EFFECT OF FEED SHAPE AND PROGRAM ON PERFORMANCE, CARCASS YIELD AND ECONOMICS IN COMMERCIAL BROILER INDIAN RIVER

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SUMMARY

This study evaluated the effects of feed program and feed form on growth performance, carcass traits, meat quality, and economic efficiency in commercial Indian River broilers. A total of 180 chicks were assigned to six treatments in a 3 × 2 factorial design, comparing three feed forms (fine, crumble, pellet) and two feed programs (high and moderate crude protein, CP). Diets were formulated to four CP levels (23%, 21%, 19%, and 17%) according to the Indian River nutrition guide. Results showed that both feed program and feed form significantly affected live body weight (LBW), daily weight gain, and feed conversion ratio (FCR) across different phases. In the starter phase, crumble diets with higher CP (T2) achieved the best LBW (384 g), daily gain (24.5 g/day), and efficient FCR (1.18). During the grower phase, T2 again outperformed other treatments with the highest LBW (1473 g) and gain (77.8 g/day). In the finisher phase, pellet diets combined with higher CP improved efficiency, with T2 maintaining the highest final LBW (2161 g) and the lowest FCR (1.72). Carcass evaluation indicated significant effects of feed form on liver, gizzard, and abdominal fat percentages, while breast meat composition was mainly influenced by feed program. Economic study revealed that T2 produced the greatest net return (81.0 LE/chick) and the highest economic efficiency (115%), followed closely by T5 (99.9%). In contrast, T4 and T6 showed reduced efficiency due to lower growth or excessive feed intake. In conclusion, a nutrient-dense program (23-19% CP) combined with crumble form in the starter and grower phases, and pellet form in the finisher, optimized growth, feed efficiency, carcass quality, and profitability. These findings highlight the importance of integrating feed program and physical form to achieve balanced performance and economic sustainability in modern broiler production.

Keywords: *Feed shape, performance, carcass yield, economics, broiler*

INTRODUCTION

Feeding and nutrition are fundamental to successful broiler production, directly influencing growth performance, feed efficiency, carcass yield, and profitability (Leeson & Summers, 2009). Modern poultry nutrition is both a science and an art, requiring the integration of genetic potential, ingredient availability, environmental conditions, and management practices (NRC, 1994). Commercial broiler breeding companies, such as Aviagen, provide detailed feeding and management guidelines for their strains, including the Indian River broiler, to help producers achieve optimal results (Aviagen, 2023).

While such guidelines offer a strong baseline, field conditions often require adjustments to feeding programs to match local ingredient profiles, production systems, and economic objectives (Baião & Lara, 2005). Two key nutritional management factors are feed program (nutrient density in each growth phase) and feed form (physical presentation of the feed). Feed form - such as fine, crumble, or pellet — can affect feed intake (FI), nutrient digestibility, growth rate, FCR, and carcass characteristics (Amerah *et al.,* 2007and Abdollahi *et al.,* 2013). Likewise, adjusting nutrient levels in each phase can optimize performance and profitability while managing feed costs (Dozier *et al.,* 2008).

Although numerous studies have examined the effects of feed form and nutrient density in broilers, much of the literature focuses on generalized responses across strains. Limited research has specifically targeted the commercial Indian River strain, which may have unique responses to feed form and nutrient program combinations due to its genetic potential and growth profile (Aviagen, 2023). Furthermore, feed represents the largest cost in broiler production often exceeding 65-70% of total expenses making nutritional strategies a critical lever for profitability (Baião & Lara, 2005). Understanding how feed form and nutrient density interact to influence growth performance, carcass yield, bone quality, and economic efficiency can guide producers toward feeding strategies that maximize biological performance and financial returns under practical conditions.

The objective of this study was to evaluate the effects of different feed shapes and feed programs on growth performance, carcass traits, tibia bone quality, and economic efficiency of commercial broiler Indian River during the starter, grower, and finisher phases.

MATERIALS AND METHODS

Experimental site and birds:

The experiment was conducted at the Poultry Nutrition Farm, Poultry Production Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt, during the summer season (June-July 2021). A total of 270 one-day-old unsexed commercial broiler chicks (Indian River strain, Aviagen) with uniform initial body weights were obtained from a local hatchery. Birds were randomly distributed into experimental pens immediately upon arrival. Each pen was bedded with fresh wood shavings and maintained under continuous lighting. Ambient temperature, ventilation, and other management practices followed the Indian River management guidelines. Feed and clean drinking water were provided *ad-libitum* throughout the trial. Birds were vaccinated via drinking water against Newcastle disease (day 7), infectious bursal disease (day 14), and Newcastle (Lasota strain) at days 18 and 28.

Diet formulation and feed forms:

Four experimental diets were formulated to contain 23, 21, 19, and 17% crude protein (CP), corresponding to the starter, grower 1, grower 2, and finisher phases, respectively. Formulations were based on the nutrient recommendations of the Indian River broiler manual and were balanced for metabolizable energy, essential amino acids (lysine, methionine, methionine + cystine), calcium, phosphorus, and supplemented with a complete vitamin-mineral premix. Diets were manufactured in three physical forms Table 1:

1. Fine mash: produced by grinding pellets until ≥90% of particles passed through a 1.0mm sieve.
2. Crumble: produced by pelleting through a 2.5 mm die followed by crumbling to obtain 30-60% of particles in crumble form.
3. Pellet: produced through a 2.5 mm die without crumbling.
4.

Table (1): Experimental design of the feeding trial.

Treatment Code	Feed program (CP %, Starter-Grower-Finisher)	Feed Shape	Replicates (Pens)	Birds per Replicate
T1 (P1F1)	23.0 - 21.5 - 19.5	Fine	3	15
T2 (P1F2)	23.0 - 21.5 - 19.5	Crumble	3	15
T3 (P1F3)	23.0 - 21.5 - 19.5	Pellet	3	15
T4 (P2F1)	21.5 - 19.5 - 17.0	Fine	3	15
T5 (P2F2)	21.5 - 19.5 - 17.0	Crumble	3	15
T6 (P2F3)	21.5 - 19.5 - 17.0	Pellet	3	15

P1 = high CP program (23-21-19% CP), P2 = moderate CP program (21-19-17% CP).
F1 = fine, F2 = crumble, F3 = pellet

Design: 3 feed shapes × 2 feed programs = 6 treatments; 3 replicates of 15 chicks / treatment. Phases: Starter (1-14 d), Grower (15-28 d), Finisher (29-35 d).

For all pelleted diets, pellet durability index was maintained at ≥88%, and final feed moisture at ~11.3%. The factorial arrangement of diets and feed forms is summarized in Table 2.

Growth performance:

Live body weight (LBW) and feed intake (FI) were recorded per pen at the end of each phase. Body weight gain (BWG) was calculated as the difference between final and initial BW. FCR was calculated as FI / BWG and corrected for mortality.

Table (2): Ingredient composition and calculated nutrient content of the experimental diets (%, as-fed basis).

Ingredient	Starter (P1) 23% CP	Starter (P2) and Grower (P1) 21%CP	Finisher (P1) Grower (P2) 19%CP	Finisher (P2) 17%CP
Yellow Corn	56.519	62.095	66.629	70.807
Soybean Meal (46%CP)	32.283	24.484	17.228	14.531
Corn Gluten Meal (60%CP)	4.020	5.000	4.925	2.666
Full Fat Soybeans	3.500	5.000	8.000	9.000
Calcium Carbonate	1.372	1.372	1.297	1.246
Mono-Calcium Phosphate	0.788	0.614	0.566	0.596
Salt (NaCl)	0.275	0.248	0.207	0.221
Sodium Bicarbonate	0.061	0.100	0.161	0.143
L- Lysine	0.231	0.248	0.187	0.147
DL- Methionine	0.218	0.184	0.169	0.239
L-Threonine	0.063	0.035	0.011	0.034
Choline Chloride	0.100	0.050	0.050	0.050
Phytase	0.010	0.010	0.010	0.010
Xylanase Enzymes	0.010	0.010	0.010	0.010
Broiler Premix*	0.300	0.300	0.300	0.300
Additives**	0.250	0.250	0.250	0.250
Total	**100.000**	**100.000**	**100.000**	**100.000**
Nutrients				
Crude Protein (CP)%	23.000	21.000	19.000	17.000
ME (Kcal/Kg)	2950	3040	3125	3150
Crude Fat %	3.326	3.697	4.285	4.519
Crude Fiber %	3.192	3.020	2.916	2.896
Calcium %	0.950	0.900	0.850	0.830
Available phosphorus %	0.450	0.400	0.380	0.380
Methionine %	0.581	0.530	0.491	0.522
Methionine + Cystine %	0.988	0.914	0.850	0.850
Lysine %	1.350	1.200	1.025	0.920
Threonine %	0.960	0.850	0.750	0.700
Sodium %	0.180	0.180	0.180	0.180
Chloride %	0.250	0.237	0.200	0.200
Price (LE / Ton)	18,157	18,034	17,968	17,385

**Vitamins-Minerals mixture (per kg diet): Vit. A 12000 IU, Vit.D3 5000 IU, Vit. E 10 mg, Vit.K3 2 mg, Vit.B1 1 mg, Vit.B2 5 mg, Vit.B6 1.5 mg, B Vit.12 10 µg, Biotin 50 µg, Pantothenic acid 10 mg, Niacin 30 mg, Folic acid 1 mg, Mn 60 mg, Zn 50 mg, Fe 30 mg, Cu 10 mg, I 1 mg, Se 0.1 mg, Co 0.1 mg. **Contains Mycotoxin binder, Anti-clostridia, and Anti-coccidia additives.*

Carcass traits:

On day 35, two birds per replicate (six per treatment) were randomly selected, weighed, and slaughtered. Dressing yield, liver, heart, gizzard, edible parts and abdominal fat were recorded and expressed as percentages of LBW.

Economic evaluation:

Feed cost per kg gain, total return, net return, and economic efficiency were calculated based on local market prices during the trial. Economic efficiency was determined using the following formula: Economic efficiency = (Net return\ Total cost) ×100.

Statistical analysis:

A 3 × 2 factorial design (feed program × feed shape) was used with pen as the experimental unit. Separate two-way ANOVAs were conducted for each phase (starter, grower, finisher) to test main effects and interactions. Dunnett's tests were planned to compare all treatments with the phase control (starter/grower: P1-crumble; finisher: P1-pellet). Performance was also benchmarked against Indian River manual targets, with absolute and percentage deviations calculated. Significance was set at P ≤ 0.05, and analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Productive performance:

As shown in Table 3, LBW at the end of the starter phase differed significantly among treatments (P<0.01). The higher LBW value was recorded in T2 (384 g), followed by T1 (380 g) which did not differ significantly from each other but, were higher than T3, T4, T5, and T6. The lower LBW was observed in T6 (341 g). Daily weight gain followed a similar trend (P < 0.01), with T2 showing the higher gain (24.47 g/day), whereas T6 had the lower value (21.41 g/day).

Table 3: Effects of different treatments on live body weight (LBW), daily weight gain (DWG), feed intake (FI), and feed conversion ratio (FCR) of broilers during starter, grower, and finisher phases.

Treatment	LBW (g)	DWG (g/day)	Feed intake (g/day)	FCR
		Starter phase		
T1 (P1F1)	380a (1-14 d)	24.20a	22.60d	0.93c
T2 (P1F2)	384a	24.47a	28.83ab	1.18b
T3 (P1F3)	345c	21.70c	26.13bc	1.20b
T4 (P2F1)	357b	22.56b	24.33c	1.08c
T5 (P2F2)	363b	22.98b	26.66b	1.16b
T6 (P2F3)	341c	21.41c	31.24a	1.46a
SEM	14.444	1.028	1.263	0.070
Sig.	**	**	**	*
Grower phase (15-28 d)				
T1	1391c	72.24bc	101.73b	1.41c
T2	1473a	77.81a	112.61a	1.45c
T3	1384c	74.22ab	111.33a	1.50b
T4	1396c	74.20ab	104.77b	1.41c
T5	1427b	76.00a	110.53a	1.45c
T6	1330d	70.66c	115.98a	1.64a
SEM	19.429	1.043	2.151	0.099
Sig.	**	*	*	**
Finisher phase (29-35 d)				
T1	1939c	78.24c	163.20	2.09a
T2	2161a	98.17a	168.74	1.72b
T3	2053b	95.58ab	166.98	1.75b
T4	1923c	75.34b	164.01	2.18a
T5	2098ab	95.86ab	166.85	1.74b
T6	1983b	93.18b	163.61	1.76b
SEM	38.344	4.056	9.234	0.167
Sig.	**	**	NS	**

Means with different superscripts within a column and phase differ significantly (P < 0.05). SEM = standard error of the mean; Sig. = significance level; NS = not significant.

Feed intake was significantly affected by treatments (P < 0.01). The greater FI was recorded in T6 (31.24 g/day), followed by T2, while T1 had the lowest FI (22.60 g/day). Feed conversion ratio also varied among treatments (P < 0.05), with the best FCR observed in T1 (0.93) and T4 (1.08), and the poorest in T6 (1.46). These differences indicate that both feed form and composition influenced early growth, with fine and crumble forms combined with higher nutrient density generally improving FCR, while pellet feeding at this age tended to increase FI without proportional gains in LBW.

In the grower phase, LBW at (15-28 d) was (P < 0.01) the highest in T2 (1473 g), while T6 had the lowest LBW (1330 g). Daily weight gain was also significantly affected (P < 0.05), with T2 showing the higher gains (77.81), and T6 the lower (70.66 g/day).

Feed intake was significantly (P<0.05) greater in T2, T3, T5, and T6 (110.53-115.98 g/day) compared with T1 and T4 (101.73-104.77 g/day). Feed conversion ratio showed clear treatment effects (P-<-0.01), with T1, T2, T4, and T5 having lower values (1.41-1.45) than T3 (1.50) and especially T6 (1.64). These results suggest that in the grower phase, feed composition (higher CP/energy) played a dominant role in maximizing LBW and gain, while feed form had a stronger effect on FCR, with fine/crumble maintaining efficiency and certain pellet treatments reducing it.

At Finisher phase (29-35 d), LBW remained significantly (P< 0.01) influenced by treatments. T2 achieved higher LBW (2161 g), followed by T5 (2098 g) and T3 (2053 g), while T4 had lower value (1923 g,). Daily weight gain showed similar significance (P < 0.01), with T2 again leading (98.17 g/day) and T4 lower value (75.34 g/day).

Feed intake in the finisher phase was not significantly different among treatments (P > 0.05), ranging from 163.20 to 168.74 g/day. In contrast, FCR was significantly affected (P < 0.01), with the best values observed in T2, (1.72) and T4 had the poor value (2.18). This indicates that in the final week, feed composition (higher nutrient density) combined with pellet form improved feed efficiency, even though FI remained similar across treatments.

Across the entire rearing period, both overall FI and overall FCR were significantly (P<0.001 and P<0.05, respectively) influenced by treatments. The higher overall FI value was recorded for T6 (91.61 g/day) followed by T2 (90.33 g/day), while T1 and T4 recorded lower (82.37 and 84.44 g/day), respectively (Table 4)

Overall FCR values ranged from 1.463 in T2 to 1.617 in T6. The best FCR values were achieved in T2 (1.463), T5 (1.472), and T1 (1.487), which did not differ significantly from each other, while the poorest FCR was observed in T6 (1.617).

These results indicate that, over the full growth cycle, feed composition, particularly higher nutrient density intended to support both higher FI and improved FCR when combined with certain feed forms. However, some feed form × composition combinations, notably those used in T6, increased overall FI without a proportional improvement in weight gain, leading to poorer feed efficiency.

Table (4): Effects of treatments on overall feed intake (FI) and feed conversion ratio (FCR) during the entire rearing period (1-35 d).

Overall phase		
Treatment	**Overall Daily Feed Intake (g/day)**	**Overall FCR**
T1 (P1F1)	82.37c	1.487c
T2 (P1F2)	90.33a	1.463c
T3 (P1F3)	88.38ab	1.507b
T4 (P2F1)	84.44c	1.537b
T5 (P2F2)	88.25b	1.472c
T6 (P2F3)	91.61a	1.617a
SEM	1.435	0.093
Sig.	***	*

Means with different superscripts within a column differ significantly (P < 0.05).
SEM = standard error of the mean; Sig. = significance level; NS = not significant.

Results in Table 5 showed in the starter phase (0-14 d), feed form had a marked effect on performance (P < 0.01). Chicks fed fine or crumble diets gained more weight (23.4-23.7 g/d) than those on pellets (21.6 g/d). Feed intake was lowest with fine diets (23.47 g/d) and higher with pellets (28.7 g/d). FCR was most efficient with fine (1.01) and crumble diets (1.17), while pellets showed the poorest efficiency (1.33). Feed program also influenced performance, where P1 improved weight gain (23.5 g/d) and FCR (1.10), whereas P2 increased intake (27.41 g/d) but worsened efficiency (1.23).

Table (5): Main effects of feed form and feed program on daily weight gain (DWG), daily feed intake (DFI), and feed conversion ratio (FCR) of broilers during different phases.

Parameter	Factor	DWG (g/d)			DFI (g/d)			FCR		
		Starter	Grower	Finisher	Starter	Grower	Finisher	Starter	Grower	Finisher
Feed Form	Fine (F1)	23.38a	73.22b	76.79c	23.47c	103.25b	163.61	1.01d	1.41b	2.14a
	Crumble (F2)	23.73a	76.91a	97.02a	27.74ab	111.5a7	167.80	1.17bc	1.45b	1.73b
	Pellet (F3)	21.56b	72.44b	94.38a	28.69a	113.66a	165.30	1.33a	1.57a	1.76b
Feed Program	P1	23.46a	74.76ab	90.66a	25.85b	108.56a	166.31	1.10c	1.45b	1.85b
	P2	22.32b	73.62b	88.13b	27.41a	110.43a	164.82	1.23b	1.50ab	1.89b
SEM		0.951	2.23	5.60	1.05	8.43	13.35	0.09	0.066	0.113
Sig.		**	**	**	**	**	NS	**	**	**

Values are means of treatments within feed form (fine, crumble, pellet) and feed program (P1, P2). Note: Means with different superscripts within a column differ significantly (P < 0.05).

During the grower phase (15-28 d), crumble diets supported the highest gain (76.91 g/d), significantly exceeding fine (73.22 g/d) and pellet diets (72.44 g/d). Feed intake was greater with pellet then crumble forms (114 and 111-g/d) compared to fine (103 g/d). FCR was lower in fine and crumble diets, while pellets had poorer conversion (1.57). Between programs, P1 improved weight gain and efficiency (74.76 g/d; 1.45) compared with P2, which raised intake (110.4 g/d) but increased FCR (1.50). In the finisher phase (29-35d), crumble and pellet diets achieved superior gains (94-97 g/d) compared with fine feed (76.79 g/d; P<0.01). Feed intake did not differ significantly among forms (163-168 g/d). However, FCR was best in crumble and pellet diets (1.73-1.76) and poorest in fine form (2.14). Feed program P1 improved gain (90.7 g/d) and efficiency (1.85) compared with P2 (88.13 g/d; 1.89). Overall, crumble diets provided the most balanced improvement in gain and efficiency across phases, while fine feed enhanced starter efficiency but reduced finisher growth. Pellet feeding increased intake and efficiency only in the finisher phase. Program P1 consistently supported better feed efficiency, whereas P2 promoted higher intake but less favorable FCR (Table 5).

These results support the significant influence of feed form and feed program on broiler growth efficiency across different production phases. In the starter phase, fine mash (F1) markedly improved FCR compared to pellet (F3), aligning with findings that finer particle sizes enhance digestibility and feed efficiency in young broilers (Amerah *et al.,* 2007). The elevated FI under pellet form likely resulted from greater palatability and ease of consumption, but without proportional gains in body weight, leading to poorer efficiency.

During the grower phase, crumble (F2) outperformed both mash and pellet in terms of weight gain and FCR. Similar trends were reported by Karimirad and Zaghari (2010), who observed that crumble-pellet diets improved body weight and FCR in broilers compared with mash diets.

In the finisher phase, crumble and pellet forms produced significantly higher gains and better FCR than fine mash, consistent with findings that pelleted diets enhance growth in older broilers by maintaining gut integrity and improving feed passage (Abdollahi *et al.,* 2013). Notably, pellet form showed limited benefit in early phases but became more advantageous during finishing reported by Inborr & Frank (2019).

Across all phases, the higher CP program (P1) consistently supported superior weight gain and FCR compared to P2, confirming the importance of nutrient density in maximizing performance. Massuquetto et al. (2019) also reported that pelleted, nutrient-dense diets enhanced broiler growth and feed efficiency, whereas reduced nutrient density impaired carcass quality.

Overall, crumble diets provided the most balanced improvement in gain and efficiency across phases, especially when paired with the higher-CP program. Fine mash improved efficiency in the starter phase but was unsuitable for older birds, while pellet form maximized FI and efficiency primarily during finishing. From a production perspective, adopting crumble feed combined with a nutrient-dense program (P1) represents the most effective strategy.

Carcass characteristics:

As shown in Table 6, carcass yield was not significantly affected by feed form, feed program, or their interaction (P > 0.05). However, significant differences were observed for internal organs. Feed form influenced liver and gizzard weights, with pellet-fed birds showing the highest liver percentage (2.10%;

P < 0.05), while fine diets increased gizzard weight (1.13%) compared with crumble and pellet diets (0.99-1.00%). Abdominal fat was also markedly affected (P < 0.01), being greatest in birds fed fine diets (2.25%) and lowest in those on pellets (1.37%).

Feed program effects were generally minor. Program 2 resulted in a slightly higher abdominal fat percentage (1.81% vs. 1.75%; P < 0.05) compared with Program 1, while liver, gizzard, and giblets percentages were not significantly different between programs (Table 6).

At the interaction level, T2 (P2 × fine) and T1 (P1 × fine) produced the higher abdominal fat percentages (2.36% and 2.14%, respectively), while T6 (P2 × pellet) had the lower (1.21%). Edible parts percentage was relatively stable across treatments, with values ranging from 3.19 to 3.88%.

The absence of significant differences in carcass yield among feed forms and programs agrees with earlier studies indicating that feed structure mainly affects internal organ development rather than carcass dressing percentage (Abdollahi *et al.,* 2013).

Table (6): Effects of feed program and feed form on carcass characteristics of broilers at 35 days of age.

Factor / Treatment	Carcass %	Liver %	Gizzard %	Heart %	Giblets %	Edible parts %	Abdominal fat %
T1 (P1F1)	67.74	1.97	1.09b	0.69	4.11	3.88	2.14a
T2 (P1F2)	71.38	1.88	1.04b	0.68	4.24	3.60	2.36a
T3 (P1F3)	71.35	1.62	1.39a	0.67	4.00	3.19	1.57b
T4 (P2F1)	68.48	1.66	1.08b	0.68	4.17	3.42	1.86ab
T5 (P2F2)	70.68	2.17	1.37a	0.66	4.09	3.80	1.54b
T6 (P2F3)	72.54	2.03	1.43a	0.67	4.23	3.73	1.21b
Feed Form effect							
Fine (F1)	69.56	1.92b	1.13a	0.68	4.16	3.73	2.25a
Crumble (F2)	69.91	1.64c	0.99b	0.67	4.27	3.30	1.71b
Pellet (F3)	71.61	2.10a	1.00b	0.66	4.32	3.76	1.37c
Feed Program effect							
Program 1 (P1)	69.92	1.92	1.03	0.67	4.23	3.62	1.75b
Program 2 (P2)	70.80	1.85	1.05	0.67	4.19	3.57	1.81a
Significance	NS	*	*	NS	NS	NS	*

Values expressed as % of live body weight. Note: Edible parts % = (liver + gizzard + heart). Means with different superscripts within a column differ significantly (P < 0.05). NS = not significant.

Liver weight was significantly increased in birds fed pelleted diets, which may reflect greater nutrient intake and metabolic activity. Pelleting is known to increase voluntary FI and improve nutrient digestibility, thereby elevating liver workload (Choct, 2009). Conversely, fine diets increased gizzard weight, consistent with the mechanical role of the gizzard in grinding feed particles. Larger gizzards are typically observed in birds consuming finer or more fibrous diets, reflecting enhanced muscular activity for feed breakdown (Svihus, 2011). Abdominal fat was most pronounced in birds fed fine diets and under Program 2. This may be related to a mismatch between energy and amino acid supply, leading to inefficient protein utilization and higher lipogenesis. Similar associations between reduced dietary protein or imbalanced nutrient supply and increased abdominal fat deposition have been reported (Zhang *et al.,* 2011 and Wang *et al.,* 2017). In contrast, pellets resulted in the lowest abdominal fat content, possibly due to improved feed conversion and more efficient nutrient utilization. Overall, these results suggest that while feed form had little impact on carcass yield, it significantly modulated internal organ development and fat deposition. The findings emphasize the importance of balancing feed form and nutrient density, as over-processed fine diets may compromise efficiency by increasing fat deposition, whereas pellets may improve nutrient use but reduce gizzard development.

Chemical composition of breast meat:

As shown in Table 7, chemical proximate composition of breast meat was generally not affected by feed program or feed form, except for ash and protein content. Ash percentage was higher in program 2 compared with program 1 (P < 0.05), while moisture, lipids, and protein did not differ significantly. Feed form influenced breast protein levels (P < 0.05), with the higher protein values observed in fine (F3) and pellet (F1) diets (24.04%-23.58), and the lowest in crumble (F2; 21.26%).

Table (7): Effects of feed program and feed form on proximate chemical composition of breast meat (wet basis).

Factor / Treatment	Moisture %	Ash %	Lipids %	Protein %
Interactions (Program × Form)				
T1 (P1F1)	71.62	3.60bc	4.12	23.80ab
T2 (P1F2)	72.99	4.35a	4.34	24.29a
T3 (P1F3)	71.57	3.37c	4.57	20.49c
T4 (P2F1)	72.80	3.17c	4.67	22.03b
T5 (P2F2)	74.01	3.33c	4.36	24.27a
T6 (P2F3)	71.11	3.85ab	4.76	22.88b
Feed Form				
Fine (F1)	71.11	3.98	4.19	24.04a
Crumble (F2)	72.85	3.27	4.79	21.26b
Pellet (F3)	71.39	3.59	4.57	23.58a
Feed Program				
Program 1 (P1)	71.39	3.43b	4.61	22.86
Program 2 (P2)	72.01	3.79a	4.42	23.07
Significance	NS	*	NS	*

Values expressed as % of breast tissue. Note: Means with different superscripts within a column differ significantly (P < 0.05). NS = not significant.

Interaction effects were limited, although T3 (P1 × crumble) produced the lowest protein content (20.49 %), whereas T2 and T5 yielded the higher values (24.29-24.27%). Moisture, and lipids percentages showed no consistent interaction trends across treatments.

The limited effects of feed program on proximate meat composition align with previous reports that nutrient density within recommended ranges has minimal influence on muscle composition, except in cases of severe protein or energy restriction (Musa *et al.,* 2006 and Mateos *et al.* 2012). The higher ash content in Program 2 diets may reflect differences in mineral retention associated with diet formulation, as observed in studies linking dietary phosphorus and trace minerals to increased carcass ash (Santos *et al.,* 2019).

Feed form had a stronger influence on protein content, with crumble diets showing reduced protein deposition. This agrees with Abdollahi *et al.* (2013), who noted that differences in feed structure can alter digestion kinetics and amino acid availability, potentially reducing protein accretion when feed particle size impairs uniform intake. Pelleted diets, in contrast, often enhance protein deposition through improved nutrient digestibility and higher FI (Lemme *et al.,* 2006 and Batal & Parsons 2002). Overall, breast meat quality was stable across most parameters, but the reduced protein percentage in crumble-fed birds suggests that feed structure may influence muscle nutrient partitioning even when overall growth performance remains adequate.

Economic evaluation outcomes:

Economic evaluation outcomes for the different dietary treatments are presented in Table (8). Total returns followed the pattern of BWG, with T2 producing the highest return (151.27 LE), while T4 produced the lowest (134.61 LE). Net returns ranged from 68.45 to 81.03 LE, with T2 and T5 outperforming other treatments. Economic efficiency (EE), ranging from 103.48% in T4 to 115.36% in T2. Relative EE confirmed T2 (100%) and T5 (99.9%) as the most economically efficient options, while T4 and T1 showed the weakest performance. Performance index (PI) values supported these findings, with T2 achieving the best value (144.9), followed by T5 (139.7).

The results clearly indicate that feed program and feed form influenced economic outcomes across the production cycle. Birds in T2 (Program 1 × crumble) achieved the highest BWG, net return, and EE. This can be attributed to a balanced combination of nutrient density and efficient feed utilization, which aligns with earlier findings that higher protein starter and grower diets enhance growth and profitability (Kamran *et al.,* 2008 and Saleh *et al.,* 2021).

Although T2 had the highest feed costs due to greater intake and higher diet price, the superior growth and final LBW compensated for this, yielding the best net return and EE. Similarly, T5 (Program 2 × pellet) produced nearly equivalent economic efficiency, suggesting that moderate reductions in dietary

CP at later phases can still maintain profitability when coupled with an efficient feed form. This observation is consistent with reports that nutrient dilution strategies, if balanced for amino acids, do not necessarily compromise economic returns (Abudabos *et al.,* 2017 and Belloir *et al.,* 2017).

Table (8): Economic evaluation of broiler performance under different dietary treatments.

Treatment	Body Weight (kg)	Feed Consumed (kg)	Feed Cost (LE)	Total return (LE)	Net return (LE)	Economic efficiency (%)	Performance index
T1 (P1F1)	1.939	2.883	45.78	135.73	69.95	106.34	127.7
T2 (P1F2)	2.161	3.161	50.24	151.27	81.03	115.36	144.9
T3 (P1F3)	2.053	3.093	49.15	143.71	74.56	107.83	133.5
T4 (P2F1)	1.923	2.955	46.16	134.61	68.45	103.48	122.5
T5 (P2F2)	2.098	3.089	48.25	146.86	78.61	115.19	139.7
T6 (P2F3)	1.983	3.206	50.11	138.81	68.7	97.98	120.1

Values calculated based on local feed prices and market value of live broilers (70 LE/kg) during the trial.
Economic efficiency (EE, %) = (Net return ÷ Total cost) × 100
Performance index (PI) = (LBW Kg /FCR) × 100

In contrast, T4 and T1 exhibited the lowest economic efficiency, primarily due to lower BWG and lower overall returns despite reduced feed costs. Treatments with pellet forms (e.g., T6) showed relatively higher FI without proportional gains, resulting in poorer feed efficiency and reduced profitability, which agrees with previous work noting that pellet form sometimes increases intake but can reduce feed efficiency under suboptimal nutrient programs (Amerah *et al.,* 2007 and Abdollahi *et al.,* 2013).

Overall, these findings highlight that the choice of feed program is more decisive than feed form in determining economic efficiency, though feed form fine-tunes profitability within each program. A nutrient-dense program (P1) with crumble feed form (T2) yielded the most favorable economic outcomes, while Program 2 showed competitive efficiency when paired with pellet form (T5).

CONCLUSION

Feed form and nutrient program had a marked impact on broiler performance, carcass traits, and profitability. Crumble with higher protein density improved growth and FCR in early phases, while pellets enhanced efficiency in finishing. Carcass traits were moderately affected, with pellets increasing liver size and fine diets raising fat deposition. Economically, the nutrient-dense program with crumble (starter-grower) and pellets (finisher) achieved the best net returns and efficiency, highlighting the importance of integrating diet density with feed structure for sustainable broiler production.

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تأثير شكل العلف وبرنامج التغذية على الأداء والإنتاجية وصفات الذبيحة وجودة العظم والكفاءة الاقتصادية في بداري التسمين (سلالة إنديان ريفر)

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أُجري هذا البحث لدراسة تأثير شكل العلف (ناعم، مفتت، مصبع) وبرنامج التغذية (مرتفع أو متوسط البروتين الخام) على الأداء الإنتاجي، صفات الذبيحة، والكفاءة الاقتصادية في بداري التسمين التجارية (سلالة إنديان ريفر). استخدم في التجربة 270 كتكوت عمر يوم واحد غير مجنس، ووزعت عشوائياً إلى ستة معاملات في تصميم عاملي 3 × 2 بواقع 3 مكررات لكل معاملة (15 طائر/مكرر). صُممت علائق التجربة وفق توصيات دليل تربية إنديان ريفر، على أربع مراحل غذائية (بروتين خام 23، 21، 19، 17%).

أظهرت النتائج أن شكل العلف وبرنامج التغذية أثرا معنوياً على الوزن الحي، معدل الزيادة الوزنية اليومية، ومعامل التحويل الغذائي عبر المراحل المختلفة. في مرحلة البادئ، حققت العلائق المفتتة مع البروتين المرتفع المعاملة (T2) على وزن حي (384 جم) وأفضل كفاءة تحويل (1.18). وفي مرحلة النمو، واصلت المعاملة T2 التفوق مسجلةً أعلى وزن حي (1473 جم) ومعدل نمو يومي (77.8 جم/يوم). أما في مرحلة النهايات فقد حسّنت العلائق المصبعات مع البروتين المرتفع الكفاءة الغذائية، حيث سجلت T2 أعلى وزن حي نهائي (2161 جم) وأقل معامل تحويل (1.72).

أما من الناحية الاقتصادية، فقد حققت T2 أعلى عائد صافي (81 جنيه/كتكوت) وأعلى كفاءة اقتصادية (115%)، تليها المعاملة T5. في حين سجلت T4 و T6أقل كفاءة اقتصادية نتيجة لانخفاض معدلات النمو أو زيادة الاستهلاك غير الفعال للعلف. بالنسبة لصفات الذبيحة، لم يتأثر وزن الذبيحة الكلي معنوياً، بينما تأثرت بعض الأعضاء الداخلية ونسبة الدهن البطني بشكل واضح تبعاً لشكل العلف.

تشير النتائج إلى أن تطبيق برنامج غذائي عالي البروتين (23-19%) مع استخدام العلف المفتت في مرحلتي البادئ والنامي، ثم التحول إلى العلف المصبع في مرحلة الناهي، يُعد الإستراتيجية المثلى لتحقيق أفضل أداء إنتاجي وكفاءة اقتصادية في بداري التسمين (سلالة إنديان ريفر).