Veterinary & Life Science Innovations

Veterinary & Life Science Innovations 2026;4(1):13-23

Review Article

Supplementation of *Morinda citrifolia* in Poultry Diets to Improve Performance, Antioxidant Status, and Immunity

Oriza Cahya RAHMADIATI [1]

[1] Faculty of Vocational Studies, Department of Health, Veterinary Paramedic Program, Airlangga University, Surabaya, 60286, Indonesia

(*) Corresponding author:

Oriza Cahya RAHMADIATI

E-mail: orizacahya@gmail.com

Received: 16-03-2026 | Accepted: 19-03-2026 | Published: 21-03-2026

The poultry industry is essential for providing animal protein to meet growing global nutritional demands. However, intensive production systems often expose birds to heat stress, oxidative imbalance, and immune suppression. Therefore, natural feed additives are increasingly explored as alternatives to antibiotic growth promoters. This review examines the potential of *Morinda citrifolia* L. (noni) as a phytogenic feed additive in poultry nutrition. Literature from databases such as Elsevier, ScienceDirect, ResearchGate, and Google Scholar indicates that *M. citrifolia* contains bioactive compounds—including flavonoids, iridoids, phenolics, and polysaccharides—with antioxidant, immunomodulatory, and metabolic regulatory properties. Supplementation in forms such as juice, extract, powder, or leaf meal has been reported to improve growth performance, feed efficiency, egg production, and product quality in poultry. It also enhances antioxidant status by reducing malondialdehyde (MDA) levels and increasing endogenous antioxidant enzymes, while modulating immune responses through cytokine regulation and Toll-like receptor pathways. Overall, *M. citrifolia* shows strong potential as a natural feed additive to support sustainable, antibiotic-free poultry production and improve productivity, product quality, and animal health.

Keywords: *Kaempferia galanga* L., ethyl p-methoxycinnamate, essential oil, poultry

INTRODUCTION

The poultry industry represents a critical component of the global livestock sector due to its essential role in meeting the growing demand for animal-derived protein (Pertiwi *et al*., 2022). In recent decades, poultry production has expanded rapidly, particularly in developing countries, driven by population growth, urbanization, and rising incomes (Hidayat *et al*., 2023). This expansion reflects increasing demand for animal-source foods (ASF), especially in low- and middle-income regions. For instance, recent analyses of ASF consumption among children aged 6–23 months in East African countries reported that approximately 51.07% consumed ASF within a 24-hour period, with considerable variation between countries (ranging from 28.26% in Burundi to 55.81% in Zimbabwe). However, specific ASF components such as fish (18.9%), eggs (11.9%), and milk (15.0%) remain relatively under-consumed among infants and young children (Mussa *et al*., 2024). These findings highlight both the nutritional importance of poultry products and the ongoing need to increase sustainable poultry production in developing regions.

Over the past decade, poultry meat and egg production have shown the highest growth rates among livestock commodities (Taheripour *et al*., 2013). While intensified production systems have improved output efficiency, they have also introduced physiological and environmental challenges. High metabolic activity, combined with the absence of sweat glands in poultry, predisposes birds to thermal stress and metabolic disturbances (Flees *et al*., 2017; Velleman, 2015). Heat stress, in particular, is a major constraint in tropical and subtropical production systems, impairing immune function, increasing oxidative stress, disrupting organ integrity, and in severe cases leading to hyperthermic collapse and mortality (Rajaei-Sharifabadi *et al*., 2017). Consequently, nutritional strategies that enhance physiological resilience and antioxidant defense mechanisms are increasingly recognized as essential components of modern poultry management.

Feed quality remains a primary determinant of poultry performance; however, high-quality commercial diets substantially increase production costs. Therefore, the development of alternative feed additives that are nutritionally valuable, cost-effective, safe, and readily available is urgently needed. Moreover, growing concerns regarding antibiotic residues in animal products and the global movement toward reducing antibiotic growth promoters (AGPs) have intensified efforts to identify natural alternatives (Retnani *et al*., 2014). Residual antibiotics in meat and eggs pose potential health risks to consumers and contribute to antimicrobial resistance.

One promising natural feed additive is *Morinda citrifolia* (Noni), a medicinal plant belonging to the Rubiaceae family (Nascimento Júnior *et al*., 2025). Noni is widely recognized for its diverse bioactive constituents. Its leaves contain substantial levels of crude protein (22.11%), calcium (10.30%), iron (437 ppm), zinc (35.80 ppm), and β-carotene (161 ppm) (Hou *et al*., 2025). In addition, various phytochemicals such as flavonoids, iridoids, and phenolic compounds have been reported to exert antioxidant and immunomodulatory effects. As a natural feed additive, Noni supplementation may contribute to improved physiological status, enhanced immune function, and reduced reliance on synthetic antibiotics in poultry production systems.

Given these attributes, investigating the role of *Morinda citrifolia* in poultry nutrition is warranted to determine its potential in improving productivity, oxidative balance, and immune competence while supporting sustainable and antibiotic-free production systems.

DATA COLLECTION

Data on *Morinda citrifolia* were collected through searches of electronic scientific databases, including Elsevier, ResearchGate, ScienceDirect, and Google Scholar. The search was conducted using the following keywords: broiler, flavonoids, meat quality, *Morinda citrifolia*, and production.

Morinda citrifolia AND ITS BIOACTIVE COMPOUNDS

Morinda citrifolia L. (noni) is a tropical plant that is widely recognized not only as a traditional medicinal plant but also as a crop that has been cultivated for thousands of years by Polynesian communities (Chan-Blanco *et al*., 2006). Currently, it is widely grown and commercially produced across the Pacific region, including Polynesia and Hawaii, where agronomic practices and cultivation techniques continue to be refined to enhance fruit productivity (Kim, 2024).

Traditionally, noni has been used to treat boils, wounds, abscesses, inflammation, fungal infections, constipation, and diarrhea (Potterat and Hamburger, 2007). The fruit can be consumed fresh; however, its strong odor and pungent taste often limit direct consumption (Hidayat *et al*., 2023). Moreover, noni fruit is highly perishable, requiring appropriate processing methods to extend shelf life, improve storage stability, and facilitate distribution (Sinar *et al*., 2013). In traditional preparation, ripe noni fruits are fermented in closed containers, and the liquid is collected through drip extraction. The extract can subsequently be formulated into solid dosage forms, such as capsules, with the addition of non-hygroscopic excipients to prevent clumping (Potterat and Hamburger, 2007).

In terms of nutritional composition, non-fermented noni juice contains approximately 10% dry matter, primarily consisting of glucose and fructose (each about 3–4%), along with small amounts of protein (approximately 0.2–0.5%) and lipids (approximately 0.1–0.2%). Its mineral profile is relatively rich in potassium (30–150 ppm), with lower levels of calcium, sodium, and magnesium (Singh, 2019). Noni juice also exhibits a relatively high Total Phenolic Content (TPC), approximately 91.90 mg gallic acid equivalents per 100 mL, and an antioxidant activity of 5.85 mmol/L, which is higher than that observed in a 5% diluted preparation (Bramorski *et al*., 2010).

Flavonoids represent one of the major groups of bioactive compounds in noni and function as natural antioxidants. Rutin is the predominant flavonoid in noni fruit, with concentrations of approximately 4060 μg/100 g in the peel and 1290 μg/100 g in the pulp (Sinar *et al*., 2013). Rutin is known for its antioxidant, antidiabetic, anticancer, hypoallergenic, anti-inflammatory, and cardioprotective properties. In addition, noni contains scopoletin and epicatechin, which have been reported to exert anti-inflammatory and analgesic effects and to stimulate nitric oxide production (Wan Osman *et al*., 2019). These compounds also contribute to protease-mediated tissue metabolism, reduce cartilage degradation, and support cartilage repair and bone formation (Wan Osman *et al*., 2019).

Other bioactive constituents, including terpenoids, damnacanthal, anthraquinones, coumarins, and scopoletin, further contribute to the biological activities of noni, including its potential role in the prevention of atherosclerosis (Adriani *et al*., 2017). Proxeronine, present in noni, functions as a precursor of xeronine and is believed to participate in the activation of the enzyme xeroninase (Sunder *et al*., 2011). Xeronine itself is an alkaloid reported to modify protein structure and enhance nutrient absorption efficiency in the intestine (Sanni *et al*., 2017).

Other parts of the noni plant also exhibit significant bioactive potential. The roots contain a broad spectrum of anthraquinones, including rubiadin, damnacanthal, and alizarin-1-methyl ether, whereas the leaves are rich in saponins, triterpenoid glycosides, amino acids, phenolic compounds, ursolic acid, and alkaloids (Hou *et al*., 2025). Noni seed extract has been reported to exhibit anti-photoaging activity at concentrations of 0.5–1.0 mg/mL and to inhibit hemagglutination at concentrations ranging from 50 to 500 ng/mL (Matsuda *et al*., 2013). These activities are associated with the presence of ursolic acid. Additionally, noni seeds contain caffeic acid (496 μg/100 g), vanillin (36 μg/100 g), and vanillic acid (21 μg/100 g), with caffeic acid known for its antitumor and antiviral activities (Hernández-Chávez *et al*., 2019).

DIETARY *Morinda citrifolia* ENHANCES POULTRY PRODUCTION PERFORMANCE

Numerous studies have evaluated the effects of *Morinda citrifolia* (noni) supplementation in poultry diets and have consistently demonstrated its potential to enhance production performance. In general, noni functions as a herbal growth promoter capable of improving growth performance, feed efficiency, and overall health status in poultry (Churchil *et al*., 2019).

In broiler chickens, supplementation with noni juice at 15 mL/bird/day has been reported to increase body weight, improve feed conversion ratio (FCR), enhance feed efficiency, and improve immune competence and water intake (Sunder *et al*., 2015). Dietary inclusion of noni at 20% (w/w) also accelerated weight gain in pullets aged 1–5 weeks, enabling birds to reach target body weight earlier than the control group (Sunder *et al*., 2013). Beyond growth enhancement, supplementation with noni powder at 5 g/kg body weight was shown to reduce plasma cholesterol levels. Similar findings were reported with noni fruit extract administered via drinking water at concentrations of 1% and 2%, which significantly reduced broiler blood cholesterol levels from 188.71 mg/dL to 120.89 mg/dL (Sulihantoro, 2019). These findings indicate that noni contributes not only to improved growth performance but also to enhanced metabolic profiles in poultry.

In addition to growth parameters, noni supplementation has been shown to improve poultry product quality. Inclusion of 10% noni leaf tip meal in native chicken diets significantly reduced total saturated fatty acids (SFA) by 5.30% and increased total unsaturated fatty acids (UFA) by 5.30% in meat (Wardiny *et al*., 2020). This modification of fatty acid composition suggests an improvement in the nutritional quality of poultry meat, making it more beneficial for consumers.

In laying hens, noni supplementation has demonstrated positive effects on egg production and egg quality. The vitamin C content of noni plays an important role in the synthesis of the organic eggshell matrix through its involvement in mineral metabolism, particularly zinc (Zn), manganese (Mn), and copper (Cu) (Sunder *et al*., 2013). These minerals act as cofactors for carbonic anhydrase enzymes involved in calcium carbonate precipitation during shell formation. Moreover, copper functions as a cofactor for lysyl oxidase, which is essential for connective tissue synthesis. Therefore, noni supplementation has the potential to enhance egg production as well as eggshell quality and thickness (Flees *et al*., 2017).

The inclusion of noni powder at 4% has been reported to increase egg production, egg quality, and shell thickness (Velleman, 2015). Supplementation of *Morinda citrifolia* at levels of 0.5% and 1.0% in laying hen diets has also been recommended, as it significantly improves shell thickness, egg weight, and yolk color intensity (Más-Toro *et al*., 2015). The enhancement in yolk pigmentation is likely associated with the β-carotene content of noni leaves, which acts as a carotenoid precursor and is deposited in the yolk, thereby increasing yolk color score (Trianto *et al*., 2017). Furthermore, Trianto *et al*. (2017) reported that noni leaf meal did not adversely affect the Haugh unit but significantly improved shell thickness and yolk color intensity.

However, the level of supplementation must be carefully considered. Inclusion of noni at 9% resulted in larger egg weight but reduced hatchability, suggesting that this level may be more suitable for table egg production rather than hatching eggs (Sinar *et al*., 2013). In contrast, supplementation with 15% noni leaf extract was reported to reduce Day-Old Quail (DOQ) mortality, increase hen-day production, and improve hatchability (Retnani *et al*., 2014). These findings indicate that the biological response to noni depends on dosage, preparation form, and poultry species.

The improvement in production performance is likely associated with enhanced digestive function and nutrient absorption efficiency. Suarjana *et al*. (2018) reported that supplementation with noni leaf extract at levels of 2% and 4% increased egg weight through improved nutrient digestibility and intestinal absorption. Secondary metabolites present in noni, such as saponins, tannins, and flavonoids, may also contribute to maintaining internal egg quality by limiting excessive water transfer from albumen to yolk (Abi *et al*., 2021).

Morphologically, supplementation with noni fruit powder at 3 g/kg diet increased villus height and intestinal surface area in hybrid ducks (Kurniawan *et al*., 2016), thereby enhancing nutrient absorption capacity. Furthermore, the combination of noni fruit extract (1.2 g/kg) and *Lactobacillus acidophilus* (12 g/kg) significantly improved crude fat digestibility, increased carcass weight, and reduced abdominal fat percentage in broilers (Setyoko *et al*., 2020). Overall, these findings support the potential of *Morinda citrifolia* supplementation as a natural nutritional strategy to enhance productivity, product quality, and physiological efficiency in poultry.

Tabel 1. Dietary *Morinda citrifolia* supplementation improves poultry production performance

Breed	Concentration	Findings	Reference
Commercial broiler chicks	5–15 mL of *Morinda citrifolia* extract administered via drinking water per bird per day	↑ Body weight; ↑ feed conversion ratio (FCR); ↑ humoral immune response (antibody titer); ↑ immune competency status	(Sunder *et al*., 2015)
Commercial broiler chicks	0.04%, 0.08%, and 0.12% Morinda citrifolia L. extract in the diet	↑ Crude fat digestibility; ↓ abdominal fat percentage; ↑ broiler carcass weight	(Setyoko *et al*., 2020)
Laying hens strain white leghorn (Hybrid L-33)	0.5%, 1.0%, and 1.5% Morinda citrifolia powder at the diet	↑ Egg weight at 1.0% and 1.5% *Morinda citrifolia* supplementation; ↑ shell thickness at 0.5% and 1.0%; ↑ yolk color intensity at all supplementation levels; ↔ laying intensity, feed intake, mass conversion, body weight, Haugh unit, albumen height, yolk height, and eggshell surface area	(Más-Toro *et al*., 2015)
Layer hens strain ISA Brown	2.5%, 5.0%, and 7.5% Morinda citrifolia leaf meal at the diet	↔ Haugh unit (no significant effect); ↑ eggshell thickness; ↑ yolk color score	(Trianto *et al*., 2017)
Commercial laying hens	6 mL of noni (*Morinda citrifolia*) extract administered in solution	↑ Internal egg quality (foam index and Haugh unit); ↑ mean values observed at 6 mL noni fruit extract	(Abi *et al*., 2021)
Sentul chicken	50-350 mg/kg *Morinda citrifolia* extract in diet, along with $CuSO_4$ and ZnO	↑ Feed utilization; ↑ protein digestibility, dry matter digestibility, organic matter digestibility, metabolizable energy, and nitrogen retention	(Azizah, 2020)

Nicobari fowl	1.5 mL *Morinda citrifolia* fruit juice via drinking water per bird per day	↑ Body weight and body weight gain in chickens supplemented with noni juice; ↑ production performance, including improved feed efficiency and earlier age at first egg; ↑ immune response (enhanced T- and B-cell responses and humoral immunity)	(Sunder *et al*., 2011)
Coturnix coturnix japonica	1 mL/L and 2 mL/L commercial noni fruit juice (Apollo Life Noni Juice®) was administered via drinking water	↑ Body weight; ↑ body weight gain; ↑ feed efficiency; ↓ feed intake; ↓ age at first egg; ↔ egg number, egg weight, and egg mass during the early laying period	(Churchil *et al*., 2019)
Coturnix coturnix japonica	9%, 10%, and 11% *Morinda citrifolia* leaf flour in the diet	↑ Egg quality parameters in quail fed noni leaf flour; ↑ Haugh unit; ↑ yolk color score	(Sinar *et al*., 2013)
Coturnix coturnix japonica	5%, 10%, and 15% *Morinda citrifolia* extract at in diet	↓ Mortality of day old quail; ↔ egg production, hen-day egg production, and hatchability	(Retnani *et al*., 2014)

Morinda citrifolia IN POULTRY FEED MODULATES ANTIOXIDANT ACTIVITY

In modern poultry production systems, oxidative stress has become a major physiological challenge due to the imbalance between the generation of reactive oxygen species (ROS) and endogenous antioxidant defense mechanisms (Oke *et al*., 2024). This condition commonly occurs during rapid growth phases, high stocking densities, pathogen exposure, and heat stress in tropical regions, and may lead to lipid, protein, and DNA damage, ultimately impairing performance and product quality (Bahadoran *et al*., 2025).

Supplementation of *Morinda citrifolia* in poultry diets contributes to redox homeostasis through two principal mechanisms: direct free radical scavenging activity and enhancement of endogenous antioxidant systems. Its phenolic and flavonoid compounds act as free radical scavengers by donating electrons or hydrogen atoms to stabilize ROS, while other bioactive constituents are suggested to activate antioxidant gene regulatory pathways such as Nrf2, thereby increasing the activity of antioxidant enzymes including superoxide-dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) (Khan *et al*., 2025). These physiological effects are reflected in increased total antioxidant capacity (T-AOC) and reduced lipid peroxidation biomarkers, particularly malondialdehyde (MDA).

Empirical findings support these mechanisms. The inclusion of noni fruit meal in laying quail diets at levels of 2.5, 5, and 7.5 g/kg feed was reported to linearly decrease MDA concentrations compared to the control group, with the greatest reduction observed at 7.5 g/kg (Adriani *et al*., 2017). The reduction in MDA indicates decreased lipid peroxidation as a marker of oxidative stress, thereby confirming the protective role of noni in maintaining cellular membrane stability. Furthermore, the vitamin C content of noni plays a crucial role in protecting cells against oxidative stress-induced cell death through ROS neutralization and regeneration of other antioxidants within biological systems (Hou *et al*., 2025).

From a productive standpoint, the improvement in antioxidant status mediated by *Morinda citrifolia* not only enhances physiological health in poultry but also improves final product quality. For example, supplementation with 2.5 g/kg *Morinda citrifolia* in the form of leaf shoot meal in indigenous chickens significantly reduced malondialdehyde (MDA) concentrations in muscle tissue, indicating reduced lipid peroxidation and increased levels of healthier unsaturated fatty acids an important indicator of improved poultry meat quality as a functional product (Wardiny *et al*., 2020).

These findings suggest enhanced oxidative stability of poultry meat and a potential extension of shelf life.

In addition, several supporting studies indicate that dietary or drinking water supplementation with *Morinda citrifolia* can optimize egg production performance and certain product quality parameters. For instance, research in laying hens demonstrated increased egg production, higher average egg weight, and improved feed conversion efficiency following supplementation with 0.15 g/kg microencapsulated noni fruit extract in the diet, suggesting that *Morinda citrifolia* contributes to enhanced production performance beyond its antioxidant effects (Krishadi *et al*., 2024).

Taken together, the empirical evidence strengthens the potential of *Morinda citrifolia* as an effective functional feed additive to enhance antioxidant capacity in poultry, improve meat quality and egg production performance, and support resilience against environmental stressors. However, its efficacy depends on dosage, formulation (e.g., shoot meal, extract, or microencapsulated extract), and the specific poultry management context in which it is applied.

EFFECT OF *Morinda citrifolia* AS AN IMMUNE-ENHANCING SUPPLEMENT

Morinda citrifolia (noni) is recognized as more prominent than many other herbal plants due to its potent immunomodulatory activity (Abou Assi *et al*., 2017). Various studies have demonstrated that noni not only acts as an antioxidant but also functions as an active modulator of the immune system. Supplementation of noni at 10 ml/mg in Nicobari fowl has been reported to induce the release of interferons and interleukins (Sunder *et al*., 2016) and to stimulate the production of multiple immune mediators from murine effector cells, including IL-1, IL-10, IL-12, interferons (IFNs), and nitric oxide (NO) (Sunder *et al*., 2015). The elevation of these mediators indicates that noni can activate innate immune responses while also contributing to the regulation of adaptive immunity.

This immunomodulatory activity is closely associated with the bioactive constituents of noni, particularly iridoids and polysaccharides, which are known to stimulate immune responses and support immune system maturation, including during the neonatal phase (Sunder *et al*., 2015). Noni polysaccharides have been reported to act as immunostimulants by activating macrophages and lymphocytes, whereas iridoids play a role in modulating inflammatory pathways and maintaining immune response balance.

At the molecular level, *Morinda citrifolia* supplementation significantly affects the expression of Toll-like receptor (TLR) genes, specifically TLR-2, TLR-3, TLR-4, TLR-5, TLR-15, and TLR-21, which are key components of innate immunity (Sunder *et al*., 2013). TLRs function as pattern recognition receptors (PRRs) that detect pathogen-associated molecular patterns (PAMPs) (Pietrocola *et al*., 2011). This mechanism is believed to be mediated by interactions between noni phytochemicals such as polysaccharides, flavonoids, iridoids, and phenolic compounds and PRRs on immune cell surfaces.

Activation of TLRs triggers intracellular signaling pathways, including NF-κB and MAPK cascades, ultimately enhancing the transcription of pro-inflammatory cytokine and interferon genes (Zhang *et al*., 2014). Consequently, there is an increased production of immune effector molecules, reinforcing the response to bacterial and viral infections. Specifically, the upregulation of TLR-3 and TLR-21 is associated with recognition of viral genetic material such as double-stranded RNA (dsRNA) and CpG DNA, whereas TLR-2, TLR-4, TLR-5, and TLR-15 are involved in detecting bacterial cell wall components, including lipopolysaccharides (LPS), lipoproteins, and flagellin (Tao *et al.*, 2019). Therefore, noni supplementation has the potential to enhance the preparedness and sensitivity of the avian immune system against diverse infectious agents.

Interestingly, noni is not only an immunostimulant but also exhibits broader immunomodulatory potential, being capable of enhancing or suppressing immune responses according to the physiological needs of the body, including through regulation of cytokine production. This capacity suggests that noni can help maintain immune homeostasis, ensuring effective pathogen responses without eliciting excessive inflammatory reactions that could damage tissues.

Tabel 2. *Morinda citrifolia* in poultry diets modulates antioxidant activity and immune-supporting effects

Breed	Concentration	Findings	Reference
Cobb 500	0.2% dried *Morinda citrifolia* in the feed	↑/modulated hepatic lipogenesis-related gene expression (time- and gene-specific effects, e.g., ↑ ACCα pre-HS); modulation of hepatic heat shock protein expression, indicating involvement in stress response regulation.	(Flees *et al.*, 2017)
Broiler chickens	0.2% *Morinda citrifolia* powder in the feed	↓ hypothalamic HSP90 and its transcription factors (HSF1, HSF2, HSF4); ↑ orexin mRNA expression; ↓ phosphorylation of AMPKα1/2 and mTOR	(Rajaei-Sharifabadi *et al.*, 2017)
Coturnix coturnix japonica	5%, 10%, and 15% *Morinda citrifolia* leaf extract in diet	↓ DOQ mortality;↑ Antibacterial activity against *Salmonella typhimurium*	(Retnani *et al.*, 2014)
Kampong chicken	0.5%, 1%, 1.5%, 2%, and 2.5% *Morinda citrifolia* leaf shoot meal in diet	↓ malondialdehyde (MDA) and saturated fatty acids (SFA); ↑ unsaturated fatty acids (UFA)	(Wardiny *et al.*, 2020)

CONCLUSION

The present review highlights the substantial potential of *Morinda citrifolia* as a functional phytogenic feed additive in poultry nutrition. The plant contains diverse bioactive compounds, including flavonoids, iridoids, phenolics, and polysaccharides, which contribute to multiple physiological benefits in poultry. Dietary supplementation with *M. citrifolia* has been shown to improve growth performance, feed utilization efficiency, egg production, and product quality in both broilers and laying hens. In addition, its strong antioxidant properties help mitigate oxidative stress by reducing lipid peroxidation and enhancing endogenous antioxidant defense systems. Beyond its antioxidant capacity, *M. citrifolia* also exhibits notable immunomodulatory effects by stimulating cytokine production, activating immune cells, and regulating Toll-like receptor signaling pathways involved in pathogen recognition. These mechanisms contribute to improved immune competence and increased resilience against environmental and infectious stressors. Overall, the integration of *Morinda citrifolia* into poultry diets offers a promising natural strategy to enhance productivity, improve product quality, and support sustainable antibiotic-free poultry production systems. Nevertheless, further studies are required to determine optimal inclusion levels, evaluate long-term safety, and clarify the molecular mechanisms underlying its biological effects in different poultry species and production conditions.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

ACKNOWLEDGMENTS

This study was supported by the Faculty of Vocational Studies, Airlangga University.

REFERENCES

1. Abi N, Lisnahan CV, Purwatiningsih TI. Effect of noni fruit extract on the internal quality, foam index, and haugh unit of the chicken eggs. J Trop Anim Sci Technol. 2021;3. doi:10.32938/jtast.v3i1.837
2. Abou Assi R, Darwis Y, Abdulbaqi IM, khan AA, Vuanghao L, Laghari MH. Morinda citrifolia (Noni): A comprehensive review on its industrial uses, pharmacological activities, and clinical trials. Arab J Chem. 2017;10. doi:10.1016/j.arabjc.2015.06.018
3. Adriani L, Indrayati N, Rusmana D, Hernawan E, Rochana A. Effect of noni (Morinda citrifolia) fruit flour on antioxidant status and hematological indices of laying Japanese quail. Int J Poult Sci. 2017;16. doi:10.3923/ijps.2017.93.97
4. Azizah TRN. Peningkatan pemanfaatan ransum pada ayam sentul yang diberi ekstrak buah mengkudu (*Morinda citrifolia*) dengan suplementasi tembaga dan seng. J Nutr Ternak Trop Ilmu Pakan. 2020;2. doi:10.24198/jnttip.v2i1.26667
5. Bahadoran S, Hashemi S, Hassanpour H. Heat stress and stocking density disrupt telomere maintenance through shelterin complex dysregulation and oxidative damage in broiler chickens. BMC Vet Res. 2025;21:710. doi:10.1186/s12917-025-05151-7
6. Bramorski A, Cherem AR, Marmentini CP, Torresani J, Mezadri T, Costa AAS. Total polyphenol content and antioxidant activity of commercial Noni (*Morinda citrifolia* L.) juice and its components. Braz J Pharm Sci. 2010;46. doi:10.1590/s1984-82502010000400006
7. Chan-Blanco Y, Vaillant F, Mercedes Perez A, Reynes M, Brillouet JM, Brat P. The noni fruit (*Morinda citrifolia* L.): A review of agricultural research, nutritional and therapeutic properties. J Food Compos Anal. 2006;19:645–654. doi:10.1016/j.jfca.2005.10.001
8. Churchil RR, Omprakash AV, Kanagaraju P, Daffine S, Pandian C. Effect of noni (*Morinda citrifolia*) fruit juice on production performance of layer type japanese quails. Indian Vet J. 2019;96.
9. Flees J, Rajaei-Sharifabadi H, Greene E, Beer L, Hargis BM, Ellestad L, Porter T, Donoghue A, Bottje WG, Dridi S. Effect of *Morinda citrifolia* (Noni)-enriched diet on Hepatic Heat Shock protein and lipid metabolism-related genes in heat stressed broiler chickens. Front Physiol. 2017;8. doi:10.3389/fphys.2017.00919
10. Hernández-Chávez G, Martinez A, Gosset G. Metabolic engineering strategies for caffeic acid production in *Escherichia coli*. Electron J Biotechnol. 2019;38. doi:10.1016/j.ejbt.2018.12.004
11. Hidayat DF, Mahendra MYN, Kamaludeen J, Pertiwi H. Lycopene in feed as antioxidant and immuno-modulator improves broiler chicken's performance under heat-stress conditions. Vet Med Int. 2023. doi:10.1155/2023/5418081
12. Hou S, Ma D, Wu S, Hui Q, Hao Z. *Morinda citrifolia* L.: A comprehensive review on phytochemistry, pharmacological effects, and antioxidant potential. Antioxidants. 2025;14. doi:10.3390/antiox14030295
13. Khan IM, Gul H, Khan S, Nassar N, Khalid A, Swelum AA, Wang Z. Green tea polyphenol epigallocatechin-3-gallate mediates an antioxidant response via Nrf2 pathway in heat-stressed poultry: A review. Poult Sci. 2025;104:105071. doi:10.1016/j.psj.2025.105071
14. Kim J. Cultivation and agronomic management of *Morinda citrifolia* in Pacific regions. J Trop Crop Sci. 2024;11:95–104.
15. Krishadi MD, Widjastuti T, Tanwiriah W. The effect of adding microencapsulation noni fruit extract (*Morinda citrifolia* Linn.) product as a feed additive on the sentul laying hens performance. J Ilmu Ternak. 2024;24:163–171. doi:10.24198/jit.v24i2.54254
16. Kurniawan D, Widodo E, Djunaidi I. Effect of noni fruit (*Morinda citrifolia*) powder as feed additive on intestinal microflora and vili characteristics of hybrid duck. Bull Peternak. 2016;40:33–33. doi:10.21059/buletinpeternak.v40i1.8677

17. Más-Toro D, Martínez-Aguilar Y, Rodríguez-Bertot R, Betancur-Hurtado C, Rosabal-Nava O. Effect of dietary supplementation with *Morinda citrifolia* on productivity and egg quality of laying hens. Cienc Agric. 2015;12. doi:10.19053/01228420.4348
18. Matsuda H, Masuda M, Murata K, Abe Y, Uway A. Study of the anti-photoaging effect of noni (*Morinda citrifolia*). Melanoma - From Early Detection to Treatment. 2013;doi:10.5772/53621
19. Mussa I, Gamachu M, Regassa LD, Birhanu A, Mohammed F, Weyessa AD, Eyeberu A, Debela A, Zakaria HF. Maternal socio-economic status determines animal source food consumption of children aged 6–23 months in East African countries: a multilevel mixed-effects generalized linear model. Front Nutr. 2024;11:1336568. doi:10.3389/fnut.2024.1336568
20. Nascimento Júnior JAC, Santos AM, Oliveira AMS, Santana Júnior CC, Serafini MR, Quintans JSS, Picot L, de Menezes IRA, Quintans-Júnior LJ. Botany, ethnomedicinal uses, biological activities, phytochemistry, and technological applications of *Morinda citrifolia* plants. Molecules. 2025;30. doi:10.3390/molecules30183831
21. Oke OE, Akosile OA, Oni AI, Opowoye IO, Ishola CA, Adebiyi JO, Odeyemi AJ, Adjei-Mensah B, Uyanga VA, Abioja MO. Oxidative stress in poultry production. Poult Sci. 2024;103:104003. doi:10.1016/j.psj.2024.104003
22. Pertiwi H, Nur Mahendra MY, Kamaludeen J. Astaxanthin as a potential antioxidant to improve health and production performance of broiler chicken. Vet Med Int. 2022. doi:10.1155/2022/4919442
23. Pietrocola G, Arciola CR, Rindi S, Di Poto A, Missineo A, Montanaro L, Speziale P. Toll-like receptors (TLRs) in innate immune defense against *Staphylococcus Aureus*. Int J Artif Organs. 2011;34:799–810. doi:10.5301/ijao.5000030
24. Potterat O, Hamburger M. *Morinda citrifolia* (noni) fruit-phytochemistry, pharmacology, safety. Planta Med. 2007;73. doi:10.1055/s-2007-967115
25. Rajaei-Sharifabadi H, Ellestad L, Porter T, Donoghue A, Bottje WG, Dridi S. Noni (*Morinda citrifolia*) modulates the hypothalamic expression of stress- and metabolic-related genes in broilers exposed to acute heat stress. Front Genet. 2017;8. doi:10.3389/fgene.2017.00192
26. Retnani Y, Wardiny Dan TM, Taryati. *Morinda citrifolia* L. leaf extract as antibacterial Salmonella typhimurium to increase productivity of quail (*Coturnix coturnix japonica*). Pak J Biol Sci. 2014;17. doi:10.3923/pjbs.2014.560.564
27. Sanni DM, Fatoki TH, Kolawole AO, Akinmoladun AC. Xeronine structure and function: computational comparative mastery of its mystery. Silico Pharmacol. 2017;5:8. doi:10.1007/s40203-017-0028-y
28. Setyoko H, Sukamto B, Wahyono F, Krismiyanto L. Kecernaan lemak kasar dan bobot karkas ayam broiler akibat penambahan ekstrak buah mengkudu (*Morinda citrifolia* L.) dan *Lactobacillus acidophilus*. SEMNAS-IPT. 2020. doi:10.25047/proc.anim.sci.2020.19
29. Sinar T, Wardiny T, Taryati D. Effect of noni leaf flour on eggs productivity of quail. Int J Agric Food Sci Technol. 2013;4:601–606.
30. Singh DR. *Morinda citrifolia* L. (noni): A review of the scientific validation for its nutritional and therapeutic properties. Afr J Med Case Rep. 2019;7:1–15.
31. Suarjana IP, Siti NW, Bidura IGNG. Pengaruh pemberian ekstrak air daun mengkudu (*Morinda citrifolia*) melalui air minum terhadap kulitas fisik telur ayam lohmann brown umur 22-30 minggu. J Peternak Trop. 2018:129–139.
32. Sulihantoro. 2019. Pengaruh ekstrak buah mengkudu (*Morinda citrifolia*) melalui air minum terhadap status hematologis dan kolesterol darah ayam broiler. Universitas Gadjah Mada, Yogyakarta.
33. Sunder J, Jeyakumar S, Sujatha T, Kundu A. Grommune: *Morinda citrifolia*-based herbal tonic for growth and immunity for commercial broilers. J Appl Anim Res. 2015;43. doi:10.1080/09712119.2014.928628
34. Sunder J, Jeyakumar S, Sujatha T, Kundu A. Effect of feeding of Morical; a herbal based supplement on production and egg quality in japanese quail. Adv Anim Vet Sci. 2013;1.
35. Sunder J, Kundu A, Singh DR, Jeyakumar S, Srivastava RC. Effect of feeding of *Morinda citrifolia* fruit juice on growth, production and immunity of Nicobari fowl. Indian J Anim Sci. 2011;81.
36. Sunder J, Sujatha T, Kundu A. Effect of *Morinda citrifolia* in growth, production and immunomodulatory properties in livestock and poultry: a review. J Exp Biol Agric Sci. 2016;4:249–265. doi:10.18006/2016.4(3S).249.265
37. Taheripour F, Hurt C, Tyner WE. Livestock industry in transition: Economic, demographic,

and biofuel drivers. Anim Front. 2013;3:38–46. doi:10.2527/af.2013-0013

38. Tao M, Zhou H, Luo K, Lu J, Zhang Y, Wang F. Quantitative serum proteomics analyses reveal shrimp responses against WSSV infection. Dev Comp Immunol. 2019;93:89–92. doi:10.1016/j.dci.2019.01.003
39. Trianto Y, Hintono A, Mahfudz LD. Effect of noni leaf meal in the diet on chicken eggs physical quality. J Pengemb Penyul Pertan. 2017;14. doi:10.36626/jppp.v14i25.47
40. Velleman SG. Relationship of skeletal muscle development and growth to breast muscle myopathies: a review. Avian Dis. 2015;59. doi:10.1637/11223-063015-Review.1
41. Wan Osman WNF, Che Ahmad Tantowi NA, Lau SF, Mohamed S. Epicatechin and scopoletin rich *Morinda citrifolia* (Noni) leaf extract supplementation, mitigated Osteoarthritis via anti-inflammatory, anti-oxidative, and anti-protease pathways. J Food Biochem. 2019;43. doi:10.1111/jfbc.12755
42. Wardiny TM, Sumiati Retnani Y, Setiyono A. Production of functional kampong chicken meat with low cholesterol, high antioxidant, and unsaturated fatty acids fed noni (*Morinda citrifolia*) leaf shoot meal. Trop Anim Sci J. 2020;43. doi:10.5398/tasj.2020.43.1.35
43. Zhang LY, Lv S, Wu SC, Guo X, Xia F, Hu XR, Song Z, Zhang C, Qin QQ, Fu BD, Yi PF, Shen HQ, Wei XB. Inhibitory effects of α-cyperone on adherence and invasion of avian pathogenic Escherichia coli O78 to chicken type II pneumocytes. Vet Immunol Immunopathol. 2014;159:50–57. doi:10.1016/j.vetimm.2014.02.005