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Assessing the impact of moringa and garlic supplementation on egg production and quality in laying hens

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Abstract

Only a limited number of researches have discussed the utilization of *Moringa oleifera* leaf powder (MLP) and *Allium sativum* bulb powder (ABP) as supplements in chicken feed. Consequently, it is interesting to examine the impact of incorporating MLP and ABP in the feed of laying hens on the produced egg quantity and quality. For that purpose, three hundred ISA brown hens that are 18 weeks old were randomly assigned to five groups and underwent a feeding experiment for 6 months. The groups were labeled as follows: T1: diet without MLP and ABP, T2: diet with MLP replacing soybean meal (SBM) at 1%, T3: diet with MLP replacing SBM at 3%, T4: diet with MLP replacing SBM at 1% + 0.1% ABP, and T5: diet with MLP replacing SBM at 3% + 0.3% ABP. Egg production and quality parameters were collected and compared using Tukey's test with a significance threshold of 5%. The results showed that incorporating moringa and garlic powders into laying hens feed (T4 and T5) decreased feed consumption, enhanced feed conversion, and increased daily egg production which reflected positively on reducing daily feed costs per hen and per egg. On the other hand, T3 treatment resulted in an increased egg and yolk weights while intensifying yolk color compared to control (T1). Consequently, incorporating *Moringa oleifera* leaf powder alone or in combination with *Allium sativum* bulb powder in the feed of ISA brown hens had a significant positive impact on egg production and quality

1. Introduction

Nigeria is the second-largest country in Africa in terms of chicken production after South Africa [1-3]. However, Nigeria has the highest poultry egg production in Africa [3]. The regularly raised breeds of laying chicken in Nigeria are Bovans Black, Dekalb-Amberlink, and ISA Brown [4]. The breeds exhibit exceptional levels of fecundity, producing an average of 300 eggs per hen during the initial laying cycle. These birds are frequently prone to subclinical infections caused by pathogenic microorganisms that reside in their gastrointestinal tract, leading to competition with the host for nutrients [5]. In the past, antibiotics were employed for therapeutic purposes to prevent subclinical infections and enhance meat and egg production in chicken. Subsequently, the utilization of these substances has been limited due to its adverse consequences of drug resistance, drug residue in animal products, and modification of the native gut microbiota [6]. Therefore, nutritionists are actively seeking natural feed options that have the potential to be both environmentally sustainable and healthy for both animals and human health [7]. Recently, researchers have focused on two effective natural feed resources, namely *Moringa oleifera* and garlic [8][9]. Additional examples include ginger, turmeric [8], and shea butter [10].

Moringa oleifera has been utilized in the poultry sector to enhance growth, feed efficiency, and laying ability. The leaves, which contain significant amounts of protein, minerals, β-carotene, and antioxidants, are used in traditional medicine as well as human and animal nutrition [11]. Prior research has indicated that moringa leaves contains

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various vitamins, flavonoids, and carotenoids [12–14]. These phytochemicals not only provide critical health benefits, but also enhance the quality of bird products (meat and eggs) and enhance the coloring of the shanks and egg yolk [15-17]. Feeding laying hens with *Moringa oleifera* leaves can enhance the production of eggs that are richer in β-carotene and have lower levels of cholesterol [18]. A recent study found that the addition of Moringa leaves to the diet of Rhode Island Red hens resulted in an increase in the quality of their eggs, specifically in terms of carotenoid yolk content [19]. Furthermore, it was noted that the addition of *Moringa oleifera* at a concentration of 5% to the feed resulted in enhancements in the color of the yolk, the height of the albumen, and the Haugh unit of the eggs [20].

Allium sativum (Garlic) is a widely utilized herb that has been extensively studied for its therapeutic properties [21]. Its composition includes various phytobiotics, such as flavonoids, saponins, tannins, alkaloids, steroids, hydrocyanide, and anthocyanin [22]. These phytobiotics have positive effects in fighting against microbes, reducing cholesterol levels, lowering blood pressure, preventing the development of atherosclerosis, treating diabetes, and combating viral and fungal infections [23][24]. Additionally, Allium sativum had significant amounts of dietary fibers, vitamin C, and folic acid and contains essential minerals such as calcium and iron and a high-quality protein. These compounds are effective in reducing the concerns related to elevated levels of allicin in the body, which has been demonstrated to decrease low-density lipoprotein, triglyceride, and cholesterol in both the bloodstream and tissues. The decreased levels of cholesterol in the serum and liver of chicken resulted in enhanced productive performance [26]. Given the aforementioned positive influences of including Moringa and garlic in chicken feed, this study aims to examine the impact of adding *Moringa oleifera* leaf powder and *Allium sativum* bulb powder to the diet of laying hens on egg production and quality.

2. Materials and Methods

2.1. Plant material collection and preparation

Moringa leaves were obtained from the Moringa plantation located at the experimental site of the Crop Science Department, Teaching and Research Farm, Federal University Oye Ekiti, Ekiti State, Nigeria. Garlic bulbs were purchased from a local market in Ado Ekiti, Ekiti State, Nigeria. Moringa leaves were left to dry for 7 days in a shaded and well-ventilated environment. The desiccated leaves were pulverized using mortar and pestle to acquire moringa leaf powder (MLP). The MLP was stored in a distinct hermetically sealed plastic container for the experiment. The bulbs of Allium sativum were divided into individual cloves, which were then sliced into chips. Garlic chips were meticulously air-dried for a duration of 2 weeks until they achieved a crisp texture. The dried garlic chips were subsequently pulverized into fine powder (ABP) and placed in a hermetically sealed container for the feeding trial.

2.2. Experimental location preparation

The experiment took place in the Animal Production and Health Research Unit in Ikole Ekiti, Nigeria, which is part of the Federal University in Oye Ekiti (5.514493^{o}E and 7.7982661^{o}N). The average yearly temperature is 24.2^{o}C. The battery cages were sterilized to house the birds over the entire duration (6 months) of the trial with each cage measuring 150×70×45 cm (length × breadth × height).

2.3. Experimental birds and design

A feeding trial was conducted with 300 ISA Brown laying hens obtained specifically for this experiment. The hens were 18 weeks old and a had a body weight of 1486±12.55 grams. The laying hens were allocated to 5 different nutritional regimens, with each treatment having 5 replicates (cages) of 12 birds each, in a completely randomized design (CRD).

The experimental groups were:

T1: a diet without the use of MLP or ABP.

T2: A diet with MLP replacing soybean meal (SBM) at a rate of 1%.

T3: A diet with MLP replacing SBM at a rate of 3%.

T4: A diet with MLP replacing SBM at a rate of 1%, along with 0.1% ABP powder.

T5: A diet with MLP replacing SBM at a rate of 3%, along with 0.3% ABP.

The NDVK vaccine (3 in 1 komorrov vaccine) was injected intramuscularly a few days after the birds' arrival. The Lasota vaccine and dewormer were provided at 2-month intervals consistently during the whole duration of the experiment. The administration of antibiotics was based on the presence of symptoms. Following the stocking process, the birds had a period of stabilization/acclimatization lasting 2 weeks. Monitoring of laying performance and feed intake commenced on the 140th day (20th week) of life, with this week being considered the first week of production.

2.4. Feed preparation

The experimental diets were prepared by manually formulating and homogenizing while incorporating MLP and ABP to create a fine mash that was fed to the birds. The traditional components were acquired from a recognized local feed mill. The MLP and ABP were included into a minimal quantity of basic feed and thoroughly blended. Subsequently, the mixture was combined with the predetermined quantity of feed for each treatment and properly blended prior to being administered to each group. The constituents and chemical makeup of the experimental diets are outlined in Table 1. Feed (125 g/bird) was given to the birds daily. The feeds were weighed with a sensitive Camry scale (sensitivity = 0.01g). Water was provided *ad libitum*.

2.5. Experimental procedure

Performance characteristics were determined by counting the number of eggs in each treatment and weighing them every day. Feed intake was obtained by subtracting the leftover feed from the total quantity of feed given each day.

Table 1. The composition (%) of the experimental diets of laying hens

Components	T1	T2	T3	T4	T5
MLP	-	0.24	0.72	0.24	0.72
ABP	-	-	-	0.1	0.3
Maize	54	54	54	54	54
Soya beans	24	23.76	23.28	23.66	22.98
Wheat offal	12	12	12	12	12
Bone meal	3	3	3	3	3
Limestone	6	6	6	6	6
Lysine	0.2	0.2	0.2	0.2	0.2
Methionine	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100
Analyzed values					
Energy (kcal/kg)	2726.76	2720.28	2707.32	2720.28	2707.32
Crude protein (%)	18.00	17.96	17.87	17.96	17.87
Crude fiber (%)	3.66	3.64	3.61	3.64	3.61
Crude Fat (%)	3.42	3.41	3.39	3.41	3.39
Lysine (%)	1.10	1.10	1.08	1.10	1.08
Methionine (%)	0.52	0.52	0.51	0.52	0.51
Calcium (%)	3.28	3.27	3.27	3.27	3.27
Phosphorus (%)	0.68	0.68	0.67	0.68	0.67

1kg of premix contains: Vitamin A (10,000,000 IU); Vitamin D3 (2,000,000 IU); Vitamin E (20,000 IU); Vitamin K (2,250mg); Thiamine B1 (1,750mg); Riboflavin B2 (5000mg); Pyridoxine B6 (2,750mg); Niacin (27,500mg); Vitamin B12 (15mg); Pantothenic acid (7,500mg); Folic acid (7,500mg); Biotin (50mg); Choline chloride (400mg); Antioxidant (125mg); Magnesium (80g); Zinc (50g); Iron (20g); Copper (5g); Iodine (1.2g); selenium (200mg); Colbat (200mg); ME: Metabolizable Energy; MLP: Moringa oleifera leaf powder; ABP: Allium sativum bulb powder; T1: diet without Moringa oleifera leaf powder and Allium sativum bulb powder; T2: diet with MLP replacing soybean meal at 1%; T3: diet with MLP replacing soybean meal at 3%; T4: diet with MLP replacing soybean meal at 1% + 0.1% ABP and T5: diet with MLP replacing soybean meal at 3% + 0.3% ABP

Daily feed intake = Provided feed – Leftover Feed

Collection and recording of eggs were done once daily, particularly in the evening. Egg production and weight of the eggs were also recoded daily. To assess egg quality criteria, a total of 20 eggs were chosen at random every 3 weeks from each treatment group. Every egg was carefully weighed and accurately documented.

2.5.1. Feed consumption and egg production performance

These criteria were calculated as follows [27]:

$$\text{Daily feed intake per hen} = \frac{\text{Daily feed intake}}{\text{Number of hens in the cage}}$$

$$\text{Daily egg production per hen} = \frac{\text{Number of eggs laid daily per cage}}{\text{Number of hens in the cage}}$$

$$\%\ \text{Hen day egg production (HDEP)} = \frac{\text{Daily produced eggs}}{\text{Number of hens in the cage}} \times 100$$

$$\text{Feed conversion ratio} = \frac{\text{Feed consumed (Kg)}}{\text{Egg produced}}$$

Daily feed cost per hen = Daily feed intake per hen (Kg) × Price of the feed per Kg

$$\text{Feed cost per egg} = \frac{\text{Daily feed cost per hen}}{\text{Number of eggs laid daily per hen}}$$

2.5.2. Egg quality assessment

Egg Weight: Eggs and separated yolk and albumen were weighed with a digital Camry scale (Sensitivity = 0.01g). The shell was rinse in water and allowed to air dried for 24 hours before weighing.

Egg dimensions: A digital Vernier caliper was used to measure the maximum egg length, maximum egg diameter, yolk diameter, yolk height (at the center of the yolk), albumen width, and albumen height (at the closest point to the yolk) and the value was recorded to the nearest mm.

Shell thickness: After drying, shell thickness was measured using a micrometer screw gauge at three different parts of the shell (the top, middle, and bottom) and the average of the three readings was taken as the shell thickness.

Yolk color: A CIE standard yolk color fan (RYC, F. Hoffman-la Roche and Ltd., Basel, Switzerland) graded from 1 to 15 (where 1 corresponds to pale yellow and 15 corresponds to dark orange) was used to determine the yolk color. The yolk color fan was positioned close to the egg yolk. The colors were matched and the corresponding value was recorded as yolk color.

Egg quality criteria were calculated as follows [27-29]:

$$\text{Shape index (\%)} = \frac{\text{Egg diameter}}{\text{Egg length}} \times 100$$

$$\text{Yolk index (\%)} = \frac{\text{Yolk height}}{\text{Yolk diameter}} \times 100$$

$$\text{Albumen index (\%)} = \frac{\text{Albumen height}}{\text{Albumen diameter}} \times 100$$

$$\text{Albumen to Yolk Ratio} = \frac{\text{Albumen weight}}{\text{Yolk weight}}$$

$$\text{Haugh unit} = 100 \times \log (AH + 7.57 - 1.7 \times EW^{0.37})$$

Where: AH = Albumen height (mm) and EW = Egg weight (g).

2.6. Data analysis

All data collected were subjected to the analysis of variance (ANOVA) [30]. The means of the treatment were compared using Turkey's Honestly Significant Difference (HSD) at 5% level of probability according to the following model:

$Y_{ijk} = \mu + T_i + \varepsilon_{ijk}$

Where: Y_{ijk} = Response in k^{th} replicate and i^{th} treatment

μ = Overall means

T_i = Effect of treatment (T = 1 to 5)

ε_{ijk} = Experimental error

3. Results

3.1. Moringa and garlic effect on egg production performance

The study revealed that the daily feed consumption was significantly reduced (*$p<0.05$*) when the test materials (T2, T3, T4, and T5) were included, as compared to T1. The hen day egg production (HDEP) in T1, throughout weeks 26–30, exhibited no significant difference (*$p>0.05$*) compared to T4 and T5, but was significantly lower (*$p<0.05$*) than T2 and T3. Between weeks 31 and 45, the HDEP in dietary treatments T2, T3, T4, and T5 were substantially higher (*$p<0.05$*) than in T1. Between the 21st and 25th weeks of age, the average weight of eggs in T2 and T5 was substantially higher (*$p<0.05$*) than in T1, but similar to that in T3 and T4. During the 26th to 30th week, the average weight of eggs in T1 was significantly higher (*$p<0.05$*) compared to T2 and T4, but not significantly different (*$p>0.05$*) from T3 and T5 (Table 2).

The feed conversion ratio (FCR) between 26th and 30th weeks indicated that T1 was similar (*$p>0.05$*) to T4 and T5, but significantly (*$p<0.05$*) lower than T2 and T3. Between weeks 31 and 45, FCR was substantially greater in T1 compared to the other dietary regimens, Which shows that all treatments (T2-T5) were superior in converting the consumed feed into egg production compared to control (T1) between the 41st and 45th weeks of the experiment (Table 2). The daily feed cost per bird between 21 weeks and 30 weeks in T1 was substantially more (*$p<0.05$*) than the costs in T2, T3, T4, and T5. Between weeks 31 and 45, the daily feed cost per bird was significantly lower in T1 compared to T5 (*$p<0.05$*), but similar to T4 (*$p>0.05$*). However, T1 had significantly higher feed costs than T2 and T3 (*$p<0.05$*). The feed cost per egg between 26th and 30th weeks indicated that T1 had a significantly reduced cost (*$p<0.05$*) compared to T2 and T3, but was similar (*$p>0.05$*) to T4 and T5. Between 31 and 35 weeks, the value of T5 was significantly lower (*$p<0.05$*) compared to T1, although it was not significantly different (*$p>0.05$*) from T2, T3, and T4. between the 41st and 45th weeks, T2, T3, and T4 exhibited a substantial decrease in feed cost per egg (*$p<0.05$*) compared to T1, but were similar (*$p>0.05$*) to the values observed in T5.

Table 2. Egg production parameters of hens fed a diet supplemented with *Moringa oleifera* leaf powder and *Allium sativum* bulb powder

Parameter	Weeks	T1	T2	T3	T4	T5	SEM	P value
Daily feed intake per hen (g)	21-25	93.22^{a}	88.20^{c}	83.10^{d}	90.69^{b}	82.65^{d}	0.95	0.00
	26-30	101.45^{a}	93.92^{b}	90.78^{c}	94.65^{b}	91.57^{c}	0.87	0.00
	31-35	91.96^{b}	91.05^{b}	88.68^{c}	91.96^{b}	96.58^{a}	0.62	0.00
	36-40	102.64^{a}	102.74^{a}	100.95^{b}	102.18^{a}	102.64^{a}	0.19	0.00
	41-45	107.45^{a}	107.08^{ab}	105.41^{c}	106.08^{bc}	105.92^{c}	0.20	0.00
Daily egg production per hen	21-25	0.24	0.23	0.18	0.22	0.24	0.01	0.32
	26-30	0.61^{a}	0.48^{b}	0.43^{b}	0.58^{a}	0.62^{a}	0.02	0.00
	31-35	0.55^{b}	0.58^{b}	0.60^{b}	0.64^{b}	0.77^{a}	0.02	0.00
	36-40	0.71^{ab}	0.77^{a}	0.68^{b}	0.80^{a}	0.80^{a}	0.02	0.03
	41-45	0.78^{b}	0.82^{a}	0.81^{a}	0.82^{a}	0.83^{a}	0.02	0.03
Hen day egg production (HDEP) (%)	21-25	24.29	22.62	18.00	21.91	24.58	1.13	0.34
	26-30	61.31^{a}	47.50^{b}	43.22^{b}	58.15^{a}	61.67^{a}	1.87	0.00
	31-35	54.76^{b}	58.46^{b}	60.36^{b}	63.33^{b}	76.67^{a}	2.03	0.00
	36-40	71.22^{ab}	76.55^{a}	67.50^{c}	79.88^{a}	80.36^{a}	1.68	0.03
	41-45	77.93^{b}	82.29^{a}	81.28^{a}	82.33^{a}	82.67^{a}	1.90	0.03
Feed conversion ratio	21-25	8.06	7.57	9.83	8.11	6.52	0.52	0.41
	26-30	3.00^{b}	3.79^{a}	3.86^{a}	3.11^{b}	2.77^{b}	0.11	0.00
	31-35	3.04^{a}	2.81^{ab}	2.57^{bc}	2.65^{bc}	2.27^{c}	0.07	0.00
	36-40	2.62^{a}	2.35^{b}	2.61^{a}	2.30^{b}	2.27^{b}	0.05	0.05
	41-45	2.88^{a}	2.23^{b}	2.21^{b}	2.30^{b}	2.26^{b}	0.08	0.01
Daily feed cost per hen ($)	21-25	0.017^{a}	0.016^{c}	0.015^{e}	0.017^{b}	0.016^{d}	0	0.00
	26-30	0.019^{a}	0.017^{d}	0.016^{e}	0.017^{b}	0.017^{c}	0	0.00
	31-35	0.017^{b}	0.016^{c}	0.016^{d}	0.017^{b}	0.018^{a}	0	0.00
	36-40	0.019^{b}	0.018^{c}	0.018^{d}	0.019^{b}	0.019^{a}	0	0.00
	41-45	0.02^{b}	0.019^{c}	0.019^{d}	0.02^{b}	0.02^{a}	0	0.00
Daily feed cost per egg ($)	21-25	0.074	0.073	0.089	0.079	0.066	0.005	0.51
	26-30	0.031^{b}	0.036^{a}	0.038^{a}	0.031^{b}	0.029^{b}	0.001	0.00
	31-35	0.031^{a}	0.029^{ab}	0.027^{ab}	0.027^{ab}	0.024^{b}	0.001	0.01
	36-40	0.027	0.025	0.027	0.024	0.025	0.001	0.23
	41-45	0.03^{a}	0.024^{b}	0.024^{b}	0.024^{b}	0.025^{ab}	0.001	0.01

Means with different letters in each row are significantly different at p<0.05
SEM: Standard error of the mean; T1: diet without Moringa oleifera leaf powder and Allium sativum bulb powder; T2: diet with MLP replacing soybean meal at 1%; T3: diet with MLP replacing soybean meal at 3%; T4: diet with MLP replacing soybean meal at 1% + 0.1% ABP and T5: diet with MLP replacing soybean meal at 3% + 0.3% ABP

3.2. Moringa and garlic effect on egg quality parameters

Egg weight in T3 was considerably greater (*p<0.05*) compared to other treatments and control. The yolk index in T1 was significantly greater (*p<0.05*) compared to T2, T3, and T5, but it was not significantly different (*p>0.05*) from T4. The yolk weight of T2 and T3 was significantly larger (*p<0.05*) than that of T1, but it was not significantly different (*p>0.05*) from T4 and T5. The yolk diameter in treatment T1 was significantly smaller (*p<0.05*) compared to T3, but similar to the other treatments. Additionally, the yolk color in treatment T1 was significantly lighter (*p<0.05*) compared to treatment T3, but similar to the other treatments. Albumen weight was significantly higher in T1 compared to T4 and T5, but it was comparable to that of T2 and T3. The Haugh unit in T1 was significantly greater

($p<0.05$) compared to T2, but not significantly different ($p>0.05$) from T3, T4, and T5. The albumen/yolk ratio of eggs from birds with nutritional interventions (T2, T3, T4, and T5) was considerably ($p<0.05$) lower compared to the ratio seen in eggs from control birds (T1). Remarkably, the inclusion of moringa and garlic supplements did not result in any substantial impact on the dimensions of the eggs, including length, diameter, and shape, as well as the yolk height, albumen index, shell thickness, and shell weight (Table 3).

Table 3. Egg quality parameters of hens fed a diet supplemented with *Moringa oleifera* leaf powder and *Allium sativum* bulb powder

Parameter	T1	T2	T3	T4	T5	SEM	P value
Egg weight (g)	57.75^{b}	57.91^{b}	59.52^{a}	57.66^{b}	57.71^{b}	0.24	0.05
Egg length (mm)	55.33	54.97	55.74	55.11	54.98	0.11	0.12
Egg diameter (mm)	42.87	43.20	43.40	42.96	42.90	0.09	0.21
Shape Index (%)	77.49	78.59	77.87	77.97	78.02	0.16	0.38
Yolk Index (%)	39.36^{a}	38.40^{b}	38.03^{b}	39.65^{a}	38.61^{b}	0.20	0.04
Yolk weight (g)	13.45^{b}	14.36^{a}	14.38^{a}	14.08^{ab}	13.91^{ab}	0.10	0.01
Yolk diameter (mm)	36.44^{b}	37.22^{ab}	37.46^{a}	36.73^{b}	37.21^{ab}	0.12	0.01
Yolk color	10.42^{b}	10.67^{b}	11.61^{a}	10.91^{ab}	11.25^{ab}	0.13	0.01
Yolk height (mm)	14.34	14.29	14.24	14.56	14.37	0.05	0.33
Albumen Index (%)	6.47	5.87	6.60	6.57	6.37	0.09	0.08
Albumen weight (g)	38.75^{a}	37.11^{ab}	37.83^{ab}	36.69^{b}	36.63^{b}	0.26	0.02
Albumen height (mm)	5.99^{ab}	5.41^{b}	6.17^{a}	6.02^{ab}	5.88^{ab}	0.09	0.05
Shell thickness (mm)	0.37	0.39	0.39	0.39	0.41	0.00	0.13
Shell weight (g)	5.31	5.39	5.74	5.36	5.61	0.06	0.04
Haugh unit	76.42^{a}	71.19^{b}	76.86^{a}	75.77^{a}	75.08^{ab}	0.57	0.01
Albumen:Yolk	2.88^{a}	2.58^{b}	2.63^{b}	2.60^{b}	2.63^{b}	0.03	0.00

Means with different letters in each row are significantly different at p<0.05
SEM: Standard error of the mean; T1: diet without Moringa oleifera leaf powder and Allium sativum bulb powder; T2: diet with MLP replacing soybean meal at 1%; T3: diet with MLP replacing soybean meal at 3%; T4: diet with MLP replacing soybean meal at 1% + 0.1% ABP and T5: diet with MLP replacing soybean meal at 3% + 0.3% ABP

4. Discussion

There is a scarcity of research in the literature about the use of *Moringa oleifera* leaf powder (MLP) and *Allium sativum* bulb powder (ABP) as suitable feed additives in laying hens' diets. The findings of this study indicate that the addition of MLP and ABP to the diet of laying hens aligns with the results of prior research. The presence of their bioactive components [31][32] may explain this phenomenon. Research on *Moringa oleifera* demonstrates its potential as a natural feed supplement for laying hens. Incorporating this plant into the diet of poultry has been found to improve the birds' productivity and overall health [33].

The daily feed consumption was markedly reduced in the dietary treatments (T2, T3, T4, and T5) compared to control (T1) throughout the experiment, without any adverse impact on egg production. This could be attributed to the increased feed conversion ratio. The presence of bioactive compounds such as flavonoid, phenols, tannins, and saponins in the added dietary supplements (MLP and ABP) can suppress microbial pathogens and endotoxins in the gastrointestinal tract. This, in turn, enhances digestion and absorption, resulting in a reduction in feed consumption among birds. According to a similar research study, a reduction in feed intake was observed in chickens that were fed with moringa 21 weeks to 55 weeks. However, the same study showed that these birds had greater laying percentage and better feed conversion ratio (FCR) compared to the groups that were not supplemented with moringa [32].

The dietary treatments (T2, T3, T4, and T5) significantly improved hen day egg production (HDEP) and feed conversion ratio (FCR) from 31 to 45 weeks compared to T1. The enhancements can be ascribed to the functions of *Moringa oleifera* and *Allium sativum* in the gastrointestinal system of laying birds, resulting in heightened feed digestibility. Research findings indicate that the utilization of moringa leaf extract as a feed supplement in poultry can enhance feed efficiency [34][35]. The utilization of *Moringa oleifera* as a feed component has been found to enhance various aspects of production performance in commercial layers, including egg production, feed intake, feed efficiency, egg weight, and overall health status [36]. On the other hand, it was previously reported that the inclusion of garlic in the diets of laying hens did not have any impact on body weight gain, egg weight, and egg production [37]. This contradicts the current findings as including ABP alongside MLP (T4 and T5) had an overall positive impact on daily egg production, HDEP, and FCR which reflected positively on reducing the costs of feeding per hen and per egg compared to the use of moringa alone. Therefore, it can be deduced that the synergistic impact of *Moringa oleifera* leaf powder and *Allium sativum* bulb powder is responsible for the reported beneficial outcome in this investigation.

A previous report showed that a diet supplemented with *Moringa oleifera* has the potential to enhance egg production and improve egg yolk color scores in comparison to groups that are not supplemented [38]. Additionally, incorporating garlic powder into the meals of laying hens resulted in enhancements in yolk weight, yolk diameter, yolk color, and chick length, as well as a decrease in hen mortality rate [39]. The quality criteria of eggs can influence consumers behavior. In T3, the inclusion of meals containing *Moringa oleifera* leaf powder resulted in considerably greater egg and yolk weights compared to the control. Additionally, yolk diameter and color in T3 were substantially greater than those of control. The notable enhancement in egg weight, yolk weight, yolk diameter, and yolk color observed in T3 treatment (A diet with *Moringa oleifera* leaf powder replacing soybean meal at a rate of 3%) can be due to the elevated concentration of carotene and antioxidants present in moringa leaves.

5. Conclusion

It can be concluded that incorporating Moringa oleifera leaf powder and Allium sativum bulb powder into the feed of ISA Brown laying hens can significantly enhance their egg production through increasing feeding efficiency. Additionally, there is a notable enhancement in the quality of the eggs, including parameters such as egg weight, yolk weight, and yolk color. This improvement is particularly notable when Moringa oleifera leaf powder replaces soybean meal at a 3% level, and when Moringa oleifera leaf powder replaces soybean meal at a 3% level along with an additional 0.3% Allium sativum bulb powder supplementation.

Conflict of interest statement

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The authors declared that all related data are included in the article.

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