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Research Article

Impacts of Phase Feeding Schedules on Performance and Economic Efficiency in Broiler Chickens

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ABSTRACT

Introduction: Family and small-scale poultry farms play important roles in livelihoods in Nigeria. Optimizing phase-feeding transitions could prevent growth loss or unnecessary feed expenses, enhance growth performance, reduce costs, and improve overall profitability. The present study aimed to identify the most effective timing of phase-feeding by evaluating key growth performance indicators alongside economic returns in broiler chickens.
Materials and methods: A total of 160-day-old Abor Acre broiler chickens were divided into five groups, each with four replicates of eight chickens, based on weight equalization ranging from 38.56 to 39.13 grams. The control group had the starter phase of 0-28 days and finisher of 29-42 days (T1), the second group had a starter phase of 0-7 days and finisher of 8–42 days (T2). The third group included a starter phase of 0-14 days and a finisher of 15-42 days (T3). The fourth group had a starter phase of 0-8 days, a grower of 9-21 days, and a finisher of 22-42 days (T4), and the fifth group included a starter phase of 0-10 days, a grower of 11-24 days, and a finisher of 25-42 days (T5), arranged in a completely randomized design. The nutrient composition of the diets was determined for groups. Final body weight and economic metrics, such as total revenue, net income, and estimated profit, were derived from growth parameters and feed costs over 42 days.
Results: The current results indicated that chickens in T4 had significantly higher final body weight (1915.34 ± 169.40 grams) and weight gain (1876.24 ± 169.34 grams) compared to other groups. Feed intake, feed conversion ratio, and feed cost per kilogram of body weight gain did not differ significantly across the groups. However, T4 resulted in the lowest feed cost per kg gain (711.42 ± 58.77 ₦ = 0.576 USD). Additionally, chickens in T4 achieved higher total revenue at 4224.00 ₦ (3.4201 USD), net income at 1611.44 ₦ (1.30477 USD), and significantly higher estimated profit (38.15%) compared to those in T1 and T3.
Conclusion: The present study indicated that starter duration of 8-10 days can significantly enhance both growth performance and economic outcomes in broiler chickens.

1. Introduction

The broiler industry is the most structured and fastest-growing agricultural sector in Nigeria[1]. According to Alemayehu et al.[2], the poultry sector contributes approximately 25-30% of Nigeria's national gross domestic product (GDP), with the agricultural sector overall accounting for 35%. Contribution of the poultry sector to GDP is 6-8%, underscoring its significant potential to support national economic growth. The broiler industry's growth is driven by improvements in breeding, nutrition, management, and production techniques, as well as processing technologies, all of which enhance the efficiency of chicken production[3]. The productivity and profitability are affected by different factors, including climate, breeding, nutritional management[4], biosecurity, and the availability and cost of high-quality feed[5-7]. Despite these challenges, several strategies and technologies are available to improve feed utilization efficiency in broiler production systems[8]. Nonetheless, feeding programs and nutritional management remain major challenges in Nigeria's poultry industry[9,10]. The traditional feed ingredients, such as fish meal, soybean meal, and maize, create competition and an increase in the cost of poultry feed[4,11]. Feed is essential for

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livestock, providing carbohydrates, proteins, vitamins (A, B, C, D, E, and K), and minerals (calcium, magnesium, phosphorus, sodium, and chloride) at each growth stage, accounting for 65-75% of total production[11,12].

Tickle et al.[13] reported that commercial broiler strains such as Ross, Cobb, Hubbard, and Arbor Acres, which are popular in Nigeria, are already close to their functional limits, and further improvements in industrial efficiency and meat production are constrained. Commercial broiler strains have been improved to reach a market weight of 2 kg in less than six weeks and have the genetic potential to multiply 50 times in body mass in six weeks post-hatching[14]. Therefore, strategies and technologies used to enhance feed intake, utilization, and meat production focus primarily on feed design and nutritional management[15], as well as biosecurity programs[16].

According to NRC[17] and Anyigor and Etuk[18], the Nigerian broiler chicken producer typically follows an 8-week feeding schedule, having a starter phase of 0-3 or 4 weeks and a finisher phase of 4 or 5–8 weeks. Given the genetic advancements in commercial broiler strains, this schedule may no longer be cost-effective and so requires re-review. Precision feeding strategies have been reported to optimize nutrient use, reduce costs, improve feed conversion ration (FCR), productivity, body weight gain (BWG) and enhance broiler chicken profitability[19]. The present study aimed to determine the most efficient feeding schedules that maximize production performance parameters (final body weight, BWG, and FCR) and profitability values (total revenue, net income, and estimated profit percentage) in broiler chickens.

2. Materials and methods

2.1. Ethical approval

All procedures performed in the present study involving animals were in accordance with the ethical standards enshrined in the Federal University of Technology, Owerri, Nigeria, Research Policy (reference number: 2023/AST/068).

2.2. Animals

The present study was conducted at the Poultry Unit, School of Agriculture and Agricultural Technology Teaching and Research Farm, Federal University of Technology Owerri, Nigeria, between May and June 2024. A total of 160 day-old, unsexed Arbor Acres broiler chicks, with an overall average initial weight of approximately 39 g, were divided into five equal groups of 32 chickens. The grouping ensured that the mean initial body weights, ranging from 38.56 ± 0.47 g to 39.13 g, were comparable across all treatments. Each group was further replicated four times, with eight chickens per replicate. Each replicate was housed in a deep-litter compartment measuring 1.6 m × 1.0 m, covered with wood shavings, in a typical open-sided tropical poultry house, with an initial temperature range of 32-34°C that decreased by 2°C per week. Relative humidity was maintained between 50% and 70%. Light intensity was 23-24 hours/day initially, set at 30-40 lux, then gradually reduced by 1 hour at 5-14 days and subsequently by 3-6 hours weekly.

2.3. Experimental design

The treatment groups were randomly assigned to the five experimental broiler diets (starter, grower and finisher) in a completely randomized design, including the control group (T1) which consisted of the starter phase of 0-28 days and a finisher phase of 29-42 days, the second group had a starter phase of 0-7 days and a finisher phase of 8-42 days (T2), the third group had a starter phase of 0-14 days and a finisher phase of 15-42 days (T3). The fourth group included a starter phase of 0-8 days, a grower of 9-21 days, and a finisher phase of 22-42 days (T4), and the fifth group included a starter phase of 0-10 days, a grower phase of 11-24 days, and a finisher phase of 25-42 days (T5). The starter, grower, and finisher diets were formulated and produced in mash form on-farm[20]. Feed and water were provided *ad libitum* throughout the 42-day experiment. Recommended vaccination schedules according to Brugère-Picoux et al.[21] was followed throughout the experimental period. On day 1, broiler chickens were vaccinated against Newcastle disease with a live Hitchner (H) strain vaccine (Phibro, Israel), administered via drinking water containing free chlorinefollowed by a booster of the same vaccine on day 19. On day 12, a combined live vaccine (Phibro, Israel) against Massachusetts-type infectious bronchitis and infectious bursal disease (Gumboro) was administered orally via drinking water containing free chlorine.

2.4. Data collection

2.4.1. Nutrient composition

The calculated nutrient composition of the experimental boiler chickens diets was obtained using values reported by Aduku[22] (Table 1). The determined proximate compositions were obtained by the method of AOAC[23], gross energy was measured by the bomb calorimeter method[24], and the metabolizable energy was estimated using the classical Carpenter formula[25]. The amino acid profile was determined using the standard method described by Otter[26]. Mineral content, such as calcium, magnesium, phosphorus, sodium, and chloride, was analyzed according to the official methods outlined by Chekri et al.[27].

Table 1. The gross composition of experimental broiler chickens' diets

Ingredients (%)	Experimental broiler chicken diets		
	Starter	Grower	Finisher
Maize	50.00	57.00	62.70
Soybean meal	27.5	28.5	27.8
Palm kernel cake	11.00	8.5	4.00
Fish meal	8.00	3.00	2.5
Bone meal	1.50	1.5	1.5

Vitamin/mineral premix	0.25*	0.25**	0.25***
Salt	0.25	0.25	0.25
Oyster shell	1.00	1.00	0.25
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Total	100.00	100.00	100.00
******Calculated nutrient composition of experimental broiler chicken diets**			
Metabolized energy (kcal/kg)	3048.30	3101.10	3206.71
Crude protein (%)	23.12	20.47	19.04
Ether Extract (%)	6.89	6.84	7.85
Ash (%)	3.64	2.76	3.08
Crude fiber (%)	4.24	4.14	3.52
Calcium (%)	1.25	1.10	1.07
Phosphorus (%)	0.96	0.89	0.87
Sodium (%)	0.11	0.11	0.11
Chloride (%)	0.15	0.15	0.15
Lysine (%)	2.01	1.92	1.94
Methionine (%)	0.68	0.56	0.63

*Micro-mix® broiler starter premix contains/2.5 kg: Vitamin A: 12,500,000.00 IU, vitamin D3: 2,500,000.00 IU, vitamin E: 40,000.00 mg, vitamin K3: 2,000.00 mg, Vitamin B1: 3,000.00 mg, Vitamin B2: 5,500.00 mg, niacin: 55,000.00 mg, calcium pantothenate: 11,500.00 mg, vitamin B6: 5,000.00 mg, vitamin B12: 25 mg, chlorine chloride: 500,000.00 mg, folic acid: 1,000.00 mg, biotin: 80,000.00 mg, manganese: 120,000.00 mg, iron: 100,000.00 mg, zinc: 80,000.00 mg, copper: 8,500.00 mg, iodine: 1,500.00 mg, cobalt: 300.00 mg, selenium: 120.00 mg, and antioxidant: 120,000.00 mg.
**Micro-mix® broiler grower premix contains/2.5 kg: Vitamin A: 10,000,000 IU, vitamin D3: 2,000,000 IU, vitamin E: 20,000.00 mg, vitamin K3: 2,000.00 mg, Vitamin B1: 3,000.00 mg, Vitamin B2: 5,000.00 mg, niacin: 45,000.00 mg, calcium pantothenate: 10,000.00 mg, vitamin B6: 4,000.00 mg, vitamin B12: 20 mg, chlorine chloride: 300.00 mg, folic acid: 1,000.00 mg, biotin: 80,000.00 mg, manganese: 120,000.00 mg, iron: 80,000.00 mg, zinc: 80,000.00 mg, copper: 8,500.00 mg, iodine: 1,500.00 mg, cobalt: 300.00 mg, selenium: 120.00 mg, and antioxidant: 120,000.00 mg.
***Micro-mix® broiler finisher premix contains /2.5 kg: Vitamin A: 8,000,000 IU, vitamin D3: 150,000 IU, vitamin E: 15,000.00 mg, vitamin K3: 1,000.00 mg, Vitamin B1: 2,000.00 mg, Vitamin B2: 3,000.00 mg, niacin: 35,000.00 mg, calcium pantothenate: 8,000.00 mg, vitamin B6: 3,000.00 mg, vitamin B12: 20 mg, chlorine chloride: 200,000.00 mg, folic acid: 1,000.00 mg, biotin: 60,000.00 mg, manganese: 90,000.00 mg, iron: 60,000.00 mg, zinc: 60,000.00 mg, copper: 6,500.00 mg, iodine: 1000.00 mg, cobalt: 250.00 mg, selenium: 90.00 mg, and antioxidant: 90,000.00 mg.
****Calculated based on values by Aduku[22].

2.4.2. Growth performance

The initial body weight (IBW) of the chickens was determined in replicates on day 1, and the final body weight on day 42. The difference between the initial and final body weights was recorded as the BWG, calculated using Formula 1[28].

BWG = Final body weight – Initial body weight (g) (Formula 1)

The total body weight gain (g) was reported accordingly. Feed intake was determined daily by calculating the difference between the feed offered and the feed leftover collected the following morning (Formula 2)[28].

Feed intake = Feed offered – Feed left over (g) (Formula 2)[28]

The data on BWG and feed intake were used to calculate the FCR and the feed cost per kilogram of weight gain (FC/WG) as follows (Formula 3)[28].

FCR = Feed intake/Body weight gain (Formula 3)[28]

FC/WG = Total feed cost(₦)/Total body weight gain (g) (Formula 4)[29]

Where FC/WG represents the economic efficiency of feed utilization in relation to weight gain[29].

2.4.3. Economic analysis

The economic evaluation was based on the feed cost consumed per kilogram (₦/kg), since all other production costs, such as chickens, labour, housing, and management, were similar across groups. The cost of feed consumed for each treatment was calculated according to Formula 5.

Cost of feed consumed = Feed intake (kg) × feed cost per kg (₦) (Formula 5)[29]

The net gain for each treatment was then determined by subtracting the total variable input cost from the total revenue obtained from live chicken sales value at the end of the experiment using the following equations[29].

Net gain = Revenue from Live chicken _ variable input cost (Formula 6)

where Revenue from Live chickens is the number of chickens multiplied by the selling price per bird.

The total cost of feed consumed (CFC, ₦) was calculated as the product of the total quantity of feed intake (QFC, kg) and the unit cost of feed (FC, ₦/kg), using Formula 7; CFC = QFC × FC. The cost of feed consumed was thereafter deducted from the cost of live chickens in each treatment to determine the net gain[29]. This approach enabled comparison of the economic efficiency of feed utilization across groups. The exchange rate applied was 1,235.04 Nigerian Naira (₦) to 1.00 US Dollar (USD).

2.5. Data analysis

The data obtained were analysed using the R statistical software of the R Core Team. Differences among treatment group means were evaluated using analysis of variance (ANOVA), and means were separated using Tukey's Honest Significant Difference (HSD) test. Statistical significance was considered at p ≤ 0.05. Data were presented as standard error mean (SEM).

3. Results

3.1. Nutrient composition

The calculated and determined nutrient compositions of the experimental broiler chicken diets are presented in Tables 1 and 2.

Table 2. Determined nutrient composition of experimental broiler chicken diets

	Broiler chicken diets		
Nutrient composition	**Starter**	**Grower**	**Finisher**
Moisture content (%)	11.33	13.49	13.65
Crude protein (%)	21.21	20. 18	19.88
Ether extract (%)	3.39	4.88	5.68
Crude fiber (%)	6.21	5.42	4.68
Nitrogen-free extract (%)	48.14	48.85	49.89
Ash (%)	9.72	7.18	6.22
Gross energy (Kcal/kg)	3061.43	3211.06	3226.65
Metabolized energy (Kcal/kg)	2928.29	3042.09	3137.17

3.1.1. Proximate compositions

The calculated crude protein levels for the starter (23.12%) and grower (20.47%) diets were higher than the determined values (21.12% and 20.18%, respectively). The calculated crude protein level for the finisher diet (19.04%) was lower than the determined crude protein level (19.88%). The determined ether extract content increased progressively from the starter (3.39%) to the finisher diets (5.68%), reflecting the elevated energy requirements of older broiler chickens, although these measured values were lower than the calculated specifications. Calculated crude fiber values decreased in starter (4.24%), grower (4.14%), and finisher diets (3.52%) compared to determined crude fiber values, which increased in the starter (6.21%), grower (5.42%), and finisher diets (4.68%).

3.1.2. Gross and metabolized energy

The gross energy of the experimental diets increased progressively from 3,050 kcal/kg in the starter diet to 3,150 kcal/kg in the grower diet, and finally to 3,250 kcal/kg in the finisher diet. The calculated metabolized energy (ME) of the diets were 3048.30 kcal/kg, 3101.10 kcal/kg, and 3206.71 kcal/kg for starter, grower, and finisher diets, respectively higher than the determined ME values. The determined gross energy, ME, crude protein (Table 3), and amino acid (Table 4) values were within the recommended range of SON[20]. The amino acid profiles generally remained within the recommended ranges for broiler chickens, supporting a balanced nutrient provision throughout the feeding phases (Table 4)[30,14].

Table 3. Comparison of the nutrient composition of experimental broiler chicken diets with recommended values of the Standards Organization of Nigeria

Phases of the diets	Gross energy (kcal/kg)	Metabolisable energy (kcal/kg)	SON recommended metabolisable energy (kcal/kg)	Comparison	Crude protein (%)	SON recommended crude protein (%)	Comparison
Starter	3050	2980	3000-3100	Within range	23	22-24	Within range
Grower	3150	2990	3100-3200	Within range	21	20-22	Within range
Finisher	3250	3000	3200-3300	Within range	19	18-20	Within range

Source: Standards Organization of Nigeria[20].

Table 4. Comparison of experimental broiler diet amino acid composition with Ross 2022 recommendations

Amino Acid	Phase	Experimental level (mg/100 g)	Ross recommended level (mg/100 g)	Acceptable range (±5%) [1]
Lysine	Starter	121	132	125-139
	Grower	110	118	112-124
	Finisher	99	108	103-113
Methionine	Starter	57	55	52-58
	Grower	65	51	48-54
	Finisher	69	48	46-50
M+C[2]	Starter	103	100	95-105
	Grower	83.5	92	87-97
	Finisher	106	86	82-90
Threonine	Starter	110	88	84-92
	Grower	106	79	75-83
	Finisher	103	72	68-76
Valine	Starter	186	100	95-105
	Grower	190	91	86-96
	Finisher	183	84	80-88
Isoleucine	Starter	159	88	84-92
	Grower	162	80	76-84
	Finisher	142	75	71-79
Arginine	Starter	212	140	133-147
	Grower	206	127	121-133

	Finisher	188	117	111-123
Tryptophan	Starter	19	21	20-22
	Grower	24	19	18-20
	Finisher	21	17	16-18
Leucine	Starter	297	145	138-152
	Grower	305	130	124-136
	Finisher	294	119	113-125

[1]Acceptable range (±5%) calculated as: Ross recommended × 0.95 to Ross recommended × 1.05. [2]M+C experimental values calculated from cystine; starter 46, grower 41.5, finisher 37 mg/100 g based on the present study. The recommended values are sourced from Ross broiler nutrition supplement[14] and Ross broiler nutrition specifications[30], converted from percentage to mg/100 g.

3.2. Growth performance

The performance of broiler chickens under phase feeding schedules is presented in Table 5.

3.2.1. Final body weight and total body weight gain

Chickens in T4 exhibited the highest final body weights (1915.34 ± 169.40 g) and total BWG (1876.24 ± 169.34 g). The final body weights were significantly higher ($p < 0.05$) in T4 than in T1 (1644.22 ± 137.71 g), T2 (1640.63 ± 128.61 g), T3 (1680.75 ± 131.51 g), and T5 (1735.47 ± 105.61 g). The total BWG in T4 was significantly higher ($p < 0.05$) than in T1 (1605.40 ± 137.25 g) and T2 (1601.80 ± 128.15 g), T3 (1642.19 ± 131.05 g), but was insignificant compared to T5 (1696.34 ± 105.15 g; $p > 0.05$).

3.2.2. Feed intake

Feed intake did not differ significantly among the groups ($p > 0.05$). Numerically, chickens in T4 had the highest total feed intake (4007.34 ± 169.71 g), while the control group had the lowest intake (3640.47 ± 173.71 g). Overall, feed intake was higher under the three-phase feeding schedules (T4 and T5), although the difference was not statistically significant.

3.2.3. Feed conversion ratio

The FCR of T4 (2.15 ± 0.1) was significantly lower than T2 (2.36 ± 0.21; $p < 0.05$), but not significantly different from T1 (2.28 ± 0.15), T5 (2.28 ± 0.08), and T3 (2.32 ± 0.17; $p > 0.05$).

3.2.4. Feed cost

The feed cost per kilogram (₦) and feed cost per kg of total BWG (₦) were significantly different across all groups ($p < 0.05$). Chickens in T4 had the lowest feed cost/kg (329.89 ± 0.72 ₦), equivalent to 0.26711 USD, and feed cost/kg BWG (711.42 ± 58.77 ₦), equivalent to 0.56030 USD, resulting in a 3.30 % savings on the cost of the feed. Chickens in T1 had the highest feed cost/kg (353.63 ± 2.16 ₦), equivalent to 0.28633 USD, and feed cost/kg BWG (806.33 ± 53.61 ₦), which was equivalent to 0.65288 USD.

3.2.5. Mortality

Mortality rate in the experimental broiler chickens in the control group was 0.75%, significantly higher ($p < 0.05$) than that of T5 (0%), but was insignificant compared to T2, T3, and T4 at 0.50% ($p > 0.05$).

Table 5. Growth performance of broiler chickens under different phase-feeding schedules

Parameter	Groups				
	T1	T2	T3	T4	T5
Starter duration (days)	0-28	0-7	0-14	0-8	0-10
Grower duration (days)	-	-	-	9-21	11-24
Finisher duration (days)	29-42	8-42	15-42	22-42	25-42
Final body weight (g)	1644.22 ± 137.71^b	1640.63 ± 128.61^b	1680.75 ± 131.51^b	1915.34 ± 169.40^a	1735.47 ± 105.61^b
Body weight gain (g)	1605.40 ± 137.25^b	1601.80 ± 128.15^b	1642.19 ± 131.05^b	1876.24 ± 169.34^a	1696.34 ± 105.15^a
Feed intake (g)	3640.47 ± 173.71	3756.69 ± 104.71	3749.05 ± 326.01	4007.34 ± 169.71	3868.77 ± 258.71
Feed conversion ratio	2.28 ± 0.15^{ab}	2.36 ± 0.21^a	2.32 ± 0.17^{ab}	2.15 ± 0.16^b	2.28 ± 0.08^{ab}
Feed cost/kg (₦)/TrT	353.63 ± 2.16^a	330.61 ± 1.53^b	335.76 ± 4.01^b	329.89 ± 0.72^b	334.43 ± 2.42^b
Feed cost/kg BWG (₦)	806.33 ± 53.61^a	779.72 ± 66.03^{ab}	775.71 ± 54.99^{ab}	711.42 ± 58.77^b	762.53 ± 21.61^{ab}
Mortality (%)	0.75 ± 0.25^a	0.50 ± 0.25^{ab}	0.50 ± 0.25^{ab}	0.50 ± 0.25^{ab}	0^b

TrT = Treatment, BWG = Body weight gain. T1 (Control): Starter phase (0-28 d) and finisher phase (29-42 d), T2: Starter phase (0-7 d) and finisher phase (8-42 d), T3: Starter phase (0-14 d), and finisher phase (15-42 d), T4: Starter phase (0-8 d), grower phase (9-21 d), and finisher phase (22-42 d), T5: Starter phase (0-10 d), grower phase (11-24 d), finisher phase (25-42 d). [a,b] Means within the same row with different superscript letters differ significantly ($p < 0.05$). The exchange rate is 1,235.04 ₦, equivalent to 1.00 USD.

3.3. Income and profitability

3.3.1. Total variable cost

The total variable cost and revenue data for broiler chickens under different phase-feeding schedules are presented in Table 6. Total variable costs differed significantly ($p < 0.05$) among groups, ranging from 2542.47 ₦ in T2 to 2612.56 ± 0.01 ₦ in T4. Feed cost per chicken was the lowest in T2 (1241.86 ± 25.71 ₦) and highest in T4 (1311.95 ± 21.61₦), reflecting differences in dietary phases and feed timing. Feed costs accounted for 49.81% (T1), 48.84% (T2), 49.42% (T3), 50.22% (T4), and 49.66% (T5) of total production costs, which differed significantly among groups ($p < 0.05$).

Revenue generated from live chicken sales was significantly different ($p < 0.05$), with the highest value in T4 (4224.00 ₦), followed by T5 (3828.00 ₦) and T2 (3740.00 ₦), while T1 (3608.00 ₦) and T3 (3696.00 ₦) yielded the lowest revenues. Net income and estimated profitability followed a similar pattern. Group T4 achieved the highest net income (1611.44 ₦) and profitability (38.15 %), which were significantly higher than those of all other groups ($p < 0.05$). The lowest net income was observed in T1 (1016.81 ₦), though it was not significantly different from T2 (1197.53 ₦) and T5 (1244.20 ₦). T3 and T4 were significantly lower than T1, T2, and T5. In contrast, T1, T2, and T5 were similar, with no significant differences among them.

Table 6. Income and profitability of broiler chickens under different phase feeding schedules

Parameters	Groups				
	T1	T2	T3	T4	T5
Starter duration (days)	0-28	0-7	0-14	0-8	0-10
Grower duration (days)	-	-	-	9-21	11-24
Finisher duration (days)	29-42	8-42	15-42	22-42	25-42
Day-old chicks (₦)	420.00	420.00	420.00	420.00	420.00
Total feed cost per chicken (₦)	1290.58 ± 51.12[ab]	1241.86 ± 25.71[b]	1270.64 ± 95.95[ab]	1311.95 ± 21.61[a]	1283.19 ± 75.95[ab]
Drugs and vaccines (₦)	150.25	150.25	150.25	150.25	150.25
Charcoal (₦)	145.09	145.09	145.09	145.09	145.09
Litter materials (₦)	-	-	-	-	-
Lighting (₦)	175.00	175.00	175.00	175.00	175.00
Disinfectant (₦)	17.86	17.86	17.86	17.86	17.86
Logistics (₦)	225.00	225.00	225.00	225.00	225.00
Labour cost (₦)	167.41	167.41	167.41	167.41	167.41
Total variable cost (₦; A)	2591.19 ± 0.00[a]	2542.47 ± 0.00[b]	2571.25 ± 0.00[c]	2612.56 ± 0.01[d]	2583.80 ± 0.00[cd]
Final body weight (kg; B)	1.64 ± 0.00[b]	1.70 ± 0.00[b]	1.68 ± 0.00[b]	1.92 ± 0.00[a]	1.74 ± 0.00[ab]
Feed cost of production (%)	49.81 ± 0.01[a]	48.84 ± 0.01[b]	49.42 ± 0.01[c]	50.22 ± 0.01[d]	49.66 ± 0.01[cd]
Price of live chicken/kg (₦; C)	2200.00	2200.00	2200.00	2200.00	2200.00
Total revenue (₦; D = B × C)	3608.00± 0.00[c]	3740.00± 0.00[b]	3696.00± 0.00[c]	4224.00± 0.00[a]	3828.00± 0.00[b]
Net income (₦) (E = D – A)	1016.81 ± 0.00[b]	1197.53 ± 0.00[b]	1124.75 ± 0.00[c]	1611.44 ± 0.00[a]	1244.20 ± 0.00[bc]
Estimated percentage profit (%)	28.18 ± 0.00[b]	32.02 ± 0.00[b]	30.43 ± 0.00[c]	38.15 ± 0.00[a]	32.50 ± 0.00[b]

T1 (Control): Starter phase (0-28 d) and finisher phase (29-42 d), T2: Starter phase (0-7 d) and finisher phase (8-42 d), T3: Starter phase (0-14 d), and finisher phase (15-42 d), T4: Starter phase (0-8 d), grower phase (9-21 d), and finisher phase (22-42 d), T5: Starter phase (0-10 d), grower phase (11-24 d), finisher phase (25-42 d). [a,b,c, and d] Means within the same row with different superscript letters differ significantly ($p < 0.05$). The exchange rate is 1,235.04 ₦, equivalent to 1.00 USD.

4. Discussion

The nutrient profile of the diets used in the present study was characterized by a gradual reduction in crude protein from starter to grower and finisher, alongside a progressive increase in ME, consistent with the recommended broiler chicken phase-feeding strategy. These values fell within the ranges recommended by the SON[20] and by guidelines from major commercial chicken breeders in Nigeria[14,30]. This alignment indicated that the feeding phases adopted in the present study were nutritionally appropriate, supporting the guideline-based approach of providing higher protein density during early growth and higher energy concentration during the finishing phase.

The amino-acid and mineral profiles of the starter, grower, and finisher diets largely followed the recommendations of the two and three-phase feeding schedules, with gradual reductions in calcium and phosphorus across phases. Methionine was above the recommended ranges, while lysine value was consistently close or slightly below recommended levels, confirming its role as a first-limiting amino acid and suggesting potential constraints on growth[14,30]. The starter diet exhibited a wide calcium/phosphorus ratio, exceeding the optimal ratio and potentially limiting phosphorus utilization and bone development[31].

The present study revealed that broiler chickens following a modified phase feeding schedule with shorter starter phases and appropriately timed grower and finisher phases (T4 and T5) achieved notably higher final body weight and total BWG. These findings suggested that adjusting the duration of feeding phases to align nutrient supply with chickens' physiological requirements across different growth stages can enhance growth performance. These findings agreed with previous studies, which indicated that precision feeding strategies optimizing protein-energy ratios across growth phases can improve broiler performance[18]. The improved performance in T4 and T5 may be due to more efficient nutrient utilization, resulting from the tailored feeding schedule.

The present results demonstrated that FCR can be maintained or improved with a well-balanced, low-crude-protein diet, which is in line with the findings of Ogunola et al.[32], who reported that FCR can be maintained on lower-nutrient diets when supplemented with organic acids, suggesting that strategic nutritional formulation can reduce feed costs. In addition, the present results revealed that shorter starter feeding schedules had improved FCR, aligning with the findings of Anyigor and Etuk[18], who found that altering the starter phase or splitting the starter phase into grower phase enabled the farmers to provide diets that more closely meet the nutrient requirements of the broiler chickens at every stage of growth and help to improve FCR. Additionally, the present result also agrees with Nawab et al.[33], who reported that precision phase feeding improved FCR.

The current results indicated that feed cost/kg BWG in broiler chickens was numerically lower in treatments with shorter phase feeding duration. Nawab et al.[33] highlighted that the optimal timing of diet transitions is critical for economic efficiency, noting that different phase-feeding schedules did not compromise performance. The present findings are consistent with those of Nawab et al.[33], who reported that precision phase feeding did not adversely affect feed cost/kg BWG in broiler chickens. Additionally, Ross[18,34] reported that a multiple-phase feeding diet reduces cost-to-weight gain ratio, which is in line with the present findings. Moreover, higher final body weight in T4 reflected superior growth performance, potentially attributable to the distribution of feed costs over weight gain, thus reducing the cost per kg. The relationship between feed intake and feed cost suggested that higher feed intake did not necessarily yield more efficient weight gain or lower feed costs. Specifically, increased feed intake did not always result in greater weight gain or cost savings, emphasizing the complexity of optimizing feed use in poultry production. This finding agrees with that of Dukhta[35], who observed that reducing crude protein can enhance cost efficiency. The improved weight gain, FCR, and feed cost efficiency observed in T4 indicated that optimizing the timing of diet transitions enhances nutrient utilization and promotes more profitable broiler production. The present results align with the findings of Moss et al.[15], who reported that increasing the number of dietary phases, such as through early and timely diet transitions, enhances nutrient utilization, improves feed efficiency, and reduces production costs.

Furthermore, Bello and Irekhore[36] reported that feed accounts for approximately 65-75% of total broiler production costs, meaning that even slight reductions in feed cost/kg BWG can yield substantial economic benefits at a commercial scale. This finding is consistent with the current improvement in feed cost per kilogram body weight gain observed in T4. Although the present findings indicated that feed costs were below the range reported by Bello and Irekhore38 (65-75%), these results still support the conclusion that any reduction in feed cost/kg BWG helps achieve notable cost savings in commercial broiler production.

The mortality observed during the feeding trial in the present study fell within the normal range of 2-5% reported in similar small-scale systems. According to Mramba and Mwantambo[37], poor management practices and improper nutrition can notably increase mortality rates in broiler and layer chickens, which aligns with the present study, indicating that suboptimal feeding practices can contribute to physiological stress, nutrient imbalances, and higher mortality.

4. Conclusion

The starter phase duration of not more than 10 days, as reflected in T2 (0-7 days), T4 (0-8 days), and T5 (0-10 days), produced higher final body weights, total BWG, improved FCR, improved feed intake, and reduced feed cost per kg body weight gain. Chickens in T4, fed a starter diet in the first 8 days, a grower diet for 9-21 days, and a finisher diet for 22-42 days, produced the best indices in the performance parameters evaluated and with the highest estimated profit margin (33.21%). Future studies should determine how these feeding schedules influence gut microbiota development and nutrient absorption efficiency throughout the production cycle.

Declarations

Competing interests

The authors declared that they have no competing interests.

Authors' contributions

Austin Emeka Anyigor conceived the study, conducted the fieldwork, and wrote the manuscript. Nnanyere Okwunna Aladi assisted with the data collection protocol and contributed to manuscript development and revision. Edeheudim Bassey Etuk designed the study and data collection protocol, supervised the fieldwork, critically revised the manuscript, contributed intellectual content, and approved the final manuscript. All authors have read and approved the final edition of the manuscript for publication.

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Availability of data and materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

This manuscript is an original work submitted exclusively to the *Journal of World's Poultry Science*. It is not under consideration elsewhere. The authors affirmed that all content has been checked carefully to prevent plagiarism, data fabrication, data falsification, and duplicate publication, in accordance with standard ethical guidelines. The authors did not use AI tools during this experiment.

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