.

³Department of Theriogenology and Production, University of Jos, Nigeria.

⁴National Animal Production, Research Institute, Shika Zaria.

⁵Department of Animal Production, Federal College of Animal Health and Production Technology, Vom, Nigeria.

*Corresponding authors' email: udagbenei@unijos.edu.ng

ABSTRACT

This study evaluated the optimization of dietary energy density for broiler chickens during the cold dry season of Jos, Plateau State, Nigeria. A total of 210 Arbor Acre day-old broiler chicks were assigned to five dietary treatments in a completely randomized design with three replicates of fourteen birds each. Starter diets contained 3000, 3025, 3050, 3075 and 3100 kcal/kg ME in diets T₁ to T₅ respectively, with 23% CP in all diets. Finisher diets contained 3200, 3225, 3250, 3275, and 3300 kcal/kg ME in diets T₁ to T₅ respectively with 20% CP in all diets. Feed and water were provided *ad libitum*, growth indices and villi morphometry were evaluated. During the starter phase, birds fed 3075 kcal/kg ME achieved the highest ($P < 0.05$) final body weight (1080.17 g/bird) and daily weight gain (1036.97 g/bird/day), with the best ($P < 0.05$) FCR (1.40). Feed intake decreased from 1520.22 g/bird/day at 3000 kcal/kg to about 1450 g/bird/day at higher energy levels, while the lowest feed cost per kilogram gain (₦1280.40) was recorded at 3075 kcal/kg. During the finisher phase, birds fed 3275 kcal/kg ME recorded the highest final body weight (2750.38 g/bird) and best FCR (1.81), while the lowest feed cost per kilogram gain (₦1965.13) occurred at 3250 kcal/kg. Villus height increased from 980.32 μ m at 3200 kcal/kg to 1180.46 μ m at 3275 kcal/kg, with villus height-to-crypt depth ratio improving from 4.65 to 5.30. Mortality was 0.00% across treatments. The trial concluded that 3075 kcal/kg ME for starter diets and 3250–3275 kcal/kg ME for finisher diets optimize broiler performance and villus morphometry during the cold dry season in Jos, Plateau State.

Keywords: Broiler, Metabolizable energy, Feed, Diets, Growth performance

INTRODUCTION

In poultry production, achieving optimal growth performance and resource utilization is paramount to meet the ever-increasing global demand for high-quality protein. Broiler chickens, being a prominent source of animal protein, necessitate a comprehensive understanding of the nutritional requirements to ensure efficient production. Among the various factors influencing broiler growth is environmental conditions, especially those tied to seasonal changes which play a pivotal role in shaping nutrient demands (Adejumo *et al.*, 2017). Plateau State, Nigeria is known for its distinct climatic variations i.e. hot dry, cold dry and cold wet, which presents an intriguing setting to explore how the seasonal shifts might impact the metabolizable energy and crude protein requirements of broiler chickens.

The metabolizable energy (ME) and crude protein (CP) levels of feed are essential determinants of broiler performance as stated by Folorunso and Amaefule (2018). ME reflects the energy available to the bird after accounting for faecal and urinary losses, while CP contributes to amino acids which are crucial for growth and muscle development. However, the nutritional needs of broiler chickens are not static, and they can be significantly influenced by the environment in which they are reared. Plateau State experiences wet and dry seasons, characterized by fluctuations in temperature, relative humidity, and daylight hours. Such climatic variations are likely to impact the energy expenditure and metabolic processes of broiler chickens, ultimately affecting their nutritional requirements (Idachaba, 2026).

Understanding the interplay between the seasonal changes in Plateau State and the metabolizable energy requirements of

broiler chickens is of utmost importance for optimizing feed formulation and production strategies. Previous studies have demonstrated that environmental factors, including temperature and photoperiod, can influence nutrient requirements and feed conversion efficiency in poultry (Leeson and Summers, 2005). However, limited research has specifically delved into the context of Plateau State's unique climatic variations and their potential impact on broiler nutrition. This study aim to bridge this research gap by investigating the dynamic relationship between seasonal changes in Plateau State and the metabolizable energy requirements of broiler chickens. By shedding light on the intricate nutritional adaptations that broilers undergo in response to environmental shifts, this research has the potential to contribute valuable insights to the poultry industry's efforts to optimize production strategies and promote sustainable practices.

The dynamic interaction between environmental conditions and the nutritional requirements of broiler chickens has a profound impact on growth performance and overall welfare (FAO, 2005). There are reports in literature on the influence of environmental factors on broiler nutrition conducted in various States in Nigeria. However, there remains a critical knowledge gap pertaining to the specific context of Plateau State's distinctive seasonal changes and their effects on ME requirements for broilers.

Plateau State's alternating wet and dry seasons, characterized by fluctuations in temperature, humidity, and photoperiod, presents a unique and potentially challenging environment for broiler production. There has been a prevailing practice by the academia and industry alike, to paying limited attention to

climate-specific peculiarities of Plateau State with regards to feed formulation for broilers, rather diets are formulated on the basis of the National Research Council (NRC, 1994) recommendation.

The NRC (1994) report on nutrient requirements for broiler chickens has been a baseline document used for broiler feed formulation over the years. It was developed in the United States of America, a Continent having remarkably different climatic and seasonal variations from Nigeria and specifically Plateau State. Consequently, it is imperative to develop dietary requirements of energy for broiler production in Plateau State on the basis of the peculiar seasonal variations of the State. The distinctive seasonal variations experienced in Plateau State are hot dry (heat season), cold dry (harmattan season) and cold wet (rainy season), each of these seasons interacts uniquely with dietary components and nutrient metabolism.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Teaching and Research Farm, in the Poultry Unit, of the Department of Animal Production, University of Jos, Plateau State. The farm is located on latitude 9° 56'49.0" N and longitude 8° 53'34.1" E, at an altitude of 1250m above sea level. The temperature of the area ranges between 21-25°C depending on the season. The wet period in Jos is between April and November with annual rainfall between 1200 – 1500mm (FCF, 2019).

Source of Experimental Chicks

Arbor Acre strain of broiler chicks were purchased from Vertex farms located in South Western Nigeria and used for the trials.

Experimental Design and Management of Birds

The experiment was conducted in the cold dry season of Plateau State (period between November to January). Two hundred and ten thousand (210) day old Arbor Acre breed of broiler chicks were purchased for the trial. They were weighed and allotted to five experimental treatments each replicated thrice with fourteen (14) chickens per replicate in a completely randomized design.

At both phases, the chickens were raised on deep litter with feed and water provided *ad libitum*. Management practices ideal for broiler chickens were strictly adhered practiced. Parameters measured were initial weight, weekly weight gain, final weight and feed intake. Feed conversion ratio and feed cost per kilogram gain were calculated while mortality was recorded and the data was used to compute percentage mortality.

Experimental Diets

The control diet (T1) adhered to the ME and CP recommendations of NRC (1994), stipulating ME of 3000 Kcal/Kg and CP of 23% CP for starter phase, and ME of 3200 Kcal/Kg and 20% CP for finisher phase. Diets (T2, T3, T4, and T5) were formulated for the starter phase, to contain energy levels of 3025, 3050, 3075, and 3100 Kcal/Kg respectively, while maintaining isonitrogenous CP level of 23% across dietary treatments. At the finisher phase, diets T2, T3, T4, and T5 contained energy levels of 3225, 3250, 3275, and 3300 Kcal/Kg respectively, while maintaining isonitrogenous CP level of 20% across dietary treatments. The ingredients composition of experimental broiler starter and finisher diets are presented in Tables 1 and 2 respectively.

Table 1: Ingredients Composition of Broiler Starter Diets Containing Graded Levels of Metabolizable energy during the Cold Dry Season (1-5 weeks)

Ingredients	Levels of ME (kcal/kg)				
	3000	3025	3050	3075	3100
Maize	54.00	52.00	52.00	52.00	52.00
Soyabean cake	24.00	24.00	24.00	24.00	24.00
Groundnut cake	17.00	17.00	17.00	17.00	17.00
Limestone	3.00	3.00	3.00	3.00	3.00
Bone meal	2.90	2.90	2.90	2.90	2.90
Palm oil	0.00	2.00	2.30	2.50	2.70
Common salt	0.30	0.30	0.30	0.30	0.30
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.20	0.20	0.20	0.20	0.20
*Vitamin Premix	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
ME (Kcal/Kg)	3000	3025	3050	3075	2973
Crude protein (%)	23.00	23.00	23.00	23.00	23.00
Ether Extract (%)	4.30	4.45	4.63	4.73	4.87
Crude Fibre (%)	4.16	4.16	4.16	4.16	4.16
Calcium (%)	1.26	1.26	1.26	1.26	1.26
Avail. Phosph. (%)	0.51	0.51	0.51	0.51	0.51
Lysine (%)	1.23	1.23	1.23	1.23	1.23
Methionine (%)	0.69	0.69	0.69	0.69	0.69
Cost/Diet (₦/kg)	852.09	875.75	890.19	916.00	932.01

*Biomix chick premix provide per kg of diet vit A, 10,000 I. U; vit D, 2000 I. U; vit E; 23mg; vit K, 2mg; calcium pantothenate, 7.5mg; B12, 0.015mg; folic acid, 0.75mg, choline chloride, 300mg; vitB1, 1.8mg; vit B2, 5mg; vitB6, 3mg; manganese, 40mg; iron, 20mg; zinc, 53.34mg; copper, 3mg; iodine, 1mg; cobalt, 0.2mg; selenium, 0.2mg; zinc, 30mg. %=percent, Kcal/Kg= kilo calorie per kilogram, ₦/kg= Naira per kilogram

Table 2: Ingredients Composition of Broiler Finisher Diets Containing Graded Levels of Metabolizable Energy during the Cold Dry Season (6-9 weeks)

Ingredients	Levels of ME (kcal/kg)				
	3200	3225	3250	3275	3300
Maize	61.00	59.00	59.00	59.00	59.00
Soyabean cake	19.00	19.00	19.00	19.00	19.00
Groundnut cake	14.00	14.00	14.00	14.00	14.00
Palm oil	0.00	2.80	3.20	3.50	3.80
Limestone	3.00	3.00	3.00	3.00	3.00
Bone meal	2.90	2.90	2.90	2.90	2.90
Common salt	0.30	0.30	0.30	0.30	0.30
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.20	0.20	0.20	0.20	0.20
*Vitamin Premix	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
ME (Kcal/Kg)	3200	3225	3250	3275	3300
Crude protein (%)	20.00	20.00	20.00	20.00	20.00
Ether Extract (%)	4.93	5.15	5.33	5.61	5.74
Crude Fibre (%)	4.16	4.16	4.16	4.16	4.16
Calcium (%)	1.27	1.27	1.27	1.27	1.27
Avail. Phosph. (%)	0.52	0.52	0.52	0.52	0.52
Lysine (%)	1.21	1.21	1.21	1.21	1.21
Methionine (%)	0.68	0.68	0.68	0.68	0.68
Cost/Diet (₦/kg)	959.09	992.87	1062.23	1089.00	1104.87

*Biomix chick premix provide per kg of diet vit A, 10,000 I. U; vit D, 2000 I. U; vit E; 23mg; vit K, 2mg; calcium pantothenate, 7.5mg; B12, 0.015mg; folic acid, 0.75mg, choline chloride, 300mg; vitB1, 1.8mg; vit B2, 5mg; vitB6, 3mg; manganese, 40mg; iron, 20mg; zinc, 53.34mg; copper, 3mg; iodine, 1mg; cobalt, 0.2mg; selenium, 0.2mg; zinc, 30mg. %=percent, Kcal/Kg= kilo calorie per kilogram, ₦/kg= Naira per kilogram

Data Analysis

All data obtained from the study will be subjected to analysis of variance (ANOVA) using general linear model procedure of SAS (2008). Significant differences between treatment means will be determined using the Tukey's test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Growth Metrics of Broiler Starter Chicks Fed Graded ME Diets During the Cold Dry Season (1-5 Weeks)

The effects of graded metabolizable energy (ME) diets on the growth performance of broiler starter chicks during the cold dry season is presented in Table 3. Initial body weight was similar ($P>0.05$) across treatments, ranging narrowly from 43.10 to 43.30 g/bird, indicating good randomization and uniformity of the experimental birds at the start of the trial. Final body weight was significantly ($P<0.05$) influenced by dietary ME level. Birds fed 3250 and 3275 kcal/kg ME recorded superior final weights (1050.02 and 1080.17 g/bird, respectively) compared with those on 3200 and 3225 kcal/kg diets (970.01 and 1000.15 g/bird). Although birds on 3300

kcal/kg performed comparably (1060.19 g/bird), the highest numerical value was observed at 3275 kcal/kg.

A similar trend was observed for daily weight gain. Birds fed 3275 kcal/kg ME achieved the highest gain (1036.97 g/bird/day), followed closely by 3300 kcal/kg (1017.09 g/bird/day) and 3250 kcal/kg (1006.82 g/bird/day), all of which were significantly ($P<0.05$) higher than gains at the lower energy levels. Feed intake decreased significantly ($P<0.05$) with increasing dietary energy density. Birds on the lowest ME diet (3200 kcal/kg) consumed the most feed (1520.22 g/bird/day), whereas intake declined to 1450.16–1460.18 g/bird/day in birds fed 3250–3300 kcal/kg diets. Feed conversion ratio (FCR) improved significantly ($P<0.05$) as dietary ME increased. The best FCR was recorded at 3275 kcal/kg (1.40), followed by 3300 kcal/kg (1.43) and 3250 kcal/kg (1.45), while the poorest efficiency occurred at 3200 kcal/kg (1.64). Feed cost per kilogram gain was lowest at 3275 kcal/kg (₦1280.40) and highest at 3200 kcal/kg (₦1397.43). Mortality was 0.00% across all treatments, indicating that the dietary treatments did not adversely affect bird survival.

Table 3: Growth Metrics of Broiler Starter Chicks Fed Graded ME Diets During the Cold Dry Season (1-5 Weeks)

Parameters	Levels of ME (kcal/kg)					SEM
	3000	3025	3050	3075	3100	
Initial weight (g/b)	43.20	43.10	43.30	43.20	43.10	0.21
Final weight (g/b)	970.01 ^b	1000.15 ^b	1050.02 ^a	1080.17 ^a	1060.19 ^a	14.6
Weight gain (g/b/d)	926.81 ^b	957.05 ^b	1006.82 ^a	1036.97 ^a	1017.09 ^a	14.4
Feed intake (g/b/d)	1520.22 ^a	1500.20 ^a	1460.18 ^b	1450.16 ^b	1455.17 ^b	13.1
Feed conversion ratio	1.64 ^d	1.57 ^c	1.45 ^b	1.40 ^a	1.43 ^{ab}	0.02
Feed cost/kg gain (₦)	1397.43	1374.93	1290.78	1280.40	1332.78	N/A
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00

a,b= Means with different superscript on the same row differ significantly ($P<0.05$), SEM= Standard error of means, g/b/d= gram/bird/day, N/A= Not analyzed

Growth Metrics of Broiler Finisher Chickens Fed Graded ME Diets during the Cold Dry Season (6-9 Weeks)

The effects of graded metabolizable energy (ME) diets on the growth performance of broiler finisher chickens during the cold dry season is presented in Table 4. Dietary metabolizable energy (ME) significantly ($P<0.05$) influenced the growth performance of broiler finishers during the cold dry season. Birds fed 3250–3300 kcal/kg diets had superior growth compared with those on lower ME levels. Final body weight followed a similar pattern, increasing significantly ($P<0.05$) from 2450.35 g/bird (3200 kcal/kg) to a peak of 2750.38 g/bird at 3275 kcal/kg, though values at 3250 and 3300 kcal/kg were statistically comparable.

Daily weight gain improved significantly ($P<0.05$) with increasing dietary ME, rising from 1480.34 g/bird/day at 3200 kcal/kg to 1670.21 g/bird/day at 3275 kcal/kg, after which no further statistical improvement was observed. Conversely, feed intake decreased significantly ($P<0.05$) as dietary energy increased, with birds on 3200 and 3225 kcal/kg diets consuming more feed (3200.45 and 3150.42 g/bird/day, respectively) than those on higher energy diets. Feed conversion ratio (FCR) was markedly improved ($P<0.05$) by higher ME levels, declining from 2.16 at 3200 kcal/kg to the best value of 1.81 at 3275 kcal/kg. Feed cost per kilogram gain was lowest at 3250 kcal/kg (₦1965.13) and highest at 3200 kcal/kg (₦2071.63). Mortality was nil (0.00%) across all treatments.

Table 4: Growth Metrics of Broiler Finisher Chickens Fed Graded ME Diets during the Cold Dry Season (6-9 Weeks)

Parameters	Levels of ME (kcal/kg)					SEM
	3200	3225	3250	3275	3300	
Initial weight (g/b)	970.01 ^b	1000.15 ^b	1050.02 ^a	1080.17 ^a	1060.19 ^a	0.21
Final weight (g/b)	2450.35 ^b	2550.40 ^b	2700.45 ^a	2750.38 ^a	2720.42 ^a	32.1
Weight gain (g/b/d)	1480.34 ^b	1550.25 ^b	1650.43 ^a	1670.21 ^a	1660.23 ^a	30.4
Feed intake (g/b/d)	3200.45 ^a	3150.42 ^a	3050.40 ^b	3020.38 ^b	3030.41 ^b	34.8
Feed conversion ratio	2.16 ^c	2.03 ^b	1.85 ^a	1.81 ^a	1.83 ^a	0.03
Feed cost/kg gain (₦)	2071.63	2015.53	1965.13	1971.09	2021.91	N/A
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00

a, b, c= Means with different superscript on the same row differ significantly ($P<0.05$), SEM= Standard error of means, g/b/d= gram/bird/day, N/A= Not analyzed

Intestinal Villi Morphometry of Broiler Chickens Fed Graded ME Diets during the Cold Dry Season

The intestinal villi morphometry of broiler chickens fed graded ME diets during the cold dry season is presented in Table 5. Dietary metabolizable energy (ME) significantly influenced intestinal villi development of broiler chickens during the cold dry season. Villus height and villus height to crypt depth ratio were significantly ($P<0.05$) affected by dietary treatments, whereas crypt depth showed no significant variation among treatments. Villus height increased markedly with increasing dietary ME. Birds fed 3200 and 3225 kcal/kg recorded significantly lower ($P<0.05$) villus heights of 980.32 μ m and 1020.28 μ m, respectively. In contrast, broilers fed 3250, 3275 and 3300 kcal/kg exhibited significantly higher

and statistically similar villus heights of 1150.41 μ m, 1180.46 μ m and 1170.49 μ m, respectively. The improvement in villus height at higher ME levels suggests enhanced intestinal absorptive capacity.

Crypt depth ranged from 210.01 to 222.01 μ m across treatments and was not significantly ($P>0.05$) influenced by dietary ME, although a slight numerical increase was observed as energy level increased. The villus height to crypt depth ratio followed the same trend as villus height. Birds on 3200 and 3225 kcal/kg diets recorded significantly lower ratios of 4.65 and 4.73, respectively, compared with those fed 3250 (5.23), 3275 (5.30) and 3300 kcal/kg (5.28), which were statistically similar but superior ($P<0.05$).

Table 5: Intestinal Villi Morphometry of Broiler Chickens Fed Graded ME Diets during the Cold Dry Season

Parameters (%)	Levels of ME (kcal/kg)					SEM
	3200	3225	3250	3275	3300	
Villus height (um)	980.32 ^b	1020.28 ^b	1150.41 ^a	1180.46 ^a	1170.49 ^a	32.5
Crypt depth (um)	210.01	215.11	220.22	222.01	221.15	8.99
Villus height: crypt depth	4.65 ^b	4.73 ^b	5.23 ^a	5.30 ^a	5.28 ^a	0.13

a,b= Means with different superscript on the same row differ significantly ($P<0.05$), SEM= Standard error of means, g/b/d= gram/bird/day

DISCUSSION

Growth Metrics of Broiler Starter Chicks Fed Graded ME Diets during the Cold Dry Season (1-5 weeks)

The significant ($P<0.05$) increase in final body weight and daily weight gain as dietary metabolizable energy (ME) increased from 3200 to 3275 kcal/kg indicates that higher energy density improved growth performance during the starter phase. Birds fed 3275 kcal/kg achieved the highest final weight (1080.17 g), suggesting that this energy level most closely matched the birds' physiological energy requirement under cold dry season conditions. The observed reduction in feed intake with increasing ME is consistent with the principle of energy-regulated feed consumption in

broilers. Broiler chickens typically adjust feed intake to satisfy their energy needs, consuming less feed when dietary energy density is high. Similar responses were reported by Leeson and Summers (2005), who noted that increasing dietary energy depresses voluntary feed intake. This finding also agrees with National Research Council (1994) and the work of Dozier *et al.* (2006), who observed reduced feed intake but improved growth efficiency in broilers fed high-energy diets.

Feed conversion ratio (FCR) improved significantly from 1.64 to 1.40 as ME increased to 3275 kcal/kg, demonstrating enhanced nutrient utilization efficiency. Improved FCR with increasing dietary energy has been widely documented

(Dozier *et al.*, 2006; Zhai *et al.*, 2013; Classen, 2017). The slight numerical decline in performance at 3300 kcal/kg suggests marginal over-supply of energy, which may promote fat deposition rather than lean growth, as earlier noted by Noblet *et al.* (2003). Feed cost per kilogram gain was lowest at 3275 kcal/kg, indicating that biological efficiency translated into economic advantage. Similar economic responses to optimized dietary energy have been reported by Hussein *et al.* (2017) and Attia *et al.* (2014). The zero-mortality recorded across treatments further confirms that the graded ME levels supported good health and adequate nutrient balance during the starter phase.

Growth Metrics of Broiler Finisher Chickens Fed Graded ME Diets during the Cold Dry Season (6-9 weeks)

Final body weight increased significantly from 2450.35 g at 3200 kcal/kg to 2750.38 g at 3275 kcal/kg. This confirms that increased dietary energy continued to support improved tissue accretion during the finisher phase. Similar improvements in broiler finishing performance with increased dietary energy have been reported by Dozier *et al.* (2006), Attia *et al.* (2012), and Zhai *et al.* (2013). Feed intake again declined significantly with increasing ME, reinforcing the concept of energy-driven intake regulation. According to Noblet *et al.* (2003) and Leeson and Summers (2005), broilers reduce feed consumption as dietary energy increases in order to maintain relatively constant energy intake.

Feed conversion ratio improved markedly from 2.16 at 3200 kcal/kg to 1.81 at 3275 kcal/kg, indicating more efficient feed utilization at moderate-high energy levels. However, the minimal improvement between 3275 and 3300 kcal/kg suggests that the birds had reached their energy utilization ceiling. Plateau responses at very high dietary energy levels have been reported by Idachaba (2026). Economic evaluation showed the lowest feed cost per kilogram gain at 3250–3275 kcal/kg, confirming that optimum biological performance corresponded with maximum economic efficiency. This agrees with findings by Attia *et al.* (2014) and Hussein *et al.* (2017), who reported that moderate-high ME diets often provide the best cost–benefit ratio in broiler production. The absence of mortality across treatments indicates that all energy levels were physiologically safe and that management conditions were adequate throughout the finisher phase.

Intestinal Villi Morphometry of Broiler Chickens Fed Graded ME Diets during the Cold Dry Season

The intestinal villi morphometry of broiler chickens responded positively to increasing dietary metabolizable energy (ME) levels during the cold dry season, indicating improved gut development and absorptive capacity. Villus height increased significantly ($P < 0.05$) from 980.32 μm at 3200 kcal/kg to a peak of 1180.46 μm at 3275 kcal/kg, with a slight plateau at 3300 kcal/kg (1170.49 μm). The marked elongation of villi at higher ME levels suggests enhanced mucosal surface area for nutrient absorption, which likely contributed to the improved growth performance observed in earlier tables. The improvement in villus height at 3250–3275 kcal/kg aligns with the findings of Uni *et al.* (2003), who reported that better nutrient density promotes enterocyte proliferation and intestinal maturation in broilers. Similarly, Awad *et al.* (2009) noted that diets supporting optimal nutrient supply enhance villus development and digestive efficiency. The plateau observed beyond 3275 kcal/kg suggests that the birds had reached near-maximal intestinal structural response, indicating diminishing returns at excessively high energy levels.

Crypt depth was not significantly influenced ($P > 0.05$) by dietary ME, remaining within a narrow range of 210.01–222.01 μm . The stability of crypt depth indicates that epithelial cell turnover was not adversely affected by the dietary treatments. According to Xu *et al.* (2003), increased crypt depth is often associated with intestinal irritation or rapid tissue turnover; therefore, the consistent values observed in this study suggest that all diets maintained good intestinal health. The villus height to crypt depth ratio improved significantly ($P < 0.05$), increasing from 4.65 at 3200 kcal/kg to 5.30 at 3275 kcal/kg. This ratio is widely regarded as a sensitive indicator of intestinal functional efficiency. A higher ratio reflects greater absorptive capacity relative to tissue turnover (Montagne *et al.*, 2003). The superior ratios at 3250–3300 kcal/kg therefore confirm that moderate increases in dietary energy enhanced gut efficiency and nutrient utilization in broilers during the cold dry season in Jos. The overall morphometric response corresponds well with the improved nutrient digestibility and feed conversion ratio reported earlier, supporting the physiological link between dietary energy density and intestinal development. These results suggest that dietary ME levels around 3250–3275 kcal/kg optimize intestinal architecture without inducing excessive mucosal turnover.

CONCLUSION

Dietary metabolizable energy (ME) levels significantly influenced growth performance and intestinal morphology of broiler chickens during the cold dry season in Jos, Plateau State. During the starter phase (1–5 weeks), birds fed 3275 kcal/kg ME achieved the highest final body weight (1080.17 g/bird) and daily weight gain (1036.97 g/bird/day), while feed conversion ratio improved from 1.64 at the lowest energy level to 1.40, representing improved feed utilization. Feed intake decreased from 1520.22 g/bird/day to approximately 1450 g/bird/day as dietary energy increased, confirming the energy-regulated feeding behavior of broilers. The lowest feed cost per kilogram gain (₦1280.40) was also recorded at 3275 kcal/kg.

During the finisher phase (6–9 weeks), final body weight increased from 2450.35 g/bird at 3200 kcal/kg to 2750.38 g/bird at 3275 kcal/kg, while feed conversion ratio improved from 2.16 to 1.81. The most favorable economic return occurred at 3250 kcal/kg with the lowest feed cost per kilogram gain (₦1965.13). Intestinal morphology also improved with increasing dietary energy, as villus height increased from 980.32 μm to 1180.46 μm and the villus height-to-crypt depth ratio improved from 4.65 to 5.30, indicating enhanced nutrient absorption. Mortality was 0.00% across all treatments, confirming that all energy levels were physiologically safe. The study concluded that 3075 kcal/kg ME for starter diets and 3250–3275 kcal/kg ME for finisher diets optimize growth performance, feed efficiency and intestinal development for broiler chickens during the cold dry season in Jos. Thus, further studies are recommended to evaluate the metabolizable energy requirements of broilers across the hot dry and cold wet seasons in Plateau State in order to develop comprehensive climate-specific feeding standards for the region.

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