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Physiological Performance and 'Productivity of Quail' Production Period with Addition Moringa Leaf Flour (Moringa oleifera L.) in Feed

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ABSTRACT

Moringa leaf powder is a processed product derived from the Moringa tree (Moringa oleifera L.). It contains a rich source of phytonutrients that are effective antioxidants that enhance the health status of humans and livestock. This study assesses quails' physiological performance and productivity during the production period when supplemented with Moringa leaf powder in their feed. The measured parameters include hematological values, stress indicators, performance, and egg chemical quality. The study used 120 female quails aged 7 weeks, reared for 4 weeks. A Completely Randomized Design (CRD) was employed, consisting of four levels of dietary treatments and three replications. The supplementation of Moringa leaf flour was administered through feed for 28 days at each treatment level. Data were analyzed using ANOVA (Analysis of Variance) and descriptive analysis. The results indicated that the addition of Moringa leaf flour in feed could maintain physiological performance, improve health status, reduce cholesterol levels in egg yolk, and increase iron (Fe) content in egg yolk. The best results in this study were obtained at a supplementation level of 7.5% Moringa leaf flour. The conclusion of this study is that Moringa leaf flour is feasible as a feed supplement at a dosage of up to 7.5%.

Keywords: antioxidant, cholesterol level, egg yolk, feed supplement, stress indicator

INTRODUCTION

Quail (*Coturnix coturnix japonica*) is a type of poultry that is increasingly favored due to its relatively simple rearing process and low maintenance costs. This bird exhibits rapid growth and requires minimal investment in terms of cost, space, and maintenance time, making it a promising alternative in livestock farming. A single quail can produce approximately 250 to 300 eggs per year, with an average egg weight ranging from 10 to 12 grams (Lokapirnasari 2017). Quail productivity is influenced by several factors, particularly environmental conditions. The environment plays a crucial role, encompassing aspects such as feed management, husbandry practices, and microclimatic conditions surrounding the livestock. Among these, ambient temperature is a critical component of the microclimate that directly affects quail productivity (Jumadin *et al*. 2023). Excessive heat stress can impair physiological performance, leading to suboptimal production outcomes. Heat stress is considered a major stressor that affects both behavioral responses and physiological conditions (Wasti *et al*. 2020).

The optimal ambient temperature for quail growth and productivity ranges from 18 to 22°C (Wasti *et al*. 2020). However, data from the Central Bureau of Statistics (BPS 2023) indicate that ambient temperatures in Indonesia range between 22 and 35°C, potentially leading to oxidative stress in quails. This condition is typically characterized by decreased feed intake and increased panting, which disrupt physiological processes and weaken the immune system. Oxidative stress occurs when the level of free radicals in the body exceeds the neutralizing capacity of the natural antioxidant system, potentially impairing various physiological functions (Jumadin *et al*. 2022). To mitigate oxidative stress, dietary supplementation with antioxidant-rich feed additives is essential. One such potential antioxidant source is the moringa plant (*Moringa oleifera* L.).

Moringa oleifera L. is rich in various phytonutrients, including carotenoids, flavonoids, chlorophyll, phenolic compounds, xanthines, alkaloids, tocopherols, and vitamin C (ascorbic acid). These compounds are known to possess potent antioxidant properties, playing a vital role in maintaining and enhancing overall health status (Falowo *et al*. 2014). *Moringa oleifera* L. has demonstrated antioxidant activity by inhibiting the formation of reactive oxygen species (ROS) and free radicals (Ogbunugafor *et al*. 2011). Moringa leaf powder is also known to contain a high level of iron (Fe), approximately 28.2 mg/100 g (Gopalakrishnan *et*

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al. 2016). Iron is essential for oxygen transport and collagen synthesis. Iron deficiency may impair hemoglobin synthesis, resulting in reduced numbers of healthy red blood cells and lower hemoglobin concentrations. Research has shown that the inclusion of 3% moringa leaf powder in laying hen diets can increase serum albumin levels while reducing leukocyte and lymphocyte counts (Voemesse *et al*. 2019).

The inclusion of 1% to 4% moringa leaf powder in the diet of male laying hens did not significantly affect blood profiles, indicating its potential to maintain normal white blood cell levels (Djaelani *et al*. 2020). Additionally, the use of moringa leaf powder at levels ranging from 2.5% to 10% in the diets of laying quails has been shown to preserve the anatomical structure and histophotometric dimensions of the oviduct, enhance cell proliferation, and maintain cellular integrity (Sunarno *et al*. 2023).

Therefore, moringa leaf powder is expected to positively influence the physiological status and productivity of laying quails as a feed additive. This study was conducted to evaluate the physiological responses and productivity levels of laying quails fed diets supplemented with moringa leaf powder.

METHODS

Time and Location of the Study

This research was conducted from November 2023 to January 2024. The phytochemical analysis of moringa leaf powder was carried out at the Laboratory of the Indonesian Center for Postharvest Research and Development, Bogor. The quail rearing was conducted at Arkan Quail Farm, located in Ciampea District, Bogor Regency. Blood sample analyses were performed at the Research and Diagnostic Laboratory of the Veterinary Teaching Hospital (RSHP), School of Veterinary Medicine and Biomedical Sciences (SKHB), IPB University. The measurement of iron (Fe) levels in blood was conducted at the Integrated Research and Testing Laboratory, Gadjah Mada University (UGM). Observations on the chemical quality of eggs were carried out at the Testing Center for Livestock Product Quality and Certification, Bogor. Analyses of Superoxide Dismutase (SOD) and Malondialdehyde (MDA) levels were performed at the Biochemistry Laboratory, Faculty of Mathematics and Natural Sciences (FMIPA), IPB University. All research procedures adhered to the guidelines established by the Animal Ethics Commission of SKHB IPB, under ethical clearance number 263/KEH/SKE/X/2024.

Materials and Equipment

The equipment used for quail rearing included tiered colony cages with dimensions of 100 cm in length, 75 cm in width, and 180 cm in height, which were divided into compartments measuring 50 cm in length. Each compartment housed 10 female quails. Additional supporting equipment included feed containers, drinkers, incandescent lamps as a source of lighting, and thermometers to monitor ambient temperature. The materials used in this study consisted of 120 female quails aged 6 weeks, which had entered their laying phase. The feed provided was commercial mash feed, supplemented with moringa leaf powder as the treatment variable. Laboratory equipment and materials used for sample analysis were adapted according to the parameters being tested.

Feed Preparation

The feed used in this study was a commercial feed (P–100) produced by PT. New Hope Indonesia. Moringa leaf powder was sourced from Pekandangan Sangrah Village, Bluto District, Sumenep Regency. The production process of the moringa leaf powder included leaf sorting, washing, and drying using an oven at 40–45°C for 16 hours. Leaves selected were at a moderate maturity level, id est, neither too young nor too old. After drying, the leaves were ground and sieved using a 300-mesh screen to obtain a fine and uniform powder. The moringa leaf powder was then thoroughly mixed with the commercial feed in a designated container, according to the predetermined treatment levels, until a homogeneous mixture was achieved.

Quail Management

Quail management involved cage preparation, environmental temperature recording, administration of treatment feed and drinking water (provided *ad libitum*), as well as egg collection. The feed mixed with moringa leaf powder was provided according to the treatment levels: 0%, 2.5%, 5%, and 7.5% (Sunarno *et al*. 2023). Egg collection was conducted every morning between 06:00 and 07:00 Western Indonesian Time (WIB). During the rearing period, performance parameters were observed, including feed intake, egg production, egg weight, egg mass, and feed conversion ratio. At the end of the rearing period (10 weeks of age), blood and liver samples were collected for physiological performance analysis. Blood sampling was conducted after the quails were subjected to a 12-hour fasting period.

Phytochemical Analysis of Moringa Leaf Powder

Phytochemical analyses included the quantification of phenols, flavonoids, saponins, and tannins. These analyses were performed quantitatively and based on the method described by Khalid *et al*. (2023).

Hematological and Iron (Fe) Compound Analysis

The physiological performance assessments included hematological parameters analyzed following the method of Nasrullah *et al*. (2020). The iron (Fe) content in the blood was analyzed using atomic

absorption spectrophotometry, referring to the procedure described by Khoirunnisa *et al*. (2020).

Stress Indicator Measurement

Stress indicators consisted of Superoxide Dismutase (SOD) and Malondialdehyde (MDA), which were measured based on the method described by Astawan *et al*. (2015). The heterophile to lymphocyte (H/L) ratio was calculated from leukocyte differential counts. Oxygen saturation was measured at 10 weeks of age using pulse oximetry.

Chemical Quality Assessment of Eggs

The chemical quality assessment of eggs included yolk cholesterol, analyzed according to the procedure outlined by Nurfianti et al. (2016), and iron (Fe) content in eggs, which was measured following the method of Maloney et al. (2008).

Data Analysis

This study was designed using a Completely Randomized Design (CRD) to evaluate the effects of Moringa Leaf Powder (MLP) supplementation through feed. Four treatment levels were applied: P0 (0% MLP), P1 (2.5% MLP), P2 (5% MLP), and P3 (7.5% MLP). Each treatment was replicated three times, with each replicate consisting of 10 quails as experimental units.

The collected data were analyzed using analysis of variance (ANOVA). If significant differences were detected among treatments, Duncan's Multiple Range Test (DMRT) was applied as a post hoc test to determine specific differences among treatment means. Hematological values, stress indicators, and feed conversion were also analyzed descriptively.

RESULT AND DISCUSSION

Environmental Temperature in the Cage

Observations showed that the average cage temperatures ranged from 21–24°C in the morning, 33–39°C during the afternoon, and 28–31°C in the evening. The optimal ambient temperature for laying-phase quails is between 22°C and 24°C (Castro *et al.* 2017). Under such conditions, quails face difficulty dissipating body heat to the environment, thereby increasing the risk of oxidative stress. Consequently, the birds become more susceptible to cellular and tissue damage, which can negatively impact their health and productivity.

Phytochemical Content of Moringa Leaf Powder

The phytochemical content of Moringa leaf powder in this study was quantitatively measured, and the results are presented in Table 1.

Flavonoids are secondary metabolites of polyphenols containing 15 carbon atoms and hydroxyl groups. They act as antioxidants by donating hydrogen atoms and stabilizing free radicals, thus slowing the autoxidation process (Arifin & Ibrahim 2018). Flavonoids are widely distributed in nature and known for their broad and beneficial bioactivities (Wang *et al.* 2018). Saponins are compounds belonging to the triterpenoid or steroid glycoside group and exhibit antioxidant and antibacterial properties (Negi *et al.* 2013; Chaudhary *et al.* 2018). Other studies report that bioactive compounds such as phenols and saponins have the ability to inhibit the growth of bacteria, fungi, and parasites by targeting cell membranes or cytoplasm (Pasaribu *et al.* 2014; Teodoro *et al.* 2015). Saponins in soybeans have also been shown to enhance antioxidant function in laying hens (Li *et al.* 2022). Tannins play a role as antimicrobial agents and are known to reduce blood cholesterol levels (Tugiyanti *et al.*' 2019; Liu *et al.* 2020; Marzoni *et al.*' 2020). Their antimicrobial effect works by disrupting cell membrane permeability, impairing substance exchange essential for bacterial survival, thereby inhibiting growth and leading to cell death. According to Jumadin *et al.* (2022) tannins may inhibit cholesterol absorption by forming complexes with mucosal proteins and epithelial cells, thereby reducing fat absorption. However, due to their protein-binding properties, excessive intake of tannins may negatively impact quail productivity if consumed beyond safe tolerance levels (Dawanto *et al.* 2024).

Hematological Values of Quails

The effects of Moringa leaf powder supplementation on hematological parameters and iron (Fe) levels in laying-phase quails are shown in Table 2.

Based on the analysis, hematological values remained within the normal range and are consistent with the findings of Mahmoud *et al.* (2013). This indicates that the quails maintained a sufficient red blood cell count. The increase in erythrocyte count, hemoglobin concentration, and hematocrit was likely due to enhanced iron absorption and antioxidant activity, which support a healthy bone marrow environment. Flavonoids found in coriander seed extract, for instance, have been shown to stimulate erythrocyte formation (Irawan *et al.* 2023). The increase in blood Fe concentration with Moringa leaf

Table 1 Phytochemical composition of moringa leaf powder

Phytochemical Compound	Concentration (%)
Phenol	2,32
Flavonoid	0,87
Saponin	1,63
Tanin	8,52

Source**:** Laboratory of the Center for Postharvest Research and Development, Bogor, 2023.

powder supplementation is attributed to the efficient absorption of dietary iron in the quail's digestive tract, which is then utilized in hemoglobin synthesis, thereby enhancing the oxygen-carrying capacity of the blood. Vitamin C facilitates the formation of an iron–ascorbate complex, which remains soluble at higher pH levels in the small intestine and converts iron to a more absorbable form (Arviyani *et al.* 2022).

Leukocytes are key components of the immune system that function in bodily defense. The higher leukocyte count observed in the control group was likely a response to oxidative stress-induced cellular damage, thereby triggering an immune response. The lower total leukocyte count in quails fed Moringa leaf powder is consistent with findings by Balami *et al.* (2018) in broilers and Voemesse *et al.* (2019) in laying hens. An elevated leukocyte count can serve as an indicator of an active immune response against infection or foreign agents (Jumadin *et al.* 2022)

The leukocyte differential analysis in this study revealed a downward trend across treatment levels, which may be associated with the presence of bioactive compounds in Moringa leaf powder that contribute positively to the health status of the quails. Leukocyte differentials consist of heterophils, which are involved in bacterial phagocytosis; lymphocytes, which respond to antigens and produce antibodies; monocytes, which act as macrophages to engulf and destroy pathogens; eosinophils, which target parasitic infections; and basophils, which defend against allergens (Verawati & Nurcahyo 2023).

Stress Indicators in Quails

The results of the analysis of average superoxide dismutase (SOD), malondialdehyde (MDA), heterophil-to-lymphocyte (H/L) ratio, and oxygen saturation are presented in Table 3.

SOD is an enzymatic antioxidant or preventive antioxidant that breaks down superoxide radicals into hydrogen peroxide and molecular oxygen (Calvani *et al.* 2022). The results showed that SOD levels increased in line with the rising dose of Moringa leaf powder in the feed. The high SOD levels in the liver of quails are attributed to the presence of bioactive compounds in Moringa leaf powder, which exhibit antioxidant effects. Antioxidants function by inhibiting the activity of enzymes that trigger free radical formation, thus increasing SOD levels. MDA is the final product of lipid peroxidation and is used as a biological biomarker to assess the degree of oxidative stress (Jumadin *et al.* 2022). The findings indicated that MDA levels in the control group were higher than those in the treatment groups with Moringa leaf powder supplementation. Naturally, cells produce free radicals and reactive oxygen species (ROS) as part of normal metabolic activity. However, when the number of free radicals exceeds the antioxidant defense system of the cell, oxidative stress occurs. In response, the liver functions as the primary detoxification organ. According to Valgimigli (2023), antioxidants prevent or inhibit the lipid peroxidation process by neutralizing or eliminating free radicals, thereby preventing adverse effects on the body. Physiological stress in quails can also be identified through the heterophil-to-lymphocyte (H/L) ratio (Santoso *et al.* 2024). A high H/L ratio is associated with increased susceptibility to infection. In this study, Moringa leaf powder reduced oxidative stress up to a 7.5% supplementation level, as indicated by a lower H/L ratio. This is due to the antioxidant and antibacterial properties of Moringa leaf powder. Oxygen saturation increased from P0 to P3. This

Table 2 Hematological parameters and blood iron levels in quails fed diets supplemented with moringa leaf powder

Parameters	P0	P1	P2	P3
Eritrosit (10^6/mm^3)	3,03±0,73	3,50±0,36	3,63±0,15	3,66±0,45
Hemoglobin (g/dL)	11,96±0,40	11,76±0,65	12,06±0,56	12,16±0,37
Hematokrit (%)	33,30±1,93	34,63±1,49	36,13±2,46	37,86±2,93
Leukosit (10^3/mm^3)	19,70±2,25	19,16±0,68	18,00±0,17	17,96±0,20
Heterofil (%)	30,33±1,52	29,66±0,57	28,33±1,15	27,66±2,51
Limfosit (%)	56,53±1,35	58,66±2,35	61,55±1,02	63,47±2,99
Monosit (%)	5,66±0,57	4,66±0,57	4,33±1,15	3,33±0,57
Eosinofil (%)	7,06±1,76	6,59±1,22	5,38±0,53	5,12±0,06
Basofil (%)	ND	ND	ND	ND
Blood Iron/Fe (mg g^{-1})	12,47±1,87	16,95±2,05	25,76±10,67	30,56±9,63

Description: P0: control, P1: control + 2,5% Moringa Leaf Powder (MLP), P2: control + 5% MLP, P3: control + 7,5% MLP, ND: not detected.

Table 3 Stress indicator values in quails fed diets supplemented with moringa leaf powder

Parameters	P0	P1	P2	P3
SOD (Unit/mL)	89,91±4,42	92,58±5,43	96,80±2,87	103.52±9.62
MDA (nmol/mg)	0,38±0,29	0,24±0,03	0,25±0,04	0,19±0,04
H/L	0,53±0,02	0,50±0,03	0,46±0,02	0,44±0,06
Oxigen Saturation (%)	82,96±2,93	85,40±0,87	89,60±0,88	91,10±0,95

Description: P0: kontrol, P1: control + 2,5% MLP, P2; control + 5% MLP, P3: control + 7,5% MLP; SOD (Superoksida DiCXsmutase); MDA (Malondialdehid); H/L (Heterofil/Limfosit).

improvement suggests that quails supplemented with Moringa leaf powder had better oxygen transport efficiency. As a source of iron and antioxidants, Moringa leaf powder contributes to the increased production of hemoglobin and cardiovascular function, ultimately improving oxygen saturation. According to Jumadin *et al.* (2022), high oxygen saturation supports the quail's ability to better adapt to oxidative stress, as an adequate oxygen supply helps mitigate the adverse effects of stress on body tissues.

Quail Performance

Observations included feed intake, egg production, egg weight, egg mass, and feed conversion ratio, as presented in Table 4.

Statistical analysis showed that average feed intake, egg weight, and egg mass were not significantly different among most treatment groups. This indicates that the rearing environment and nutrient intake were consistent, resulting in uniform feed consumption across groups. Factors such as crop capacity, metabolic energy needs, nutrient and mineral content can influence feed intake and support egg mass (Ashour *et al.* 2020; Mone *et al.* 2016). However, supplementation of Moringa leaf powder showed a significant difference in egg production. This can be attributed to the antioxidant-rich properties of Moringa leaf powder, which reduce oxidative stress and optimize egg production. Abou–Elkhair *et al.* (2020) reported that Japanese quails supplemented with *Moringa oleifera* powder demonstrated improved heat stress tolerance and increased egg productivity, along with enhanced feed intake. The best feed conversion ratio (FCR) was recorded in quails supplemented with 7.5% Moringa leaf powder (P3). The presence of flavonoids and saponins in the powder may enhance physiological performance and increase resistance to heat stress and bacterial infection, resulting in healthier quails and more efficient feed utilization. A lower FCR indicates better efficiency in converting feed into egg mass (Jumadin *et al.* 2022).

Chemical Quality of Quail Eggs

Egg quality was evaluated chemically by analyzing the yolk for cholesterol and iron (Fe) content. The results are shown in Table 5.

According to the data presented, there were significant differences in both cholesterol and iron levels. Cholesterol content in egg yolks significantly decreased from P0 to P3. This reduction is attributed to the bioactive compounds in Moringa leaves, such as flavonoids, which inhibit the activity of the HMG-CoA reductase enzyme, and saponins, which suppress lipid metabolism. Crude fiber content in Moringa leaf powder also plays a role in reducing cholesterol. In this study, the crude fiber content in Moringa leaf powder reached 8.59%. Other studies have reported that Moringa leaf powder contains approximately 7%–13% crude fiber. Crude fiber can bind bile acids, which are essential for fat absorption, thereby inhibiting lipid absorption, including cholesterol, and enhancing fat excretion via feces (Teru *et al.* 2017). Flavonoids also improve poultry health by altering fatty acid profiles and reducing cholesterol content (Tan *et al.* 2022). Saponins in Moringa leaf powder inhibit enzymes and act as hypocholesterolemic agents in the intestinal lumen due to their specific chemical structure that is essential for efficient activity (Hierro *et al.* 2018). Fe content in egg yolk increased from P0 to P3, corresponding to the iron-rich supplementation of Moringa leaf powder. The iron content in the powder reached 27.40 mg $100g^{-1}$. Previous studies have reported iron contents ranging from 20.96 mg $100g^{-1}$ to 42.8 mg $100g^{-1}$ (Glover–Amengor *et al.* 2016; Diop *et al.* 2024). Dietary iron is absorbed into the bloodstream and incorporated into the egg yolk along with other nutrients. The increase in Fe levels in the yolk is beneficial, as iron is crucial for hemoglobin synthesis and anemia prevention. Supplementation of *Moringa oleifera* leaf powder has been shown to significantly reduce anemia prevalence in children under two years by 53.6% and improve hemoglobin levels (Shija *et al.* 2019).

Table 4 Average performance of quails fed diets supplemented with moringa leaf powder

Parameters	P0	P1	P2	P3
Feed Intake (g $bird^{-1}$ day^{-1})	22,81±0,05	22,84±0,08	22,88±0,04	22,88±0,05
Eggs Production (%)	61,00±0,01^{a}	65,33±0,02^{b}	69,33±0,01^{c}	67,67±0,02^{bc}
Egg Weight (g egg^{-1})	9,06±0,41	9,03±0,15	8,53±0,25	8,66±0,15
Egg Mass (g)	1641±54,62	1694±43,98	1710±30,61	1717±59,13
Feed Conversion Ratio	3,89±0,12	3,77±0,08	3,74±0,06	3,73±0,12

Description: Superscripts indicate significant differences ($p<0.05$) when values in the same row differ. P0: control, P1: control + 2.5% MLP, P2: control + 5% MLP, P3: control + 7.5% MLP.

Table 5 Egg quality parameters of quails fed diets supplemented with moringa leaf powder'

Parameters	P0	P1	P2	P3
Yolk Cholesterol (mg g^{-1})	29,82±32,36^{a}	21,32±20,17^{b}	18,42±4,75^{bc}	15,90±18,43^{c}
Yolk Iron (mg g^{-1})	8,75±23,43^{a}	15,62±31,63^{ab}	17,87±53,93^{ab}	19,06±75,35^{b}

Description: Superscripts indicate significant differences ($p<0.05$) when values in the same row differ. P0: control, P1: control + 2.5% MLP, P2: control + 5% MLP, P3: control + 7.5% MLP.

CONCLUSION

The supplementation of Moringa leaf powder in the diet effectively reduces oxidative stress, enhances physiological performance, and improves the productivity of laying quails during the production period. A dietary inclusion level of 7.5% Moringa leaf powder yielded optimal results in terms of hematological parameters, stress indicators, feed conversion ratio, and the chemical quality of quail eggs.

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