Original Article

# Effect of Diet Supplemented with Different Levels of Moringa Powder on Growth Performance, Carcass Characteristics, Meat Quality, Hematological Parameters, Serum Lipids, and Economic Efficiency of Broiler Chickens

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## ABSTRACT

The present study aimed to investigate the effect of supplementing broiler chickens' diet with graded levels of moringa powder on growth performance. A total of 192 one-day-old broiler chicks were individually weighed and randomly distributed into four dietary treatments. Each treatment comprised four replicates with 12 chicks in each. Moringa powder was added to their diet by 0.0%, 0.25%, 0.5%, and 0.75%. The diet and water were offered ad libitum during the feeding trial, which lasted 42 days. One chicken was selected from each replicate at the end of the experiment to measure the carcass characteristics and meat quality, as well as the serum biochemical parameters of broilers. Regarding the overall growth performance, body weight gain and feed conversion ratio substantially improved ($P<0.05$) in broilers whose diet was supplemented with moringa powder, compared to the control group. Furthermore, the carcass yield considerably increased ($P<0.05$) in broilers whose diet was supplemented with 0.5% and 0.75% moringa powder, in comparison with the control group. In addition, birds fed with a diet supplemented with moringa powder showed a significant increase in their hemoglobin level ($P<0.05$). Moreover, the findings showed that a diet supplemented with moringa powder led to a significant decrease in the total cholesterol level, low-density lipoprotein, and the A/G ratio ($P<0.05$) but increased total protein and globulin levels ($P<0.05$), compared to the control group. In conclusion, the supplementation of 0.75% moringa powder in the diet as a growth promoter reduces the cost of production by improving growth performance and enhancing the health status of birds.

**Keywords:** Broiler, Carcass characteristics, Growth performance, Hematology, Moringa oliefera

## 1. Introduction

Due to the advancement of human existence and the rise in global population, more human food must be produced to accommodate such population increase (1, 2). The world's population is expected to reach 9.1 billion in 2050 (3). Therefore, the demand for poultry products for human consumption would rise (4). Because chickens have a high biological value, whether for their meat or eggs (5), they are one of the main sources of food for humans. Due to the infection of birds with infectious diseases that cause a reduction in growth performance and an increase in veterinary costs, scientists are interested in learning how to develop medications with no negative effects on the health of birds. Since herbs are a part of nature, herbal plant remedies aid digestion. The use of herbal plants is thought to be risk-free, economical, and environmentally benign, with no negative side effects. Therefore, encouraging their consumption in diet will improve birds' performance, feeding efficiency, and physiological characteristics.

To organically stimulate growth in a safer way than antibiotics, natural feed additives are gaining a position of primary importance in poultry nutrition (6). Growth promoters are compounds that, when included in a nutritionally balanced diet, may cause the host to respond by growing faster and having a higher feed conversion ratio (FCR) (7). Due to the rising worry over the spread of resistant bacteria across the food chain, antibiotic growth promoters are currently prohibited in several countries. Investigations on alternative feed additives for animal production have been concerned with the ban on the use of antibiotics as feed additives. As a result, a wide range of phytochemicals, including herbs, spices, and essential oils, have been utilized as natural growth promoters in chickens in recent years to test their potential as substitutes for antimicrobial growth promoters (8, 9). Secondary metabolic substances, including flavonoids, flavones, anthocyanins, lignans, coumarins, iso catechins, and catechins, are found in medicinal plants. These bioactive molecules are primarily responsible for medicinal plants' abundance of antioxidants as they are valuable sources for pharmaceutical and healthcare industries, as well as for food, flavor, and fragrance (10). As a result, there has been an increasing interest in medicinal plants because they have powerful anti-microbial, anti-inflammatory, as well as anti-oxidant compounds (11, 12), and they are frequently used in farm animal feeding to enhance the performance and quality of animals' products (13).

To learn more about how certain blood parameters in birds are affected by medicinal herbs, numerous studies have been undertaken. One of the plants that can be included in poultry feed is moringa (Moringa oliefera). Moringa is a highly precious nutritive plant that spreads from India to Africa and can be grown throughout various climatic zones over the world. The moringa tree is capable of growing in arid and drought regions (14), which could be a promising manner in terms of food security in developing countries. The leaves could be used to substitute antibiotics growth promoters, as they contain reasonable amounts of nutritional, growth boosters, prophylactic, antimicrobial, and antioxidant properties (15). In addition, it is considered that moringa leaves are rich sources of amino acids and vitamins and have medical applications (16). In addition, the leaves, flowers, and pods are valued for their high concentrations of vitamins, minerals, amino acids, β-carotene, antioxidants, anti-inflammatory elements, phytochemicals, as well as omega-3 and omega-6 fatty acids (17). Phytochemicals are secondary aromatic plant metabolites that can be considered for disease prevention. These compounds are widely used for preventing and minimizing chronic diseases risk, such as cancer, as well as cardiovascular and neurological ones (14). According to the beneficial properties of moringa, the current experiment sought to determine the influence of moringa leaves powder (Moringa oliefera) on growth performance, carcass characteristics, hematological parameters, serum lipids, meat quality, and economic efficiency of broiler chickens.

## 2. Materials and Methods

### 2.1. Preparation of Moringa Powder

Fresh moringa leaves were collected and then air-dried at room temperature for one week. Afterward, they were gathered, finely powdered, and stored at room temperature for further analysis. The proximate analysis of moringa was determined according to the AOAC (18) (Table 1).

**Table 1.** Proximate analysis of moringa leaves

| Nutrient | (%) |
|---|---|
| Dry matter | 92.68 |
| Crude protein | 21.91 |
| Crude fiber | 10.95 |
| Ether extract | 5.63 |
| Ash | 15.21 |
| Nitrogen free extract* | 46.30 |

* Nitrogen free extract (NFE) = 100 – (CP%+ CF%+EE%+Ash%)

### 2.2. Experimental Birds and Diets

A total of 192 one-day-old unsexed Cobb 500 broiler chicks were reared in two-tiered floor batteries with cages, distributed randomly, and kept in similar managerial conditions. For the first few days after birth, the temperature in the brooding house was 33±0.5°C. It was then lowered two degrees weekly and maintained between 25-27°C from week four until the end of the experiment. Food and water were offered to the birds ad libitum during the feeding trial.

The chicks were split into four groups, 48 birds each. Each group comprised four replicates of 12 birds. All of the birds received starter and finisher diets throughout the experiment. The diets were formulated according to the NRC (1994) and Cobb Broilers Management Guide. For the first three weeks, the chicks were given a starter ration, which was subsequently switched to grower feed until the end of the experiment on day 42 (Table 2). Moringa powder was added to the chickens' diet by 0.0%, 0.25%, 0.5%, and 0.75%. The birds were vaccinated against common infectious diseases.

**Table 2.** Ingredients and chemical composition of broiler diets (% as fed)

| Ingredients (kg) | Starter 0 to 21 Day | Grower 22 to 42 day |
|---|---|---|
| Yellow Corn | 52.40 | 60.00 |
| Soybean Meal 44% | 29.00 | 26.05 |
| Corn Gluten Meal | 10.00 | 6.19 |
| Di-calcium phosphate | 2.20 | 2.05 |
| Lime stone | 1.10 | 1.00 |
| Salt (NaCl) | 0.25 | 0.25 |
| Veg. oil | 4.55 | 4.00 |
| L-lysine | 0.15 | 0.15 |
| DL-Methionine | 0.05 | 0.01 |
| Vitamin and Mineral Premix * | 0.30 | 0.30 |
| Total | 100 | 100 |
| ***Calculated analysis*** | | |
| Crude protein (%) | 22.09 | 18.02 |
| M.E (kcal/ kg) | 2975 | 3161 |
| C/P | 134.67 | 175.41 |
| Fat (%) | 3.79 | 6.30 |
| Crude fiber (%) | 2.42 | 2.61 |
| Calcium (%) | 1.05 | 0.99 |
| Available phosphorus (%) | 0.45 | 0.40 |
| Methionine (%) | 0.52 | 0.41 |
| Lysine (%) | 1.14 | 0.98 |

* Each 1 kg Premix contained: Vit A 3350000 IU; Vit D3 760 000 IU; Vit E 6700 IU; Vit K3 335 mg; Vit B1 334 mg; Vit B2 1670 mg; Vit B6 500 mg; Vit B12 3.4 mg; Niacin 10000 mg; Ca.D. Pantothenate 3334 mg; Biotin 16.7 mg; Folic acid 334 mg; Trace minerals: Iron 13350 mg; Copper 3335 mg; Zinc 16700 mg; Manganese 25000 mg; Iodine 500 mg; Cobalt 84 mg; Selenium 100 mg; Additives: Ethoxyquine 600 mg; and Carrier ($CaCO_3$) up to 1 kg

### 2.3. Growth Performance

The left feed was collected and weighed to get the actual feed consumption per week in grams. The weights of the birds were individually taken weekly, and the average body weight, as well as the body weight gain (BWG), were calculated. Furthermore, the weekly FCR for each replicate was calculated as the weekly feed intake to the weekly BWG and as an overall FCR at the end of the experiment.

### 2.4. Carcass Characteristics

On day 42, four birds from each treatment were randomly selected and individually weighed. The pre-slaughter weights of the birds were recorded after they fasted overnight, and the birds were slaughtered by halal neck cut (19). All slaughtered birds were scalded once they had bled out completely, and their feathers were removed. Heads and shanks were separated from the eviscerated carcasses. The carcass, internal organs, and abdominal fat were expressed relative to the live body weight (LBW).

### 2.5. Blood Samples

Samples were randomly selected from four birds from each treatment (one bird per replicate) at the end of the experiment. The hematological and biochemical characteristics were analyzed based on the methods described by Kairalla, Alshelmani (9).

### 2.6. Meat Quality

The analyses of meat quality were applied to the pectoralis and sartorius muscles based on the methods described by (4, 20).

#### 2.6.1. Determination of Muscle pH

Before taking readings, the pH meter was calibrated at 7.0 and 4.0. Using an electric blender, 25 ml of distilled water and about 5 g of the sample were homogenized. After transferring the homogenate into a beaker, the pH was measured. The pH probe was rinsed with distilled water after each measurement.

#### 2.6.2. Measurement of Meat Color

A handheld colorimeter (WR-10, Shenzhen, China) was used to measure the lightness (L*), redness (a*), and yellowness (b*) of samples using the D65 illuminant. The procedures of color measurement were applied based on the method described by Zamani, Loh (21).

#### 2.6.3. Determination of Drip Loss

The drip loss was determined as described by Alshelmani, Loh (20). It was calculated as follows:

Drip loss (%)=(Initial weight-Final weight/Initial weight)×100

#### 2.6.4. Determination of Cooking Loss

The cooking loss was determined based on the method described by Alshelmani, Loh (20). The samples were cooked in a pre-heated water bath at 80°C for 20 min. Afterward, the samples were removed and cooled with running tap water for 15 min, and the cooking loss was calculated as follows:

Cooking loss (%)=(Initial weight-Final weight/Initial weight)×100

### 2.7. Economic Efficiency

The economic efficiency of dietary treatments was estimated as mentioned by Bayoumi (22). The assessment was carried out using various indicators, such as total revenue (TR), net revenue (NR), total feed cost (TFC), economic efficiency (EE), and relative economic efficiency (REE). The LBW and the final live body weight (FLBW) were also recorded. The REE was estimated as follows:

TR=FLBW×market price of 1 kg of LBW

NR=TR-TFC, whereas TFC=total feed intake×price of feed

EE=NR/TFC

REE=(EE for the treatment group/EE for the control group)×100

### 2.8. Statistical Analysis

The experimental design used for the current experiment was completely randomized. All data generated for all parameters were subjected to analysis using a general linear model procedure of statistical analysis system (SAS, 2003). Tukey's test was used to separate means at a significance level of ($P$<0.05). Orthogonal polynomial contrasts were used to test the linear and quadratic effects of the increasing proportion of supplemented moringa powder, compared to the control group, on broiler performance. The statistical model used for the feeding trial was $Y_{ijk}=\mu+T_{ij}+E_{ijk}$, where $Y_{ijk}$=response variables, $\mu$=the overall mean, $T_{ij}$=the effect of dietary treatment, and $E_{ijk}$=the experimental error.

## 3. Results and Discussion

### 3.1. Broiler Performance

Table 3 presents the effect of moringa supplementation on broiler performance during the feeding trial. The supplementation of moringa powder significantly increased the BWG in the treatment groups (linear, $P$=<0.0001; quadratic, $P$=0.0418), compared to those fed with a diet supplemented with 0.25% or the control group on day 21. In addition, the supplementation of moringa powder significantly increased feed intake (linear, $P$=0.0034; quadratic, $P$=0.1322) and improved FCR at 0.75% (linear, $P$=0.0019; quadratic, $P$=0.0721).

**Table 3.** Effect of dietary supplementation of Moringa on broiler performance

| Traits | Moringa powder Level (%) | | | | | Contrast, *P*-value | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 | SEM[1] | Linear | Quadratic |
| **0 – 21 days** | | | | | | | |
| Body weight gain (g/bird) | 790.85[c] | 792.12[c] | 823.17[b] | 870.59[a] | 4.7376 | <.0001 | 0.0418 |
| Feed intake (g/bird) | 954.77[b] | 955.39[b] | 959.00[ab] | 964.50[a] | 1.5780 | 0.0034 | 0.1322 |
| Feed conversion ratio (FCR) | 1.20[a] | 1.20[a] | 1.16[ab] | 1.10[b] | 0.01539 | 0.0019 | 0.0721 |
| **22 – 42 days** | | | | | | | |
| Body weight gain (g/bird) | 1068.18[c] | 1083.93[c] | 1188.93[b] | 1292.58[a] | 13.437 | <.0001 | 0.1241 |
| Feed intake (g/bird) | 3027.93[a] | 3006.87[b] | 2995.43[c] | 2989.50[c] | 2.0893 | <.0001 | <.0001 |
| Feed conversion ratio (FCR) | 2.02[a] | 1.98[a] | 1.84[b] | 1.72[b] | 0.03173 | <.0001 | 0.2260 |
| **Overall (0 – 42 days)** | | | | | | | |
| Body weight gain (g/bird) | 2284.84[c] | 2307.19[c] | 2442.84[b] | 2606.59[a] | 13.474 | <.0001 | 0.0096 |
| Feed intake (g/bird) | 3982.71[a] | 3962.27[b] | 3948.50[b] | 3959.94[b] | 3.5337 | 0.0002 | 0.0007 |
| Feed conversion ratio (FCR) | 1.74[a] | 1.71[a] | 1.61[b] | 1.52[c] | 0.01392 | <.0001 | 0.0271 |

[a, b, c] Means ± SEM. Means within the same row with different superscripts are significantly different at ($P$<0.05)
[1] Pooled standard error

In the finisher phase, the BWG linearly improved (linear, *P*=<0.0001; quadratic, *P*=0.1241). Likewise, feed intake decreased (linear, *P*=<0.0001; quadratic, *P*=<0.0001), and FCR improved (linear, *P*=<0.0001; quadratic, *P*=0.2260) in broilers whose diet was supplemented with moringa powder, compared to the control group.

Regarding growth efficiency, BWG (linear, *P*=<0.0001; quadratic, *P*=0.0096) and FCR (linear, *P*=<0.0001; quadratic, *P*=0.0271) improved, whereas feed intake decreased (linear, *P*=0.0002; quadratic, *P*=<0.0007), in broilers whose diet was supplemented with moringa powder, compared to the control group.

The improvement in BWG and FCR could be attributed to the nutrient digestibility and utilization as a result of the presence of flavonoids which play an important role as antimicrobial and antioxidant agents. In addition, this improvement might be due to the beneficial effect on the gut microflora, which leads to enhanced digestion, absorption, and utilization of nutrients. The results are in agreement with Hassan, El-Moniary (23), Alshukri, Ali (24), claiming that broiler chickens' performance improved as a result of a diet supplemented with moringa leaves. The enhancement of broiler performance could be due to the presence of high content of vitamin C in moringa leaves (12, 23), which can have a key role in decreasing heat stress and improving broiler growth (25).

### 3.2. Carcass Characteristics

The effect of moringa supplementation on carcass yield is shown in table 4. The carcass yield increased (linear, *P*=<0.0001; quadratic, *P*=0.2597) for those birds fed with a diet supplemented with 0.5% and 0.75% moringa powder, compared to those fed with 0.25% moringa-based diet or the control group. In contrast, the abdominal fat pad significantly decreased (linear, *P*=0.0139; quadratic, *P*=0.0554) as moringa powder increased in broiler diets. The findings are consistent with Alshukri, Ali (24), referring that a diet supplemented with 0.5% and 0.75% moringa leaf meal led to an improvement in carcass yield, compared to the 0% or 0.25% moringa leaf meal. Similar findings were shown by Ahmed and El-Rayes (26), applying moringa supplementation to Japanese quail.

### 3.3. Hematological Parameters

The effect of moringa supplementation on blood hematology is presented in table 5. The findings exhibited that broilers whose diet was supplemented with moringa powder had higher glucose (linear, *P*=0.0042; quadratic, *P*=0.0208) than the control group. Additionally, compared to the control group, broilers fed with a diet supplemented with moringa powder showed a significant enhancement in hemoglobin (linear, *P*=0.0004; quadratic, *P*=0.6463). Experimental treatments, however, did not affect (*P*>0.05) white blood cells, red blood cells, packed cell volume, and lymphocyte concentrations in broiler chickens. The results are in line with Hassan, El-Moniary (23), Abbas, Ali (27), claiming that moringa leaves meal increased hemoglobin, compared to the diet in the control group. This result could be attributed to the iron content in moringa leaves.

### 3.4. Serum Biochemical Parameters

Table 6 shows the influence of moringa supplementation on biochemical parameters. The supplementation of 0.75% moringa powder led to a significant decrease in total cholesterol (linear, *P*=0.0283; quadratic, *P*=0.1239) and low-density lipoprotein (linear, *P*=0.0012; quadratic, *P*=0.1651) and lowered the A/G ratio (linear, *P*=0.0238; quadratic, *P*=0.5776). On the other hand, it increased high-density lipoprotein (linear, *P*=0.0004; quadratic, *P*=0.0101), total protein (linear, *P*=0.0141; quadratic, *P*=0.8914), and globulin (linear, *P*=0.0150; quadratic, *P*=0.9297) in treatment groups, compared to the control group. The outputs are in line with Hassan, El-Moniary (23), Abbas, Ali (27), mentioning that total protein and globulin content in broiler blood increased as the amount of moringa leaves increased in the broiler diet. This can refer to the better immune response given by the broiler. These findings could be attributed to the effect of moringa content, which is rich in nutrients, such as protein and minerals.

### 3.5. Meat Quality

Table 7 shows the impacts of moringa supplementation on meat quality. In the sartorius and pectoralis muscles, no significant differences (*P*>0.05) were observed among dietary treatments in the parameters of meat quality. However, in the pectoralis muscle, the drip loss decreased (linear, *P*=0.0003; quadratic, *P*=0.0546) in the group of chickens fed with a diet supplemented with moringa powder, compared to those fed with other experimental diets. Wideman, O'bryan (28) reported that the higher level of pH in meat has a strong effect on its color, resulting in a dark color. Therefore, meat color could be considered an indicator of its quality. The color can be affected by strain, nutrition, age, intramuscular fat, gender, or broiler processing (20). A strong relationship has been found between breast meat color and pH (20). A rapid decline of meat pH, while the temperature of the carcass is still high, may lead to the denaturation of proteins in muscles. Therefore, the meat color becomes pale. The pale color is due to a decline in the water holding capacity, drip loss, and cooking loss (20).

The pH is one of the important factors for the quality of meat and depends on many factors, such as season, age, method of slaughter, stunning, bleeding, deboning, packaging, animal health, and storage conditions (29, 30). Pipek, Haberl (31) reported that meat with a higher pH may have a gummy texture, increased water-holding capacity, and a different taste. Many researchers reported that the pH value 15 to 30 min after slaughter could indicate broiler meat quality (32).

The range of breast pH was documented not to be less than 5.70 within 15 to 30 min postmortem (20, 33). The results are in accordance with Nduku, Mabusela (15), Cui, Wang (34), finding that meat color (L*) was less than 50 for broiler chickens whose diet was supplemented with moringa leaves. Meat color is highly correlated with the amount of hem-containing compounds, such as myoglobin, hemoglobin, and cytochrome C. Among these three hem-iron-containing compounds, myoglobin contributes the most to the color of poultry meat (28). Our results showed that meat color (L*) was less than 50, which could be attributed to the high content of iron in moringa powder (14).

### 3.6. Economic Efficiency

The influence of moringa supplementation on TR, NR, and EE is shown in table 8. The TR, NR, and REE were higher for the broilers whose diet was supplemented with 0.75% moringa, followed by the birds fed with 0.5%, compared to other dietary treatment groups. The findings are in line with Alshukri, Ali (24), referring that broiler chickens fed with a diet supplemented with moringa leaves had an improved European performance efficiency factor index.

**Table 4.** Effect of moringa supplementation on carcass characteristics and some internal organs

| Parameters (%) | Moringa powder Level (%) | | | | | Contrast, *P*-value | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 | SEM[1] | Linear | Quadratic |
| Carcass yield | 65.35 [c] | 66.02 [c] | 67.33[b] | 68.58[a] | 0.2524 | <0.0001 | 0.2597 |
| Abdominal fat | 1.070[a] | 1.035[ab] | 1.022 [b] | 1.015[b] | 0.0105 | 0.0139 | 0.0554 |
| Gizzard | 1.90 | 1.89 | 1.89 | 1.88 | 0.0130 | 0.7439 | 1.000 |
| liver | 1.92 | 1.92 | 1.92 | 1.92 | 0.0069 | 0.9460 | 0.5813 |
| Heart | 0.45 | 0.45 | 0.45 | 0.45 | 0.0060 | 0.9812 | 1.000 |
| Spleen | 0.10 | 0.10 | 0.10 | 0.10 | 0.0015 | 0.5772 | 0.4998 |
| Bursa | 0.09 | 0.09 | 0.09 | 0.09 | 0.0003 | 0.8732 | 0.6312 |
| Thymus | 0.22 | 0.22 | 0.22 | 0.22 | 0.0026 | 0.4948 | 0.1582 |

[a, b, c] Means ± SEM. Means within the same row with different superscripts are significantly different at ($P$<0.05)
[1] Pooled standard error

**Table 5.** Effect of moringa supplementation on hematological parameters

| Parameters | Moringa powder Level (%) | | | | Contrast, *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 | SEM[1] | Linear | Quadratic |
| WBC's, 106/mm3 | 12.94 | 13.08 | 13.02 | 13.17 | 0.37845 | 0.9763 | 0.9919 |
| RBC's, 106/mm3 | 2.44 | 2.44 | 2.45 | 2.44 | 0.02997 | 0.9942 | 0.9323 |
| Hemoglobin,g/dL | 10.43 [c] | 10.87 [bc] | 11.76 [ab] | 12.42 [a] | 0.24256 | 0.0004 | 0.6463 |
| PCV, % | 35.11 | 35.22 | 35.08 | 35.13 | 0.29370 | 0.9890 | 0.9208 |
| Lymphocytes, % | 74.80 | 75.04 | 76.06 | 76.37 | 0.84914 | 0.5129 | 0.9678 |
| Glucose | 180.12[b] | 194.39 [a] | 193.43 [a] | 193.88 [a] | 2.5085 | 0.0042 | 0.0208 |

[a, b, c] Means ± SEM. Means within the same row with different superscripts are significantly different at ($P$<0.05)
[1] Pooled standard error

**Table 6.** Effect of moringa supplementation on serum lipid of broiler chickens

| Parameters | Moringa powder Level (%) | | | | Contrast, *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 | SEM[1] | Linear | Quadratic |
| Total cholesterol (mg/dL) | 226.50 [a] | 215.00[ab] | 215.75 [ab] | 213.75[b] | 2.8450 | 0.0283 | 0.1239 |
| Triglycerides (mg/dL) | 92.58 | 93.19 | 93.46 | 93.10 | 0.4616 | 0.6092 | 0.2955 |
| LDL-cholesterol (mg/dL) | 100.73 [a] | 95.85 [ab] | 93.68[b] | 92.11[b] | 1.1657 | 0.0012 | 0.1651 |
| HDL-cholesterol (mg/dL) | 110.53 [b] | 120.51 [a] | 120.60 [a] | 121.51 [a] | 1.4116 | 0.0004 | 0.0101 |
| Total protein (g/L) | 2.72 [b] | 2.97 [ab] | 3.85 [ab] | 4.02 [a] | 0.2763 | 0.0141 | 0.8914 |
| Albumin(g/L) | 1.21 | 1.22 | 1.23 | 1.21 | 0.0100 | 0.4760 | 0.1812 |
| Globulin | 1.51[b] | 1.75 [ab] | 2.62 [ab] | 2.80 [a] | 0.2767 | 0.0150 | 0.9297 |
| A/G ratio | 0.92 [a] | 0.76 [ab] | 0.47 [ab] | 0.43 [b] | 0.1103 | 0.0238 | 0.5776 |
| Creatinine (µmol/L) | 0.67 | 0.67 | 0.67 | 0.66 | 0.0203 | 0.9638 | 0.6174 |
| Uric acid (mg/dL) | 4.54 | 4.34 | 4.53 | 4.46 | 0.1242 | 0.6575 | 0.5873 |
| Urea (mg/dL) | 1.71 | 1.71 | 1.73 | 1.73 | 0.0522 | 0.9781 | 0.9611 |
| ALT (IU/L) | 19.36 | 19.98 | 19.84 | 19.47 | 0.6270 | 0.8808 | 0.4278 |
| AST(IU/L) | 130.03 | 131.12 | 130.10 | 130.20 | 0.9936 | 0.8495 | 0.6204 |

[a, b,] Means ± SEM. Means within the same row with different superscripts are significantly different at ($P$<0.05)
[1] Pooled standard error

**Table 7.** Effect of moringa supplementation on meat quality

| Indices | Moringa powder Level (%) | | | | | Contrast, *P*-value | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 | SEM[1] | Linear | Quadratic |
| ***Sartorius*** | | | | | | | |
| Drip loss (%) | 3.48 | 3.72 | 3.70 | 3.76 | 0.1097 | 0.3298 | 0.4496 |
| Cooking loss (%) | 9.52 | 9.43 | 9.35 | 9.52 | 0.1323 | 0.7745 | 0.3280 |
| pH | 5.70 | 5.60 | 5.70 | 5.72 | 0.1210 | 0.8282 | 0.5677 |
| **Meat color** | | | | | | | |
| L* | 45.40 | 45.52 | 45.59 | 45.47 | 0.1387 | 0.8064 | 0.3901 |
| a* | 6.48 | 6.50 | 6.47 | 6.64 | 0.1345 | 0.7933 | 0.5934 |
| b* | 7.47 | 7.71 | 7.55 | 7.68 | 0.2171 | 0.8373 | 0.8004 |
| ***Pectoralis*** | | | | | | | |
| Drip loss (%) | 5.68 [a] | 4.66[b] | 4.47[b] | 4.19[b] | 0.1731 | 0.0003 | 0.0546 |
| Cooking loss (%) | 12.08 | 11.99 | 11.75 | 11.84 | 0.2549 | 0.7978 | 0.7360 |
| pH | 5.70 | 5.70 | 5.85 | 5.60 | 0.1085 | 0.4236 | 0.1957 |
| **Meat color** | | | | | | | |
| L* | 43.92 | 43.93 | 43.62 | 43.53 | 0.2852 | 0.6835 | 0.8730 |
| a* | 4.39 | 4.34 | 4.31 | 4.30 | 0.2454 | 0.9913 | 0.9213 |
| b* | 9.36 | 9.38 | 9.44 | 9.24 | 0.1687 | 0.8613 | 0.5216 |

[a, b]Means ± SEM. Means within the same row with different superscripts are significantly different at ($P<0.05$)
[1] Pooled standard error
L*: Lightness, a*: Redness, b*: Yellowness

**Table 8.** Effect of moringa supplementation on the economics of broiler chickens

| Items | Moringa powder Level (%) | | | |
|---|---|---|---|---|
| | 0 | 0.25 | 0.5 | 0.75 |
| Average Live body weight /bird (kg) | 2.33 | 2.35 | 2.48 | 2.65 |
| Average feed intake/bird (kg) | 3.98 | 3.96 | 3.95 | 3.96 |
| Price of feed* E.P.\1 kg | 6.00 | 6.09 | 6.19 | 6.29 |
| Total feed cost (L.E) | 23.89 | 24.12 | 24.43 | 24.90 |
| Price/kg body weight (L.E) | 33.00 | 33.00 | 33.00 | 33.00 |
| Total revenue | 76.75 | 77.48 | 81.93 | 87.38 |
| Net revenue | 52.86 | 53.36 | 57.50 | 62.48 |
| Economic efficiency | 2.21 | 2.21 | 2.35 | 2.50 |
| Relative economic efficiency | 100 | 100 | 106 | 113 |

* Price of 1 kg Moringa leaves meal. = 120.00 LE

In conclusion, the supplementation of 0.75% moringa powder in the broiler diet could be used as an alternative to antibiotics as a growth promoter. This may minimize the cost of production by promoting growth performance and enhancing the health status of birds.

## Authors' Contribution

Study concept and design: M. A. K. and M. I. A.
Acquisition of data: M. A. K.
Analysis and interpretation of data: M. A. K.
Drafting of the manuscript: M. A. K. and M. I. A.
Critical revision of the manuscript for important intellectual content: M. A. K., M. M. I. and M. I. A.
Statistical analysis: M. I. A.
Administrative, technical, and material support: M. A. K., M. I. A and M. M. I.

## Ethics

All ethical standards related to animal care and husbandries were applied in the current study and approved by the ethics committee of the Faculty of Agriculture, University of Sebha.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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