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Moringa oleifera Leaf Meal: A Sustainable Approach for Poultry Production: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Poultry production is among the fastest ways to address the shortage of animal protein supply and intake in many nations. With the prohibition of antibiotics as growth promoters in the poultry industry due to rising bacterial resistance and growing public concern over health and food safety, the sector has been prompted to seek safe alternatives. This shift has led to a focus on finding natural antibiotic substitutes and optimizing feed management to enhance chicken health and growth. Consequently, phytogenics have emerged as promising natural alternatives to antibiotics in the poultry sector. *Moringa oleifera* has attracted significant research interest recently as a natural supplement with numerous health advantages for poultry. Known for its antimicrobial, antioxidant, anti-inflammatory, and cholesterol-lowering properties, Moringa also aids in activating digestive

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enzymes in the stomach due to its wealth of bioactive compounds. This review emphasizes the potential impact of *Moringa oleifera* as a natural feed additive on growth performance, nutrient digestibility, blood biochemical profile, antioxidant effects, immune response, and egg production in poultry.

Keywords: Body weight; egg production; growth performance; immunity; Moringa oleifera leaf meal, nutrient utilization

1. INTRODUCTION

Poultry production is one of the quickest methods to address the deficiency of animal protein supply and consumption in various countries. Energy and protein sources make up 95% of the total feed costs in poultry farming. Plant-based protein feedstuffs play a crucial role in meeting dietary protein needs in many practical poultry rations formulated globally. Rations that include soybean meal and groundnut meal are generally preferred over other protein sources. However, with the rising population and increasing demand, there is a looming shortage of key feed ingredients like maize and soybean (Thirumalaisamy et al., 2016). Moringa leaves, which contain a high crude protein content (24-29%), can be used as a feed supplement for poultry (Su and Chen, 2020). They offer several benefits, including promoting growth, and possessing antibacterial, antifungal, antioxidant, and anti-inflammatory properties (Mahanta et al., 2017).

Moringa oleifera, often referred to as the "Miracle tree," is rich in essential nutritional bioactive compounds that are vital for both livestock and human health (Anjorin et al., 2010). The Moringa genus includes 13 species globally, with two found in India: *Moringa concanensis* Nimmo ex Dalz. and *Moringa oleifera* Lam. *Moringa oleifera* Lam. is recognized in over 80 countries, including India, and is known by more than 200 local names due to its diverse applications (Bhargave et al., 2015).

Synonyms for *Moringa oleifera* include various names in different languages. In Hindi, it is known as Sajana, Lingru, Shajna, Saina, Mungaera, Shaijmal, Segra, and Sahjan. In Punjabi, it is referred to as Sanjina, Soanjana, and Sejana. In Rajasthan, it is called Lal Sahinjano and Lingru. In Sindhi, it is known as Swanjera. In English, common names include Horseradish Tree, Ben Tree, Drumstick Tree, Miracle Tree, Mother's Best Friend, and Gold of the Poor. In Bengali, it is called Sajna or Sajina, in Gujarati as Saragavo, and in Pakistan as Sohangna (Fahey, 2005).

2. *Moringa oleifera* TREE

Moringa oleifera is a rapidly growing, drought-resistant tree that belongs to the Moringaceae family and is widely cultivated in tropical and subtropical regions across the globe. It thrives in areas such as India, Africa, Arabia, the Caribbean Islands, South and Central America, Mexico, Hawaii, and throughout Southeast Asia, typically reaching heights of 1.5 to 2.0 meters (Foidl et al., 2001). This species produces a significant amount of biomass, ranging from 43 to 115 tons per hectare annually (Kholif et al., 2016). In terms of leaf production, each tree yields about 1 to 5 kilograms of fresh leaves each year, which translates to an impressive 10,000 to 50,000 kilograms per hectare at a spacing of 1 meter by 1 meter (Sánchez et al., 2006).

Moringa oleifera offers numerous benefits, as various parts of the tree—including leaves, fruits, immature pods, and flowers—are edible and commonly included in traditional diets in many tropical and subtropical countries (Anhwange et al., 2004). Three notable non-governmental organizations—"Trees for Life" (2005), "Church World Service," and "Educational Concerns for Hunger Organization" (2004)—have promoted *Moringa oleifera* as a source of "Natural nutrition for the tropics." The leaves of *Moringa oleifera* are particularly nutrient-rich, making the plant a valuable potential food supplement and protein source (Mendieta Araica et al., 2011). Additionally, the leaves are high in zeatin, a cytokinin, along with other growth-promoting compounds such as ascorbates, phenolics, and essential minerals like calcium, potassium, and iron, which enhance crop growth (Anjorin et al., 2010).

3. *Moringa oleifera* AS A TRADITIONAL MEDICINE

Ayurveda, a traditional system of medicine, suggests that Moringa can help prevent over 300 diseases in humans (Ganguly et al., 2013). Additionally, Moringa oil holds significant cosmetic value and is utilized in body and hair care products as a moisturizer and skin conditioner. Its use in skin treatments and ointments dates back to ancient Egyptian times (Fugile, 2001).

4. *Moringa oleifera* LEAF AS A THERAPEUTIC USE

Moringa oleifera leaves contain various phytochemicals, including sterols, tannins, terpenoids, saponins, alkaloids, phenolics, and flavonoids such as isoquercetin, isothiocyanates, quercetin, and kaempferitrin, as well as glycoside compounds (Jung, 2014). Extracts from both mature and young leaves exhibit strong antioxidant properties, effectively combating free radicals and preventing oxidative damage to key biomolecules, thus offering significant protection against oxidative stress (Patel, 2011). Additionally, Moringa leaves have demonstrated sympatholytic and antiviral effects against herpes simplex virus type-1, as well as the ability to lower cholesterol levels, antibacterial properties (Talreja, 2010), antifungal effects (Nickon et al*.,* 2003), hepatoprotective benefits (Pari and Kumar, 2002), and growth promotion alongside antimicrobial effects (Mbikay, 2012).

5. NUTRITIONAL ROLE OF *Moringa oleifera* LEAF

One of the most remarkable aspects of *Moringa oleifera* leaves is their rich nutrient profile, which includes vitamins (such as β-carotene, vitamins A, D, E, B-complex, and C), minerals (including calcium, chromium, copper, magnesium, manganese, phosphorus, selenium, and zinc), and amino acids (Nkukwana et al*.,* 2015). The nutritional composition of Moringa leaves can vary depending on the region (Anjorin et al*.,* 2010).

Dry Moringa leaves are particularly nutrient-dense, containing seven times more vitamin C than oranges, ten times more vitamin A than carrots, seventeen times more calcium than milk, fifteen times more potassium than bananas, twenty-five times more iron than spinach, and nine times more protein than yogurt (Fuglie, 1999; Dhakar et al*.,* 2011). The protein content in *Moringa oleifera* leaves ranges from 20% to 33% on a dry matter basis and includes all essential amino acids. Amaglo et al. (2010) reported that dry Moringa leaves contain 34.80% ether extract, 31.65% protein, 7.54% fiber, 8.9% moisture, and 6.53% ash based on dry matter. Additionally, Kakengi et al. (2005) found that Moringa leaf meal has a crude protein content of 29.71%, 22.5% crude fiber, 4.38% ether extract, 27.9% calcium, and a minimal tannin content of 1.23 g/kg.

6. INCORPORATION OF *Moringa oleifera* LEAF MEAL IN POULTRY FOR SUSTAINABLE PRODUCTION

6.1 Effect on Growth and Production Performance

Ashong and Brown (2011) found that chicks fed a diet containing 10% Moringa leaf meal exhibited reduced feed intake and weight gain. In contrast, Olugbemi et al. (2010) reported that adding 5% *Moringa oleifera* leaf meal to cassava-based diets (20% and 30%) for broilers had no significant effect (P > 0.05) on feed conversion ratio (FCR), body weight gain, feed consumption, or the economics of production compared to diets without cassava or Moringa. This lack of effect was attributed to the increased fiber content, which may have hindered nutrient digestibility and absorption. Similarly, Ayssiwede et al. (2011) observed that including *Moringa oleifera* leaf meal (MOLM) at levels of 0%, 8.0%, 16.0%, and 24.0% in the diets of growing indigenous Senegal chickens did not adversely affect live body weight, average daily weight gain, FCR, or mortality rates, even at 24% MOLM. However, a significant decreased in feed intake was noted at 16.0% and 24.0% MOLM, while birds fed 8.0% and 16.0% MOLM showed better growth performance, lower feed costs, and improved economic margins. Hassan et al. (2016) found that broiler chicks supplemented with 0.3% MOLM had the highest body weight gain and FCR, while Elkloub et al. (2015) reported that Japanese quail chicks receiving 0.2% MOLM had the lowest feed consumption (P ≤ 0.01), the best feed conversion ratio, and a higher European Production Efficiency Index (EPEI) compared to the control group. Khalifa et al. (2018) showed that birds on a diet with 5% *Moringa oleifera* meal gained significantly more weight than those on the control diet, while the group with 20% Moringa had the lowest feed consumption (P ≤ 0.01) and the best feed conversion ratio. Fouad and Raye (2019) demonstrated that birds fed 7g MOL/kg of diet experienced significantly higher (P < 0.05) body weight gain and feed intake, along with improved FCR compared to other dietary treatments. Talukdar et al. (2020) found that adding *Moringa oleifera* leaf meal at levels of 0.25% to 0.50% to Japanese quail diets improved body weight,

weight gain, FCR, and increased gross profit. Baloch et al. (2021) reported that 2.5% *Moringa oleifera* leaf meal supplementation led to maximum body weight and feed intake in chickens compared to other groups. The control group had the lowest feed intake, while the 2.5% Moringa group showed significantly better FCR (P < 0.05). Furthermore, Varalakshmi et al. (2021) revealed significant increases (P < 0.01) in body weight gain, overall feed intake, and improved FCR with 3.0% *Moringa oleifera* leaf meal incorporated into the diet compared to other treatment groups of Japanese quail.

6.2 Effect on Nutrient Utilization

Tijani et al. (2016) found that feeding a diet with 15% Moringa leaf meal resulted in significantly higher (P < 0.05) digestibility values for crude protein (CP) and ether extract. In contrast, the lowest CP digestibility was observed in broiler chickens consuming a diet containing 20% Moringa leaf meal. This decline in digestibility is likely due to the high proportion of Moringa in the diet, which may lead to an increased concentration of anti-nutritional factors. Furthermore, Fouad and Raye (2019) reported that Japanese quail receiving 7g of *Moringa oleifera* leaf meal per kilogram of diet exhibited the best nutrient digestibility (dry matter, crude protein, crude fiber, ether extract, and nitrogen-free extract) compared to other dietary treatments. Similarly, Siti et al. (2019) found that incorporating Moringa leaf powder at levels of 4-6% in the diets of laying hens enhanced dry matter and organic matter digestibility. Harshini et al. (2022) noted that adding *Moringa oleifera* leaf powder (at 0%, 5%, 10%, and 15%) to the basal diet of Kadaknath chickens did not result in significant (P > 0.05) differences in apparent nutrient digestibility, and the reduced feed intake in the supplemented groups did not negatively impact their nutrient retention.

6.3 Effect on Haemato-Biochemical Constituent

The effect of *Moringa oleifera* leaf meal on various hematological and biochemical parameters in poultry has been extensively studied. Ebenebe et al. (2013) reported a significant (P>0.05) increased in packed cell volume and hemoglobin levels in broiler chickens fed with a 10% Moringa leaf diet. Similarly, Divya et al. (2014) found that a 1.5% Moringa leaf powder supplement had a hypocholesterolemic effect in broiler chicks. Makanjuola et al. *(*2014) observed no significant changes in serum protein, albumin, globulin, or aspartate aminotransferase levels with the inclusion of 0.2%, 0.4%, and 0.6% MOLM in laying bird diets. Elkloub et al. (2015) reported decreases in plasma cholesterol, aspartate aminotransferase, and alanine transaminase in Japanese quail fed 0.2%, 0.4%, and 0.6% MOLM, with increases in total protein and globulin levels at 0.6% and 0.4% inclusion rates, respectively, compared to controls. Further, Hassan et al. (2016) found that 0.2% and 0.3% MOLM supplementation in broilers significantly (P<0.05) increased hemoglobin concentration. Abbas et al. (2018) demonstrated that 0.25% to 1.0% MOLM inclusion significantly boosted red blood cell counts in broilers, though other metrics like packed cell volume, white blood cell count, and lymphocyte levels showed no significant differences among groups. Hemoglobin was significantly enhanced at 0.75% and 1.0% MOLM inclusion, while albumin-to-globulin ratios were highest at 0.25% and 0.5% MOLM. MOLM supplementation also led to significant reductions in serum cholesterol, low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) levels compared to controls. Fouad and Rayes (2019) observed increases in red blood cells, hemoglobin, packed cell volume, white blood cells, total protein, albumin, calcium, and high-density lipoprotein (HDL) in Japanese quail fed with 3g, 5g, and 7g of MOLM per kg of feed, while plasma cholesterol, total lipids, aspartate aminotransferase, alanine transaminase, and glucose levels were decreased. Similarly, Ajantha et al. (2020) reported that MOLM-treated broilers exhibited lower serum cholesterol and triglycerides but had significantly higher (P<0.01) high density lipoprotein levels than the control. Sharmin et al. (2021) observed that a 1.5% MOLM dietary inclusion significantly reduced serum cholesterol and triglyceride levels in laying birds. Similarly, Garcia et al. (2021) found increased serum alkaline phosphatase at 4% MOLM in Japanese quail diets, with lower cholesterol and triglycerides at 6% MOLM. Meel et al. (2022) noted significantly higher hemoglobin, packed cell volume, total erythrocyte count, and lymphocyte levels in broilers fed a 1.5% MOLM diet, alongside reduced heterophil counts, heterophil-to-lymphocyte ratios, albumin, globulin, total protein, blood glucose, triglycerides, and creatinine compared to controls.

6.4 Effect on Carcass Characteristics and Quality

Zanu et al. (2012) observed that the inclusion of *Moringa oleifera* leaf meal (0, 5, 10, and 15%) in broiler diets had no significant impact (P>0.05) on carcass traits. In contrast, Tesfaye et al. (2013) reported that adding *Moringa oleifera* leaf meal at 0, 5, 10, 15, and 20% significantly reduced (P<0.05) parameters such as dressed weight, eviscerated weight, breast, thighs, and drumstick weights in broilers. Safa and Tazi (2014) found that supplementing broiler diets with 5% *Moringa oleifera* leaf meal improved carcass yield percentage compared to controls. Similarly, Elkloub et al. (2015) indicated that *Moringa oleifera* leaf meal at 0.2, 0.4, or 0.6% significantly reduced abdominal fat in Japanese quail and improved spleen proportion without notable differences from the control group. Karthivashan et al. (2015) found that adding Moringa leaf meal extracts at 0, 0.5, 1.0, and 1.5% significantly enhanced (P<0.05) dressing percentage in broilers, with 1.0% showing the highest dressing rate. Tijani et al. (2016) showed that up to 15% *Moringa oleifera* leaf meal in broiler diets significantly improved (P<0.05) dressing percentage, though 10% and 20% levels reduced breast, wing, and abdominal fat. Khalifa et al. (2018) showed that 20% MOLM increased heart and liver weights (P<0.05), though there were no significant differences in weights of the gizzard, carcass, and edible parts among other treated Japanese quails. Additionally, Fouad and Rayes (2019) found Japanese quails fed 7g MOL/kg diet had the highest carcass weight among treatments. Ajantha et al. (2020) reported that MOLM-supplemented groups showed a significant (P<0.01) decrease in cholesterol in thigh and breast muscle compared to controls. Baloch et al. (2021) observed that diets with 1.25%, 2.5%, and 3.75% MOLM had a significant (P<0.05) effect on broiler dressing percentage compared to controls. Furthermore, Varalakshmi et al. (2021) indicated that a 3.0% *Moringa oleifera* leaf meal level increased carcass and ready-to-cook yield (P<0.05). Harshini et al. (2022) reported that adding 0, 5, 10, and 15% *Moringa oleifera* leaf powder to the basal diet increased crude protein and decreased crude fat in meat, though the difference was not significant (P>0.05) from the control group. Meat oxidative stability, however, significantly improved (P<0.05) with higher inclusion levels in Kadaknath chicken diets.

6.5 Effect ON Oxidative Stress Markers in Serum and Meat

Cowan (1999) reported that caffeic and cinnamic acids in *Moringa oleifera* contribute to its antioxidant properties. Saini et al. (2014) also highlighted that *Moringa oleifera* is rich in antioxidants, such as ascorbic acid and tocopherol, which support birds in managing stress. According to Rao et al. (2019), *Moringa oleifera* reduces lipid peroxidation, thereby lowering stress levels in birds. Similarly, Elkloub et al. (2015) found that total antioxidant capacity in plasma was highest in Japanese quail fed 0.6% MOLM, followed by 0.4% and 0.2%, compared to the control. Mousa et al. (2016) also found that plasma antioxidant capacity was significantly higher at 0.6% and 0.4% MOLM in Japanese quail during the laying period. Cui et al. (2018) observed a gradual increase in total antioxidant capacity, superoxide dismutase, and glutathione peroxidase activities in plasma, with a quadratic decrease in MDA levels in broiler breast muscle with MOL supplementation. Additionally, Khan et al. (2021) reported that broilers showed significantly lower stress levels with *Moringa oleifera* leaf extract supplementation compared to an antibiotic group, indicated by reduced blood MDA concentrations during the finisher phase.

6.6 Effect on Immune Status in Serum

Chollom et al. (2012) demonstrated that *Moringa oleifera* seed extract showed strong antiviral effects against Newcastle disease (ND) in ovo. Eze et al. (2013) also found that a methanolic extract of *Moringa oleifera* at 200 mg/kg body weight increased ND HI titers in both vaccinated and non-vaccinated chicken groups, recommending it as an immune booster for non-vaccinated birds. Likewise, Liaqat et al. (2016) suggested that replacing canola meal with *Moringa oleifera* leaf meal as a plant protein source could enhanced immune response to Newcastle disease and Infectious bursal disease vaccinations, with no effect on growth, organ weights, or blood hematology in broilers. Ramadan (2017) further observed that adding 3%, 5%, and 8% *Moringa oleifera* leaf meal to bird feed significantly increased (P < 0.05) antibody titers against ND compared to unsupplemented birds. Similarly, Khan et al. (2021) reported a significant (P< 0.05) rise in antibody titers against ND and Infectious bronchitis (IB) when *Moringa oleifera* was added to drinking water at 60, 90, and 120 ml/litre.

Kumar et al. (2021) noted that *Moringa oleifera* leaf extract combined with various levels of ascorbic acid improved antibody titers in response to ND vaccinations, strengthening immune resistance in broilers. Additionally, Kumari et al. (2022) found that supplementing Moringa leaf extract in drinking water significantly (P< 0.05) raised antibody titers in the treated group compared to the control group.

6.7 Effect on Egg Production and Egg Quality

Kwari et al. (2011) observed that including *Moringa oleifera* leaf meal at 1–2% in Vanaraja laying hen diets had no significant effects on feed conversion or egg weight. Similarly, Ebenebe et al. (2013) reported that adding MOL had no effect on egg shape index, which relates to eggshell strength and egg grading. Etalem et al. (2014) found that the hatchability rate was significantly higher in groups supplemented with 5% *Moringa oleifera* leaf meal than in the control group. Additionally, Makanjuola et al. (2014) found that *Moringa oleifera* seed meal at 5% and 7.5% levels was effective in enhancing eggshell thickness in laying hens. Alebachew (2016) noted that *Moringa oleifera* leaves, rich in zinc and vitamin E, could enhance hatchability and improve egg quality through antioxidants, essential oils, minerals (Ca, Mg, K, Se, P, Zn), and vitamins (A, C, D, K, and E). Riry et al. (2016) also observed a reduction in feed intake when Japanese quails were fed a 5% *Moringa oleifera* seed meal diet compared to controls. Mousa et al. (2017) found that supplementing Japanese quails' diets with 0.4% MOLM improved hatchability of all eggs, while 0.6% MOLM improved hatchability of fertile eggs. Further, Abdelnour et al. (2018) suggested that up to 10% Moringa leaves had no negative impact on egg production in laying birds; however, levels over 10% could be detrimental due to anti-nutritional factors, leaf dustiness, and reduced energy and protein digestibility. Tesfaye et al. (2018) highlighted that 5% *Moringa oleifera* leaf meal could serve as a feed additive, enhancing product quality in the poultry sector. Akinola and Ovotu (2018) found that high-density lipoprotein (HDL) in eggs increased significantly (P<0.05) with 1% and 1.5% MOLM, positively affecting egg cholesterol levels by week one. Siti et al. (2019) observed that diets containing 2-6% Moringa leaf powder enhanced yolk color in laying birds (P<0.05). Similarly, Ashour et al. (2020) reported that *Moringa oleifera* leaf diets did not affect feed conversion ratio, egg weight, fertility, hatchability, egg and yolk index, or Haugh units, although egg production, mass, shell thickness, and hatchability improved with *Moringa oleifera* seed meal supplementation. Moreover, Atuahene et al. (2020) found no adverse effects on egg quality, fertility, or hatchability of quail eggs when soybean meal was partially replaced by *Moringa oleifera* leaf meal up to 15%, though yolk color was enhanced in Japanese quails. Talukdar et al. (2020) observed that Japanese quail egg traits, including weight, shape index, albumen index, and yolk index, showed no significant changes (P>0.05), except for yolk color, which increased significantly (P<0.05) in the 1% MOLM group. Organoleptic qualities, such as color, flavor, texture, juiciness, and acceptability, remained consistent (P>0.05) across groups. Farhana Sharmin et al. (2021) also found that egg quality, weight, length, and width were unaffected by adding 1.5% MOL to the diet, though cholesterol levels significantly dropped (P<0.05) at 1.5% MOLM. In addition, 1.0-1.5% MOLM supplementation increased omega-3 fatty acids in the yolk. Finally, Garcia et al. (2021) noted that adding Moringa reduced feed intake up to 1.2% and increased egg weight up to 3.80% with a linear increase in yolk weight and intensified yolk color with higher Moringa levels.

7. CONCLUSION

Moringa oleifera, often called the "Miracle Tree," offers numerous benefits for sustainable poultry production. Its leaf meal, rich in nutrients, can be seen as an invaluable, cost-effective natural resource.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that no generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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