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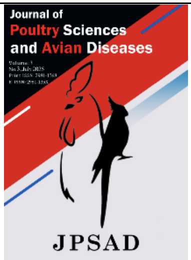

Impact of Dietary Protein Reduction on Broiler Performance, Carcass Composition, and Meat Quality

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ABSTRACT

Protein is a crucial nutrient in poultry nutrition, influencing growth, metabolism, and carcass composition. Optimizing dietary crude protein (CP) levels while ensuring adequate amino acid supplementation is essential for maximizing broiler performance and economic efficiency. This study evaluated the effects of reducing dietary CP levels on broiler growth performance, feed efficiency, carcass composition, and meat quality. A total of 150 one-day-old Ross 308 broilers were randomly assigned to three dietary treatments: low protein (LP), medium protein (MP), and high protein (HP). The LP group received 18%-16%-14% CP, the MP group received 20%-18%-16% CP, and the HP group received 22%-20%-18% CP across different growth phases. Results indicated that the HP group achieved the highest final body weight (2.78 kg), followed by the MP (2.53 kg) and LP (2.29 kg) groups ($p<0.05$). The Feed Conversion Ratio (FCR) was significantly lower in the LP group, indicating higher feed efficiency, although this was associated with reduced weight gain. The HP group exhibited the highest carcass weight, breast muscle percentage, and protein deposition, whereas the LP group had increased abdominal fat accumulation ($p<0.05$). Meat quality assessments revealed that the LP group had higher pH values, lower water-holding capacity, and reduced texture and tenderness scores compared to the MP and HP groups. These findings suggest that while reducing dietary CP improves feed efficiency and may reduce nitrogen excretion, excessive reductions negatively impact growth performance, carcass composition, and meat quality. A moderate CP reduction and optimized amino acid supplementation may provide a sustainable strategy for balancing economic feasibility, environmental impact, and broiler productivity.

Keywords: *Broiler performance, Crude Protein, Feed conversion ratio, Carcass composition, Amino acid supplementation, Meat quality, Low protein*

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1 Introduction

Protein is an essential macronutrient in poultry nutrition, serving critical roles in structural integrity, metabolism, and overall broiler productivity. It is required for tissue development, enzyme synthesis, and immune system function. Dietary protein must be carefully optimized in poultry diets to meet maintenance, growth, and feathering requirements. A protein deficiency can lead to poor growth, increased body fat accumulation, and reduced carcass quality, whereas excessive protein intake may disrupt metabolism and lead to conditions such as gout (1, 2). Feed represents the most significant cost in broiler production, and thus, optimizing protein intake while ensuring efficient feed conversion is crucial for economic sustainability. One approach that has gained attention in recent years is reducing dietary crude protein (CP) levels while supplementing essential amino acids such as lysine and methionine. This strategy aims to improve feed efficiency, reduce nitrogen excretion, and minimize production costs without negatively affecting broiler performance (3, 4).

A well-balanced broiler diet must provide adequate levels of essential amino acids, as poultry cannot synthesize them endogenously. Lysine and methionine are the most critical amino acids in determining carcass composition, feed efficiency, and muscle growth. Lysine is particularly important for breast muscle development, whereas methionine plays a key role in protein synthesis, energy metabolism, and immune function (5-7). Research has shown that broilers fed reduced-protein diets supplemented with adequate methionine and lysine can maintain comparable growth rates to those fed high-protein diets while demonstrating improved feed conversion ratios (8, 9). However, factors such as energy intake and amino acid balance influence the relationship between dietary protein levels and broiler performance. Chickens on high-energy diets tend to store more fat, while those consuming insufficient energy experience restricted growth (10, 11). The "ideal protein" concept, introduced by Michel (1964), suggests that optimizing dietary amino acid composition to mimic high-quality protein sources such as egg whites and casein enhances nutrient utilization and growth efficiency (12).

The effectiveness of protein reduction strategies remains debatable, as some studies indicate that broilers can maintain similar growth performance with reduced CP levels when supplemented with essential amino acids (13). However, others suggest that excessive reductions in protein content can negatively impact weight gain, feed intake, and carcass composition if not properly balanced with amino acid supplementation (14). The balance between protein and amino acid availability is crucial, as amino acid deficiencies can lead to impaired muscle development, poor feather growth, and reduced immune responses (15). Methionine is the first growth-limiting amino acid in poultry diets, influencing muscle development, feed efficiency, and carcass composition. At the same time, lysine plays a vital role in breast meat yield and overall muscle growth (16).

Reducing dietary protein levels can provide significant benefits from an environmental and economic perspective. High-protein diets increase nitrogen excretion, contributing to environmental pollution via ammonia emissions (14). Studies have shown that lowering dietary protein while supplementing essential amino acids can reduce nitrogen waste without compromising growth performance, making it a sustainable approach to poultry production (17). However, concerns remain regarding the impact of protein reduction on broiler meat quality, including moisture retention, fat deposition, and pH levels (18). Lower pH values in meat are associated with improved tenderness, while higher pH values can result in undesirable characteristics such as excessive water retention and reduced shelf life (19). Maintaining optimal meat quality while implementing low-protein diets is essential for ensuring consumer acceptance and economic viability (20).

This study evaluates the effects of reducing dietary CP levels while supplementing essential amino acids on broiler growth performance and carcass composition. By analyzing parameters such as weight gain, feed conversion ratio (FCR), and carcass traits under different protein regimens, this research seeks to identify the optimal dietary protein level that maintains broiler productivity while minimizing feed costs and nitrogen excretion. Furthermore, the study will investigate the influence of protein level adjustments on meat quality factors, including moisture content, crude fat percentage, and pH levels (21, 22). Understanding these effects is critical for developing feeding strategies that optimize economic and environmental sustainability.

2 Method and Material

2.1 Experimental Design and Birds

This study evaluated the effects of reducing dietary crude protein (CP) levels while ensuring sufficient supplementation of essential amino acids on broiler growth performance and carcass composition. A total of 150 one-day-old commercial Ross 308 broilers were randomly assigned to three experimental groups (low-protein (LP), medium-protein (MP), and high-protein (HP)), with 50 birds per group. The birds were identified using numbered tags for tracking throughout the experimental period. Each group received a specific dietary protein regimen. The LP group received 18% CP in the starter phase, 16% in the growth phase, and 14% in the finisher phase. The MP group was fed 20% CP in the starter phase, 18% in the growth phase, and 16% in the finisher phase. The HP group received 22% CP in the starter phase, 20% in the growth phase, and 18% in the finisher phase.

A 24-hour lighting program was applied for the first 48 hours, followed by a 1-hour dark period at midnight to reduce stress. Birds were fed ad libitum via automated feeders, and water was supplied continuously through a nipple drinking system. A standard vaccination schedule was followed, including B1 (day 9), Newcastle-Influenza (day 10), and D78 Gumboro (days 14 and 24). Strict biosecurity measures were implemented, including facility disinfection, fumigation, and restricted access. Environmental conditions like temperature, humidity, and ventilation were monitored to optimize bird health and growth.

The study lasted six weeks, during which birds were weighed weekly, and feed consumption was recorded. Feed conversion ratio (FCR) was calculated as total feed intake divided by weight gain. Mortality rates were recorded, and any unusual health issues were noted. At the end of the experiment, carcass composition was assessed by slaughtering selected birds and analyzing their muscle mass, fat content, and overall carcass yield.

2.2 *Diet Formulation*

The experimental diets were formulated using locally available feed ingredients, following NRC (1994) breed requirement tables to meet the nutritional needs of broilers at different growth stages. The diet formulation included yellow maize, soybean meal, dicalcium phosphate, DL-methionine, L-lysine hydrochloride, salt, animal oil, and a vitamin-mineral premix. The specific composition of the diets for each experimental group is provided in (Table 1). The energy-to-amino acid ratio, including lysine and total sulfur amino acids (TSAA: methionine + cysteine), was maintained at similar levels across all three groups to ensure comparability. Broilers had ad libitum access to feed and continuous access to water via a nipple drinking system.

Table 1. Experimental diets of calculated compounds in three staged feeding *

Nutrient	LP1	MP1	HP1	LP2	MP2	HP2	LP3	MP3	HP3
Energy	2970	2920	2996	3024	2974	2924	3067	3016	2968
Crude protein (%)	18.01	19.98	21.99	16.02	17.99	20.07	14.00	16.03	18.00
Methionine (%)	0.59	0.55	0.54	0.56	0.52	0.47	0.57	0.53	0.48
Lysine (%)	1.27	1.25	1.28	1.16	1.14	1.12	1.08	1.07	1.05
Cysteine (%)	0.23	0.26	0.30	0.20	0.23	0.27	0.17	0.20	0.23
Energy to Protein	164.91	146.15	136.26	188.72	165.33	145.55	219.08	188.16	164.88
Energy to Methionine	5009.2	5336.33	5591.53	5413.62	5766.38	6247.23	5350.05	5716.34	6132.52
Energy to Lysine	2341.14	2340.24	2340.09	2614.57	2612.52	2611.52	2828.32	2826.37	2828.90
Energy to TSAA	3605.27	3695.22	3605.56	3978.99	3970.83	3976.99	4126.15	4128.76	4129.37
Na (%)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
K (%)	0.97	1.11	1.26	0.84	0.98	1.13	0.70	0.84	0.98
Cl (%)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.32

*LP1: low protein starter, LP2: low protein grower, LP3: low protein finisher, MP1: medium protein starter, MP2: medium protein grower, MP3: high protein finisher, HP1: high protein starter, Hp2: high protein grower, HP3: high protein finisher.

2.3 *Growth Performance*

Birds were weighed individually at the beginning of the trial and then weekly throughout the six weeks. Body weight gain (BWG) was recorded to monitor growth trends among the different dietary groups. Feed intake was measured daily, and the feed conversion ratio (FCR) was calculated weekly by dividing total feed intake by total weight gain. Mortality rates were recorded, and any unusual health conditions observed in the broilers were documented.

2.4 *Carcass and Meat Quality Evaluation*

At the end of the experiment, birds were slaughtered following standard poultry processing protocols. Three male and three female broilers were randomly chosen from each dietary group for detailed carcass evaluation. Post-slaughter parameters were assessed: live weight and carcass yield, breast muscle percentage, abdominal fat weight, moisture, protein, fat, and ash content.

For meat quality assessment, breast and thigh meat samples were collected and analyzed for pH, water-holding capacity, and organoleptic properties. Sensory evaluation was conducted by 15 trained panelists from the Faculty of Veterinary Medicine, Shiraz University using a 5-point scoring system to assess appearance, color, odor, texture, and taste.

2.5 Statistical Analysis

Data were analyzed using ANOVA (General Linear Model) and Kruskal-Wallis tests in SPSS version 24.0. Results were expressed as Mean± Standard Deviation (SD). Differences between treatment groups were statistically considered significant at $p \leq 0.05$. Where significant differences were found, post-hoc tests were performed to compare mean values between the dietary groups.

3 Results

3.1 Growth Performance

The effects of dietary crude protein (CP) levels on broiler growth performance were assessed through weekly body weight gain (BWG) and feed conversion ratio (FCR) over the six-week experimental period. The results indicate significant differences in growth performance among the three experimental groups.

The HP group demonstrated the highest BWG, especially during the second and third weeks, while the LP group consistently exhibited the lowest BWG throughout the study (Table 2). At the end of the experiment, broilers in the HP group had the highest final body weight (average of 2.78 kg), followed by the MP group (2.53 kg). In comparison, the LP group had the lowest final body weight (2.29 kg), showing a significant reduction compared to the other groups ($p<0.05$). The FCR was significantly lower in the LP group compared to the MP and HP groups ($p<0.05$), indicating better feed conversion efficiency in birds receiving lower CP levels (Table 2). These results suggest that although reducing CP levels led to lower weight gain, it improved feed conversion efficiency.

Table 2. Comparison of weekly weight gain (Mean+SD*) and weekly feed conversion ratio in the three groups

Groups	Low Protein		Medium Protein		High Protein	
1st week weight gain (g) - FCR	100.22 ± 27.30	0.99	78.30 ± 25.20	1.08	110.47 ± 23.96	0.96
2nd week weight gain (g) - FCR	184.53 ± 41.90	1.25	180.34 ± 44.30	1.34	215.20 ± 46.91	1.36
3rd week weight gain (g) - FCR	227.10 ± 43.43	1.43	278.42 ± 46.64	1.62	362.98 ± 43.16	1.69
4th week weight gain (g) - FCR	303.30 ± 56.62	1.76	300.06 ± 62.80	2.02	322.00 ± 66.35	2.02
5th week weight gain (g) - FCR	434.40 ± 79.70	1.91	647.51 ± 94.36	2.05	651.75 ± 119.83	2.08
6th week weight gain (g) - FCR	573.45 ± 96.68	1.87	594.68 ± 92.87	2.1	639.87 ± 105.50	2.14
7th week weight gain (g) - FCR	427.86 ± 88.23	1.94	409.70 ± 78.06	2.22	430/08 ± 82.79	2.27

* Standard deviation

Mortality rates across all groups were recorded, with no significant differences observed among dietary treatments. Each group experienced the loss of one bird during the trial. This indicates that varying CP levels did not affect bird survival rates during the study period.

3.2 Carcass Composition

Carcass traits were evaluated at the end of the experiment, with significant differences observed in live weight, carcass yield, and breast muscle percentage among the three groups (Table 3). The HP group exhibited the highest carcass weight and breast muscle percentage, whereas the LP group had the lowest carcass yield but a higher percentage of abdominal fat deposition ($p<0.05$). This suggests that reducing dietary CP levels may lead to increased fat accumulation and a reduction in lean muscle mass.

Table 3. Comparison of carcass-related factors in all three groups (Mean+SD)

Groups	Carcass to live weight	Abdominal fat weight (G)	Breast weight (G)	Breast weight (%)	Moisture (%)	Protein (%)	Crude fat (%)	Carcass Ash (%)
Low Protein	0.844 ± 0.011	69.0 ± 10.6	522.6 ± 77.7	87.60 ± 0.54	71.8 ± 0.43	24.2 ± 1.34	29 ± 0.7	95.8 ± 0.44

Medium Protein	0.848 ± 0.014	58.4 ± 12.0	628.6 ± 119.3	85.20 ± 2.30	72.2 ± 0.44	24.6 ± 1.5	27.5 ± 0.7	95.0 ± 0.58
High Protein	0.856 ± 0.010	58.2 ± 10.7	706.6 ± 123.5	91.32 ± 1.02	72.3 ± 0.51	25.4 ± 1.22	27 ± 0.8	95.5 ± 0.37

Meat Composition & Quality

The proximate composition of breast and thigh meat, including moisture, crude protein, fat, and ash content, was analyzed (Table 3). Crude protein content was highest in the HP group, followed by the MP and LP groups ($p<0.05$), indicating a positive correlation between CP levels and protein deposition in muscle tissues. Conversely, fat content was significantly higher in the LP group ($p<0.05$), suggesting that lower dietary CP intake promotes fat deposition in broilers. However, moisture and ash content did not differ significantly among the treatment groups ($p>0.05$).

Meat quality was assessed by analyzing pH, water-holding capacity, and organoleptic properties (Table 4). The pH values of meat were significantly higher ($p<0.05$) in the LP group compared to the MP and HP groups, indicating potential effects on meat texture and shelf life. Additionally, water-holding capacity was significantly lower in the LP group ($p<0.05$), whereas the HP group exhibited the highest water retention, contributing to better meat texture and juiciness.

Table 4. Comparison of chemical factors and organoleptic test in all three groups (Mean + SD)

Groups	pH	Water-holding capacity	Tenderness	Texture	Color	Smell	Taste
Low Protein	5.83 ± 0.12	51.2 ± 6.0	3.6 ± 0.55	3.6 ± 0.55	3.4 ± 0.6	3.6 ± 0.54	3.6 ± 0.89
Medium Protein	5.42 ± 0.11	59.6 ± 3.2	3.8 ± 0.55	4.0 ± 0.54	3.6 ± 0.61	3.8 ± 0.45	3.8 ± 0.84
High Protein	5.28 ± 0.11	60.8 ± 5.2	4.0 ± 0.54	4.2 ± 0.53	3.6 ± 0.6	3.8 ± 0.53	3.6 ± 0.90

3.3 Sensory Attributes

Meat sensory attributes were assessed by 15 trained panelists using a standardized 5-point scoring system. The HP and MP groups received significantly higher scores ($p<0.05$) in texture, tenderness, and overall acceptability than the LP group. The LP group exhibited lower scores for texture and appearance, likely due to higher fat content and reduced muscle density. No significant differences ($p>0.05$) were observed in color, taste, or smell among the three groups.

The results indicate that reducing dietary CP levels adversely affects broiler carcass composition and meat quality, increasing fat deposition and reducing protein retention. However, low-CP diets improve feed efficiency, which may benefit cost-sensitive production systems. The results highlight the importance of optimizing dietary CP levels to balance broilers' growth performance, carcass quality, and feed utilization.

4 Discussion

The present study investigated the effects of reducing dietary crude protein (CP) while supplementing essential amino acids on broiler growth performance, carcass composition, and meat quality. The results demonstrated that reducing CP levels negatively impacted weight gain, carcass yield, and meat quality, whereas moderate to high CP levels promoted better muscle deposition, improved feed conversion efficiency, and enhanced meat characteristics.

The findings on growth performance indicated that broilers fed a high-protein diet (HP group: 22%-20%-18% CP) had the highest final body weight, followed by the medium-protein (MP group: 20%-18%-16% CP), while the low-protein (LP group: 18%-16%-14% CP) exhibited the lowest body weight gain. This aligns with previous studies, which reported that reducing CP levels can significantly limit protein availability for muscle growth, leading to slower weight gain (2, 23). The significant differences observed in weekly body weight gain and total feed intake confirm that sufficient CP levels are necessary for optimal broiler growth (4, 24).

Total feed intake was highest in the HP group, followed by the MP group, whereas the LP group had the lowest cumulative feed consumption. The feed conversion ratio (FCR) was significantly lower in the LP group, indicating better feed efficiency despite lower body weight gain (8). These findings suggest that reducing dietary CP levels may improve feed efficiency but at the cost of reduced growth performance (10, 11). However, the potential cost savings from improved feed conversion should be weighed against the economic losses associated with lower final body weights (12).

Carcass analysis showed that breast muscle yield was significantly lower in the LP group, while abdominal fat deposition was significantly higher compared to the MP and HP groups. This suggests that reducing dietary CP increases fat accumulation and reduces lean muscle mass. This agrees with previous findings that protein deficiency promotes excess energy storage as fat instead of muscle deposition (13). The higher crude protein content in breast muscle of HP-fed birds compared to LP-fed birds further supports this conclusion (16). These findings highlight that while a 2% CP reduction can benefit nitrogen excretion control, it may lead to undesirable fat accumulation and reduced carcass quality (17, 18).

Meat quality analysis revealed that the LP group exhibited higher pH values, lower water-holding capacity, and lower sensory scores compared to the MP and HP groups. The observed increase in pH with reduced CP levels may be linked to metabolic changes affecting muscle glycogen content (19). The HP and MP groups had significantly better texture, tenderness, and overall acceptability scores. In contrast, the LP group had lower ratings for meat appearance and texture, likely due to increased intramuscular fat and lower muscle density (21, 22).

From an environmental and economic perspective, reducing CP levels can minimize nitrogen excretion and improve feed efficiency (25). However, the study suggests that excessive CP reduction negatively affects broiler productivity and meat quality, which may outweigh the potential environmental benefits. Therefore, a moderate CP reduction and optimized amino acid supplementation may provide a balanced approach to sustainable broiler production.

5 Conclusion

This study demonstrates that dietary CP levels significantly influence broiler growth performance, carcass composition, and meat quality. High-protein diets supported better weight gain, improved feed conversion efficiency, and increased breast muscle yield. In contrast, low-protein diets led to reduced growth rates, higher fat deposition, and lower meat quality scores.

The results highlight the importance of maintaining adequate CP levels in broiler diets to optimize growth efficiency and meat quality. While a 2% reduction in levels can improve feed conversion efficiency, excessive reduction may lead to poor muscle development and increased fat accumulation. Therefore, formulating diets that balance CP levels with essential amino acids is crucial to achieving sustainable broiler production.

The findings suggest that moderate CP reductions with proper amino acid supplementation may help optimize production efficiency while minimizing environmental nitrogen excretion. Future studies should explore precision feeding strategies and alternative protein sources to enhance broiler growth and meat quality without compromising sustainability. These results provide valuable insights for poultry nutritionists and producers aiming to balance growth performance, economic feasibility, and environmental impact.

Future research should explore alternative protein sources, amino acid optimization, and precision feeding strategies to enhance feed efficiency while mitigating the environmental impact of poultry production. These findings provide practical insights for poultry nutritionists and producers, emphasizing the need for strategic protein management in broiler feeding programs.

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Conflict of Interest

The authors declare no competing interests.

Author Contributions

All authors contributed equally.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Ethical Considerations

This study was approved by the local ethics committee of the University of Shiraz for animal experiments.

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