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# Moringa (*M. oleifera*) Leaf Meal in Diets for Broilers and Laying Hens: A Review

Abdulkarim Abdulmageed Amad[1,2] & Jürgen Zentek[2]

[1] Department of Animal Production, Faculty of Agriculture and Veterinary Medicine, Thamar University, Dhamar, Yemen

[2] Institute of Animal Nutrition, Department of Veterinary Medicine, Free University of Berlin, Berlin, Germany

Correspondence: Abdulkarim Abdulmageed Amad, Department of Animal Production, Faculty of Agriculture and Veterinary Medicine, Thamar University, P.O. Box 87319, Dhamar, Yemen. E-mail: al_absie@yahoo.com

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**Abstract**

The cost of feed ingredients in poultry production is constantly increasing and it is one of the main constraints globally and especially in low income countries. As a consequence, scientists search for cheap and available sources of feed protein. The *M. oleifera* leaves have not only high protein but also excellent nutritive and biological properties. This review summarises results and findings of research related to the application of *M. oleifera* leaf as source of feed protein in broiler and egg production. Studies showed that leaf meals used as protein source led to improvement in growth and egg production parameters with up to 10% *M. oleifera* leaves in chicken diets. On the other side, there are restrictions on utilization of leaf meal in chicken diets by its high dietary fibre content and the presence of anti-nutritive compounds. This review also highlights previous results indicating a positive effect of *M. oleifera* leaves on carcass traits and egg quality, specially pigmentation of broiler meat and egg yolk and a tendency in cholesterol reduction in blood and eggs. A couple of studies have shown a beneficial influence on the antioxidant status and intestinal microbiota which were considered as health promoting in birds. In conclusion the use of *M. oleifera* leaves meal can improve growth performance and egg production. Of high interest is its potential to promote animal health. However, more research is needed to find out effects of *M. oleifera* leaves meal on functional traits, including ileal nutrient digestibility, especially considering amino acids, and on the gut microbiota for a better understanding of the mode of action of this plant.

**Keywords:** *Moringa oleifera*, growth performance, egg performance, antioxidant, microbiota

## 1. Introduction

The consumption of poultry products, including meat and eggs, has consistently increased worldwide and feeding is a critical cost factor. Importantly, the feed makes up to 70% of total production costs which mostly depends on ingredients costs and the global market for the most often used protein, soya bean meal. Ideally, suitable alternatives should have excellent nutritional properties, should be cheaper, constantly available and be not competitive to human nutrition (Van der Poel et al., 2013). Local ingredients for poultry diets are often used and should ideally support animal health, improve performance and product quality (Gadzirayi et al., 2012). *Moringa oleifera* is one of the alternative sources of plants which has been traditionally used in many countries. In addition to their nutritive effects, many of these plants can also produce physiological effects in the animal that are of interest in maintaining the performance, well-being and health. The World Health Organization (WHO) promotes the use of herbs and plants to minimize the use of chemicals and support the global trend towards natural feed ingredients. Many plants or parts are widely accepted as feed compounds with a potential to improve efficiency of feed utilization and performance (Levic et al., 2008). Some have been identified to contain bio-active compounds with effects similar to antibiotic growth promoters (Hernandez et al., 2004). One interesting source of protein is the leaf meal of tropical legumes and non-legumes, among them *M. oleifera* with its various primary and secondary components and due to its multiple advantages with nutritive and medicinal properties (Santos et al., 2015). Adding the fresh or dried leaves to animal feed can improve performance and contributes significantly in fighting nutritional deficiencies in tropical countries (Bhargave, 2015). There are several studies relating to the effects of *M. oleifera* leaves meals as a substitute to established protein resources in diets in poultry production. So, in this context, this review will discuss the use of the *M. oleifera* leaves meal in broiler and layer hen's diets and its effects on growth and egg production, blood parameters and intestinal microbiota.

## 2. General Description of *M. oleifera* Plant

*Moringa oleifera* is a foliage plant and belongs to the family *Moringaceae*. *Moringa oleifera* is native in Himalaya north India but is currently spread in many areas. This genus comprises 13 species, all of which are trees growing in tropical and semi-tropical climates. So, the plant has been naturalized by South West Asia, East and West Africa, the Arabian Peninsula and in South America (Bosch, 2004). The most cultivated and used species are *M. oleifera* species, which are grown for various purposes (Daba, 2016). *Moringa oleifera* can be grown by direct seeding, transplanting, or using stem cuttings (Olson et al., 2019). *Moringa* is fast-growing, deciduous tree and drought tolerant, growing in all types of soils and can survive in temperatures between 25-40 $^{o}$C. This plant has slender softwood, is branching freely, and can grow to 10 m high, while its trunk can reach a diameter of 40 cm. It is considered as small to medium size tree. *Moringa oleifera* is a perennial plant that can be harvested several times during the growing season and it has a high biomass yield per hectare (Makkar & Becker, 1997). It grows in wild and is also planted in farms and compounds. *Moringa* is free flowering and depending on the type, the flowering occurs 4-12 months after planting, some selections can flower 4-5 months after planting (Paliwal et al., 2011). The leaves of *Moringa* are compound, tripinnate small in size and oval to obovate with leaflets averaging 1-2 cm in length and 0.5-1 cm in width. *Moringa* leaves grow on a tree with drooping branches and are also known for their hanging. This plant has sparse foliage, white flowers and long pods. *Moringa* flowers are pentamerous, zygomorphic, 7-11 mm long and the fruit is typically 3-valved capsule, 10-60 cm in length (Bosch, 2004). Leaves, fruits and flowers are edibles and entered in traditional foods in many tropical countries, leaves and young green pods are often used as a vegetable. Studies confirmed that every part of the *M. oleifera* tree has beneficial properties and uses in human and animal, so it is called as a miracle tree, tree of life (Nduwayezu, 2007) or multipurpose tree (Kakengi et al., 2007). The plant is resistant to most pests and diseases, thus making it an interesting and sustainable source of feed for animals.

### *2.1 Nutrients of M. oleifera*

*Moringa oleifera* is nutritious owing to the presence of a variety of essential nutrients and phytochemicals in its leaves, pods and seeds. Mostly, it is an interesting source of protein, lipids, minerals and vitamins, especially the leaves are of high interest (Table 1).

Table 1. The nutrient composition of dried leaves of *M. oleifera*

| **Components** | **% dry matter** | **References** |
|---|---|---|
| Protein | 26.8-30.3 | Mabruk et al. (2010), Moyo et al. (2011), Sharma et al. (2012), Chatepa and Mbewe (2018), Antyev et al. (2020), Meireles et al. (2020), Mgbemena and Obodo (2016), Cui et al. (2018), Su and Chen (2020), Abu Hafsa et al. (2020), Shen et al. (2021) |
| Fat | 6.4-13.4 | |
| Carbohydrate | 36.0-50.05 | |
| Crude fiber | 4.8-27.6 | |
| Crude ash | 7.6-14.8 | |
| ME (kcal/kg) | 3040-3374 | |
| **Minerals** | **mg/100 g dry matter** | **References** |
| Phosphorus | 252 -310 | Moyo et al. (2011), Tijani et al. (2015), Cui et al. (2018), Antyev et al. (2020) |
| Calcium | 2185-2280 | |
| Copper | 0.53 | |
| Iron | 25.6-49 | |
| Zinc | 0.82-5.9 | |
| Selenium | 0.076 | |
| **Vitamins** | **mg/100 g dry matter** | **References** |
| Vitamin A | 0.4 | Cui et al. (2018), Antyev et al. (2020) |
| Vitamin C | 0.7 | |
| Vitamin E | 2.6 | |

Leaf meal of *Moringa* has a high content of crude protein up to 30.3% DM (Olugbemi et al., 2010; Mabruk et al., 2010). The protein content of *Moringa* leaf meal is higher than the content in *Medicago sativa* (Alfalfa) and many other of the commonly consumed green leafy vegetables, spinach (2%), mint (4.8%) and an equivalent of the protein content of many pulses such as moth beans or soybeans, which contain 22-24% protein of DM (Joshi & Mehta, 2010). Therefore, several reports have demonstrated that the leaves could be used for various food and feed applications. The spectrum of essential amino acids has been studied (Moyo et al., 2011; Wei et al., 2016) and it was concluded that the amino acid profile (Table 2) of *M. oleifera* leaves is comparable to that of soya bean meal (Makkar & Becker, 1997).

Table 2. Amino acid composition (g/100 g protein) of leaves of *M. oleifera*

| | **Mean** (n = 3) | **±SE** |
|---|---|---|
| *Essential amino acids* | | |
| Cysteine | 0.79 | 0.29 |
| Histidine | 2.39 | 0.31 |
| Isoleucine | 4.78 | 0.15 |
| Leucine | 9.20 | 0.29 |
| Lysine | 5.58 | 0.02 |
| Methionine | 1.73 | 0.17 |
| Threonin | 4.71 | 0.31 |
| Tryptophan | 2.10 | 0.00 |
| Tyrosine | 3.36 | 0.58 |
| Phenylalanine | 5.65 | 0.54 |
| Valine | 5.91 | 0.38 |
| *Non-essential amino acids* | | |
| Alanine | 7.77 | 1.04 |
| Arginine | 5.98 | 0.90 |
| Aspartic acid + asparagine | 9.30 | 0.38 |
| Glutamic acid + glutamine | 10.76 | 0.33 |
| Glycine | 7.11 | 1.73 |
| Proline | 4.68 | 0.89 |
| Serine | 4.66 | 0.55 |

*Note*. ±SE = Standard Error.

Source: Makkar and Becker (1997); Mune et al. (2016); Islam et al. (2021).

*Moringa oleifera* leaves content 6.4-13.4% crude fat on DM basis, the fatty acids are dominated by linoleic, linolenic and oleic acid which have the ability to control cholesterol (Makkar et al., 1997; Lalas & Tsaknis, 2002; Nouala et al., 2006; Moyo et al., 2011). *Moringa oleifera* leaves have a high concentration of dietary fiber. Crude fiber reaches 4.8-27.6% DM (Melesse, 2011; Sharma et al., 2012; Cui et al., 2018) whereas the values of NDF and ADF reach about 16 and 10.7% respectively (Makkar & Becker, 1997; Melesse, 2011). It is also considered good source of major and trace mineral elements, of vitamins A, E and vitamin B (thiamine, Riboflavin, Niacin, pantothenic acids, vitamin B6, folate (B9) and Vitamin C (Abbas et al., 2018; Olugbemi et al., 2010a). *Moringa oleifera* leaves are higher in calcium, sodium and potassium content than other common leafy vegetables like cassava, amaranth, taro and pumpkin (Tijani et al., 2015). It has an adequate content of zinc which is a component of enzymes and important for nutrients metabolism and the synthesis of DNA and RNA. The proximate content of vitamins and minerals in *M. oleifera* leaf meal are within the requirement of broiler chicken (Antyev et al., 2020). In addition, it must be mentioned that *M. oleifera* leaves do not contain heavy metals such as mercury, arsenic and cadmium (Donkor et al., 2013). As shown in Table 1, there is a variation in the nutrient content of *M. oleifera* leaves meal and is attributed to several causes such as, genetic variation of the plants, soil type and fertilization, climate condition, age of tree, leaf maturity, cutting frequency, part of the plant harvested and storage conditions (Aslam et al., 2005; Ogbe & Affiku, 2011).

### *2.2 Bioactive Compounds of M. oleifera*

The *Moringa* tree provides a rich and rare combination of bioactive substances and the most important are alkaloids, flavonoids, phenolics, glucosinolates, carotenoids, sterols, saponins, phenolic acids, tannins and isothiocyanates (Verma et al., 2009; Meireles et al., 2020), which are present in significant amounts in various part of the plant. Earlier results indicated that *M. oleifera* contains large amount of β- carotene, approximately 20 mg/100 g on fresh weight and it is known that carotenoids play an important role in poultry nutrition due to their strong antioxidant property (Bhaskarachary et al., 1995; Kuhnen et al., 2009). Makkar and Becker (1996), Moyo et al. (2011), and Leone et al. (2015) showed that the total polyphenolic in leaves of *M. oleifera* ranging is between 1.13 and 4.43%. Bukar et al. (2010) isolated saponins and flavonoids from ethanol extract and then tannins and alkaloids were isolated by Kasolo et al. (2010). Moreover, by quantitative phytochemical analysis found Maqsood et al. (2017) that leaves possessed high amounts of flavonoids (21.76%), followed by tannins (14.3%), saponins (12.56%), and alkaloids (2.4%). The main flavonoids found in the leave of *M. oleifera* are myrecytin, quercetin and kaempferol, in concentrations of 5.8, 0.207 and 7.57 mg/g, respectively (Coppin et al., 2013). Additionally, the phytochemical screening indicated the presence of tannins, flavonoids, glycosides, terpenoids and phenols in leaf extract of *M. oleifera* as major components and showed potent antibacterial activity against *S. Aureus* and *E. coli*, antifungal effects and antioxidant activities (Elangovan et al., 2014; Malhotra & Mandal, 2018). Also, study from Valeria and Williams (2011) reported that *M. oleifera* leaves and seeds meals act as a good source of vitamins, selenium, flavonoids, phenolics and carotenoids, which makes it suitable to be utilized as a nutritionally valuable and healthy additive ingredient for poultry diet and could be valuable in preventing diseases and other side increase the shelf-life of fat containing foods. In general, as documented in many reports, *M. oleifera* possesses many biological agents with various effects including improving digestion and metabolism, anti-analgesic, antimicrobial, antioxidant, anti-inflammatory, hepatoprotective, antiviral, antifungal and hypocholesterolemic (Leone et al., 2015; Shah & Oza, 2020; Dzuvor et al., 2022; Khan et al., 2021), which might lead to stabilizing and improving the performance of animals (Abbas 2013) and makes an important contribution to the mode of action of this plant in animals.

### *2.3 Antinutrients in M. oleifera*

Some parts of this plant contain toxins and other anti-nutritional factors that might decrease its potential as a source of nutrients for animals, for instance tannins, alkaloids, phytate, saponins and hydrogen cyanide (Makkar et al., 1990; Makkar & Becker, 1997; Balami et al., 2018). The leaves contain 12 g/kg tannins, 80 g/kg saponin expressed as diosgenin equivalent and 21 g/kg phytate (Makkar et al., 1997; Moyo et al., 2011). Saponin has a pungent and irritating taste and at high concentration can reduces the feed intake and consequently body growth. Table 3 shows concentrations of antinutritional substances in *M. oleifera* leaves after different references. It must be considered that the anti-nutritional content is dependent on various factors such as genetics, age, growth stadium and environmental conditions (Sultana et al., 2014).

Table 3. Antinutritional substances in *M. oleifera* leaves (% DM)

| Antinutritional Substances | Balami et al. (2018) | Teixeira et al. (2014) |
|---|---|---|
| Tannins | 2.19 | 2.06 |
| Saponins | 1.06 | - |
| Phytate | 2.57 | - |
| Oxalates | 0.45 | 1.05 |
| Trypsin inhibitor | - | 1.45 TUI/g* |
| Cyanides | 0.1 | Absence |

*Note*. - Not detected, *TIU: trypsin inhibitors units.

The content of oxalates of *Moringa* leaves is insoluble and below that in spinach (822 mg) and are not harmful to chickens. In relating to trypsin inhibitors, it found at relatively low level (Ogba & Affiku, 2011) or not exist as indicated by (Makkar & Becker, 1996, 1997), also, it showed much lower activity than those of soybeans (107 TIU/mg) as indicated by Franco (2005), and Da Silva and Kerr (1999) cited by Teixeira et al. (2014). Hydrogen cyanide (HCN) does not exist or present in much reduced concentrations in *Moringa* leaves and has no harmful effect to birds (Teixeira et al., 2014). In contrary, it has been reported that negative effects can arise from the anti-nutritional factors present in *M. oleifera* leaves. Tannins have the ability to form complex bonds with metal ions and macromolecules (protein and polysaccharides), ultimately leading to decreased nutrient bioavailability (Igwilo et al., 2010). High concentration of tannins and phytate have been seen to affect negatively the digestibility and metabolism and therefore reduced the utilization rate of dietary nutrients and can negatively influence the growth rate from one side and other side can lead to deteriorate effect on red blood cells and haemoglobin in broiler and non-ruminants as reported by (Okai et al., 1984; Esonu, 2001; Akubugwo et al., 2007; Igwilo et al., 2010; Edu et al., 2019). In addition, phytate has a strong binding affinity for calcium, magnesium, iron, copper and zinc, preventing their absorption in the gut and can negatively influence the development of skeletal and red blood cells (Falowo et al., 2018; Emiola et al., 2003; Odetola et al., 2012). However, it must be noted that the amounts of anti-nutrients in *Moringa* are generally low and do not constitute any health risks to animal and on other hand, these anti-nutrients can be reduced or neutralized through various treatments like soaking, boiling or by heat steaming and fermentation with microorganisms (Gidamis et al., 2006; Nouman et al., 2013).

## 3. Effects on Growth Performance and Carcass Traits

### *3.1 Growth Performance*

Many studies focused on the use of *M. oleifera* as an economic feed source for poultry diets. *Moringa* leaves have quality characteristics making it a potential substitute for soybean meal or fish meal (Kakengi et al., 2007). *Moringa oleifera* leaf meal inclusion in the diets up to 24% did not impact performance or mortality in birds (Ayssiwede et al., 2011) and 25% *M. oleifera* meal in broiler diets indicated similar growth rate compared to conventional commercial feeds (Gadzirayi et al., 2012). Some studies with *M. oleifera* leaves added to broiler feed found an enhancing effect on growth performance (Donkor et al., 2013; Abdulsalam et al., 2015). A substitution of soya bean meal in broiler feed at concentrations up to 5% was without negative effect on performance (Tesfaye et al., 2013). The inclusion of 7.5% *M. oleifera* leaf meal in broiler feeds had not affected weight gain, feed intake and feed conversion ratio, but above this level feed intake decreased (Gakuya et al., 2014). *Moringa oleifera* leaf meal at 8% dietary level improved weight gain, but no effects were shown regarding feed intake and feed conversion ratio (Egu, 2019), while the inclusion of 7.5 and 10% in diets for one-week old chicken decreased growth rate (Limcangco-Lopez et al., 1989). Several previous studies agreed that the use of *M. oleifera* leaf meal up to a level of 10% had no negative effect on the performance of broiler chicken, while levels above 10% showed negative effects on performance (Kakengi et al., 2007; Olugbemi et al., 2010; Onu & Aniebo, 2011; Abou-Elezz et al., 2011; Zanu at al., 2012; Gadzirayi et al., 2012; Banjo, 2012). Further results about the effect of *M. oleifera* meal on broiler performance are summarized in Table 4. The positive effect on broiler performance might be related to the presence of different bioactive compounds. Reports demonstrating that extracts of many herbal plants contain many secondary metabolite (plant bioactive) and could improve the broiler performance by increasing the live weight gain and feed efficiency of broiler chicken (Jamroz & Kamel, 2002; Hernandez et al., 2004; Al-Kassie, 2009; Amad et al., 2011). Such compounds could modulate the intestinal micro-architecture which might lead to improved absorption of nutrients (Khan et al., 2017; Teteh et al., 2017). The lower FCR values (higher feed efficiency) in *M. oleifera* supplemented treatment might be due to better feed utilization and presence of quantity of vitamins and minerals and several antioxidant compounds in *Moringa* leaves which led to better growth performance (Verma et al., 2021). The decrease of feed intake in some studies could result from improved digestion and metabolism activities by the bioactive compound of *M. oleifera* leaf meal which led to meeting the nutrients requirement of birds and lowering the feed intake. On the other side the bioactive compound of the *M. oleifera* affected the growth and improved health of gastro intestinal tract (GIT) and better utilization of macronutrients in feed (Ghazalah & Ali, 2008; Teixeira et al., 2014) might be due to greater content of crude fiber and calcium with increasing dietary levels of *M. oleifera* leaf meal which dilute other nutrients, because, according to increased CF, EE and Ca in diets can inhibit digestibility of protein and energy and depress feed intake as well as enzymatic activity (McDonald et al., 2002; Mirnawati et al., 2011). Also, the reduced feed intake is associated with sensory properties of bioactive substances such as saponins (Siddiqui et al., 2017). Additionally, *M. oleifera* leaf meal more than 10% had negative effect on intestinal structure and consequently influenced feed efficiency and body weight gain (Kavoi et al., 2016).

### *3.2 Carcass Traits*

Results of studies suggest that different part of the plant have effects on carcass traits, however, studies of *M. oleifera* meal have shown inconsistent results (Table 4). Zanu et al. (2012) stated none of the measured carcass parameters was significantly affected by inclusion of 5, 10, and 15% of *M. oleifera* meal in the feed. Replacement of 5-20% *M. oleifera* leaf meal for SBM significantly lowered dressing weight, breast weight, thigh weight, drumstick weight and giblet weight due to reduced feed intake and growth rate of the birds (Tesfaye et al., 2013) and 7.5, 15 and 30% *M. oleifera* leaf meal reduced abdominal fat pad in Broiler (Gakuya et al., 2014). Additionally, the proportion of abdominal fat decreased ($P < 0.05$) as the inclusion level of *M. oleifera* leaves meal increased (Aderinola et al., 2013; Kumar et al., 2020). No effects of dietary treatments were observed on carcass yield or dressing percentage and internal organs, liver weight and heart weight by addition of aqueous *M. oleifera* leaf extracts at 60-150 ml/l (Alabi et al., 2017) and at 90 ml/l (Kumar et al., 2020). There was significant increase in dressing%, liver, spleen heart and intestinal weights by addition of 1.25, 2.4 and 3.75% *M. oleifera* leaf meal to broiler diets (Baloch et al., 2021). Also, Edu et al. (2019) showed higher values of dressing percentage in birds fed diets with 10% *M. oleifera* leaf meal. Sebola and Mokoboki (2019) studied the supplementation of *M. oleifera* on three chicken strains and found that higher inclusion levels of *Moringa* leaf meal (10%) resulted in longer small intestines and heavier gizzards. Higher inclusion rates of *M. oleifera* leaf meal led to more yellowish carcass colour because of high levels of carotenoids in the *Moringa* leaf meal (Gakuya et al., 2014). Birds had yellow coloration of body parts, probably by the presence of xanthophylls and carotenoid pigments in *M. oleifera* leaf meal (Gadzirayi et al., 2012). The same authors stated that various inclusion levels did not influence the levels of lower density lipids (LDL), cholesterol (TC) and triglycerides (TG). Otherwise it was concluded that dietary *Moringa* leaf meal inclusion in broiler diet could improve poly-unsaturated fatty acids status, meat oxidative stability, and colour of muscle by increasing the redness of meat (Cui et al., 2018). Other studies found no significantly effect on the aroma, flavor and color of broiler meat by inclusion of 0.2, 0.4 and 0.6% *M. oleifera* leaf meal (Ologhobo et al., 2014) or by 3, 5 and 7.5% (El Tazi, 2014). Supplementation of 50 ml and 100 ml of *M. oleifera* aqueous leaf extract (ethanol extract)/l drinking water significantly improved freeze storage of meat (shelf live), color, odor, taste and overall acceptance (AbouSekken, 2015).

Table 4. Effects of *M. oleifera* leaf meal addition on the growth performance and carcass traits in broiler chickens

| Dietary level | Growth period | Growth performance | Carcass traits | Reference |
|---|---|---|---|---|
| 0, 1, 1.5 and 2% | 35 days | - Increase ($p < 0.05$) the BWG<br>- Decrease FI and FCR (except by 2%) | Not determined | Verma et al. (2021) |
| 0, 2.5, 5 and 7.5% | 36 days | - NS effect on BW and BWG, but by 7.5% the growth decreased ($p < 0.05$)<br>- NS effects on FI and FCR<br>- Mortality was decreased ($p < 0.05$) | - NS effect on carcass yield%<br>- Slight decrease effect on relative organ weight liver and gizzard<br>- Slight increase in breast and thigh yield | Mikhail et al. (2020) |
| 0, 0.25, 0.50 0.75 and 1% | 56 days | - Increased ($p < 0.05$) the end BW, total BWG<br>- Improved FCR ($p < 0.05$)<br>- NS effect on FI | - Increase ($p< 0.05$) dressed weight and carcass percentage<br>- Increase ($p< 0.05$) breast, thigh and wing<br>- NS effect on liver, heart, kidney, gizzard and intestinal length | Antyev et al. (2020) |
| 0, 1, 3, 5, and 7% | 42 days | - Higher BW by 3% ($p < 0.05$) and better FCR<br>- FI no affected | - Increased ($p < 0.05$) dressed weight and dressed percentage by 3%<br>- NS effect on organ relative weight (%) | Alwaleed et al. (2020) |
| 0, 1, 2, 5, 10 and 15% | 42 days | - Decreased body weight and average daily gain ($p < 0.01$),<br>- Increased FCR<br>- NS effect on FI | - NS effects on breast and leg muscle (%)<br>- Abdominal fat decreased ($p < 0.01$)<br>- Improved meat color | Cui et al. (2018) |
| 0, 5, 10, 15 and 20% | 56 days (Vanaraj birds) | - FI reduced with increased *Moringa* leaf in feed<br>- NS effect on BW except by 5%<br>- Decrease ($p < 0.05$) the FCR | - NS effect on dressing %<br>- Liver and heart reducing with *Moringa* meal increase in feed<br>- NS effect on Gizzard and intestine<br>- Reduction of Abdominal fat and spleen | Kumar et al. (2018) |
| 0, 5, 7.5 and 10% | 49 days | - NS difference in the average daily FI, DWG and FCR | - NS impact on dressing percentage (%)<br>- NS effect on wing breast and thigh<br>- The highest value had the liver, kidney and spleen by 10.0% *Moringa* leaf | Onunkwo & George (2015) |
| 0, 3, 5 and 7% | 49 days | - Improved the performance live BW, FI and FCR | - Improved the carcass weight and percentage, breast weight and drumstick weight | El Tazi (2014) |
| 0, 1, and 2% | 28 days | - Improved daily WG<br>- NS effect on FI<br>- Improve ($p < 0.05$) FCR | - Increased the relative organ weights of liver, pancreas and spleen | Teteh et al. (2013) |

*Note*. BWG = Body weight Gain; FI = Feed Intake; FCR = Feed Conversion Ratio; NS= No Significant.

## 4. Effects on Laying Performance and Egg Quality

### *4.1 Laying Performance*

In a study by Kakengi et al. (2007), *M. oleifera* leaf meal could replace sunflower seed meal up to 20% without any adverse effects in laying hens and at the same time increased the egg weight, however, 10% inclusion level of *M. oleifera* leaf meal in layer diets was found to be optimal for efficiency. The supplementation of *M. oleifera* fresh leaves to layers improved egg layer rate, FCR and lowered feed intake (Abou-Elezz et al., 2012) and moreover the addition of 100 mL/L of water *moringa* leaves extract elevated egg production and egg weight (Briones et al., 2017). Results revealed no significant difference ($P < 0.05$) between hens fed 0.2, 0.4, 0.6 and 0.8% *M. oleifera* leaf powder and control hens without leaves powder regarding feed intake, FCR and egg production (Paguia et al., 2014). Gakuya et al. (2014a) found a decreasing trend in feed intake with increasing levels of *M. oleifera* leaf meal in layers' diets, while the addition of up to 10% *M. oleifera* leaf meal with cassava chip-based diets in laying hens had no effect on feed intake (Olugbemi et al., 2010). The inclusion of 5% *M. oleifera* leaf meal had a positive effect on egg production, while using higher levels (10 and 15%) negatively affected performance (Abou-Elezz et al., 2011). Moreover Table 5 shows results of various studies in relation to *M. oleifera* leave meal effects on egg performance. A positive effect of *M. oleifera* on the egg production and higher egg weights could be attributed to increasing the feed intake and feed efficiency (Etches, 1996; Raphael et al., 2015; Alebachew et al., 2016; Wei et al., 2016) and to its specific bioactive components and their multifunctional properties which ultimately can promote the production parameters (Makkar & Becker, 1996; Al-Kassie, 2009; Prasad & Ganguly, 2012; Marrufo et al., 2013; Ahmad et al., 2017). The discrepancies in the results of several studies regarding the egg performance may be due to the use of different hen's genotype, age, production stage, plant parts, agroclimatic conditions, herb compositions, addition levels, application and cultivation methods as documented by Abdel-Wareth and Lohakare (2021).

### *4.2 Egg Quality*

Egg quality, includes the internal and external egg quality, is considered as one of the most important criteria in the egg production and has an important economic value. External quality includes shell cleanliness, texture and egg shape index, whereas internal quality refers to egg white (albumen) cleanliness and yolk shape, strength and color and the egg nutrient composition, which is the main factor to be consider by the consumer. Therefore, several studies have considered the effects of *M. oleifera* on egg quality and at the same time the costs of egg production. Olugbemi et al. (2010) indicated that inclusion of 10% *M. oleifera* leaves meal in cassava-based diets improved the egg shape index, shell percentage and shell thickness. *Moringa oleifera* leaf meal at 0, 5, 10, and 15% in the diet had no adverse effects on shell thickness and egg shape index (Abou-Elezz et al., 2011). Supplementing diets with *M. oleifera* fresh leaf improved egg mass and egg quality (Abou-Elezz et al., 2012). Also, findings showed that high density lipoprotein and lutein content increased in the eggs whereas the cholesterol and low-density lipoprotein reduced with supplementation at 0.5, 1.0, 1.5 and 2.0 g/kg of *M. oleifera* leaves meal in diets of the layers (Lala et al., 2012). HDL was reduced, but no difference in total cholesterol, triglyceride and LDL of the eggs by addition of 0.5, 1.0 and 1.5% *M. oleifera* leaves (Akinola & Ovotu, 2018). The supplementation of diets for hens with *M. oleifera* fresh leaf significantly improved the yolk colour (Abou-Elezz et al., 2011, 2012; Lala et al., 2012), but there was no difference in egg yolk colour score between eggs from *Moringa* leaf meal diets and those from supermarkets (Gakuya et al., 2014a). The total cholesterol in the egg yolk linearly decreased with dietary levels of *M. oleifera* leaf meal, and was the lowest when hens were fed 1.5% *Moringa* leaf meal (Ahmad et al., 2018). Siti et al. (2018) indicated that the fermented *Moringa* leaf extract added to drinking water (2, 4 and 6%) significantly decreased yolk cholesterol contents of eggs. In addition, Antara et al. (2019) stated that supplementation 2 and 4%/l drinking water of *Moringa* leaves extract significantly decreased the cholesterol in egg yolk. Further findings regarding the egg quality are indicated in Table 5. The improvement of egg quality seems related to active components of *Moringa* leaf which may have the ability to improve calcium storage, uterine functions and intestinal secretions, which ultimately lead to increase egg shell weight, thickness and Haugh units (Nadia et al., 2008; Liu et al., 2020). Some phytochemicals such as phenolics, flavonoids and carotenoids can decrease fat absorption, which might reduce cholesterol content in eggs (Srinivasan 2005; Sikora et al., 2008) and increase the elimination of cholesterol through feces (Benakmoum et al., 2013). A recent study stated that carotenoid supplementation to hens feed in 43 weeks of age reduced cholesterol content in egg yolk and improved the shell thickness and yolk oxidative stability (Panaite et al., 2021).

Table 5. Effects of *M. oleifera* leaf meal addition on the egg performance and quality in layer hens

| Dietary level | Period | Egg performance | Egg quality | Reference |
|---|---|---|---|---|
| 0, 0.3, 0.6, and 0.9% | 64-72 weeks of ages | - Increase ($p < 0.05$) the egg production, egg weight and mass<br>- Improved ($p < 0.05$) FCR<br>- NS effect on FI | - Improving the shell thickness and Hough unit ($p < 0.05$)<br>- No effect on albumen and yolk | Abdel-Wareth & Lohakare (2021) |
| 0, 2.5, 5, 7.5 and 10% (powder) | 37-43 weeks of ages | - By < 5% leaf powder no adverse effect on laying rate<br>- The FI and FCR reduced ($p < 0.05$)<br>- NS effect on egg weight | - Eggshell strength was higher at week 2<br>- No difference in eggshell weight, albumen height, Haugh unit or yolk rate<br>- Yolk color increased as more leaf powder was added to the feed | Shen et al. (2021) |
| 0, 0.5, 1 and 1.5% | 26-42 weeks of age | - No difference in BW (except by 0.5%)<br>- NS effect on FI<br>- No difference in egg production (hen day%), egg weight and mass | - No effect on egg shape index and shell thickness<br>- No difference in albumen and yolk index and Haugh unit<br>- Improved the yolk color ($p < 0.05$) | Sharmin et al. (2021) |
| 0, 2, 4 and 6% (powder) | 30 weeks of ages | - The addition of 2 and 4% improved ($p < 0.05$) the egg production, egg weight and mass and FCR<br>- NS effect on FI | Addition of 2 and 4% significantly increased shell thickness, Ca in shell and yolk, β-carotine but reduced the yolk cholesterol contents in eggs | Bidura et al. (2020) |
| 0, 0.5, 1, 1.5 and 2% (powder) | 22-34 weeks of ages | - Increased BW, laying rate and egg weight<br>- Reduced FI and FCR | - Improved egg shell thickness and yolk color<br>- Egg cholesterol contents reduced ($P \leq 0.05$) by increasing MOL powder in diets | Abdel-Azeem et al. (2017) |
| 0, 0.5, 1, 1.5 and 2% | 22-30 weeks | - Increased the egg production, egg weight and improved the FCR by 0.5% | Albumen (%), yolk (%), shell (%), shape index and shell thickness were similar in all experimental groups | Swain et al. (2017) |
| 0, 5, 10 and 15% | 41-53 weeks of age | - Improved final BW, FI, total egg weight and production by hens get 5 MO leave. By others group no difference | - Hatchability percentage was better by egg hens get 5% *Moringa*. No significant by other group | Alebachew et al. (2016) |
| 0, 1, and 2% | 21-40 weeks | - Increasing laying rate<br>- Significant improved egg weight and FCR by 1%, but lower egg weight by 2%<br>- No difference in FI | - No difference in shell and yolk ratio<br>- High albumen ratio by 1% and lower by 2%<br>- More yolk colour intensity with *M. oleifera* | Teteh et al. (2016) |
| 0, 0.1, 0.15 or 0.2% | 32-38 weeks of age | - NS effect on egg production, FI and FCR<br>- Improved egg weight | - Higher ($p < 0.05$) shell and albumin weight-slightly lower yolk weight ($p < 0.05$)<br>- Significantly decrease the total lipid and cholesterol | El-Sheikh et al. (2015) |
| 0, 1.25, 2.5, 5, 7.5 and 10% | 30-34 weeks | - NS effects on FI, BWG and egg weight<br>- Decreasing egg production with increasing MOLM level | - NS effect on egg yolk colour from MOLM diet | Gakuya et al. (2014a) |

*Note*. BWG = Body weight Gain; FI = Feed Intake; FCR = Feed Conversion Ratio; NS = No Significant; MOLM = *Moringa oleifera* leave meal.

## 5. Effects on Blood Parameters of Broiler and Layer Hens

### *5.1 Haematological Parameters*

The use of 15% *Moringa* leaf meal as substitute to fish meal in broiler diets had no significant effect on white Blood Cells (WBC), packed cell volume (PCV) heamoglobin (Hb), mean corpuscular hemoglobin concentration (MCHC) and lymphocytes (Zanu et al., 2012), similar findings were reported for broiler chicken fed *Moringa* leaves meal at level from 0.2 to 0.6% (Makanjuola et al., 2014). WBC count and PCV indices were not affected by 0.25-1.0% *M. oleifera* leaf meal (Antyev et al., 2020). Moreover, the application of *M. oleifera* leaf meal at 5, 10 and 15% in broiler diets increased haemoglobin (Hb) concentration, red blood cells (RBC) count, PCV, mean cell volume (MCV) and MCHC (Alnidawi et al., 2016), and these results are similar to the those from Abbas et al. (2018) and Verma et al. (2021). This increase might be at least partly attributed to the abundance of iron (Table 1) in the leaves of *Moringa* (Lutz & Prytulski, 2008; Elbashier & Ahmed, 2016). At higher inclusion levels, PCV, Hb, RBC, WBC and neutrophils were reduced in birds fed 20% *Moringa* leaf meal which could, probably, be caused by the combined effects of anti-nutritional factors like phytate and tannin (Tijani et al., 2016) which reduce the absorption of vitamin B12 as an important factor for synthesis of red blood cells (Liener, 1994; Doss et al., 2011; Teteh et al., 2013). In layer hens reduced levels of Hb, PCV, MCH and MCV as the inclusion of *M. oleifera* leaf meal increased from 0.5 to 1.5%, but RBC, MCHC and WBC were not affected (Akinola &

Ovoto, 2018). Voemesse et al. (2019) found that RBC, WBC, PCV and lymphocytes decreased with the increasing *M. oleifera* level from 1 to 3% in the layer diet. Other side, studies suggest that a high WBC count was associated with a bacterial infection and the presence of foreign bodies or antigens in the circulating system (Ahamefule et al., 2008) and Voemesse et al. (2019) indicated that the antimicrobial activity of phytochemicals in the *Moringa* leaves might have led to decrease in WBCs and lymphocytes in *Moringa* leaf meal treated birds due to a reduction of intestinal microflora.

### *5.2 Biochemical Parameters*

The addition of 0.2, 0.4 and 0.6% *M. oleifera* meal leaves reduced aspartic transaminase (AST) activity insignificantly, but there was a significant decrease in alanine transaminase (ALT) by the addition of 0.4% *M. oleifera*, which may reflect normal liver function of the birds fed diets containing *M. oleifera* leaves meal (Makanjuola et al., 2014; Akinola & Ovotu, 2018). Egu (2019) indicated that urea, cholesterol, glucose, calcium and alkaline phosphatase values were reduced in group fed 10% *M. oleifera* leaf meal comparing to control birds. There was significantly reduction in serum cholesterol level as the inclusion level of *M. oleifera* leaf increase (0.5, 1.0, 1.5 and 2.0%). Aderinola et al. (2013) and Antyev et al. (2020) also found a decrease in low-density lipoprotein cholesterol and very low-density lipoprotein at a level 0.25, 0.50, 0.75 and 1.0%, of *M. oleifera* leaf meal in broiler diets which agrees with findings of Olugbemi et al. (2010), Aderinola et al. (2013) and Abbas et al. (2018a). *Moringa* leaf meal (0, 1 and 2% in diet) did not affect the blood glucose, but the total protein was higher in hens fed *M. oleifera* and the highest triglyceride was by the groups get *M. oleifera* which can be caused by estrogen synthesis from the steroids in the leaves (Teteh et al., 2016). The use of the *M. oleifera* leaf reduced cholesterol, triglycerides, AST, ALT, creatinine and uric acid of laying hens during the laying period (Ahmad et al., 2017; Abdel-Wareth & Lohakare, 2021). There was reduced levels of Serum Glutamic-pyruvic Transaminase (SGPT), creatinine, glucose and cholesterol in the serum of layers due to the positive effect of bioactive compound flavonoids and carotenoids in *Moringa*, which showed improved liver and kidney function (Melesse et al., 2013; Elkloub et al., 2015). Furthermore, layer hens offered *Moringa* leaf meal in feed showed significantly higher blood total protein, albumen level and the same trend by Ca, Mg and Fe, but the uric acid was significantly lower (Voemesse et al., 2018) and the low serum uric acid may be attributed to good quality of protein utilization in *M. oleifera* leaf meal (Abbas et al., 2018a). Ahmad et al. (2018) reported that the hens fed the highest *Moringa* leaf level (1.5%) indicating lowest SGPT, glucose levels, creatinine and cholesterol values. This improvement is attributed to flavonoids and carotenoids (β-carotene) content in *Moringa* which positively affect these compounds and to present nutrient quality and abundant of mineral elements in *Moringa* (Elkloub et al., 2015). Further effects of *M. oleifera* meal on serum biochemical parameters in broiler and laying are summarized in Table 6.

Table 6. Effects of *M. oleifera* leaves meal on serum biochemical parameters in broiler and laying hens

| Addition | Experimental Period | Effects | Reference |
|---|---|---|---|
| *Broiler chicken* | | | |
| 90 ml/L (MO leaves extract) | 5 weeks | - No significant effect on AST, ALT, cholesterol, triglyceride, LDL and HDL | Kumar et al. (2021) |
| 0, 0.25, 0.50, 0.75 and 1.0% | 6 weeks | - Significant effect on total protein, globulin, ALP, uric acid, total cholesterol, LDL-c VLDL-c and HDL-c | Abbas et al. (2018a) |
| 0, 2500 and 5000 mg/kg MO leaf extract | 6 weeks | - NS effect on total protein, albumin and globulin<br>- No effect on ALT and AST, but increase ALP ($P \geq 0.05$) | Faluyi & Agbede (2018) |
| 0, 5, 10, 15 and 20% | 8 weeks | - Reductions ($P < 0.05$) in total protein, albumin, AST and ALT contents<br>- Higher ($P < 0.05$) creatinine content in birds fed MOLM | Tijani et al. (2016) |
| 0, 5, 10, 15 and 20% | 6 weeks | - T-cholesterol decreased ($p \geq 0.05$) with increasing the supplementation of *M. oleifera*<br>- Gradually increase in HDL, but decrease in LDL and triglyceride | Alnidawi et al. (2016) |
| 0, 0.5, 1.5 and 2% | 6 weeks | - NS reduction in level of protein, cholesterol and triglyceride<br>- Significantly decrease of uric acid and liver enzymes AST and ALT | Divya et al. (2014) |
| *Layer hens* | | | |
| 0, 5, 7.5 and 10% | 34-49 weeks of age. | - Insignificant reduction in total protein and albumin.<br>- Significant decrease in cholesterol<br>- Significance elevation in Ca and P | Rajesh et al. (2021) |
| 0, 0.3, 0.6 and 0.9% | 64-72 weeks of age | - Decreased ($p < 0.001$) Cholesterol and triglycerides with the increase of MOLM levels in diets<br>- Reductions ($p < 0.001$) of AST, ALT, creatinine and uric acid | Abdel-Wareth & Lohakare (2021) |
| 0, 0.5, 1, 1.5% MOLM | 50-65 weeks | - Significant decrease of glucose, creatinine, cholesterol and SGTP | Ahmed et al. (2018) |
| 0, 0.5, 1, 1.5% MOLM | 74 -86 weeks | - No effect ($P>0.05$) on AST, ALT, glucose and HDL<br>- Significant effect on the total protein, total cholesterol, triglyceride and LDL | Akinola & Ovotu (2018) |
| 0, 5, 10 and 15% MOL | 27-37 weeks | - No effect on ALT activity, the AST activity increased quadratically as the dietary supplemental level of MOL increased ($p < 0.05$).<br>- The TP-concentration decreased quadratically with the increasing level of MOL ($p < 0.05$) | Wei et al. (2016) |

*Note*. NS = No Significant; MOLM = *Moringa oleifera* leave meal; TP = Total protein.

## 6. Antioxidant Effects of *M. oleifera* in Chickens

Oxidative stress is seen as major factor during infectious and metabolic diseases in poultry. There are several enzyme systems within the body or natural plant bio-compound and vitamins (E, C) which scavenge free radicals (Nair et al., 2003). *Moringa oleifera* is known for its antioxidant properties, and its leaves are rich in antioxidant compounds which can protect cells from harmful free radicals (Siddhuraju & Becker, 2003; Valeria & Williams, 2011; Sharma et al., 2012; Luqman et al., 2012). *Moringa* leaf extracts could improve the activities of endogenous antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and glutathione-S-transferase (GST) (Sharma & Singh, 2010) and reduce lipid peroxidation (Nkukwana et al., 2014). Antioxidant enzymes (GST, SOD and CAT) act as a first barrier in the antioxidant defense system, and therefore higher levels of these enzymes in serum or tissues indicate strong antioxidant capacity (Surai et al., 2019). Rao et al. (2018) concluded that supplementation of *Moringa* leaves meal (0.05-0.1%) significantly reduced lipid peroxidation in the liver of broilers. *Moringa* meal supplementation to broiler diets reduced malondialdehyde (MDA) levels comparing to the control group (Karthivashan et al., 2015; Cui et al., 2018) and by laying hens (Darmala et al., 2018). Besides, the inclusion of 90 ml/L *M. oleifera* leaves extract in the drinking water of broiler chicken improved the performance by enhancing the antioxidant status and immune reaction (because of the presence of antioxidant and immunomodulatory properties) without any effect on metabolism of nutrients (Kumar et al., 2021). Regarding laying hens, Darmala et al. (2018) indicated that addition of 0.5% *Moringa* leaf meals significant increase the SOD and GSH in serum and egg yolk comparing to the control birds which was attributable to the antioxidant compounds in moringa leaf meal. Khan et al. (2021a) showed significantly lower concentrations of

MDA in serum which confirmed a reduction of oxidative deterioration in birds. *Moringa oleifera* leave meal lowered the MDA and significantly increased the activity of glutathione peroxidase in blood plasma of laying hens but no difference in total-SOD activity was observed among all studied groups (Wei et al., 2016). MDA is a secondary product of lipid oxidation and uses as an indicator of oxidative stability (Jiang & Xiong, 2016) and a reduction of MDA concentration in serum could be caused by the presence of high amount of antioxidants like flavonoids, ascorbic acids, tocopherol and saponins or due to the presence of various trace minerals such as Mn, Cu, Zn and Se, which play an important role in oxidative enzymes action (Makkar & Becker, 1997; Moyo et al., 2016). On the other hand, *M. olefeira* leaves aqueous extract (2 or 3%) in drink water had indicated no effect on the total antioxidant capacity (TAC) by broiler (Ross or Cobb breed) (Younis & Elbestawy, 2017). It has been suggested that season, agroclimatic locations environmental temperature and soil properties have significant effects on antioxidant activity of *M. oleifera* leaves (Iqbal & Bhanger, 2006; Leone et al., 2015).

## 7. Effects on Intestinal Microbiota in Chickens

Intestinal microbiota of animals has positive effects including maintenance of the intestinal epithelial integrity and barrier, immunomodulation, production of neurotransmitters and different metabolites such as vitamins and short chain fatty acids (CFAs) (Simon et al., 2001; Al-Asmakh & Zadjali, 2015; Sanchez et al., 2017) which can support the nutrition and the health of the host animals (Rinttilä & Apajalahti, 2013). Feed is an important environmental factor that can directly affect the host's gut microbiota (Yadav & Jha, 2019). From this point of view, it is well reported that the *M. oleifera* provides high quality primary nutrients (protein, energy, fiber and minerals) and secondary metabolites that are of great importance for the composition and activity of intestinal microbiota in chickens. Gaia (2005) stated that use of *M. oleifera* reduce the activity of pathogenic bacteria and moulds. *Moringa oleifera* is rich in antibacterial substances, roots and flowers contain pterygospermin, which has powerful antibacterial and fungicidal effects (Rao et al., 2001). The fresh leaf juice was found to inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Caceres et al., 1992). Studies suggested that *Moringa* leaves contain bio-components or secondary metabolites such as tannins, alkaloids, flavonoids with antibacterial potentials against all Gram-negative and Gram-positive bacteria tested (Anwar et al., 2007; Rahman et al., 2009; Abd El-Moez et al., 2014). Moreover, Suarez et al. (2003) and Prabhll et al. (2011) found *M. oleifera* extracts had bacteriostatic and bactericidal effects on *S. aureus*. Also, *Moringa* leaves have high saponins concentrations which could affect the intestinal microbiota (Alabi et al., 2017; Wina et al., 2017). *Moringa* based feed additives have the potential to improve gut health of broiler chickens by increasing beneficial bacteria and by reducing pathogens (David et al., 2016). Application of *M. oleifera* in broiler feed at 0-2% decreased the microbial load and coliform population compared with the control (Divya et al., 2014). Also, it was noted that addition of *Moringa* leaves have an inhibiting effect against pathogen proliferation and at the same time an enhancing effect on the beneficial microbes (Teteh et al., 2017). Younis and Elbestawy (2017) found that water supplementation of *M. oleifera* leaves aqueous extract slightly increased *Lactobacillus* count as beneficial bacteria in the intestinal tract. In similar study, the inclusion of *M. oleifera* extracts strongly inhibited the increase of bacteria and fungi (Castillo et al., 2018). On the other hand, results revealed that there was no significant effect on total viable intestinal bacterial and coliform count among broiler chickens fed 0, 1, 5 and 7.5% *M. oleifera* leaf powder (Abd El-Ghany & Eraky, 2020). Abu Hafsa et al. (2020) showed that broilers received 1 and 5% *M. oleifera* leaf meal in their feed had a significantly lower ileum pH, which possibly led to changes in the composition of the commensal intestinal microbiota, and they concluded that *M. oleifera* leaf supplement reduced the levels of harmful micro-organisms and promoted at the same time the growth of beneficial bacteria in broilers' microbiota. A recent study showed that addition of *Moringa* polysaccharides in feed could cause an increase of beneficial bacteria and a decrease of harmful bacteria in caecum (Tian et al., 2021). So, these above-mentioned results indicate that *M. oleifera* leaf meal may have a positive and beneficial effect on gut microbiota which might lead to improving nutrients digestibility and the healthy status of broilers and layers.

## 8. Conclusion

The *Moringa oleifera* leaf could be used as a good feed material. It was shown to be effective without any adverse effects in poultry production and studies have demonstrated an improvement in growth and egg laying performance and also better quality of carcass and eggs. This improvement could be attributed to its composition like macro- and micronutrients and bioactive compounds which additionally reduce oxidative stress, have antimicrobial activity and modulate the gut microbiota and thus can promote health status of birds. Otherwise, several studies indicated that high addition of *M. oleifera* leave reduced the performance by broiler and layers due to the presence of antinutritional factors such as tannins, phytate, phenols and saponins. Effects of *M. oleifera* leaves meal on the ileal nutrient's digestibility and gut microbiota, have not yet been widely studied. In addition, further studies in conjunction with other additives such as probiotics, enzymes and phytogenic are needed to determine whether this combination will have potential synergistic effects in poultry production.

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