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Research Article

Responses of Grower Turkeys Exposed to Different Graded Levels of Protein and Amino Acids

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ABSTRACT

Introduction: Performance characteristics, carcass yields, organ proportions, and economic aspects of production are statistical indicators that can be utilized to assess the protein and amino acid ratios responsible for reducing ammonia emissions in turkey waste, while simultaneously optimizing yield outcomes at the lowest feasible costs. The present study aimed to accurately identify the optimal combination of crude protein (CP) and amino acids to enhance performance and carcass yield, reduce production costs, and minimize ammonia excretion.

Materials and methods: A total of 360 grower turkeys were randomly assigned to a completely randomized design. In the present study, each treatment group consisted of four sub-replicate groups, each containing ten poults per replicate. The local turkeys were assigned to nine different treatment diets, including T1 with 22% CP, 0.1% methionine, and 0.2% lysine, T2 with 22% CP, 0.2% methionine, and 0.4% lysine, T3 with 22% CP, 0.3% methionine, and 0.6% lysine, T4 with 20% CP, 0.1% methionine, and 0.2% lysine, T5 with 20% CP, 0.2% methionine, and 0.4% lysine, T6 with 20% CP, 0.3% methionine, and 0.6% lysine, T7 with 18% CP, 0.1% methionine, and 0.2% lysine, T8 with 18% CP, 0.2% methionine, and 0.4% lysine, and T9 with 18% CP, 0.3% methionine, and 0.6% lysine.

Results: The current findings indicated that the final weight and weight gain in Group T3 were significantly higher than those of the turkeys fed other treatment groups. Turkeys in Group T3 had the best feed conversion ratio, indicating that they utilized diet 3 more effectively for weight gain compared to the other diets. The carcass weight of T3 was significantly higher than that of the other groups, while turkeys in group T7 had a better dress percentage. Carcass protein was significantly higher in T9, while energy content was significantly higher in T3 and T6 compared to other treatments. Group T3 exhibited significantly higher revenue and gross margin compared to all other treatment groups.

Conclusion: Levels of amino acid and protein used in the present study improved growth parameters, carcass characteristics, and organ proportion of turkeys.

1. Introduction

Meeting the crude protein (CP) and amino acid requirements for grower turkeys is vital for achieving optimal growth and productivity. Targeted feeding strategies are crucial not only for improving feed efficiency and reducing excessive nitrogen excretion, which contributes to environmental concerns, but also for lowering feed costs and enhancing animal health[1]. It is important to prioritize these factors while addressing protein requirements, particularly in the context of insufficient animal protein consumption among much of the Nigerian population[2]; despite earlier reports on the importance of protein in biological processes[3]. A reliable source of these limiting amino acids is fish, which is rare and costly[4]. Therefore, there is a necessity to explore sustainable alternatives to replace energy and protein concentrates[5]. Turkey (*Meleagris gallopavo*), among other protein species, was selected for the present study due to its large size, high protein content, adequate carcass quality, fast growth rate, and high disease resistance[6]. The productivity of indigenous poultry breeds, such as chickens and turkeys, has improved through proper housing, effective disease control, and balanced nutrition diets[7]. The nutritional requirements for turkeys and commercial chickens, along with other poultry stocks, have been characterized based on estimates provided by the NRC[8].

A major limiting factor to fulfill turkeys' protein requirements is the insufficient supply of a balanced diet. This problem stems from the poor ratios of energy, protein, and essential amino acids in turkey feed, compounded by a lack of

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awareness about the potential of turkey production to meet consumer protein demands. It may also originate from a limited understanding of effective management and production practices turkeys[9]. High-protein turkey diets are known to increase ammonia excretion, and the accumulation of this ammonia contributes to environmental pollution through greenhouse gases that harm both human and animal health[10]. This environmental pollution leads to the depletion of the ozone layer and environmental deterioration. Therefore, the current study aimed to accurately identify the CP and amino acid combinations that would optimize performance, improve carcass yields, lower production costs, and reduce ammonia excretion, since excess protein cannot be stored in animal cells.

2. Materials and Methods

2.1. Ethical approval

The current study using turkey was approved by the Ethical Committee and the Research Directorate at Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, with reference number: MOUAU//2024/1195.

2.2. Study area and management

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm at Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Umudike lies between latitude 50°28' North and longitude 70°31' East, at an altitude of 123 meters above sea level. It is located in the rainforest zone of Southeast Nigeria, with an annual rainfall of 2177 mm, temperatures ranging from 22℃ to 36℃, and relative humidity between 50% and 90%[11].

The poults were exposed to the same environment, medication, and climatic conditions. They were allowed free access to feed and water using the appropriate feeding and watering troughs. Newcastle disease vaccine (NDV) intraocular was given to the poults on the first day to prevent an early infection of Newcastle disease virus. The second dose of NDV (Lasota) was administered orally at 7 days, and the final dose was given at 21 days of age[7]. Coccidiostat was given orally between 14 and 17 days of age[12]. Fowl pox vaccine was administered orally at seven weeks of age. Antibiotics and anti-stress drugs were applied at extreme environmental temperatures above 36°C. The vaccines were manufactured at the National Veterinary Research Institute (NVRI) in Vom, Plateau State, Nigeria, which was established in 1924. A foot-dip containing a mixture of water and disinfectant was provided at the entrance of the poultry house to prevent the transfer of diseases from outsiders to the pens. Electric bulbs were provided as a source of light during night hours for illumination. The turkey pen was highly aerated with wire gauze for cross ventilation.

2.3. Experimental design and diet

A total of 360 day-old unsexed local turkey poults, each with a mean weight of 43.85 g, were used for the present study. The experiment followed a completely randomized design, with a stocking density of five growers per square meter. Nine experimental diets were formulated based on the NRC[8] recommendations for nutrient requirements of 9-16-week turkey poults. The study comprised a total of nine treatment groups (T1 to T9), with each group consisting of a sample size of 10 turkeys across four replicates, resulting in 40 grower turkeys per treatment group (Table 1). The nutrient requirements for turkey poults were informed by the recommendations of Aduku[13]. Factor A was determined based on three levels of CP, including A1 (22%), A2 (20%), and A3 (18%). Additionally, Factor B1 comprised varying levels of amino acids, specifically Methionine, with concentrations of B1 at 0.10%, 0.20%, and 0.30%. Factor B2 included levels of Lysine, represented as 0.20%, 0.40%, and 0.60%. The proximate values of the diets were subjected to chemical analysis. The duration of the grower study was 56 days (Table 2).

Table 1. Percentage composition of experimental diets fed to local grower turkeys (56 days)

	T1	T2	T3	T4	T5	T6	T7	T8	T9
CP	22%	22%	22%	20%	20%	20%	18%	18%	18%
M	0.10%	0.20%	0.30%	0.10%	0.20%	0.30%	0.10%	0.20%	0.30%
L	0.20%	0.40%	0.60%	0.20%	0.40%	0.60%	0.20%	0.40%	0.60%
Ingredients (kg)									
Maize	40.00	40.00	40.00	43.16	43.16	43.16	49.16	49.16	48.86
Wheat offal	12.75	12.45	12.15	13.85	13.85	13.75	13.85	13.85	13.85
Palm kernel cake	9.56	9.56	9.56	11.50	11.20	11.00	11.50	11.20	11.20
Soybean meal	30.00	30.00	30.00	23.80	23.80	23.80	17.80	17.80	17.80
Fish meal	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Common salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30
Lysine	0.20	0.40	0.60	0.20	0.40	0.60	0.20	0.40	0.60
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Chemical/Lab. analysis									
Crude protein (%)	22.17	22.13	22.08	20.33	20.28	20.23	18.35	18.30	18.28
ME (Kcal/kg)	2743	2738	2732	2726	2718	2712	2735	2727	2717
Methionine (%)	0.49	0.59	0.60	0.46	0.56	0.62	0.43	0.53	0.63
Lysine (%)	1.42	1.61	1.79	1.26	1.45	1.64	1.11	1.30	1.49

CP: Crude protein, M: Methionine, L: Lysine, *1kg of premix contains: Vitamins A (5,000.000 I.U), Vitamin D3 (1,000.000 I.U), Vitamin E (16,000mg), Vitamin K3 (800mg), Vitamin BI (1,200mg), Vitamin B2 (22,000gm), Niacin (22,000mg), Calcium pantothenate (4,600mg), Vitamin B12 (10mg), Folic acid (400mg), Biotin (32mg), Choline chloride (260,000mg), Manganese (948,000mg), Iron (40,000mg), Zinc (32,000mg), Copper (3,400mg,) Lodine (600mg), Cobalt (120mg), Selenium (48mg), Anti-oxidant (48,000mg), ME: Metabolizable Energy.

Table 2. Treatment diets combination of different graded levels of protein and amino acids fed to local grower turkeys (56 days)

Factor A (CP%)	Factor B_1 (Methionine %)	Factor B_2 (Lysine %)	Treatments
A_1 CP 22%	B_1a 0.1%	B_2a 0.2%	$A_1B_1aB_2a$
	B_1b 0.2%	B_2b 0.4%	$A_1B_1bB_2b$
	B_1c 0.3%	B_2c 0.6%	$A_1B_1cB_2c$
A_2 CP 20%	B_1d 0.1%	B_2d 0.2%	$A_2B_1dB_2d$
	B_1e 0.2%	B_2e 0.4%	$A_2B_1eB_2e$
	B_1f 0.3%	B_2f 0.6%	$A_2B_1fB_2f$
A_3 CP 18%	B_1g 0.1%	B_2g 0.2%	$A_3B_1gB_2g$
	B_1h 0.2%	B_2h 0.4%	$A_3B_1hB_2h$
	B_1i 0.3%	B_2i 0.6%	$A_3B_1iB_2i$

CP: Crude protein

2.4. Data collection

2.4.1. Performance characteristics

The initial live weight of the turkeys was recorded at hatch. Weekly weighing of turkeys was conducted to determine the final weight and daily weight gain, and daily weighing of feed was performed to assess daily feed intake and FCR. The weighing was done without fasting since feed and water were provided *ad libitum*.

2.4.2. Carcass yield and internal organ proportions

After 8 weeks of the feeding trial, three turkeys with average weights from each replicate were chosen. Their dressed weights were measured, and the dressing percentage was calculated. The proportions of carcass cut-up parts and internal organs were determined.

2.4.3. Production economics

The production economics parameters were calculated at 16 weeks of age for turkeys to assess the experiment's profitability. The cost of diets was calculated by adding the expense of each feedstuff used to make up the 25 kg of each diet, then converted to US dollars per gram of diet. The cost of producing turkeys was determined by averaging the feed intake cost per turkey over the entire production period, while the cost per kg of feed was found by multiplying the proportion of each ingredient in the diet by the cost of each 100. Additionally, the cost per weight gain was calculated by dividing the total production cost by the weight gain.

2.5. Statistical analysis

All data collected from the study were analyzed using Analysis of Variance (ANOVA) for a completely randomized design. Treatment means with a significance level ($p < 0.05$) that were different were separated using the New Duncan Multiple Range Test (Duncan, 1955). The SPSS software version 25 was used for data analysis. Differences in the means were shown by the standard error of the mean (SEM).

3. Results and discussion

3.1. Growth performance

The results of the interaction effect on turkey performance fed treatment diets are shown in Table 3. The final body weight of local turkeys in Group T3 was significantly higher than that of other treatment groups ($p < 0.05$), while those in Group T2 had the lowest value (3050 g). The daily feed intake of grower turkeys in Group T3 (133 g) was significantly higher than that of the other groups ($p < 0.05$), whereas turkeys fed in Group T4 had the lowest daily feed intake (115 g). The daily feed intake range of 115-133 g/turkey observed in the present study exceeds the 77.87-81.13 g reported by Utama et al.[14] for turkeys. Additionally, Shukla et al.[15] reported an average intake of 75-90 g of turkey/day for grower turkeys, which is lower than the values found in the present study. The weight gain and FCR of local turkeys in Group T3 were significantly lower than those of other treatment groups ($p < 0.05$). The weight gain of turkeys in Group T3 (4589 g) was significantly higher ($p < 0.05$) than in other treatment groups, whereas those in Group T2 had the lowest value (3006 g). The range of average daily weight gain in the present study (26.84 g-40.97 g) obtained were higher than 9.11 g reported by both Utama et al.[14] and Lestari et al.[16]. The FCR of T1, T5 and T9 were not significantly different ($p > 0.05$) from other treatment groups but were significantly higher ($p < 0.05$) than other treatment groups. However, Group T3 had the best FCR, indicating that poult utilization for weight gain was higher in this group compared to the other treatments. This could be due to the high level of quality essential amino acids in the diet, which were used efficiently as reported by Bryan and Classen[17]. The inclusion of lysine and methionine in these grower turkeys clearly stimulated pancreatic insulin secretion, resulting in increased plasma insulin levels. This process prompted the release of amino acids and fatty acids from storage sites in the body, resulting in enhanced protein synthesis and a corresponding decrease in nitrogen in turkey wastes[18]. No mortality was observed among the turkeys in all the groups.

Table 3. Interaction effects on growth performance of turkeys fed graded levels of crude protein and essential amino acids (9- 16 weeks)

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
IW (g/turkey)	43.67	43.85	43.90	43.88	43.90	43.85	43.88	43.95	44.00	0.04
FW (g/turkey)	4140^{bd}	3050^{e}	4633.1^{a}	3233.7^{de}	4133.7^{b}	3233.7^{de}	3316.7^{d}	3583.7^{c}	4192^{b}	105.66
ADFI (g/turkey)	130^{b}	120^{d}	133^{a}	115^{e}	126^{c}	118^{de}	119^{d}	124^{c}	126^{c}	1.50
ADWG (g/turkey)	36.57^{b}	26.84^{e}	40.97^{a}	28.48^{d}	36.52^{b}	28.48^{d}	29.22^{d}	31.61^{c}	37.10^{b}	1.60
WG (g/turkey)	4096^{b}	3006^{e}	4589^{a}	3190^{d}	4090^{b}	3190^{d}	3273^{dc}	3540^{c}	4148^{b}	105
FCR	3.55^{d}	4.47^{a}	3.25^{e}	4.04^{bc}	3.45^{d}	4.14^{b}	4.07^{bc}	3.92^{c}	3.40^{d}	0.07
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

IW: Initial weight, FW: Final weight, ADFI: Average daily feed intake, ADWG: Average daily weight gained, WG: Weight gained, FCR: Feed conversion ratio. T1: CP 22%, M 0.1%, L 0.2%, T2: CP 22%, M 0.2%, L 0.4%, T3: CP 22%, M 0.3%, L 0.6%, T4: CP 20%, M 0.1%, L 0.2%, T5: CP 20%, M 0.2%, L 0.4%, T6: CP 20%, M 0.3%, L 0.6%, T7: CP 18%, M 0.1%, L 0.2%, T8: CP 18%, M 0.2%, L 0.4%, T9: CP 18%, M 0.3%, L 0.6%. CP: Crude protein, M: Methionine, L: Lysine. SEM: Standard error of Mean. $^{a,b,c,d, \text{and } e}$ Means in the same row followed by different superscript letters are significantly different ($p < 0.05$).

3.2. Carcass yield and cut-up parts parameters

Table 4 presents the interaction effect results on carcass yield and cut-up parts. Significant differences ($p < 0.05$) were observed in dress weight, dressing percentage, breast, drumstick, back cut, and wing, while the thigh showed no significant difference ($p < 0.05$). Additionally, the dressed weights of turkeys in groups T1, T2, T3, T6, and T7 differed significantly ($p < 0.05$). Turkeys fed in Group T3 were significantly heavier than those in the other treatment groups ($p < 0.05$). The live weight appeared to influence the dressed weight, which aligns with the report by Baeza et al.[18], who noted that weight reflects feed intake and its nutrients. Turkeys in Group T7 had the highest average dressed weight percentage (66.74%), which was similar to groups T1, T2, T3, T4, T5, and T9, while those fed diet T6 had the lowest (52.61%) but were similar ($p > 0.05$) to diet T9. The percentage dressed weight in the present study ranged from 52.61% to 66.74%, which was similar to the range of 61.53% to 75.70% reported by Ojewola et al.[19] for indigenous turkeys. Poults in Group T9 had a significantly higher breast weight compared to those on diets T4, T6, and T7 ($p < 0.05$), but showed no significant difference from poults fed diets T1, T2, T3, T5, and T8 ($p > 0.05$). The turkeys on diet T7 had the lowest breast weight at 22.41%. The breast cut range (22.41%-28.83%) was higher than the 22.52% to 30.02% reported by Utama et al.[14]. The drumstick weight was significantly ($p < 0.05$) higher in turkeys in Group T4 compared to other groups, except those in Group T7, while turkeys in Group T3 had the lowest value at 14.84%. The back-cut weight of turkeys in Group T3 was significantly higher than in the other groups ($p < 0.05$), except for those in Group T5, whereas turkeys on diet T4 had the lowest value (15.00%). The wing weight of poults in Group T8 was significantly higher than that in T3, T4, and T5 ($p < 0.05$), while diet T3 had a significantly lower weight at 14.67% ($p < 0.05$). Therefore, high-quality carcasses are generally considered to have a large amount of muscle with minimal bone and fat[20]. The current results indicated that diet T3 significantly improved carcass yields (Dressed weight) compared to other diets ($p < 0.05$), which suggested that including methionine and lysine in the turkey diet is more effective than relying solely on a high CP diet. It implied that turkeys probably utilized the diet efficiently to develop carcass tissue rather than feathers and offal.

Table 4. Interaction effects on carcass yield and cut-up part of grower turkeys fed graded levels of crude protein and essential amino acids

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
LW (g/turkey)	4150^{b}	3050^{e}	4633^{a}	3234de	4133.5^{b}	3233.7^{de}	3316.67^{d}	3583.67^{c}	4192.00^{b}	105.66
DW (g/turkey)	2600^{b}	1900^{e}	2900^{a}	2000de	2550^{b}	1700^{f}	2200^{c}	2100^{cd}	2500^{b}	73.20
DP (% LW)	62.66^{ab}	62.29^{ab}	62.57^{ab}	61.92^{ab}	61.70^{ab}	52.61^{c}	66.74^{a}	58.59^{bc}	59.67^{b}	0.91
Breast (% LW)	26.95^{ab}	28.00^{a}	27.61^{a}	25.00^{bc}	26.42^{abc}	24.11^{cd}	22.41^{cd}	28.61^{a}	28.83^{a}	0.46
Thigh (% LW)	15.40	14.77	14.91	15.00	14.91	15.92	15.07	14.83	14.78	0.12
DS (% LW)	15.01^{cd}	15.29^{cd}	14.84^{d}	21.00^{a}	15.38^{cd}	17.69^{b}	20.44^{a}	15.12^{cd}	16.18^{c}	0.46
Back cut (% LW)	16.36^{d}	17.87^{c}	22.29^{a}	15.00^{e}	21.65^{a}	19.46^{b}	16.43^{d}	19.08^{bc}	19.38^{b}	0.47
Wings (% LW)	16.36^{ab}	16.08^{abc}	14.67^{d}	15.00^{cd}	15.53^{bcd}	16.69^{ab}	16.79^{ab}	16.93^{a}	16.38^{ab}	0.18

LW: Live weight, DW: Dressed weight, DP: Dressing percentage, DS: Drum stick. T1: CP 22%, M 0.1%, L 0.2%, T2: CP 22%, M 0.2%, L 0.4%, T3: CP 22%, M 0.3%, L 0.6%, T4: CP 20%, M 0.1%, L 0.2%, T5: CP 20%, M 0.2%, L 0.4%, T6: CP 20%, M 0.3%, L 0.6%, T7: CP 18%, M 0.1%, L 0.2%, T8: CP 18%, M 0.2%, L 0.4%, T9: CP 18%, M 0.3%, L 0.6%. CP: Crude protein, M: Methionine, L: Lysine. SEM: Standard error of mean. $^{a,b,c,d,e, \text{and } f}$ Means in the same row followed by different superscript letters are significantly different ($p < 0.05$).

3.3. Internal organ proportions

Table 5 displays the interaction effect of treatment diets on grower turkeys' internal organ proportions. Significant differences appeared in the evaluated parameters ($p < 0.05$). The heart weight of grower turkeys in Group T3 was significantly higher than that of turkeys fed other treatment diets ($p < 0.05$). The heart weight of turkeys in Group T2 was the lowest (1.12%). The liver weight of turkeys in Group T9 was significantly higher than in other treatment groups ($p < 0.05$), while turkeys in Group T8 had the lowest liver weight (0.39%). The lung weight of turkeys in Group T3 was significantly higher ($p < 0.05$), whereas turkeys in Group T8 had the lowest lung weight (0.20%). The kidney weights of turkeys in groups T4, T5, T7, and T9 did not differ significantly ($p > 0.05$) from each other but were significantly different from those in groups T1, T2, T3, T6, and T8, respectively ($p < 0.05$). The kidney weight of poults in Group T1 was the lowest (0.29%). Additionally, turkeys in Group T8 had the highest spleen weight and gizzard plus proventriculus weight, with values of 0.22% and 2.43%, respectively. The intestinal weight of turkeys in Group T3 was significantly higher than that of poults in groups T1, T4, T6, and T8 ($p < 0.05$), while the intestine weight in Group T1 was the lowest (2.24%), which may indicate increased digestive metabolic activity in the organs of turkeys fed diet 1[21].

Table 5. Interaction effects on internal organs of grower turkeys fed graded levels of crude protein and essential amino acids

Parameters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	SEM
LW (g)	4150^{b}	3050^{e}	4633.7^{a}	3233.7^{de}	4133.7^{b}	3233.7^{de}	3316.7^{d}	3583.7^{c}	4192^{b}	105.7
Heart (% LW)	1.28^{d}	1.12^{e}	1.19^{a}	1.29^{d}	1.35^{cd}	1.40^{c}	1.36^{cd}	1.67^{b}	1.38^{cd}	0.04
Liver (% LW)	0.43^{b}	0.59^{ab}	0.49^{ab}	0.40^{b}	0.41^{b}	0.40^{b}	0.54^{ab}	0.39^{b}	0.67^{a}	0.03
Lungs (% LW)	0.39^{b}	0.36^{c}	0.43^{a}	0.31^{e}	0.39^{b}	0.28^{f}	0.39^{b}	0.20^{g}	0.33^{d}	0.01
Kid (% LW)	0.29^{e}	0.33^{d}	0.49^{b}	0.43^{c}	0.44^{c}	0.53^{a}	0.42^{c}	0.36^{d}	0.43^{c}	0.01
Spleen (% LW)	0.09^{d}	0.12^{b}	0.12^{b}	0.11^{c}	0.07^{f}	0.07^{f}	0.09^{e}	0.22^{a}	0.09^{de}	0.01
GXPro (% LW)	1.78^{c}	2.30^{ab}	2.05^{c}	2.20^{ab}	2.30^{ab}	2.38^{ab}	2.40^{ab}	2.43^{a}	2.38^{ab}	0.05
LXSI (% LW)	2.24^{d}	2.82^{a}	2.83^{a}	2.51^{c}	2.71^{ab}	2.51^{c}	2.66^{abc}	2.57^{bc}	2.69^{abc}	0.04

LW: Live weight, Kid: Kidney, GXPro: Gizzard and proventriculus, LXSI: Large and small intestine. T1: CP 22%, M 0.1%, L 0.2%, T2: CP 22%, M 0.2%, L 0.4%, T3: CP 22%, M 0.3%, L 0.6%, T4: CP 20%, M 0.1%, L 0.2%, T5: CP 20%, M 0.2%, L 0.4%, T6: CP 20%, M 0.3%, L 0.6%, T7: CP 18%, M 0.1%, L 0.2%, T8: CP 18%, M 0.2%, L 0.4%, T9: CP 18%, M 0.3%, L 0.6%. CP: Crude protein, M: Methionine, L: Lysine. SEM: Standard error of mean. $^{a,b,c,d,e,f, \text{ and } g}$ Means in the same row followed by different superscript letters are significantly ($p < 0.05$) different.

3.4. Carcass nutrient composition

Table 6 displays the interaction effects on carcass nutrient composition in turkeys fed different treatment diets. Significant differences were observed in all parameters except dry matter ($p < 0.05$). Notably, turkey meat from Group T9 (70%) had a highly significant CP level ($p < 0.05$), while Group T2 showed the lowest value at 56.88%. The current results met the nutritional needs for turkey growth and maintenance, which was aligned with Njeri et al.[12], who found that turkeys require more protein than broiler chickens at the same age and that turkeys adapt better to a broader range of dietary energy levels, performing better at higher protein contents than broilers. The ether extract content of grower turkey meats in groups T2 and T3 was similar ($p > 0.05$). However, this content was significantly higher than that in meats from other treatment diets ($p < 0.05$), with diets T7 and T9 showing the lowest levels at 9.10% ($p < 0.05$). The combination of low CP and high amino acid levels in groups T7 and T9 likely prevented fat accumulation. Such low-fat meat is considered healthier for human consumption[12]. In addition, the turkey meat of group T7 had significantly higher crude fibre compared to other treatments ($p < 0.05$), except for those fed diets T4 and T8, which exhibited similar levels ($p > 0.05$). Group T1 had the lowest crude fibre content in the carcass at 0.63%. Poults in Group T9 showed significantly higher ash levels compared to groups T1 and T2 ($p < 0.05$), while group T1 had the lowest ash value at 6.49%. The nitrogen-free extract was significantly different across treatments ($p < 0.05$), with Group T9 exhibiting the lowest value at 0.73%, followed by groups T7 and T6. The current findings suggested that a diet with low protein and high amino acid levels can enhance feed digestibility, potentially leading to improved performance, higher breast yield, and superior meat quality. Additionally, the metabolizable energy in Group T3 was significantly higher than that of other treatment groups ($p < 0.05$).

Table 6. Interaction effect on carcass nutrient composition of grower turkeys fed levels of crude protein and essential amino acids

Parameters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	SEM
DM (%)	88.25	87.85	88.05	88.20	88.15	88.40	88.18	87.92	88.25	0.15
CP (%)	59.50^{f}	56.88^{g}	62.13^{e}	64.75^{d}	59.50^{f}	65.6^{cd}	66.50^{c}	68.25^{b}	70.00^{a}	0.83
EE (%)	9.96^{b}	10.30^{a}	10.37^{a}	9.71c^{d}	9.86^{bc}	9.56^{d}	9.10^{f}	9.35^{e}	9.10^{f}	0.09
CF (%)	0.63^{d}	0.65^{cd}	0.66^{bc}	0.81^{a}	0.65^{cd}	0.66^{bc}	0.83^{a}	0.81^{a}	0.69^{b}	0.02
Ash (%)	6.49^{b}	6.58^{b}	6.80^{ab}	7.27^{ab}	7.18^{ab}	7.09^{ab}	7.34^{ab}	7.26^{ab}	7.87^{a}	0.12
NFE (%)	11.7^{b}	13.54^{a}	8.18^{d}	5.69^{e}	10.91^{c}	5.49^{f}	4.53^{g}	2.27^{h}	0.73^{i}	0.81
ME (kcal/kgDM)	3937^{c}	3906^{d}	3961^{a}	3948^{b}	3905^{d}	3962^{a}	3930^{c}	3957^{a}	3948^{b}	4.16

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, ME: Metabolizable energy. T1: CP 22%, M 0.1%, L 0.2%, T2: CP 22%, M 0.2%, L 0.4%, T3: CP 22%, M 0.3%, L 0.6%, T4: CP 20%, M 0.1%, L 0.2%, T5: CP 20%, M 0.2%, L 0.4%, T6: CP 20%, M 0.3%, L 0.6%, T7: CP 18%, M 0.1%, L 0.2%, T8: CP 18%, M 0.2%, L 0.4%, T9: CP 18%, M 0.3%, L 0.6%. M: Methionine, L: Lysine. SEM: Standard error of mean. $^{a,b,c,d,e,f,g;h, \text{ and } I}$ Means in the same row followed by different superscript letters are significantly different ($p < 0.05$).

3.5. Economics of turkey production

The results of the interaction effect on the economics of turkey production are shown in Table 7. The current findings indicated that total feed intake, production cost, body weight gain, cost per kilogram of weight gain, revenue, and gross margin were significantly affected by the treatment diets ($p < 0.05$). Poults in Group T3 (14876 g) had a significantly higher total feed intake than the others ($p < 0.05$), while those in Group T4 had the lowest value (12916 g). There was a significant difference in production costs among the diets ($p < 0.05$). Turkeys in Group T3 had significantly higher production costs than others ($p < 0.05$), while poults in Group T4 recorded the lowest value at 1.28$. The weight gained by turkeys in Group T3 (4589 g) was significantly greater than in other treatment groups ($p < 0.05$). The cost per weight gained of poults in Group T2 was significantly higher than in other treatment groups ($p < 0.05$). The cost per weight gained has been used by many studies as an economic indicator to measure the efficiency of diets[21]. Therefore, diet T2 was less economically efficient than the other diets. However, turkeys in Group T3 produced significantly higher revenue (2.99 $) compared to those in groups T1, T2, T4, T5, T6, T7, T8, and T9 ($p < 0.05$). Gross margin analysis showed that diet T3 achieved a significantly higher market price per turkey than the other diets ($p < 0.05$). The feed cost analysis revealed that, across nearly all economic parameters measured, local turkeys in

Group T3 generated the highest profit and return on investment ($p < 0.05$). Poultry is a profitable industry, and the aim of every business is to make a profit. In poultry, as in other businesses, minimizing input or maximizing output leads to higher profit[12].

Table 7. Interaction effects on the economics of turkey production fed graded levels of crude protein and essential amino acids (0-16 weeks)

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
TFI (g/turkey)	14528^{b}	13415^{e}	14876^{a}	1285^{g}	14123^{c}	13251^{f}	13331^{e}	13878^{d}	14096^{c}	130
COST/PD ($/turkey)	1.5^{a}	1·43^{b}	1.42^{b}	1.28^{e}	1.45^{b}	1.40^{c}	1.29^{e}	1.38^{d}	1.45^{b}	52.5
BWG (g/turkey)	4096^{b}	3006^{d}	4589^{a}	3190^{e}	4090^{b}	3190^{e}	3273^{d}	3540^{c}	4148^{b}	105
Cost/kgWG ($/turkey)	0.36^{d}	0.47^{a}	0.31^{e}	0.40^{c}	0.35^{d}	0.43^{b}	0.39^{c}	0.39^{c}	0.35^{d}	20
Revenue ($/turkey)	2.67^{b}	1.96^{e}	2.99^{a}	2.08^{cde}	2.67^{b}	2.08c^{de}	2.13^{cd}	2.31^{c}	2.71^{b}	103
GM ($/turkey)	1.17^{b}	0.52^{e}	1.57^{a}	0.79^{d}	1.22^{b}	0.67^{de}	0.84^{cd}	0.92^{c}	1.25^{b}	70

TFI: Total feed intake, Cost/ PD: Cost of production, BWG: Body weight Gain, COST/kg WG: Cost per kg weight gain, GM: Gross margin. T1: CP 22%, M 0.1%, L 0.2%, T2: CP 22%, M 0.2%, L 0.4%, T3: CP 22%, M 0.3%, L 0.6%, T4: CP 20%, M 0.1%, L 0.2%, T5: CP 20%, M 0.2%, L 0.4%, T6: CP 20%, M 0.3%, L 0.6%, T7: CP 18%, M 0.1%, L 0.2%, T8: CP 18%, M 0.2%, L 0.4%, T9: CP 18%, M 0.3%, L 0.6%. CP: Crude protein, M: Methionine, L: Lysine. SEM: Standard error of mean. $^{a,b,c,d,e,f, \text{and } g}$ Means in the same row followed by different superscript letters are significantly different ($p < 0.05$).

5. Conclusion

The current results indicated that different levels of amino acids and proteins used in the present study improved growth parameters, carcass characteristics, and organ proportions of turkeys. Local turkeys fed a diet containing crude protein at 22%, methionine at 0.3%, and lysine at 0.6% appeared to perform best in measured parameters, such as weight gain (4,589 g), feed conversion ratio of 3.25, dressed weight of 2,900 g, and the highest gross margin of $1.57. No mortality was recorded during the experiment, regardless of the treatment diets. This could be attributed to proper management and the safety of the diet used. It is recommended that any diet combination could help local turkey farmers achieve significant results, especially diet 3. Further studies should investigate the optimal levels for the starter and finisher phases of local turkeys.

Declarations

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Availability of data and materials

The data from the present study will be accessible upon proper request from the corresponding author.

Ethical considerations

The authors affirmed that the present study adheres to ethical standards. It is free from plagiarism and has not been submitted to any other journal for publication. It preserves its originality from empirical study.

Conflict of interests

The authors declared no conflicts of interest.

Authors' contributions

Eze, Joy Orife Jacob conceptualized, investigated, and developed the methodology of the study. Eze, Jacob Chinenye Raymond handled, analyzed the data curation, and wrote the manuscript. Ugwuene, Michael Chikezie, originally drafted, designed, and supervised the study. All authors have read and confirmed the last edition of the manuscript.

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