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Effect of Dietary Supplementation with *Spirulina platensis* and *Moringa oleifera* as Alternatives to Antibiotics on Growth Performance, Carcass Traits and Cost-Effectiveness in Broiler Chickens

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ABSTRACT

A study was conducted to determine the comparative and combined efficacy of *Moringa oleifera* dry leaf powder and *Spirulina platensis* powder as natural feed additives on productive performance and cost-effectiveness in broilers, in comparison to an antibiotic-based diet. Accordingly, a total of 120-day-old Lohmann Meat broiler chicks were randomly assigned to four treatment groups using a completely randomized design, with three replicates, each containing 10 chicks. Among the four treatment groups, one group was fed a basal diet supplemented with antibiotics and served as the control, while the other groups were fed the same diet supplemented with 2% *Moringa* leaf powder, 1% *Spirulina* powder, and 1% *Moringa* leaf powder with 0.5% *Spirulina* powder. The results of the experiment indicated that the combined addition of *Moringa* and *Spirulina* powder improved the growth performance of broilers. However, no significant differences ($P > 0.05$) were found in final live weight, feed intake, body weight gain, and feed conversion ratio among the treatment groups. The synergistic effect of these natural feed additives significantly ($P < 0.05$) increased the weights of breasts, drumsticks, wings, livers, intestines, hearts and dressing percentage compared to other treatments. However, no significant differences ($P > 0.05$) were observed in breast, back, neck, gizzard, or spleen weight among any of the groups. Overall, the present study suggests that the combined effect of *Moringa* and *Spirulina* positively influenced broiler performance and cost-effectiveness. Therefore, it can be concluded that these two natural feed supplements can be utilized as alternatives to antibiotics.

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Introduction

The antibiotic ban in feed and increasing consumer demand for antibiotic-free meat drives the search for safe, nutrient-rich natural feed additives. Poultry farming, particularly broiler production, is a vital sector in the global food industry. However, ensuring efficient growth and maximizing broiler performance remains an ongoing challenge. The poultry production plays a major role in bringing the protein gap in developing countries where average daily consumption is far below recommended standards (Onyimonyi et al., 2009). The most important sources of animal protein in the world are poultry meat which alone contributes 37% of the total meat production in Bangladesh (Hamid et al., 2017). Broiler production performance is constrained by several factors, including rapid population growth, the spread of diseases, escalating feed costs, and limited access to high-quality feed ingredients essential for formulating balanced diets. In broiler industry, feed costs considered as one of the greatest challenges especially in developing countries which constitutes about 60-80% of the total cost of poultry meat production (Teguia and Beynen, 2005). The rising costs and demand for conventional energy and protein sources like fish meal and soybean meal encouraged the search for alternative feeds to economize and lessen competition for traditional feedstuffs (Gaia, 2005). Conventional methods often rely on antibiotic growth promoters, which raise concerns about antibiotic resistance (Deepa et al., 2018) This research explores the effectiveness of *Moringa oleifera* leaf powder and *Spirulina platensis* powder as alternatives to conventional antibiotics. *Moringa oleifera* leaves are a rich source of protein, essential vitamins, minerals and antioxidants, whereas *Spirulina platensis*, a blue-green alga, is known for its high protein content, essential fatty acids, and immune-boosting properties. The dried, ground leaves of *M. oleifera* contain 25.1% crude proteins, 5.4% lipids, 11.5% ash, 21.9% NDF (neutral detergent fibre), and 11.4% ADF (acid detergent fibre), along with 44.4% carbohydrates (Teixeira et al., 2014).

Moringa leaves are a nutritional powerhouse, containing high levels of calcium (comparable to 4 glasses of milk), iron (3 times more than spinach), vitamin A (4 times more than carrots), protein (twice that of milk), potassium (3 times more than bananas), and vitamin C (7 times more than oranges). Additionally, heavy metals are absent in *Moringa* leaves (Loren, 2007). However, there is limited and conflicting data on the impact of incorporating *Moringa oleifera* leaf powder (MOLP) extract into broiler chicken diets, with some studies reporting decreased intake and others observing no detrimental effects on growth performance up to a 10% inclusion level. Gakuya et al. (2014) reported a decrease in intake but an increase in feed conversion ratio. Olugbemi et al. (2010) observed a decline in the growth performance of broiler chickens when MOLM exceeded a 5% inclusion level in the feed. In general, Kakengi et al. (2007) and Abou-Elezz et al. (2011) concurred that the utilization of MOLM up to a 10% inclusion level had no detrimental impact on the productive performance of broiler chickens; however, levels surpassing 10% resulted in adverse effect. On the other hand, Spirulina contains higher amounts of protein (55-60%) and all essential amino acids, vitamins, and minerals (Doreau et al., 2011). It is also a rich source of carotenoids and fatty acids, especially gamma-linolenic acid (GLA), which provides health benefits (Guroy et al., 2012). Throughout the world, *Spirulina* has been used as a feed component in broiler and layer diets to enhance yolk color, meat quality, and egg fertility (Ross and Dominy, 1990). Additionally, *Spirulina* is rich in polysaccharides, which may function as prebiotics (Beheshtipour et al., 2013; de Jesus Raposo et al., 2016). The response of broilers to *Moringa* and *Spirulina* supplementation have been studied independently in several investigations. However, limited research has been conducted on the synergistic impact of *Moringa* leaf and *Spirulina* on growth performance, carcass traits, and cost-effectiveness in broilers. Hence, the present study aimed to evaluate the impact of incorporating these natural feed additives into broiler diets on key performance parameters, including body weight gain, feed conversion ratio (FCR), overall broiler growth performance and cost-effectiveness.

Materials and Methods

Place of work

This study was performed at the poultry farm of Sher-e-Bangla Agricultural University, located in Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh.

Preparation of Moringa leaf powder and Spirulina powder

Fresh moringa leaves were harvested from the Sher-e-Bangla Agricultural University medicinal plant garden and air-dried for 5 days to retain their nutritional value. After air drying, the leaves were ground into a fine powder using a laboratory grinder. The powder was then sieved through a 0.20 mm sieve to remove coarse particles. Finally, the dried MOLP was tightly packed in laboratory plastic jars and stored at room temperature until use in the experiment. Commercially available dried organic *Spirulina* powder was obtained from a reputable company, SK+F pharmaceuticals limited.

Experimental design and birds

A total of 120-day-old Lohmann meat commercial broilers chicks of uniform body weight were used in this study. The birds were randomly allocated into four groups, each with three replicates of 10 birds. The experiment followed a completely randomized design (CRD) and lasted for 28 days to assess the individual and synergistic effects of MOLP and *Spirulina* powder on broiler performance.

Dietary treatments and managements practices

The experimental shed, including the ceiling, walls, floor, feeders and drinkers, was completely cleaned and flushed with water. The floor was subsequently disinfected using a diluted Iodophor solution at a concentration of 3 ml per liter of water. Throughout the experiment, the birds received consistent care and management. Upon arrival at the farm, day-old chicks were weighed and randomly distributed into electrically heated brooders for the initial seven-day brooding period. Afterward, the birds were transferred to their designated pens. The internal temperature of the broiler shed was initially maintained at 34°C during the first week and gradually reduced by 3℃ each week until reaching 23℃, which was maintained during the entire experimental phase. During the brooding period, the birds received 23 hours of light followed by 1 hour of darkness. The birds were housed in floor pens measuring 3 ft × 2 ft, each bedded with fresh rice husk litter at a uniform depth of 3 cm to ensure adequate bedding conditions. Room temperature and humidity were recorded daily using a digital thermometer and an automatic thermo-hygrometer. Vaccinations against Newcastle disease virus and Infectious bronchitis virus were administered through eye drops at day 3, while Infectious bursal disease virus vaccination was provided through drinking water at days 9 and 17. Clean drinking water was provided *ad libitum*, whereas feed was supplied in accordance with the age-specific dietary requirements recommended for the Lohmann Meat strain. Each pen had one feeder and one round drinker for 10 birds. The birds' basal diet was formulated to meet the nutrient requirements of broilers as established by the National Research Council (NRC) and was provided for a total of 4 weeks in two stages: starter (0-10 days) and grower (11-28 days). Four dietary treatment groups were established based on the basal feed: Antibiotic control (T_0), 2% Moringa leaf powder (T_1), 1% Spirulina powder (T_2), and 1% Moringa leaf powder + 0.5% Spirulina powder (T_3). Body weight (BW) was recorded at 7-day intervals (7, 14, 21 and 28 days). BW gain was calculated as the difference between the final and initial body weights. Feed intake (FI) was calculated as the difference between feed offered and feed refused. FCR was calculated as FI per unit of BW gain on a pen weight basis. The formulations and chemical constituents of the diets for different groups are listed in Table 1.

Table 1. Ingredients and chemical analysis of the starter and grower diet

Ingredients (%)	Starter (d 0-10)				Grower (d 11-28)			
	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
Broken maize	52.90	52.40	53.20	54.56	59.50	56.00	57.40	57.51
Rice polish	15.00	14.90	13.90	12.60	10.00	12.10	10.80	10.70
Soyabean oil	0.70	0.30	0.52	0.40	1.40	1.43	1.56	1.54
Soybean meal	15.00	14.70	15.90	15.59	11.60	13.10	13.90	13.35
Fish meal	10.50	9.60	9.40	9.20	10.10	9.20	9.20	9.20
Poultry meal	3.00	3.20	3.20	3.30	4.50	3.30	3.30	3.30
Moringa leaf powder	0	2	1	1	0	2	1	1
Spirulina powder	0	0	0	0.5	0	0	0	0.5
Salt (NaCl)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DCP	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Lysine-HCl	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
DL-methionine	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Limestone	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Phytase	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Vit-Min premix*	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	100	100	100	100	100	100	100	100
Nutrient (%) and energy content (as feed basis)								
Metabolic Energy (kcal/kg)	3004.06	3000.54	3000.67	3001.60	3100.00	3100.63	3100.22	3100.73
Crude Protein (%)	22.02	22.03	22.02	22.03	21.02	21.04	21.00	21.03
Calcium (%)	0.93	0.93	0.93	0.93	0.91	0.91	0.91	0.91
Phosphorus (%)	0.47	0.47	0.47	0.47	0.46	0.47	0.47	0.47
Lysine (%)	1.20	1.20	1.20	1.20	1.10	1.10	1.10	1.10
Methionine (%)	0.49	0.49	0.49	0.49	0.47	0.47	0.47	0.47
Threonine (%)	0.79	0.79	0.79	0.79	0.75	0.75	0.75	0.75

*Vitamin-mineral premix provided per kg of diet: vitamin A 12,000 IU; vitamin D_3 2,000 IU; vitamin E 20 IU; vitamin K 2 mg; vitamin B_{12} 0.02 mg; folic acid 0.6 mg; calcium pantothenate 10 mg; and choline chloride 500 mg. The mineral content of the premix included manganese 120 mg, iron 80 mg, zinc 60 mg, copper 5 mg, iodine 1.5 mg, cobalt 0.2 mg, and selenium 0.15 mg

Slaughter procedure

At 28 days of age, three birds were randomly selected from each replicate and weighed individually. The birds were then fasted for 8 hours with *ad libitum* access to water before being weighed again prior to slaughter. All birds were slaughtered humanely using the halal method. This involved severing the jugular vein, carotid artery, and trachea in a single incision with a sharp knife, followed by a minimum 2-minute bleed-out period. After slaughter, the outer skin was carefully removed using sharp scissors and hand movements. The carcasses were then manually washed to remove any loose feathers or foreign material. Evisceration and dissection were performed according to the methods outlined by Jones (1984). This involved removing the liver and heart by carefully cutting them loose from the viscera. The gall bladder was then removed from the liver, followed by the gizzard. Dressing yield was calculated by subtracting the weight of feathers, blood, head, shanks, heart, liver and the digestive system from the live weight of each bird.

Statistical analysis

Statistical analysis was performed using one-way ANOVA in SPSS (version 27). Mean differences were evaluated through Duncan's Multiple Range Test, with statistical significance determined at $P<0.05$, and results expressed as standard error of the mean (SEM).

Results and Discussion

Growth performance

The data on live weight (LW), body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) obtained in this study are summarized in Figure 1. There were no significant differences ($P > 0.05$) in any of the measured parameters (LW, FI, BWG, FCR) between the treatments (T_1-T_3) and the control group (T_0). Weekly body weight gain was non-significant ($P > 0.05$) during the 1st, 2nd, and 4th weeks; however, a significant effect ($P < 0.05$) was found at the end of the 3rd week (Figure 2). Interestingly, birds fed a combination of 1% MOLP and 0.5% *Spirulina platensis* (T_3) had increased the final live weight and body weight gain compared to the control and other treatment groups. This observation suggests a potential synergistic effect of MOLP and Spirulina powder on broiler chicken growth. However, feed intake in T_3 was not statistically different ($P> 0.05$) from the control group which displayed the highest overall feed intake. This finding indicates a potential improvement in feed efficiency for birds supplemented with MOLP and *Spirulina*. Although not statistically significant, birds in treatment groups T_2 (1% *Spirulina*) and T_3 (MOLP and *Spirulina*) exhibited a slight improvement in FCR compared to the control group (T_0).

The inclusion of MOLP and *Spirulina platensis*, either individually or in combination, did not significantly affect ($P > 0.05$) feed consumption, body weight gain, or feed conversion ratio compared to the control and other treatment groups. However, birds fed a combination of MOLP and spirulina (T_3) exhibited numerically higher final live weight and body weight gain, suggesting a potential improvement in feed efficiency.

The present study aligns with the findings of Gadzirayi et al. (2012), who reported that no significant difference was found in the final live weight of broilers supplemented with MOLP compared to the control group. This finding contrasts with those of Olugbemi et al. (2010) and Banjo (2012), who mentioned that the inclusion of 1% *Moringa oleifera* leaf meal in the diet of the broilers significantly ($P < 0.05$) enhanced body weight gain. However, Ochi et al. (2015) observed a reduction in body weight gain at the inclusion of 2.0% MOLP, potentially due to anti-nutritional factors like phytates. Notably, in the present study, 2% MOLP also did not significantly affect body weight gain compared to the control group. This finding suggests that the impact of MOLP on broiler weight gain might be dose-dependent, with potentially negative effects at higher inclusion levels. In contrast to the present findings, Kharde et al. (2012) reported that feeding broiler chickens a diet supplemented with *Spirulina* significantly increased mean body weight, weight gain and feed efficiency compared to the control group.

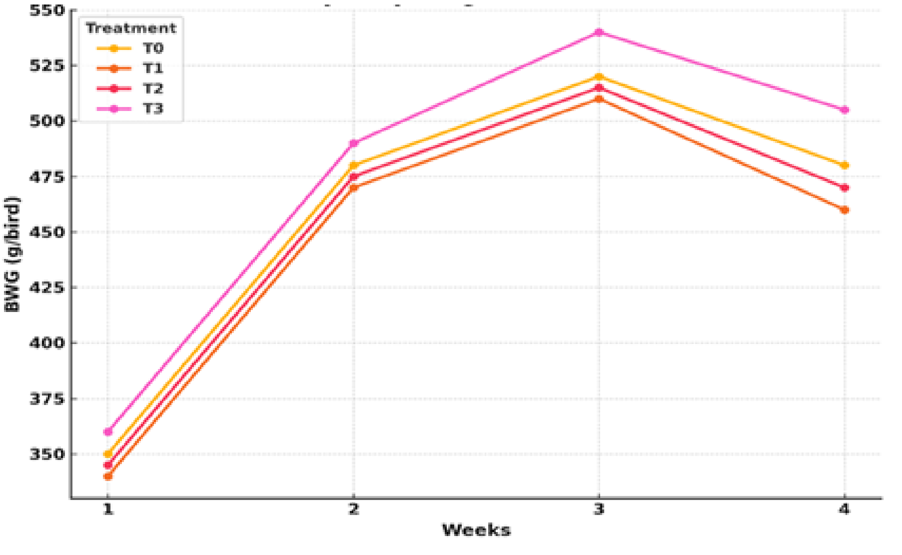

Figure 1. Weekly body weight gain of broiler chickens

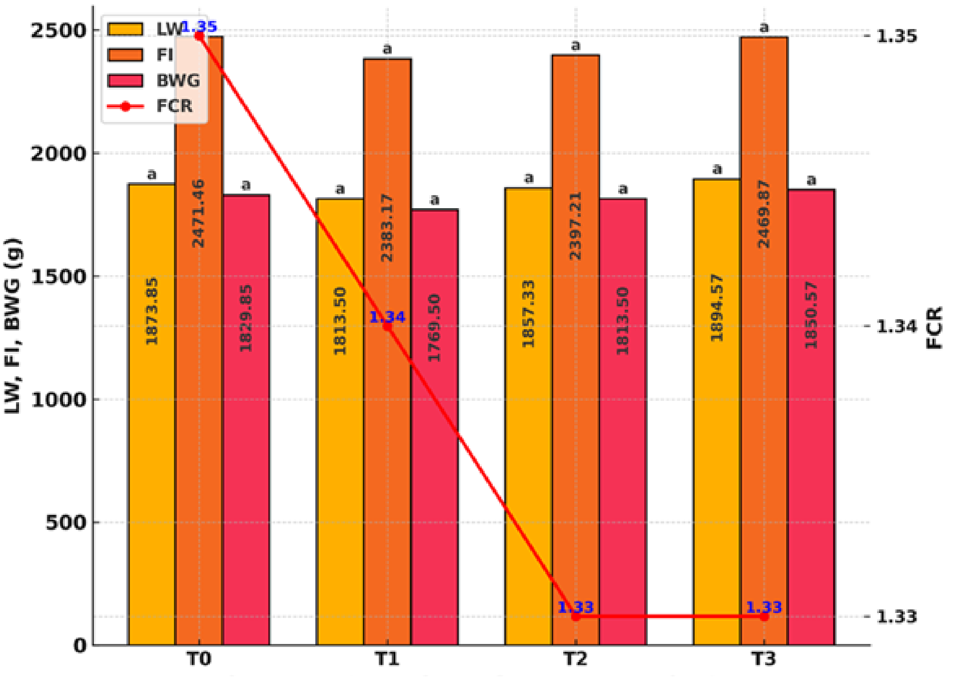

Figure 2. Growth performance and FCR of broiler chickens

Regarding weekly body weight gain, the present findings contradict those of Okafor et al. (2014), who reported that *Moringa oleifera*-supplemented groups recorded a higher daily weight gain. Similarly, Banjo (2012), Gadzirayi et al. (2012), and Kout et al. (2015) found that birds fed MOLP gained significantly ($P < 0.05$) more body weight than those fed a control diet. On the other hand, the current results are consistent with previous studies by Kharde et al. (2012) and Shanmugapriya and Saravana Babu (2014), who reported that dietary Moringa significantly ($P < 0.05$) improved weight gain in chickens compared to control groups. Supplementation of moringa leaf powder in broiler diets did not significantly ($P > 0.05$) influence feed intake in broilers, aligning with the findings of Banjo (2012) who reported that *Moringa oleifera* leaf meal at a 2% inclusion level did not significantly enhance feed intake. Similarly, Divya et al. (2014) observed that the addition of MOLP at 0.5%, 1.0%, 1.5%, and 2.0% inclusion levels did not significantly change feed intake in broiler chickens. On the other hand, Fathi et al. (2018) and Shanmugapriya et al. (2014) reported that birds fed diets containing Spirulina had useful impacts on productive performance as a result of increased feed intake. In the present study, while no significant differences were observed in feed conversion ratio (FCR) among all treatment groups, the best FCR was found in broilers fed diets containing either 1% Spirulina powder alone or a combination of 1% MOLP and 0.5% Spirulina powder, compared to the control group. These results are in agreement with the findings of Banjo, (2012) and Divya et al. (2014) who reported that the inclusion of MOLP in broiler diet did not significantly enhance feed conversion. However, Shanmugapriya et al. (2014) and Kaoud et al. (2012) also reported a significant decrease in FCR by the dietary inclusion of 1% *Spirulina platensis* as compared to the control, which aligns with the findings of the present study.

Characteristics of carcass

The effect of *M. oleifera* and *S. platensis* as natural feed additives on carcass characteristics is presented in Figure 3 and Table 2. Birds fed the combination of MOLP and Spirulina (T_3) had significantly increased the weight of breasts, drumsticks, wings, livers, intestines, and hearts compared to other treatments. No significant differences ($P>0.05$) were found in breast, back, neck, gizzard, or spleen weight between any groups. Interestingly, birds in T_1 (2% *Moringa*) had the lowest wing weight and the lowest liver weight compared to all other treatment groups. Additionally, birds in T_1 (2% *Moringa*) had significantly lower thigh and drumstick weight compared to T_3. The dressing percentage of broilers were significantly ($P < 0.01$) influenced by dietary treatments. The highest dressing percentage (64.47%) was observed in birds supplemented with 1% *Spirulina platensis*, followed by 63.97% in T_1 (2% *Moringa*) group, while the lowest (61.88%) was recorded in the antibiotic control (T_0). The findings indicate that incorporating a combination of *Moringa* and *Spirulina* (T_3) into broiler chicken feed might positively influence the weight of specific carcass components, potentially due to the presence of beneficial nutrients in these natural feed additives.

Supplementation of MOLP and Spirulina powder in broiler diets resulted in significantly increased ($P<0.05$) weight of thighs, drumsticks, wings, livers, hearts, intestines, and proventriculus compared to the control and other treatment groups. These findings align with Ologhobo et al. (2014) who reported higher slaughter weights in birds fed diets containing MOLP. Similarly, Asafa et al. (2012) observed no significant effect on breast weight in broilers fed diets containing MOLP, which is consistent with the present findings. While Kaoud (2012) and Mariey et al. (2014) reported increased carcass weight with *Spirulina platensis* supplementation, the present study did not find any significant impact of *Spirulina* on breast, back, neck, gizzard, or spleen weight. In the present study, the effects of *Spirulina* and *Moringa* on broiler performance parameters, including average dressing percentage (DP), were consistent with the findings of El-Tazi (2014), Elbushra et al. (2019), and Abbass et al. (2020). However, Venkateswarlu et al. (2023) reported that dietary supplementation with *Spirulina* did not have a significant effect on dressing percentage in broiler chickens.

Table 2. Effect of *M. oleifera* and *S. platensis* as natural feed additives on carcass characteristics of broiler chicken

Parameters	Treatments				SEM	P-value
	T_0	T_1	T_2	T_3		
ALW	2015.00^b±54.84	1920.00^b±69.28	1970.00^b±28.86	2222.50^a±27.42	40.38	0.01
EW	1246.50^b±27.42	1228.50^b±50.51	1270.50^b±29.15	1400.50^a±21.07	24.96	0.01
DP	61.88^c±0.32	63.97^{ab}±0.93	64.47^a±0.93	63.08^b±0.14	0.33	0.01
Breast	473.00±1.73	503.50±27.42	468.00±8.66	521.50±12.41	9.42	0.342
Back	263.50±28.00	261.00±0.57	266.00±4.04	287.00±5.77	6.90	0.451
Neck	44.53±2.02	39.33±1.20	45.00±3.46	53.00±1.73	1.76	0.661
Gizzard	29.50±3.75	27.50±3.17	28.00±0.57	29.50±0.86	1.10	0.335
Heart	11.50^a±0.28	11.50^a±0.28	10.00^b±0.57	12.00^a±0.00	0.27	0.001
Proventriculus	9.00^a±0.57	7.50^b±0.28	9.00^a±0.00	8.50^{ab}±0.28	0.23	0.001
Spleen	1.68±0.07	1.68±0.10	1.60±0.17	1.88±0.02	0.05	0.333

Here, ALW = Average live weight, EW = Eviscerated weight, DP = Dressing percentage, T_0 = (Control), T1 = (2% *Moringa* leaf powder), T2 = (1% *Spirulina*), T3 = (1% *Moringa* leaf powder + 0.5% *Spirulina*). ^{ab} Means values within the same row with different superscripts differed significantly (P < 0.05)

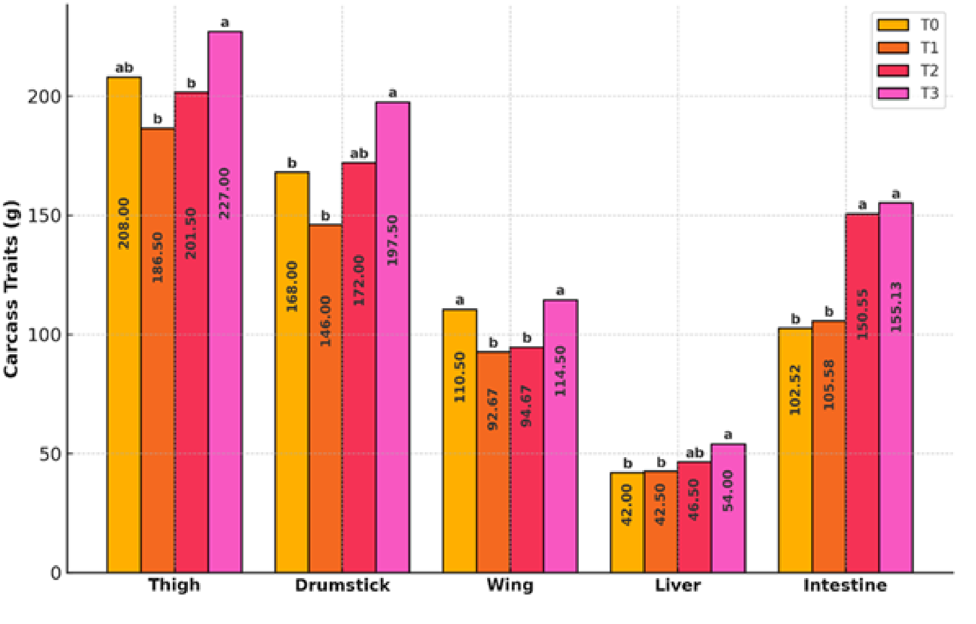

Figure 3. Carcass traits of broiler chickens

Cost-Effectiveness

The total feed cost, chick cost, other costs, and overall production cost per bird did not differ significantly among the treatment groups ($P > 0.05$) (Table 3). However, the cost of supplements (*Moringa*, *Spirulina*, or antibiotics) varied significantly ($P < 0.01$), the lowest cost was recorded in the T_1 (2% *Moringa*) and T_2 (1% *Spirulina*) groups. Although birds in the T_3 group (1% *Moringa* + 0.5% *Spirulina*) showed the highest sale price and profit per bird (BDT 246.29 and BDT 57.75, respectively), these differences were not statistically significant ($P > 0.05$). Profit per kg body weight also followed a similar trend but combined supplementation may enhance economic returns without increasing production cost.

Due to concerns over antibiotic use in poultry, natural alternatives are sought. This study showed that *Moringa* and/or *Spirulina* supplementation resulted in comparable profits to antibiotic use, which suggests they can serve as effective, natural substitutes. This result agrees with the findings of Paul et al. (2018) who reported that *Moringa* can be considered as an alternate to synthetic antibiotics as a growth promoter to fight the emergence of antibiotic resistance in poultry industry.

Table 3. Cost-Effectiveness of *Moringa* and *Spirulina* Supplementation in Broiler Feeding

Parameters	Treatments				SEM	P-Value
	T_0	T_1	T_2	T_3		
Feed cost (BDT/bird)	108.74±3.57	104.83±0.29	105.47±0.64	108.70±1.28	0.98	0.390
Moringa/Spirulina or Moringa & Spirulina cost and antibiotic cost (control)	10.00^{a}±0.00	9.54^{b}±0.03	9.59^{b}±0.06	9.87^{a}±0.12	0.06	0.003
Chick cost (BDT/bird)	40±0.00	40±0.00	40±0.00	40±0.00	0.00	-
Other cost (BDT/bird)	30±0.00	30±0.00	30±0.00	30±0.00	0.00	-
Total cost (BDT/bird) (a + b + c + d)	188.74±3.58	184.40±0.32	185.07±0.70	188.55±1.39	1.02	0.324
Total cost (BDT/kg body weight)	100.75±1.32	101.73±1.51	99.76±2.27	99.54±0.85	0.72	0.750
Sale price (BDT/bird)	243.60±4.84	235.76±3.96	241.45±6.28	246.29±2.75	2.29	0.469
Profit (BDT/bird)	54.86±3.11	51.36±3.63	56.39±5.73	57.75±2.17	1.80	0.692
Profit (BDT/kg)	29.25±1.33	28.27±1.51	30.24±2.26	30.46±0.86	0.72	0.750

Here, T_0 = (Control), T_1 = (2% *Moringa* leaf powder), T_2 = (1% *Spirulina*), T_3 = (1% *Moringa* leaf powder + 0.5% *Spirulina*).
[ab] Means values within the same row with different superscripts differed significantly ($P < 0.05$).

Overall Performance

The radar chart (figure 4) illustrates a multivariate comparison of treatments (T_0-T_3) based on body weight gain, feed intake, feed conversion ratio (FCR), dressing percentage and profit per bird. T_3 shows the highest body weight and profit, indicating its superior impact on broiler performance. Similarly, T_3 has the lowest FCR, reflecting efficient utilization of feed, while T_1 shows the highest FCR. The radar chart shows a noticeable increase in profit for T_2 and T_3, correlating with improved body weight and carcass traits. The radar chart highlights that treatment T_3 consistently outperformed other groups in terms of body weight gain, feed efficiency, dressing percentage, and profit, while T_2 provided moderate but balanced improvements across all measured traits compared to the control (T_0).

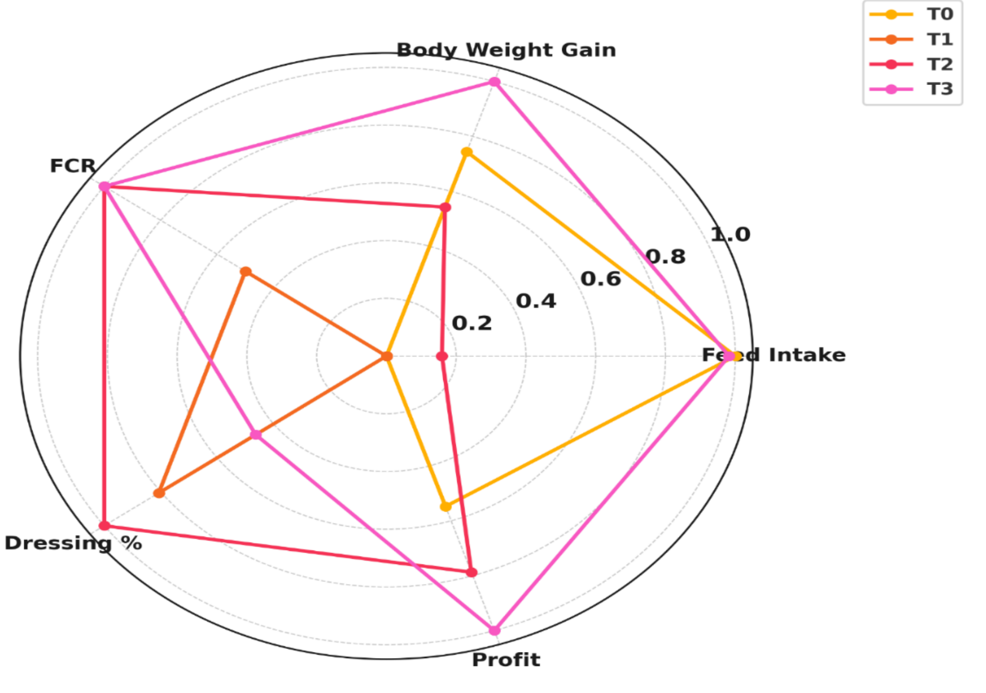

Figure 4. Overall performance of broiler chickens

Conclusion

The research found that while neither MOLP nor Spirulina powder alone significantly improved overall broiler growth performance (body weight gain, feed intake, feed conversion ratio), their combined use led to increased weights of breasts, drumsticks, wings, livers, intestines, and hearts. This suggests a potential synergistic effect of these natural feed additives on broiler performance. While limited research exists on the synergistic effects of MOLP and spirulina, further investigation is needed to optimize their individual and combined dosing levels for maximizing broiler performance. Exploring a wider range of dosing levels, beyond those used in the present study, would be valuable in establishing a more precise recommendation for broiler diets. Additionally, investigating the impact of these supplements on blood parameters, immune function, and meat quality would provide valuable insights into their overall effects on broiler health and production.

Conflict of interest

The authors declare no conflict of interest.

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