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Dietary supplementation of moringa leaf powder improves the productive and reproductive performance of Pekin duck

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ABSTRACT

Duck production is often considered advantageous compared to other poultry species due to its lower management requirements. However, intensive duck farming necessitates balanced nutrition and additional feed supplements to maximize profitability. Moringa leaves, rich in high-quality proteins, vitamins, minerals, and various bioactive compounds, have been proven to enhance the production and reproduction performance of poultry. The present study was conducted to elucidate the beneficial effect of Moringa leaf powder (MLP) on the productive and reproductive parameters of Pekin ducks. The experiment involved supplementing the basal ration of Pekin ducks with different percentages of MLP (0%, 2%, 4%, and 6%). The results indicated that 4% MLP supplementation improved production and reproduction parameters most effectively. This supplementation increased mature body weight and live weight gain by lowering the feed conversion ratio (FCR), enhancing the dressing percentage, and reducing triglycerides and cholesterol levels in blood lipids without adversely affecting other blood parameters. Notably, the ducks fed with 4% MLP-supplemented diet reached sexual maturity 7-10 days earlier than other MLP-treated or control groups. Additionally, MLP supplementation improved the fertility and hatchability of ducks. Remarkably, drakes fed with 4% MLP-supplemented diet showed increased semen volume and better sperm quality parameters, including total motility, progressive motility, viability, and concentration, with reduced sperm abnormalities compared to other MLP-treated and control groups. Therefore, it is suggested that 4% MLP can be supplemented in duck rations to enhance the productive and reproductive profiles.

INTRODUCTION

The poultry sector is a fundamental component of animal agriculture in Bangladesh, significantly contributing to food security by providing meat and eggs. Among the poultry genetic resources in Bangladesh, ducks hold the second position next to chickens in terms of farming prominence [1]. Duck rearing has become a lucrative business in low-lying areas of Bangladesh [2]. Moreover, raising ducks has become a livelihood method for poor and landless people living in Haor, Bills, and small river areas because they can exploit common natural feed resources. Moreover, small-scale duck farming has proven beneficial for small and marginal farmers and offers a prospective source of self-employment for the youth and women [3]. The duck population has been estimated to be 66.016 million in Bangladesh [4]. Livestock and poultry contribute to the national GDP at 3.23%, whereas this sector contributes to the total agricultural GDP at 16.52%. Although the reported daily meat demand is 120 grams per person, current production is approximately 137.38 grams per person per day [4]. However, large rural communities suffer from malnutrition due to rising food prices. Currently, the prices of beef, mutton, and native chicken are beyond the reach of low-income families. Increasing duck meat production could play a crucial role in addressing this issue. Duck production is considered more advantageous than other poultry species because it requires less care and management. Ducks can feed on natural water bodies, marshlands, haors, rivers, ponds, and canals. It has been reported that approximately one-ninth of the land in Bangladesh is low-lying, which is particularly well-suited for duck rearing. Ducks are easy to rear, requiring minimal space, feed, housing, and management. Additionally, ducks are hardy, well-adapted to local climates, and relatively disease-resistant [5].

Pekin is a highly recommended meat-type duck breed for their environmentally hardy nature and robust immune system [6]. On average, Pekin ducks lay 200 to 300 extra-large white eggs annually, and their farming has recently gained popularity in different areas of Bangladesh [7]. Moreover, Pekin ducks are more fertile and superior regarding feed conversion and growth rate [8]. Smallholder farmers traditionally raise ducks under scavenging in haors and low-lying areas with minimal or no feed supplementation [9]. Thus, there is a great potential for increasing the productivity of ducks through supplementary feeding [10]. Moreover, the Pekin duck breeds are the best fit for intensive duck farming. The increasing demand for duck eggs and meat paved the way for intensive duck farming, making it profitable [6]. However, intensive farming of ducks requires balanced nutrition and supplementation of feed additives to attain maximum profit [11]. Although ducks are proven to be disease-resistant [5], they are considered a possible source of zoonotic infectious organisms, including pathogenic bacteria like *Campylobacter* spp. [12]. Therefore, intensive duck farming requires special attention regarding zoonosis. In contrast, the extensive use of antibiotics in poultry production has posed significant public health threats [13]. The issue of antibiotic resistance has driven substantial efforts to limit antibiotic use in livestock and poultry production [14]. Consequently, as reported, there has been increasing interest in using natural herbs as alternative antibiotics in poultry production [15]. Growing concerns about health issues and focusing on alternative antibiotics for organic meat and egg production have fueled significant demand [16]. Moreover, it is well established that various natural medicinal plants and their extracts have been used as feed supplements to replace antibiotics in poultry production [17].

Moringa oleifera is a well-known cultivated species in Bangladesh in the Moringaceae family under the order Brassicales [18]. Moringa leaves have extraordinarily high nutritional and therapeutic values [19,20]. It contains various bioactive compounds, including flavonoids, steroids, saponins, phlorotannins, and terpenoids [21]. Moreover, moringa leaves contain zeatin, a naturally occurring cytokinin with antimicrobial activities [22], an immune booster [23], and a potent antioxidant [24]. In addition to the proteins, vitamins, minerals, and amino acids, it is a tremendous source of carotene [25] and polyunsaturated fatty acids (PUFAs), especially omega-3 fatty acids [26]. It has been reported that omega-3 fatty acids improved the overall reproductive performance with enhanced sperm quality and endocrine functions in male birds [27]. Moreover, dietary supplementation of fermented moringa leaf powder increases feed consumption, feed conversion ratio, and weight of eggs in laying ducks [28,29]. Therefore, it was hypothesized that dietary supplementation of moringa leaf powder could improve the productive and reproductive performance of ducks. Considering these, the present study intended to evaluate the effect of moringa leaf powder on the productive and reproductive performance of Pekin duck as a natural feed supplement.

MATERIALS AND METHODS

Materials, chemicals, and reagents

All the chemicals and reagents were procured from Merck KGaA (Darmstadt, Germany). Moringa leaf powder (MLP) was collected from a renowned supplier in Bangladesh (Natural Sheba). MLP was stored in a sealed glass jar until use. Besides the nutrient composition of the MLP stated on the label, we have analyzed it in the Animal Nutrition Laboratory of BSMRAU. The chemical composition of MLP is indicated in Table 1.

Table 1. Chemical composition of Moringa leaf powder (MLP).

Nutrient Content	As labeled in the packet	Laboratory analysis
Metabolizable Energy (Kcal/Kg)	1665.83	1646.71
Crude Protein (%)	26.70	25.56
Crude Fat (%)	18.94	19.02
Ether Extract (%)	6.10	5.92
Ash (%)	6.32	6.45
Calcium (%)	1.90	1.94
Phosphorus (%)	0.56	-
Lysine (%)	1.92	-
Methionine (%)	0.20	-

Collection and rearing of ducks

The study was conducted in the well-constructed duck shed of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. Pekin grower ducks (8 weeks of age) were purchased from a well-known commercial duck breeding farm in Kishoreganj, Bangladesh. A total of 360 ducks were collected and allocated into four treatment groups with three replications, each having 25 ducks and 5 drakes. The groups were supplied with either only basal feed (T1; 0% MLP) as control, basal feed with 2% MLP (T2; 2% MLP), basal feed with 4% MLP (T3; 4% MLP), or basal feed with 6% MLP (T4; 6% MLP). The ingredients and diet composition of experimental rations are summarized in Table 2. Ducks were reared under a semi-intensive management system. For the fertile egg, the male-female ratio was 1:5 in each group. A 3.5 sq.ft./bird floor space was allowed up to 16 weeks of age. After that, a floor space of 4 sq.ft./bird was provided. A photoperiod of 14 to 16 hours per day was ensured for optimum production. Ducks were grown with an average 130 gm/bird/day mash feed of a renowned feed company (Aftab Feed Products Limited), maintaining proper energy and protein according to the stage of the bird with *ad libitum* safe drinking water. Chemical analysis of concentrate mash was performed for nutrient level analysis according to the Association of Official Analytical Chemists (AOAC) method [30]. Metabolizable energy (ME) content in the experimental rations was calculated based on chemical composition [31]. Moringa powder was supplemented with wet mash feed by proper hand mixing and supplied to the treatment groups accordingly. Ducks were fed twice a day, i.e., in the morning and late afternoon. The vaccination schedule was strictly followed throughout the experimental period. The study was ethically approved by the Animal Research Ethics Committee (AREC), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh (BSMRAU/DEAN (FVMAS)-23/AREC/2019/6753).

Table 2. Feed ingredients and nutrient composition of the experimental diets.

Feed ingredient level of experiment diet				
Ingredients	**Treatment diets**			
	T1 (0% MLP)	T2 (2% MLP)	T3 (4% MLP)	T4 (6% MLP)
Ready feed (Mash)	100	98	96	94
Moringa leaf powder (MLP)	0	2	4	6
Total	100	100	100	100
Nutrient Composition				
Metabolizable Energy (Kcal/Kg)	2780	2757.33	2702.19	2648.14
Crude Protein (%)	18.75	18.89	18.51	18.14
Ether Extract (%)	5.15	5.17	5.06	4.96
Crude Fibre (%)	3.5	3.81	3.73	3.66
Calcium (%)	3.5	3.47	3.40	3.33

Growth performance measurement

Body weight (weekly), feed supplied (daily), and residual feed (daily) were recorded using a digital weighing scale (Mega digital scale, Mega regular ACS-CS, Japan Standard). Weight gain was calculated as below:

Weight gain (g) = Final body weight (g) – Initial body weight (g).

Feed intake was calculated by subtracting the remaining feed from the feed offered using the following equation:

Feed intake (g) = Feed offered (g) – Remaining feed (g).

The feed conversion ratio (FCR) was calculated weekly by the following formula:

FCR= Feed intake (g) / Body weight gain (g)

Carcass quality assessment

At the end of the experimental period, 3 ducks were randomly selected from each replication of the respective treatment group, weighed, and slaughtered following the Halal method. The carcass was obtained after removing feathers, and viscera and separating the head, neck, and shanks, as described [32]. The dressing percentage was determined as the dressed weight (g) divided by the live weight (g). Meanwhile, the liver, gizzard, breast muscles, thigh muscles, and abdominal fats were also weighed as the relative weight of the live weight (g/100g). Breast length and width were measured and expressed as cm/100g.

Blood parameters analysis

Blood samples were collected from slaughtered ducks. For analyzing hematology, the blood was collected in the heparinized tube to prevent clotting. The hematological parameters were determined using an automatic blood analyzer (Veterinary Automatic Hematology Analyzer, Changchun Blaser Medical Technical Co. Ltd, Jilin Sheng, China). For biochemical analysis, the blood was collected in a clot activator tube and kept at room temperature for 20-30 minutes to clot. Then, the serum was alienated by centrifugation at 2000 rpm for 10 minutes and collected from the upper portion of the tube. The biochemical parameters were determined using the specific colorimetric kit (Total protein, Albumin, and Globulin, 'Genuine Biosystem pvt ltd, Chennai, India'; Glucose, Triglyceride, and Cholesterol, 'Crescent Diagnostics, Jeddah, Saudi Arabia') according to the manufacturer's instructions.

Reproductive parameters analysis

After the experimental period, the reproductive organs, including the ovary, follicle, oviduct, and uterus of the slaughtered ducks, were separated carefully from the corpse. The weight of the ovary and ovarian follicles was measured using a digital balance (Mega digital scale, Mega regular ACS-CS, Japan Standard). The number of follicles as small yellow follicles (SYF, with a diameter >4 and <8 mm) and large white follicles (LWF, with a diameter >8 mm) were counted. The follicle diameter was measured by a digital caliper hardened (accuracy 0.01mm) according to Kasiyati et al. [33]. Egg weight was measured using a digital balance. The fertility of the egg was determined using candling of the egg during incubation, whereas hatchability was calculated after the hatch of ducklings using the following formula:

a. Fertility (%) = (Number of eggs fertile / Number of eggs laid) × 100

b. Hatchability (%) = (No of ducklings' hatch / Total number of eggs set in the incubator) × 100

Semen was collected from three drakes from each replication of the respective treatment group using the dorso-abdominal massage method with a day interval into a 15 ml graduated collection vial. The vials were positioned in a thermo flask at 41°C and transported to the laboratory immediately. The semen was examined for color, opacity, and the presence of foreign substances. The motility, concentration, viability, and morphology of the sperm were analyzed using pooled semen for each replication, according to Taskin et al. [34]. Briefly, total motility (%) and progressive motility (%) were evaluated by placing a 10 μl drop of fresh semen onto a clean, pre-warmed (37°C) glass slide, covering it with a 22×22 mm coverslip and observing under a light microscope at 40× magnification. Sperm concentration (billion/ml) was analyzed using the hemocytometer method. The live sperm count was determined by mixing one drop of Eosin-Nigrosin stain with a small drop of semen on a pre-warmed slide. After smearing, the slide was examined under a microscope with 40× objective. The normal sperm count was calculated after staining with Rose-Bengal Stain. Semen pH was measured using a calibrated pH meter (Hanna Instruments®, Portugal). All values related to semen evaluation parameters were expressed as mean ± standard error (SE).

Statistical analysis

All data from three replicates in each group, both treated and control, were analyzed according to Hoque et al. [35], by one-way analysis of variance (ANOVA) followed by LSD posthoc test using IBM SPSS Statistics for Windows, Version 20.0 [36].

RESULTS

Effect of MLP on growth performance and carcass quality of duck

The effects of MLP on the growth parameters are summarized in Figure 1, and the carcass quality parameters in Table 3. Initially, the weights of ducks were similar across all groups (Figure 1A). However, mature weights in all MLP-treated groups were significantly ($p<0.05$) increased compared to the control. Among the treatments, ducks given 4% MLP showed significantly ($p<0.05$) higher weights than those fed with 2% or 6% MLP (Figure 1A). Live weight gain in 2% MLP-treated ducks was similar ($p>0.05$) to control; however, maximum weight gain was observed at 4% MLP followed by 6% MLP-treated ducks (Figure 1B). Notably, feed intake was not changed ($p>0.05$) by MLP treatments as compared to control (Figure 1B). Although the feed conversion ratio (FCR) of the ducks treated with 2% MLP did not show any improvement (p>0.05), the higher MLP levels at 4% and 6% significantly reduced (p<0.05) the FCR compared to the of control (Figure 1C).

Regarding carcass quality, the dressing percentage was observed significantly (p<0.05) higher in MLP-treated groups than in control, with the 4% MLP treatment showing a significantly higher (p<0.05) dressing percentage than those of 2% or 6% MLP group. Additionally, the weight of abdominal fat, liver, heart, and gizzard was found to be significantly (p<0.05) increased by MLP treatments, with maximum (p<0.05) at 4% level compared to other treatment groups (Table 3). The weights carcass cuts, including breast, thigh, drumstick, wing, and back, showed no significant (p>0.05) improvement at 2% MLP treatments; however, the 4% and 6% levels of MLP treatment significantly (p<0.05) increased the weight of all the carcass cuts, compared to the control group. Notably, the dressing percentage and the weights of carcass cuts were observed significantly (p<0.05) reduced when MLP supplementation increased beyond 4% (Table 3). Therefore, it is clear that 4% of MLP treatment outperformed all other treated or untreated groups.

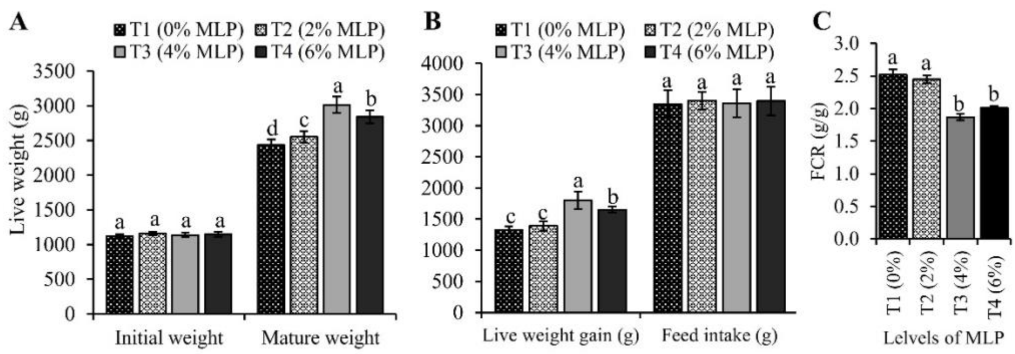

Figure 1. The effects of MLP on the growth parameters of ducks. (A) represents the initial and final live weight, (B) represents the Live weight gain and Feed intake, and (C) represents the FCR. Values are Mean±SE; Values with different lowercase superscripts (a, b, or c) in the same parameter differ significantly (p<0.05). T1 (0% MLP) refers to control (only basal feed), T2 (2% MLP) refers to basal feed with 2% MLP, T3 (4% MLP) means basal feed with 4% MLP and T4 (6% MLP) means basal feed with 6% MLP.

Table 3. Carcass quality of duck at different treatments of MLP.

Carcass quality Parameters	Treatment diets			
	T1 (0% MLP)	T2 (2% MLP)	T3 (4% MLP)	T4 (6% MLP)
Dressing percentage (%)	59.12± 0.42^{c}	62.32± 0.28^{b}	65.23± 0.47^{a}	62.78± 0.37^{b}
Abdominal fat weight (g)	2.31±0.02^{c}	3.70±0.03^{b}	4.61±0.01^{a}	4.42±0.02^{a}
Liver weight (g)	29.25± 3.22^{c}	39.32±3.61^{b}	55.21±1.18^{a}	43.86±3.50^{b}
Heart weight (g)	19.81±1.07^{b}	22.8±1.39^{ab}	23.6±1.33^{a}	22.8±0.66^{ab}
Gizzard weight (g)	55.28±1.05^{c}	64.43±1.72^{b}	80.61±1.21^{a}	70.42±1.63^{b}
Breast weight (g)	226.63±2.34^{c}	249.69±1.21^{c}	312.81±1.32^{a}	273.67±1.99^{b}
Thigh weight (g)	127.28±1.56^{c}	149.19±1.32^{bc}	192.17±1.20^{a}	169.41±1.47^{b}
Drumstick weight (g)	142.23±2.80^{c}	153.85±1.66^{c}	207.89±1.98^{a}	180.27±2.06^{b}
Wing weight (g)	191.21±1.74^{c}	215.42±1.78b^{c}	257.54±0.95^{a}	242.62±2.99^{b}
Back weight (g)	126.23±1.85^{c}	129.05±4.11^{c}	153.25±2.15^{a}	141.81±2.22^{b}

Values are Mean±SE; Values with different lowercase superscripts (a, b, c or d) in the same parameter (row) differ significantly (p<0.05). T1; 0% MLP refers to control (only basal feed), T2; 2% MLP refers to basal feed with 2% MLP, T3; 4% MLP means basal feed with 4% MLP and T4; 6% MLP means basal feed with 6% MLP.

Effect of MLP on blood parameters of duck

The effects of MLP on the serum and hematological parameters of ducks at different levels are summarized in Table 4. Regarding serum parameters, there was no significant ($p>0.05$) difference in glucose levels between the control group and the 2% MLP and 4% MLP groups; however, the glucose level in the 6% MLP group was significantly ($p<0.05$) decreased. The total protein, albumin, and globulin content were unchanged ($p>0.05$) in all MLP-treated groups compared to the control (Table 4). Although both the total cholesterol and triglyceride levels were observed significantly ($p<0.05$) increased in all MLP-treated groups compared to the control, no significant differences ($p>0.05$) were observed among the MLP levels (Table 4).

In terms of hematological parameters, the white blood cell (WBC) count showed a significant ($p<0.05$) increase in the 2% MLP-treated group, which was observed to be further significantly ($p<0.05$) increased in 4% and 6% MLP groups. However, there was no significant difference ($p>0.05$) between the 4% and 6% MLP groups (Table 4). The lymphocyte counts, hemoglobin (Hb), and red blood cell (RBC) counts were found to be significantly ($p<0.05$) increased by MLP treatments compared to the control; however, no significant ($p>0.05$) differences were observed among the different levels of MLP treatments (Table 4). The mean corpuscular hemoglobin (MCH), platelet (Plt) and mean corpuscular hemoglobin concentration (MCHC) counts were observed to be significantly ($p<0.05$) increased in MLP 4% and 6% treatment groups; however, 2% MLP treated groups showed no change ($p>0.05$) compared to those of control group (Table 4). The other parameters, like mean corpuscular volume (MCV) and hematocrit percentage (HCT%), did not show any change ($p>0.05$) between the control and different levels of MLP treatment groups.

Table 4. Different blood parameters of duck at different treatments of MLP.

Blood Parameters	**Treatment diets**			
	T1 (0% MLP)	**T2 (2% MLP)**	**T3 (4% MLP)**	**T4 (6% MLP)**
Serum biochemical parameters				
Glucose (mg/dl)	222.84± 3.39[a]	217.00± 3.50[a]	209.69±4.37[ab]	187.10± 3.18[b]
Total Protein (g/dl)	3.32±0.03[a]	3.26±0.03[a]	3.47±0.03[a]	3.52±0.04[a]
Albumin (g/dl)	0.93±0.02[a]	0.99±0.03[a]	1.05±0.05[a]	1.01±0.02[a]
Globulin (g/dl)	2.35±0.05[a]	2.21±0.03[a]	2.38±0.03[a]	2.41±0.03[a]
Total Cholesterol (mmol /L)	188.50±2.18[a]	168.67±2.60[b]	162.89±2.58[b]	156.92±3.26[b]
Triglycerides (mmol/L)	184.93±2.62[a]	153.45±2.04[b]	149.86±2.60[b]	156.53±2.65[b]
Hematological parameters				
WBCs($\times10^3/\mu l$)	106.34±2.72[c]	129.78±3.09[b]	147.77±2.65[a]	147.80±1.70[a]
Lymphocyte (%)	86.53±2.98[b]	93.14±2.87[a]	98.88±2.92[a]	96.64±2.56[a]
Hb (g/dl)	18.58±0.65[b]	20.50±0.55[a]	21.46±0.42[a]	20.66±0.45[a]
MCH (pg)	84.58±0.72[b]	85.77±0.64[b]	92.40±1.07[a]	91.39±0.61[a]
MCHC (g/dl)	56.98±0.83[b]	58.64±0.55[b]	65.41±1.16[a]	64.87±0.77[a]
RBCs ($\times10^6/\mu l$)	2.35±0.03[b]	2.60±0.03[a]	2.50±0.02[a]	2.55±0.03[a]
MCV (fL)	148.65±0.76[a]	149.56±0.94[a]	145.77±1.65[a]	148.63±0.93[a]
Plt ($\times10^3/\mu l$)	5.22±0.28[b]	5.88±0.32[b]	7.10±0.18[a]	7.07±0.18[a]
HCT (%)	33.95±1.21[a]	32.76±0.69[a]	31.04±0.87[a]	31.60±1.39[a]

Values are Mean±SE; Values with different lowercase superscripts (a, b or c) in the same parameter (row) differ significantly ($p<0.05$). T1; 0% MLP refers to control (only basal feed), T2; 2% MLP refers to basal feed with 2% MLP, T3; 4% MLP means basal feed with 4% MLP and T4; 6% MLP means basal feed with 6% MLP.

Effect of MLP on the reproductive performance of duck

The follicular parameters of ducks treated with or without MLP are shown in Figure 2, and other reproductive parameters are in Table 5. The weight of the ovaries was not affected (p>0.05) by MLP treatment (Figure 2A). The number of small yellow follicles (SYF) and large white follicles (LWF) of control ducks were also similar (p>0.05) with 2% MLP-treated ducks (Figure 2B). However, the number of both follicles was significantly (p<0.05) increased by 4% and 6% MLP treatment compared to the control, where there was no significant (p>0.05) difference observed between 4% and 6% MLP (Figure 2B). The diameters of SYF and LWF, as well as the egg weight, were observed to be similar (p>0.05) among the control, 2% and 6% MLP-treated groups; however, these parameters were significantly (p<0.05) increased in the MLP 4% treatment group compared to control and other MLP-treated groups (Figure 2C). The age at sexual maturity was not improved (p>0.05) by 2% and 6% MLP treatments; however, 4% MLP treatment showed comparatively earlier (p<0.05) sexual maturity than other treatment groups (Table 5). Regarding fertility and hatchability, it was observed that 2% MLP treatment showed similar (p>0.05) results compared to the control. However, these parameters were significantly (p<0.05) increased by 4% and 6% MLP treatment compared to the control with no significant (p>0.05) between them (Table 5). Considering the overall reproductive performance of ducks, it is clear that 4% MLP treatment is better than all other MLP treatments.

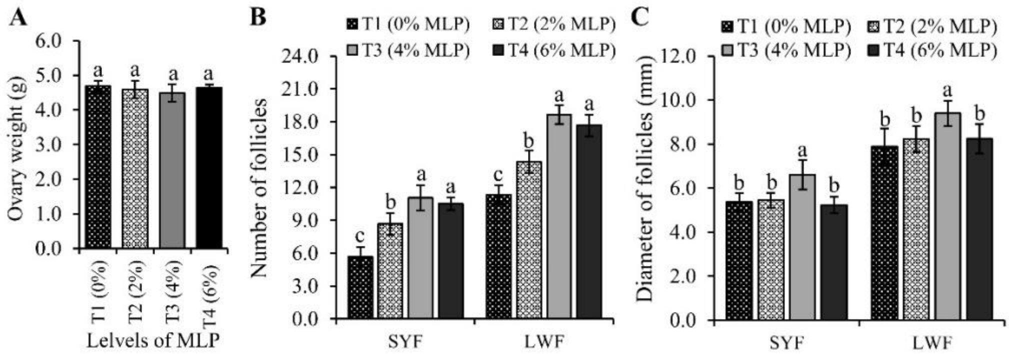

Figure 2. The follicular parameters of ducks treated with or without MLP. (A) represents the weight of the ovary, (B) represents the number of follicles, and (C) represents the length of follicles. SYF: Small Yellow Follicles and LWF: Large White Follicles. Values are Mean±SE; Values with different lowercase superscripts (a, b, or c) in the same parameter differ significantly (p<0.05). T1 (0% MLP) refers to control (only basal feed), T2 (2% MLP) refers to basal feed with 2% MLP, T3 (4% MLP) means basal feed with 4% MLP and T4 (6% MLP) means basal feed with 6% MLP.

Table 5. Reproductive performances of duck at different treatments of MLP.

Parameters	Treatment diets			
	T1 (0% MLP)	**T2 (2% MLP)**	**T3 (4% MLP)**	**T4 (6% MLP)**
Age at sexual maturity (Days)	207.00±3.79^{a}	202.67±2.91^{a}	192.33±3.76^{b}	203.17±4.16^{a}
Egg weight (g)	80.88±1.02^{b}	81.25±1.34^{b}	85.34±1.46^{a}	81.58±0.66^{b}
Fertility (%)	78.77±1.12^{c}	82.57±0.45^{b}	91.29±1.28^{a}	85.41±0.66^{b}
Hatchability (%)	73.96±0.73^{c}	79.47±0.56^{b}	85.64±1.38^{a}	82.98±0.87^{ab}

Values are Mean±SE; Values with different lowercase superscripts (a, b, or c) in the same parameter (row) differ significantly (p<0.05). T1; 0% MLP refers to control (only basal feed), T2; 2% MLP refers to basal feed with 2% MLP, T3; 4% MLP means basal feed with 4% MLP and T4; 6% MLP means basal feed with 6% MLP.

Effect of MLP on the reproductive performance of drake

The reproductive parameters of drake, including semen and sperm quality, are summarized in Table 6. It was observed that the semen volume was similar (p>0.05) between the control and 2% MLP-treated groups. However, the semen volume was significantly (p<0.05) increased in 4% and 6% MLP-treated groups compared to control. The 4% MLP treatment showed a significantly (p<0.05) higher semen volume when compared to the 6% MLP group (Table 6). The semen pH was observed unchanged ($p>0.05$) in all MLP-treated or control groups. Among the sperm quality parameters, the sperm concentration, live sperm (%), progressive motility (%), and total motility (%) were observed not affected ($p>0.05$) by 2% MLP treatment. However, these parameters were significantly ($p<0.05$) increased in 4% and 6% MLP-treated groups with an insignificant ($p>0.05$) difference between them, as compared to the control group (Table 6). Interestingly, the proportion of abnormal sperm was found to be similar ($p>0.05$) among all the MLP-treated groups; however, the values were observed significantly lower ($p>0.05$) compared to the control group (Table 6). Considering all aspects, it is clear that MLP treatment improved the reproductive output of drake; however, 4% MLP treatment is better than all other MLP treatments.

Table 6. Reproductive performance of drakes at different treatments of MLP.

Parameters	Treatment diets			
	T1 (0% MLP)	T2 (2% MLP)	T3 (4% MLP)	T4 (6% MLP)
Semen Volume (ml)	0.29 ± 0.02^{c}	0.30 ± 0.05^{c}	0.43 ± 0.02^{a}	0.36 ± 0.04^{b}
Semen pH	7.18 ± 0.25^{a}	7.15 ± 0.07^{a}	7.33 ± 0.20^{a}	7.20 ± 0.26^{a}
Sperm Concentration (10^8 cells/ ml)	660.51 ± 5.70^{b}	671.07 ± 4.86^{b}	734.81 ± 6.27^{a}	698.58 ± 3.12^{ab}
Live sperm (%)	77.02 ± 0.68^{b}	79.38 ± 1.21^{b}	86.24 ± 0.77^{a}	84.15 ± 1.32^{a}
Progressive motility (%)	37.42 ± 1.45^{b}	39.45 ± 2.19^{b}	52.85 ± 1.53^{a}	51.81 ± 1.92^{a}
Total motility (%)	78.99 ± 2.19^{b}	79.18 ± 1.30^{b}	84.86 ± 0.89^{a}	83.08 ± 2.35^{a}
Sperm abnormality (%)	13.12 ± 1.09^{a}	9.85 ± 0.38^{b}	8.56 ± 0.85^{b}	9.23 ± 0.58^{b}

Values are Mean±SE; Values with different lowercase superscripts (a, b, or c) in the same parameter (row) differ significantly ($p<0.05$). T1; 0% MLP refers to control (only basal feed), T2; 2% MLP refers to basal feed with 2% MLP, T3; 4% MLP means basal feed with 4% MLP and T4; 6% MLP means basal feed with 6% MLP.

DISCUSSION

Duck farming is an effective tool for breaking the cycle of poverty among smallholder, resource-poor families in low-income countries [3]. The Pekin duck, a well-known meat breed, thrives in the low-lying areas of Bangladesh with minimal inputs, making it an ideal choice for commercial meat duck farming [1]. However, effective nutritional management is crucial for maximizing profitability in commercial-intensive and semi-intensive farming systems.

Moringa is a well-known cultivated native species in Bangladesh. Renowned for their nutritional and medicinal value, the seeds, flowers, and leaves are commonly incorporated into human food and used as herbal medicine [37]. However, the residual leaves could be a good source of animal and poultry feed [18]. In this study, different levels of MLP were supplemented with basal feed in Pekin ducks. It was observed that the MLP supplementation improved the overall production parameters, including mature live weight, live weight gain, and FCR, with a maximum improvement of 4% in MLP treatments. It is well-known that moringa leaves possess high nutritional value, contain plenty of high-quality proteins [38] and antioxidants [24,39], and have antibiotic properties [40]. Moreover, it was revealed that the essential nutrients and minerals in moringa leaves enhance the growth performance and health of poultry [41]. Furthermore, various studies reported that ration containing moringa leaves improved the performance of growing Japanese quails [42], layer chicken [43], geese [44], and broiler chicken [45]. In addition, Yang et al. [46] reported that the best FCR was observed in ducks fed with 4% MLP supplementation. Interestingly, different levels of MLP supplementation showed no significant effect on the feed consumption of ducks in this study. Similar results were also observed in broilers [47] and geese [44]. However, the overall production performance of ducks fed with 6% MLP in this study declined as compared to 4% MLP. Ibrahim et al. [48] also reported that the mature body weight and weight gain of ducks decreased as the MLP increased. In addition, Onu and Aniebo [41] stated that the birds treated with 2.5% and 5% MLP achieved the highest live weight gain. Similar to production performance, MLP treatments increased the dressing percentage and carcass yield with the maximum at 4% MLP level in this study. This improvement may be attributed to the improvement in the final body weight of ducks fed with MLP, as described previously. In another study, Abd-El-Samee et al. [49] recorded a higher dressing percentage with increased heart, liver, and gizzard weights in ducks fed with an MLP-supplemented diet compared to the control group.

The production and carcass characteristics are the outcome of the health and physiology of birds. The hematology and biochemical properties are the indicators of birds' physiological status. It has been reported that the polyphenols content in MLP can limit the absorption of lipids and cholesterol by increasing the liver's ability to excrete the lousy cholesterol, and other bioactive compounds, including zeatin, can accelerate the pancreatic activity to lower the blood glucose levels [33]. Moreover, it is well known that MLP strengthens the immune system to shield against invading microorganisms [22,50], thereby contributing to reinforcing cellular mechanisms through antibacterial activity [51]. In this study, the concentrations of serum proteins, albumin, and globulin were not changed; however, the serum glucose, cholesterol, and triglycerides were decreased in ducks fed with MLP-supplemented diets. Similar to our results, Ahemen et al. [52] reported that the serum total protein and its fractions did not change when birds were fed with MLP-containing ration. However, Ashong and Brown [53] observed that the control group had significantly higher cholesterol and triglyceride levels in broilers compared to MLP-treated groups. The hematological reports in this study revealed that 4% of MLP-treated groups had the highest concentration of Hb along with WBC, RBC, and platelet counts, which supports the immunogenic activity of MLP. Moreover, it was reported that dietary supplementation with MLP can increase the immunity of broilers [54].

The reproductive efficiency of both ducks and drakes is crucial for the continuous supply of healthy ducklings. The improved reproductive performance of parents reflects the ultimate performance of the offspring. Early sexual maturity is augmented by rapid ovarian follicle development, positively impacting fertility and hatchability [55]. In this study, ducks supplemented with 4% MLP reached sexual maturity 7-10 days earlier than other MLP-treated or control groups. Moreover, the number and diameter of follicles, egg weight, fertility, and hatchability are significantly improved in the 4% MLP-treated group compared to the control. The accelerated follicular growth in this study might be attributed to incorporating bioactive components into the yolk of MLP-treated ducks, which ultimately improves fertility and hatchability. Various studies also reported that moringa leaves, either in meal or powder form, notably improved the reproductive performance of ducks [56] and chickens [57]. Regarding male reproduction, the low sperm concentration with decreased motility and viability results in low fertility [58]. Moringa leaves are a good source of antioxidants and can prevent cellular oxidative damage, thus improving cell viability [24,59]. Moreover, Sebola et al. [60] reported that vitamin E and selenium content in moringa leaves increases sperm motility. In addition, it was observed that MLP contains antioxidants, phytochemicals, minerals, and vitamins that enhance growth and stimulate reproduction in poultry [18]. The increased semen volume and sperm quality parameters, including sperm concentration, viability, progressive motility, and total motility with reduced sperm abnormality in drakes fed with 4% MLP in this study, support the beneficial impacts of MLP on male reproductive performance.

Pekin duck farming has recently gained popularity in different areas of Bangladesh [7]. On the contrary, Moringa is a well-known cultivated native species in Bangladesh and renowned for its nutritional and medicinal value [37]. This study revealed that MLP positively impacts the overall production and reproduction performance of Pekin ducks. Therefore, the results of this study would be helpful for commercial meat duck farming with effective nutritional management to maximize profitability.

CONCLUSIONS

In conclusion, it can be stated that 4% MLP enhances live weight gain by reducing FCR, increasing dressing percentage, lowering blood sugar, and reducing triglycerides and cholesterol in blood lipids without hampering other blood parameters. Most importantly, 4% MLP supplementation in the diets increases the fertility and hatchability of ducks along with the semen and sperm quality of drakes. Therefore, rearing Pekin duck supplemented with 4% MLP in the diet will be beneficial for the farmers considering the production and reproduction parameters. The findings of the present study will be helpful for duck farming, especially for those who are thinking of commercial-intensive or semi-intensive meat-type duck farming.

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AUTHOR CONTRIBUTIONS

MMI and SAMH were involved in the conception and design of the experiments. MMI and IJM contributed to performing the experiments. SAMH analyzed data. MMI, SAMH, and ASMS contributed to drafting the article. MMR contributed to revising it critically for important intellectual content. MMI and SAMH made the final approval of the version to be published.

CONFLICTS OF INTEREST

There is no conflict of interest among the authors.

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