DOI: 10.54083/ResBio/6.1.2024/17-27

Res. Bio., 2024, 6(1):17-27

Research Biotica

Crossref

e-ISSN: 2582-6743

January-March, 2024

Article ID: RB205

Review Article

Value and Prospects of *Moringa oleifera* as Non-Conventional Feedstuff in Livestock Production: A Review

Adeyinka Oye Akintunde[1*], Lois Chidinma Ndubuisi-Ogbonna[1], Bolatito Adenike Shobo[1], Olufunso Emmanuel Akinboye[1], Rufus Olusegun Animashaun[2] and Oluwafunmike Omowunmi Oyekale[1]

[1]*Dept. of Agriculture and Industrial Technology, Babcock University, Ilishan-Remo, Ogun State (PMB 4003), Nigeria*
[2]*Dept. of Basic Sciences, Babcock University, Ilishan-Remo, Ogun State (PMB 4003), Nigeria*

Corresponding Author

Adeyinka Oye Akintunde

✉: adeyinka.akintunde@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Akintunde, A.O., Ndubuisi-Ogbonna, L.C., Shobo, B.A., *et al*., 2024. Value and Prospects of *Moringa oleifera* as Non-Conventional Feedstuff in Livestock Production: A Review. *Research Biotica* 6(1), 17-27. DOI: 10.54083/ResBio/6.1.2024/17-27.

Abstract

There is need to improve livestock production in Africa and developing countries across the world, to combat dietary animal protein insufficiency. *Moringa oleifera* is a fast growing plant that thrives well in almost all climatic conditions and is proven to contain high levels of protein (26% in dried leaf), vitamins, minerals and phytochemicals which have antioxidant, antibiotic, anti-inflammatory and other properties and show a lot of prospects for organic agriculture, particularly in the current climate of consumer ambivalence about use of synthetic antibiotics and other additives in the livestock industry. The leaves have been proven to contain all the essential amino acids, the anti-nutritional factors are minimal and it is a proven hypocholesterolemic agent; it therefore has good potential for use particularly in poultry and swine production towards satisfying animal protein and mineral requirements and for satisfying consumer demand for lean meat. Whole seed and its components have desirable but largely untested properties for animal feeding, as does leaf stalk (rich in fibre, minerals and desirable phytochemicals). Woody stem is a potential source of bactericidal/ bacteriostatic bedding/ litter and when combusted may augment traditional fuels for supplying heat for brooding chicks or general heating of livestock housing in colder climes. Scientists should therefore be encouraged to research and demonstrate safety and effectiveness of *Moringa oleifera* products and by-products in animal agriculture and equally, crop farmers should be encouraged to take up moringa farming to enlarge supply and lower price per unit which is a critical requirement for its adoption in animal farming.

Keywords: Feeds and feeding, Livestock, *Moringa oleifera*, Non-conventional feedstuff, Poultry

Introduction

The Moringaceae family includes *Moringa oleifera*. The tree is expanding swiftly. In its first year of growth, moringa can reach a height of three meters. Dry conditions are ideal for moringa's growth and it can endure droughts. From the Indian subcontinent, it is neutralized everywhere in the world that is tropical. The *Moringa oleifera* tree, sometimes referred to as the horseradish tree or drumstick tree, grows quickly and is resistant to drought. It can grow as a tree or shrub and usually reaches a height of about 12 meters (Fuglie, 2001; Olson, 2002; Radovich, 2009; Korsor *et al.*, 2016). Beyond its impressive growth, Moringa has gained interest for its potential health benefits. Studies have shown that it has antibacterial, anti-inflammatory, antitrypanosomal, antispasmodic, antiulcer, hypotensive, hypocholesterolemic and blood sugar-lowering properties (Eilert, 1978; Eilert *et al.*, 1981; Ezeamuzie *et al.*, 1996; Awodele *et al.*, 2012; Akintunde *et al.*, 2021a). This has led to recent exploration of Moringa as a valuable addition to livestock feed.

Article History

RECEIVED on 02nd December 2023 RECEIVED in revised form 01st March 2024 ACCEPTED in final form 08th March 2024

Balakumbahan *et al*. (2020) also concluded that the nutrient-dense (vitamins, minerals, dietary fiber, protein and antioxidants) *Moringa oleifera* leaf promotes a healthy lifestyle through its medicinal qualities and nutraceuticals.

Moringa oleifera Parts

Leaves

Moringa leaves are a nutritional powerhouse, packing essential vitamins and minerals that can help ward off illness. They even contain every essential amino acid, which is rare in plant-based diets. Numerous of these nutrients are present in higher concentrations in the concentrated dried leaves, with the exception of vitamin C (Islam *et al.*, 2021).

Seed

Because of their antibacterial and anti-inflammatory properties, *Moringa oleifera* seeds are mainly used to treat boils, rheumatism, gout, cramps and STDs. *Pseudomonas aeruginosa* and *Staphylococcus aureus* are two bacteria that cause skin infections; moringa seeds help prevent them. The seeds contain terygospermin, a potent fungicide and antibiotic. Moringa seeds are multi-talented. They can be extracted to yield oil for cooking or turned into flavorful curry powder. Perhaps most surprisingly, Moringa seeds can even be used to purify water (Saa *et al.*, 2019).

Flowers

Moringa oleifera flowers are used in various ways: mothers drink the juice to potentially boost milk production, a tea made from boiled flowers is believed to aid urinary problems and in Haiti, it is a common cold remedy (Fuglie, 2001).

Pods

Pods help with joint pain, spleen and liver problems and deworming. Their high fiber and protein content makes them useful in the treatment of malnourishment and diarrhea. Bioactive substances with anti-inflammatory properties are present in *M. oleifera* pod constituents and they may help to mitigate the pathophysiology of chronic diseases linked to inflammation (Muangnoi *et al.*, 2012).

Nutritional Value

The leaves of *Moringa oleifera have* much potentials as animal feed. The leaves are loaded with protein, vitamins and minerals; they offer a valuable source of nutrition for animals. These leaves are particularly noteworthy for their protein content, containing all the essential amino acids that cattle need to grow and develop properly. The leaves of *Moringa oleifera* are also abundant in vital minerals like calcium, potassium and iron, alongside vitamins A, B and C. This rich blend of nutrients is vital for maintaining overall animal health and productivity. Moringa leaves are a valuable addition to animal feed. The composition of *Moringa oleifera* seed meal (MOSM) as reported was as follows: 16.39 MJ kg^{-1} energy; 21.67 M.eq. kg^{-1} cyanide, 0.11% phenol, 0.09% tannin, 1.16% alkaloid, 18.90% saponin and 0.07% glucosinolate; 3.67% ash, 53.13% carbohydrates, 17.88% crude fiber, 36.50% crude fat and 21.67% crude protein (Akintunde and Toye, 2014). The fully grown seeds have the following composition: 412.0 g of crude fat, 211.2 g of carbohydrates, 332.5 g of crude protein and 44.3 g of ash kg^{-1} of dry matter. The profile of essential amino acids revealed deficiencies in valine, threonine and lysine. The protein content of 43.6 g kg^{-1} of cysteine + methionine was significantly higher than that of human milk, chicken eggs and cow's milk. The findings revealed that the percentages of protein, fiber and ash were 26.50-32.0%, 5.80-9.29% and 5.60-7.50%, in that order (Dahot and Memon, 1985).

Oluwaniyi *et al.* (2020) conducted a proximate analysis of various plant parts, revealing diverse composition ranges. Ash content ranged from 4.00% to 12.13%, protein from 7.53% to 38.23%, moisture from 29.7% to 76.48%, crude fat from 8.70% to 25.8% and crude fiber from 21.1% to 27.7%. Vitamin C content varied among parts, with the stem bark at 7.85 mg g^{-1}, seeds at 14.42 mg g^{-1} and leaves at 19.34 mg g^{-1}. Mineral content ranged from 4.50 to 13.70 mg kg^{-1} for copper, 19.75 to 73.25 mg kg^{-1} for zinc, 0.00 to 0.25 mg kg^{-1} for cadmium and 11.75 to 23.50 mg kg^{-1} for nickel, with no lead detected. Antioxidant activity, measured using DPPH scavenging capacity, showed that at low extract concentrations (5 µg ml^{-1}), the seeds exhibited the highest activity (64.53±1.96% inhibition), whereas at high concentrations (125 µg ml^{-1}), the leaves showed the highest activity (82.79±0.79% inhibition). All of the components fell short of the benchmark BHA's antioxidant activity, which ranged from 96.30% to 99.81% (Oluwaniyi *et al.*, 2020).

According to Guevara *et al.* (1999), the seeds' crude ethanolic extract exhibited anti-tumor activity against the early antigen of the Epstein-Barr virus (EBV-EA). According to Grubben and Denton (2004), 100 g of the edible leafy tips of *Moringa oleifera* contain the following nutrients: 268 kJ (64 kcal), 78.7 g of water, 9.4 g of protein, 1.4 g of fat, 8.3 g of carbohydrates, 2.0 g of total dietary fiber, 185 mg of calcium, 147 mg of magnesium, 112 mg of phosphorus, 4.0 mg of iron, 0.6 mg of zinc, 7564 IU of vitamin A, 0.3 mg of thiamine, 0.7 mg of riboflavin, 2.2 mg of niacin and 51.7 mg of carotenes.

Bosch (2004) stated that 100 g of the plant's raw fruits have the following nutritional value: energy 155 kJ (37 kcal), water 88.2 g, protein 2.1 g, fat 0.2 g, carbohydrates 8.5 g, total dietary fiber 3.2 g, calcium 30 mg, magnesium 45 mg, potassium 50 mg, iron 0.4 mg, zinc 0.4 mg, 44 µg of folate,

Table 1: Nutritional analysis (g/ 100 g) of different plant parts *Moringa oleifera*

Sample	Moisture %	Ash %	Crude fat %	Crude fibre %	Protein %	Vitamin C (mg g^{-1})
Seeds	29.70± 5.12^{a}	4.00±1.00^{a}	25.80±0.04^{c}	21.10±2.4^{c}	38.23±0.59^{c}	14.42^{b}±2.03
Stem bark	76.48±1.05^{b}	12.13±4.63^{b}	8.70±0.08^{a}	27.70±3.03^{c}	7.53±0.90^{a}	7.85^{b}±0.54
Leaves	73.66±0.57^{b}	6.33±4.51^{a,b}	16.88±1.26^{b}	25.85±5.55^{c}	12.97±1.39^{b}	19.34^{c}±0.26

thiamin 0.05 mg, riboflavin 0.07 mg, niacin 0.6 mg, and 44 µg of vitamin A. The analysis of moringa's nutrients was shown in table 1.

Results are means ± standard deviations of triplicate determinations. Values in the same column having the same letter superscript are not significantly different at $p<0.05$. NB: Moisture was done on wet basis while other determined based on the dry matter (Source: Oluwaniyi *et al.*, 2020)

The results of a study by Oluwaniyi *et al.* (2020) showed that, in comparison to the stem bark and seeds, *Moringa oleifera* leaves have higher concentrations of important minerals like sodium, potassium, calcium, magnesium and iron and this was presented in table 2. These results therefore suggest that the leaves can make a substantial contribution to animal nutrient requirements and ought to be included in diets especially if organic agriculture is to be embraced. The leaves could supply the mineral needs of ruminant animals hence there would be reduction in the demand for mineral licks thus lowering the cost of production in ruminant animals' enterprise.

Table 2: Macro-elements of *Moringa oleifera* (g kg^{-1})

Sample	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)
Seeds	8.88	9.52	0.91	2.24	0.14
Stem bark	12.95	12.96	23.38	3.38	0.18
Leaves	16.09	17.62	236.25	38.75	0.19

(Source: Oluwaniyi *et al.*, 2020)

Table 3: Micro-elements of *Moringa oleifera* (mg kg^{-1})

Sample	Copper (Cu)	Zinc (Zn)	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)
Seeds	5.75	73.25	0.00	0.00	23.50
Stem bark	4.50	19.75	0.00	0.00	11.75
Leaves	13.75	39.00	0.25	0.00	13.25

(Source: Oluwaniyi *et al.*, 2020)

The zinc and nickel contents of the seeds were highest, whereas the copper and cadmium contents of the leaves were highest, according to the observations of Oluwaniyi *et al.* (2020) and presented in table 3. Lead was absent from every part, but cadmium was absent from the seeds and stem bark. This suggested that the plant is safe for consumption by poultry and livestock as there would not be the fear of lead poisoning. Table 4 also showed an examination of the nutritional content of dried leaf powder, fresh (raw) leaves and moringa pods per 100 g of edible portion.

In a proximate analysis in three regions-Ife and Lafia in Nigeria and South Africa, the nutrient compositions observed varied from region to region. This implies that the nutrient composition of *Moringa oleifera* can be influenced by the diverse weather conditions as well as the nutrient composition of the soil in which it is planted. The nutrient composition was higher in South Africa followed by Ife in Nigeria and least in Lafia in Nigeria as presented in table 5.

Table 4: Nutritional analysis of moringa pods, fresh (raw) leaves and dried leaf powder per 100 g of edible portion

Components	Pods	Leaves	Leaf Powder
Moisture (%)	86.90	75.00	7.50
Calories	26.00	92.00	205.00
Protein (g)	2.50	6.70	27.10
Fat (g)	0.10	1.70	2.30
Carbohydrates (g)	3.70	13.40	38.20
Fibre (g)	4.80	0.90	19.20
Minerals (g)	2.00	2.30	-
Ca Calcium (mg)	30.00	440.00	2003.00
Cu Copper (mg)	3.10	1.10	0.57
Fe Iron (mg)	5.30	7.00	28.20
K Potassium (mg)	259.00	259.00	1324.00
Mg Magnesium (mg)	24.00	24.00	368.00
P Phosphorus (mg)	110.00	70.00	204.00
S Sulphur (mg)	137.00	137.00	870.00
Se Selenium (mg)	-	-	0.09
Zn Zinc (mg)	-	-	3.29
Oxalic acid (mg)	10.00	101.00	1600.00
Vitamin A (mg)	0.11	6.80	18.90
Vitamin B (mg)	423.00	423.00	-
Vitamin B_1 (mg)	0.05	0.21	2.64
Vitamin B_2 (mg)	0.07	0.05	20.50
Vitamin B_3 (mg)	0.20	0.80	8.20
Vitamin C (mg)	120.00	220.00	17.30
Amino Acids			
Arginine (mg)	90.00	402.00	1325.00
Histidine (mg)	27.50	141.00	613.00
Isoleucine (mg)	110.00	422.00	825.00
Leucine (mg)	163.00	623.00	1950.00
Lysine (mg)	37.50	288.00	1325.00
Methionine (mg)	35.00	134.00	350.00
Phenylanaline (mg)	108.00	429.00	1388.00
Threonine (mg)	98.00	328.00	1188.00
Tryptophan (mg)	20.00	127.00	425.00
Valine (mg)	135.00	476.00	1063.00

(Source: Booth and Wickens, 1988; Posmontier, 2011)

Furthermore, Becker (1995) conducted a comparative analysis to determine the nutritional value of dried *Moringa oleifera* leaves in three different countries: Niger, Nicaragua and India. Table 6 shows that India had the highest values for CP, Ash, NDF, ADF and ADL, while Nicaragua had the highest value for Gross Energy and Niger the highest value for CL.

Table 5: Proximate composition of *Moringa oleifera* in Ife and Lafia, Nigeria and South Africa

Particulars	Ife, Nigeria	Lafia, Nigeria	South Africa
Dry Matter (%)	87.70	96.79	90.48
Crude Protein (%)	23.50	17.01	30.29
Crude Fibre (%)	28.20	7.09	-
Ether Extract (%)	5.50	2.11	6.50
Ash (%)	5.90	7.93	7.64
Organic Matter (%)	94.10	-	-

[Sources: Odeyinka *et al*. (2008); Ogbe and Affiku (2011); Moyo *et al.* (2011)]

Table 6: Nutrient composition of *Moringa oleifera* leaves in India, Nicaragua and Niger

Country	CP	CL	Ash	NDF	ADF	ADL	GE
India	33.0	5.7	11.8	31.4	15.1	5.4	18.9
Nicaragua	26.2	5.2	8.9	23.2	12.1	2.1	20.1
Niger	28.5	9.6	9.4	28.7	13.1	2.8	19.7

Note: CP - Crude Protein, CL - Crude Lipid, NDF - Neutral Detergent Fibre, ADF - Acid Detergent Fibre, ADL - Acid Detergent Lignin, GE - Gross Energy (MJ g^{-1}) (Source: Becker, 1995)

The sensitivity of the nutrients to light, heat and oxygen are the factors that influence the nutrient content following food processing. The mineral contents of Moringa leaf samples varied depending on the drying methods employed, as well as the macro- and micromineral contents of the samples from different locations, according to a study by Gyamfi *et al.* (2011). They tried air, freeze and oven drying; however, because air drying lost less minerals, they came to the conclusion that air drying was the most effective method for drying *Moringa oleifera* leaves. But according to Price (2007), drying *Moringa oleifera* leaves in the shade will prevent vitamin A and other vitamin loss. It was believed that when leaves are dried in direct sunlight, only 20-40% of the vitamin A content is retained; when leaves are dried in the shade, 50-70% of the vitamin A content was thought to be retained (Subadra *et al.*, 1997).

In a research by Manh *et al.* (2005) the composition of the plants was found to be unaffected by plant spacing, but the amount of dry matter was low (16-19%) because the plants were harvested during the rainy season. The study evaluated *Moringa oleifera* for biomass production and as goat feed in the Mekong Delta. A high ether extract value suggests a rich source of pigments and carotene (Foidl *et al.*, 2001). The result of their findings is presented in table 7.

Table 7: Effect of plant spacing on the composition of Moringa (% in DM, except for DM which is on fresh basis)

Particulars	Space (cm)		
	40×20	40×30	40×40
Dry Matter (DM)	18.90	17.66	16.80
Ash	8.57	7.91	8.38
Organic Matter (OM)	91.43	92.09	91.62
Crude Protein (CP)	25.54	26.39	25.92
Neutral Detergent Fibre (NDF)	21.50	24.09	22.83
Acid Detergent Fibre (ADF)	17.06	18.26	17.78
Ether Extract (EE)	10.22	11.04	11.47

(Source: Manh *et al*., 2005)

Response of Animals to Utilization of *Moringa oleifera*

In a research by Akintunde and Toye (2014), the effect of *Moringa oleifera* seed meal (MOSM) on performance traits and nutrient retention was investigated for Yoruba Ecotype Nigerian Local Chickens (YENLC) and Marshall broilers. It was found that the birds fed 5% MOSM had a significantly higher body weight (p<0.05) than the birds fed other treatments. Furthermore, they reported that YENLC fed 10% MOSM had the significantly highest weight and YENLC fed 5% MOSM had the best FCR. Furthermore, the retention of crude fiber was found to be superior in YENLC and Marshall broilers fed up to 15% MOSM; on the other hand, the best retention of total ash and carbohydrates was observed in YENLC fed 5% MOSM. Nevertheless, they concluded that genotypes affected the performance of chickens and the patterns of nutrient retention. Furthermore, they proposed that YENLC and Marshall broiler chicken genotypes would benefit from feeding 5% MOSM in relation to nutrient retention, feed conversion ratio and weight gain.

Subtle variations in the dietary levels of Undecorticated Undefatted *Moringa oleifera* Seed Meal (UUMOSM) were found to significantly influence the biological growth program of young broilers in a different study by Toye *et al.* (2013) on the nutrigenetic effect of *Moringa oleifera* seed meal on the biological growth program of young broiler chickens. Size and the relationships between various body parts, such as shape and conformation, were affected by this. They also demonstrated how estimates of inter-trait relationships within populations are influenced by substructures, such as groups with voluntary or forced non-overlapping eating habits.

Akintunde *et al.* (2020a) conducted a study to investigate the correlation between the dietary levels of *Moringa oleifera* (Lamarck) seed meal and the body weight and morphometric traits of both exotic and local chickens. The findings demonstrated that every association was positive and that the degree to which body weight and body morphometric parameters were related changed when MOSM was included. As MOSM levels increased, the relationship between morphometric parameters and body weights weakened considerably (p<0.05) (r decreased from 0.72 to 0.52). However, they concluded from their research that feeding 5% MOSM to YENLC and Marshall broiler chickens would improve their growth performance.

To support this, Akintunde *et al.* (2021b) also noted that the performance of YENLC and Marshall broilers was greatly affected by the addition of MOSM to their diet and that the responses varied depending on the genotype.

The results of a different study by Akintunde and Toye (2023) compared the egg qualities of Isa Brown and Yoruba Ecotype Nigerian Local Chickens fed varying amounts of *Moringa oleifera* seed meal. The study's conclusions indicated that the inclusion of MOSM in the diet had an impact on the study also examined how MOSM impacted egg quality in two chicken breeds: YENLC (Yoruba Ecotype Nigerian Local Chicken) and Isa Brown. Higher levels of MOSM (over 5%) led to smaller eggs with lighter yolks (significant decrease in egg length, width, yolk weight and height, $p<0.05$). Interestingly, the effect of MOSM depended on the chicken breed ($p<0.05$ interaction). While both breeds laid more eggs with up to 5% MOSM, egg production declined with higher MOSM levels. Overall, the study suggests that YENLC chickens might tolerate MOSM better at higher levels (15%), but for both breeds, a maximum of 10% MOSM inclusion seems optimal. Furthermore, Akintunde and Toye (2021) reported that this study investigated how *Moringa oleifera* seed meal (MOSM) affected egg weight prediction in chickens. They fed chickens increasing levels of MOSM (0% to 15%) and observed a surprising result. The relationship between a chicken's body size and the weight of its eggs became weaker (statistically significant decrease, $p<0.05$) as the MOSM content in their diet increased. This suggests that MOSM may influence egg weight independently of a chicken's size, especially for the breeds studied (YENLC and Isa Brown hens).

A study by Riry *et al.* (2018) investigated the effects of replacing some soybean meal in quail diets with varying levels of MOSM (5%, 7.5% and 10%) during their egg-laying period. The quail fed these MOSM diets showed improvements in several areas:

• *Egg Quality*: The overall quality of the eggs, including performance and HDL cholesterol levels, increased.

• *Antioxidant Capacity*: The quail fed MOSM diets had a stronger overall antioxidant defense system.

• *Reproductive Health*: The study also found positive impacts on the reproductive health of the quail.

M. oleifera can be used as green fodder on its own or in conjunction with other crops or concentrate feeds to improve ruminant performance, including growth rate, yield, and milk composition. It poses no harm to the health of animals. The beneficial nutritional composition of *M. oleifera*, which contains proteins and bioactive substances like phenolics, flavonoids, glucosinolates, carotenoids, sterols, saponins, tannins, and isothiocyanates, may be responsible for the increased productivity (Amad and Zentek, 2023). It has also been demonstrated that this plant can be grown in large quantities, suggesting that it could be a great carbon dioxide sink that absorbs and uses carbon dioxide to lessen the amount of carbon dioxide that humans contribute to the atmosphere. Furthermore, ruminal methane emissions are dramatically reduced when cattle and other ruminants are fed *M. oleifera* leaves or seeds, which may help them adjust to farming practices that are more climate-friendly. Therefore, using moringa can contribute sustainably to boosting animal production, particularly in nations with scarce feed supplies (Amad and Zentek, 2023).

Studies in Nicaragua have shown impressive results when Moringa leaves and stems are added to cattle feed. These natural supplements led to significant increases in both milk production (by 43-65%) and daily weight gain (by 32%) (Fuglie, 2000; Foidl *et al.*, 2001). This highlights the potential of Moringa as a cost-effective way to improve cattle health and productivity for farmers.

When Manh *et al.* (2005) compared the feeding practices (hanging and trough) of *Leucaaena leucocephala* and *Moringa oleifera*, they found no appreciable variations in either nitrogen retention or nutrient digestibility. The reason for this could be that the goats' eating and ruminating rates differ based on the kind of feeding they receive, or it could be due to the way the leaves are attached to the petioles and stems, which can be easily detached in the case of both Leucaena and Moringa. They also noted that while all of the test goats ate Leucaena with ease, Moringa did not win over the goats right away when it was offered as the only food; however, after two days of adaptation, Moringa did gain acceptance. Consequently, they surmised that the indigenous goats could be more circumspect and picky than the exotic variety, which was seen to eat the moringa with ease right from the start. They concluded that moringa foliage can be used as goats' only feed because, among other things, no health problems occurred during the Leucaena or moringa experimental period.

Studies have shown that Moringa leaves can be a valuable addition to sheep feed. Compared to traditional alfalfa diets, Moringa improved both average daily weight gain and milk yield in Najdi ewes (Babiker *et al.*, 2016; 2017). Moringa also holds promise for fattening lambs. Research by Sultana *et al.* (2017) found that lambs fed rice straw supplemented with Moringa foliage (75% or 100%) had good carcass characteristics, with less subcutaneous fat and positive growth performance. These findings suggest Moringa can be a beneficial and cost-effective feed option for sheep farmers.

In the past, animal feeds were made with soybean meal; however, studies have indicated that giving cows' daily doses of Moringa leaves can boost their milk production from 32% to 60%. When beef cattle consumed moringa feed, they gained 1,200 g of weight every day. The weight gain day^{-1} without the Moringa feed was 900 g. According to a study conducted by Japanese poultry experts, feeding laying chickens with moringa meal produces the desired effects. Fish feed was also made of granulated moringa seed cake (Foidl *et al.*, 2001).

A series of studies have highlighted the potential of Moringa leaves as a valuable feed supplement for livestock, particularly cattle. Sánchez *et al*. (2006) found that supplementing dairy cows' diets with Moringa increased milk production and improved milk composition. Similarly, Sonkar *et al*. (2020) reported that replacing a portion of the concentrate with dried Moringa leaves in the diet of lactating cows was cost-effective and did not negatively impact their health. Briones *et al.* (2017) further supported these findings, demonstrating that Moringa supplementation improved the growth performance of goats and broiler chickens, as well as the laying performance of quails and layer chickens. Teteh *et al.* (2013) also found that incorporating Moringa leaves in broiler feed improved growth and feed conversion. These studies collectively suggest that Moringa leaves have the potential to enhance livestock production, particularly in terms of milk yield and weight gain in cattle.

Studies suggest Moringa leaves can be a valuable feed supplement for swine and poultry. Research by Price (2007) indicates that adding the enzyme phytase to Moringa leaves can further enhance their nutritional value. Phytase helps break down phytates, improving phosphorus absorption by these animals. However, it's important to add the enzyme without heating the leaves to preserve their nutrients. The same study reported interesting observations on the effects of Moringa on Jersey calves. When Moringa comprised 40-50% of their feed, the average birth weight has increased by 3-5 kg. Additionally, there was a significant rise in twin births, from an average of 1 in 1,000 to 3 per 20 births. While more research is needed to confirm these findings, they suggest Moringa has the potential to improve animal health and productivity in various ways.

For use in livestock feed, moringa leaf concentrate can occasionally be preferred over fresh leaves. Although chickens will not voluntarily eat moringa leaves or powder (Price, 2007), but will do so when incorporated at low levels (published evidence exists for up to 30% in feed). On the other hand, a concentrate made from about half of the protein content of the leaves can be added to chicken feed, among many other applications. In chicken feed, a 22% protein content is preferred. Price (2007) proposed that moringa leaves be combined with water and then put through a hammer mill in order to extract the concentrate. For ten minutes, this mash needs to be heated to 70 °C. After clumping, the protein will sink to the bottom. The liquid can be poured off and the protein can then be freeze-dried according to Price (2007).

A summary of recent concerted researches on the utilization of Moringa as a non-conventional poultry feedstuff are presented in Tables 8 and 9.

Studies suggest *Moringa oleifera* may hold promise for managing both acute and chronic inflammatory diseases due to its anti-inflammatory properties. However, it is important to note that an earlier study by Fabiyi *et al.* (1993) reported Moringa leaves as a source of free radicals, which can actually contribute to inflammation. More research is needed to fully understand the interplay between Moringa's various components and their effects on the body.

Table 8: Effect of *Moringa oleifera* on serum and yolk cholesterol

Variable	1	2	3	4	SEM
Serum Cholesterol (mg dl^{-1})	181[a]	155[ab]	145[b]	141[b]	25.1
Yolk Cholesterol	282[a]	263[a]	261[a]	248[a]	17.3

(Source: Olugbemi *et al*., 2010)

Studies have investigated the antimicrobial activity of various Moringa parts (leaves, roots, bark and seeds) against different pathogens, including bacteria, yeast, fungi that cause skin infections (dermatophytes) and parasitic worms (helminths). Researchers found that aqueous extracts from seeds and fresh leaf juice were particularly effective in inhibiting the growth of common bacteria like *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Encouragingly, a study using mice showed that Moringa seed extract displayed strong antibacterial activity against *S. aureus*, the bacteria responsible for skin infections like pyodermia (Fahey *et al.*, 2004).

Studies suggest *Moringa oleifera* may hold promise for heart health. Research suggests various parts of the Moringa pod, including the whole pod, its coat, pulp and seeds, along with extracts (both ethanol and water-based), may have hypotensive effects, potentially helping to lower blood pressure (Delisle and Bakari, 1997). Additionally, some studies have investigated Moringa's impact on cholesterol levels. A study by Mehta *et al.* (2011) found Moringa fruits to have a hypolipidaemic effect, meaning they may help lower blood fat levels. In a study with hypercholesterolemic rabbits, Faizi *et al.* (1998) observed that Moringa consumption increased the "good" high density lipoprotein (HDL) cholesterol levels (HDL-to-total cholesterol ratio) while decreasing overall cholesterol, phospholipids, triglycerides and other markers associated with increased heart disease risk.

A study by Akintunde *et al.* (2021a) investigated the effects of MOSM on local YENLC and exotic Marshall broiler chickens. While the study found promising results for weight management and heart health, there were also some trade-offs to consider.

Positive Effects

• *Reduced Body Mass Index (BMI)*: Chickens fed the highest MOSM level (15%) had significantly lower BMI, suggesting potential benefits for weight management.

• *Lower Cholesterol*: MOSM consumption led to significantly lower cholesterol levels compared to the control group.

• *Increased Heart Weight*: Interestingly, MOSM intake was linked to increased relative heart weight, which could be a positive sign of a stronger heart muscle.

Potential Concerns

• *Kidney Function*: Higher MOSM levels were associated with increased creatinine levels, a marker of kidney function.

• *Liver Function*: While cholesterol decreased, MOSM also increased alanine transaminase (ALT) levels, an enzyme linked to liver damage. The study suggests this may not be a significant concern, but close monitoring is advisable.

• *Increased Liver Weight*: Similar to heart weight, MOSM intake was linked to increased relative liver weight. More research is needed to understand the implications of this finding.

Table 9: Daily laying percentage, feed intake, egg weight and feed conversion ratio of the laying chickens fed with different levels of *Moringa oleifera* leaf meal in Tanzania and *Moringa oleifera* seed meal in Yoruba Ecotype Nigerian Local Chickens and Isa Brown Hens

Particulars	0%			5%		10%			15%			20%
	Tanzania	YENLC	Isa Brown	YENLC	Isa Brown	Tanzania	YENLC	Isa Brown	Tanzania	YENLC	Isa Brown	Tanzania
Daily laying percentage, %	80.40	8.33	82.14	5.32	76.19	79.30	4.76	63.10	77.30	4.76	65.48	75.40
Daily feed intake, g bird^{-1}	109.00	129.67	109.75	113.42	109.42	108.00	110.17	129.08	112.00	103.75	105.92	115.00
Egg weight, g	53.20	32.85	50.39	29.35	49.65	54.20	30.61	42.02	53.50	25.73	42.84	52.50
Feed conversion ratio, kg feed kg^{-1} eggs	2.71	3.96	2.18	3.55	2.22	2.64	3.60	3.08	2.90	4.04	2.47	3.29

YENLC: Yoruba Ecotype Nigerian Local Chickens [Sources: Kakengi *et al*. (2007) and Akintunde *et al*. (2023)]

• *Breed Differences*: The YENLC chickens seemed to tolerate higher MOSM levels with less pronounced increases in some enzyme levels compared to the Marshall broilers.

Moringa seed meal shows promise for promoting weight management and heart health in chickens. However, the potential impact on kidney and liver function warrants further investigation. Additionally, breed-specific responses suggest tailoring MOSM inclusion levels based on chicken types (Akintunde *et al.*, 2021a).

Akintunde *et al.* (2019) investigated how MOSM affects blood cell health in local YENLC and imported Marshall broiler chickens. Their study focused on both genetic variations and dietary MOSM levels. It was observed on the overall blood cell counts that adding MOSM to the diet significantly increased red blood cell counts (RBC), white blood cell counts (WBC), packed cell volume (PCV) and hemoglobin concentration (Hb) ($p<0.05$). This suggests MOSM may have potential to improve overall blood health in chickens. While RBC counts increased, some red blood cell characteristics changed with higher MOSM levels. Mean corpuscular hemoglobin concentration (MCHC) increased significantly ($p<0.05$) in Marshall broilers, while mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) decreased significantly ($p<0.05$). Also, all types of white blood cells measured (monocytes, lymphocytes, eosinophils and heterophils) increased significantly ($p<0.05$) with increasing MOSM levels, except for basophils in YENLC chickens (which only increased significantly from 5% to 15% MOSM). This suggests MOSM may influence the immune system in chickens. The study also revealed breed-specific responses. YENLC chickens seemed to tolerate higher MOSM levels with less pronounced changes in some blood cell parameters compared to Marshall broilers. This study suggests that MOSM has the potential to improve blood health in chickens.

Studies have investigated the effects of *Moringa oleifera* extracts on rat reproduction (Fuglie, 1999, 2000; Galan *et al.* 2004; Attah *et al.*, 2020).

• *Anti-Fertility Effects*: Aqueous extracts from the root and bark, at specific doses, were found to prevent pregnancy in rats (Fuglie, 1999).

• *Fetal Impact*: Aqueous extracts of the root and bark, at 200 mg kg^{-1} and 400 mg kg^{-1}, respectively, induced foetal reabsorption in late pregnancy and had an anti-fertility effect after coiteration in rats (Fuglie, 1999). Additional studies suggest that the root's aqueous or ethanolic (90%) extract had teratogenic and abortifacient properties (Fuglie, 2000).

• *Hormonal Influence*: Research suggests that the root extract may interfere with estrogen and progesterone, hormones crucial for pregnancy (Galan *et al.* 2004).

Mechanism of action: One study observed changes in the female reproductive organs of spayed rats exposed to the root extract (Gassenschmidt *et al.*, 1995), hinting at a potential impact on reproductive function. The observed a biphasic effect on the adult intact rat's oestrus cycle periodicity (Gassenschmidt *et al.*, 1995). Rats showed anti-implantation activity when exposed to an aqueous extract of roots (Attah *et al.*, 2020).

A study by Akintunde *et al.* (2020b) investigated how MOSM affects sperm quality in both local YENLC and exotic Isa Brown cocks. Their findings suggest MOSM may benefit sperm health, but the optimal level depends on the breed. For YENLC, including MOSM in the diet (especially at 10% and 15%) significantly improved semen volume, sperm concentration and mass activity (a measure of sperm movement) compared to no MOSM. While for Isa Brown cocks, the sperm concentration improved across all MOSM levels, the best results for mass activity and motility were seen at 10% MOSM. Semen volume was better at inclusion levels of 5% and 15% MOSM. The study suggests that for YENLC, a 10% MOSM diet might be ideal for optimal growth and reproduction while for Isa Brown cocks, the benefit seems to peak at 10% MOSM for sperm quality. MOSM appears to have a positive impact on sperm health in roosters, although the ideal level may vary depending on the genotype.

A follow-up study by Akintunde *et al.* (2021c) examined the link between MOSM, sperm production and body weight in YENLC and Isa Brown roosters. Their findings build on previous research. The study found a positive correlation ($p<0.05$) between body weight and sperm reserves in the testes of YENLC. This suggests that heavier YENLC may naturally have higher sperm stores in their testes. The study also observes that including MOSM at 15% decrease sperm reserves of YENLC compared to lower levels. MOSM levels up to 10% appeared to have a positive effect on sperm reserves in the epididymis (another sperm storage location) of both YENLC and Isa Brown cocks ($p<0.05$). Sperm motility and body weight were negatively correlated before they started to positively correlate at 15% MOSM inclusion, with a significant low ($p<0.05$) correlation. For YENLC, bodyweight can significantly predict spermatozoa reserves in the testes ($p<0.05$) and bodyweight can significantly predict spermiogramic parameters ($p<0.05$) (R^2=82.40%). Nevertheless, for Isa Brown cocks, predictions of spermiogramic parameters and body weight were not possible due to significantly low R^2 values ($p<0.05$), which indicates extremely low reliability. On the other hand, there were correlations between spermiogramic parameters and body weight and body weight predicted sperm characteristics. However, according to Akintunde *et al.* (2021c), these parameters might be utilized to select for specific sperm traits in YENLC and Isa Brown Cocks.

Potentials

Moringa is easy to grow for farmers in rural or peri-urban areas because it grows quickly and adapts well to the climate, flourishing even in harsh conditions. It is easy for farm households, including those with women and children, to produce moringa leaves, extract oil and make seed cakes. With a better amino acid balance, moringa leaves have the potential to partially or completely replace soybean meal, which is primarily used as a plant protein source but lacking in certain amino acids. If moringa plantations are expanded, livestock farmers could be able to purchase moringa leaves and seed cakes at a reduced cost.

To be engaged in moringa plantation requires little financial investment. It can be cultivated without using chemicals. Dried moringa leaves and the seeds can be easily stored and very much durable. Moreso, moringa foliage can be available throughout the year to feed ruminants whose feedstuffs are relatively scarce during the dry season as moringa can be available throughout the year. *Moringa oleifera* is a potential inexpensive source of proteins, vitamins and minerals. It can serve as a potential source of antibiotics as it has some anti microbial activities and anti oxidant activities especially in monogastrics.

The leafstalk of *Moringa oleifera* has a high fiber content (24%) that may make it a valuable prebiotic for animal feed. It can potentially modulate the gut microbial profiles in a way that reduces disease and increases animal productivity while avoiding public concerns about the safety of feed additives and the possible side effects of synthetic additives due to the antibiotic properties of its constituent chemicals. The inclusion of *Moringa oleifera* leaf in the diets of laying birds may reduce the cholesterol in their eggs, which may deter some individuals from consuming eggs.

Moringa oleifera seed meal is underexplored as a potential nonconventional feedstuff for animals. It seems reasonable to assume that the high level of polyunsaturated fatty acids in moringa seed oil and the good balance of amino acids in its component protein make it a potentially valuable source of nutrients required for building biological membranes and muscle (meat).

The increasing potential of *Moringa oleifera* seed to serve as a source of oil suitable for biodiesel use will likely create an increasing production of defatted seed cake. There is paucity of peer reviewed evidence for the utility of defatted seed meal in fishery, poultry and other animal diets though it may serve as a valuable source of protein at par with, or better than soya bean cake.

Moringa stem is a by-product of leaf harvesting activity and it seems plausible that shredded woody stem material may find use as litter/ bedding material in poultry and other animal production. If for example the established antibiotic properties of moringa are preserved in dried stem, they may act as bacteriostatic agents that control the proliferation of undesirable bacteria (which contribute to the release of adverse odours and green house gases) from poultry droppings.

Challenges

All component parts of *Moringa oleifera* are relatively expensive presently as there is competition for its usage between man and livestock. Detailed study has not been carried out on the effective utilization of *Moringa oleifera* (all the parts) by the various categories of livestock taking cognizance of the qualities of the meat and the various animal products.

Conclusion

From the points mentioned above, it is evident that *Moringa oleifera* is a good source of nutrients for livestock. The plant has the potential of serving as a partial replacement for soybean which is largely used as the major plant source of protein in livestock feeds since it has been reported that it contains all the nine essential amino acids and it has some health and nutritional benefits.

The integral antioxidant content of moringa leaf and its modulatory effect on the host's antioxidant system may be leveraged through feeding of livestock and poultry to enhance post-slaughter meat resistance to oxidative degradation as an alternative or complement to synthetic agents. The claimed beneficial effects of moringa leaf on milk let down could be harnessed in nursing animals and the dairy industry in general.

The established capacity of moringa seed powder to act as a flocculent and selective sterilizer of water could be harnessed to supply good quality drinking water for animals in remote livestock operations towards guaranteeing good animal health and productivity plus profitability in consequence. There is need for more research on whether and to what extent incorporation of *Moringa oleifera* component parts (leaf, seed, leafstalk, root and stem) in animal feeds can safely substitute ingredients in current usage and yield equivalent or more animal productivity. If the growing of *Moringa oleifera* is encouraged among the farmers the plant parts will be readily available and will be an inexpensive protein source for livestock.

References

Akintunde, A.O., Toye, A.A., 2023. Comparative study on egg characteristics of Yoruba Ecotype Nigerian local chickens and Isa Brown chickens fed graded levels of *Moringa oleifera* seed meal. *Agricultural Science Digest* 43(6), 877-882. DOI: https://doi.org/10.18805/ag.DF-430.

Akintunde, A.O., Toye, A.A., Ademola, A.A., 2021a. Effects of dietary *Moringa Oleifera* seed meal on obesity, liver and kidney functional parameters of local and exotic chickens. *Aceh Journal of Animal Science* 6(3), 97-103.

Akintunde, A.O., Toye, A.A., Ademola, A.A., 2021b. Principal component analysis of body measurements in two genotypes of chickens fed graded levels of *Moringa oleifera* seed meal. *Journal of Animal Production Research* 33(1), 1-13.

Akintunde, A.O., Toye, A.A., Ademola, A.A., Chimezie, V.O., Ajayi, O.A., 2021c. Genotype-diet effect on comparative semen parameters of chickens fed graded levels of *Moringa oleifera* seed meal. *Malaysian Journal of Animal Science* 24(1), 41-55.

Akintunde, A.O., Toye, A.A., 2021. Egg characteristics and prediction of egg weight in chickens fed graded levels of *Moringa oleifera* Seed Meal. *Nigerian Journal of Genetics* 35(1), 141-151.

Akintunde, A.O., Toye, A.A., Ademola, A.A., Jubril, A.E., 2020a. Correlation between body weight and morphometric traits in local and exotic chickens to dietary levels of *Moringa oleifera* (Lamarck) seed meal. *Nigerian Journal of Animal Production* 47(3), 1-6. DOI: https://doi.org/10.51791/njap.v47i3.112.

Akintunde, A.O., Toye, A.A., Ademola, A.A., Chimezie, V.O., Ajayi, O.A., 2020b. Sperm characteristics of Nigeria local cocks and exotic strain of cocks fed graded levels of *Moringa oleifera* seed meal. *Tropical Animal Production Investigation* 23(2), 1-10.

Akintunde, A.O., Toye, A.A., Ogundere, A.A., 2019. Genetic differences in the body weight and haematological traits of local and exotic chickens fed graded levels of *Moringa oleifera* seed meal. *Wayamba Journal of Animal Science* 11, 1836-1849.

Akintunde, A.O., Toye, A.A., 2014. Nutrigenetic effect of graded levels of *Moringa oleifera* seed meal on performance characteristics and nutrient retention in local and exotic chickens. *International Journal of Moringa and Nutraceutical Research* 1, 56-73.

Amad, A.A., Zentek, J., 2023. The use of *Moringa oleifera* in ruminant feeding and its contribution to climate change mitigation. *Frontiers in Animal Science* 4, 1137562. DOI: https://doi.org/10.3389/fanim.2023.1137562.

Attah, A.F., Moody, J.O., Sonibare, M.A., Salahdeen, H.H., Akindele, O.O., Nnamani, P.O., Diyaolu, O.A., Raji, Y., 2020. Aqueous extract of Moringa oleifera leaf used in Nigerian ethnomedicine alters conception and some pregnancy outcomes in Wistar rat. *South African Journal of Botany*, 129, 255-262. https://doi.org/10.1016/j.sajb.2019.07.041.

Awodele, O., Oreagba, I.A., Odoma, S., da Silva, J.A.T., Osunkalu, V.O., 2012. Toxicological evaluation of the aqueous leaf extract of *Moringa oleifera Lam.* (Moringaceae). *Journal of Ethnopharmacology* 139(2), 330-336. DOI: https://doi.org/10.1016/j.jep.2011.10.008.

Babiker, E.E., Al Juhaimi, F., Ghafoor, K., Mohamed, H.E., Abdoun, K.A., 2016. Effect of partial replacement of alfalfa hay with *Moringa* species leaves on milk yield and composition of Najdi ewes. *Tropical Animal Health and Production* 48(7), 1427-1433. DOI: https://doi.org/10.1007/s11250-016-1111-9.

Babiker, E.E., Juhaimi, F.A.L., Ghafoor, K., Abdoun, K.A., 2017. Comparative study on feeding value of moringa leaves as a partial replacement for alfalfa hay in ewes and goats. *Livestock Science* 195, 21-26. DOI: https://doi.org/10.1016/j.livsci.2016.11.010.

Balakumbahan, R., Sathiyamurthy, V.A., Janavi, G.J., 2020. Moringa leaf - A super food. *Biotica Research Today* 2(6), 438-440.

Becker, K., 1995. Studies on utilization of *Moringa oleifera* leaves as animal feed. *Institute for Animal Production in the Tropics and Subtropics*. Volume 480. University of Hohenheim, Stuttgart. p. 15.

Booth, F.E.M., Wickens, G.E., 1988. Non-timber uses of selected arid zone trees and shrubs in Africa. FAO Conservation Guide, Rome. pp. 92-101.

Bosch, C.H., 2004. USDA National Nutrient Database for Standard Reference. In: *Plant Resources of Tropical Africa*. (Eds.) Grubben, G.J.H. and Denton, O.A. PROTOA Foundation, Wageningen, Netherlands. pp. 392-393.

Briones, J., Leung, A., Bautista, N., Golin, S., Caliwag, N., Carlos, M.A., Guevarra, J., Miranda, J., Guevarra, J.K., Pili, N.L., Mendoza, D., De Jesus, N., 2017. Utilization of *Moringa oleifera* Lam. in animal production. *Acta Horticulturae* 1158, 467-474. DOI: https://doi.org/10.17660/ActaHortic.2017.1158.54.

Dahot, M.U., Memon, A.R., 1985. Nutritive significance of oil extracted from *Moringa oleifera* seeds. *Journal of Pharmacy of the University of Karachi* 3(2), 75-80.

Delisle, H., Bakari, S., 1997. Provitamin A content of traditional green leaves from Niger. *Cahiers Agricultures* 6(6), 553-560.

Eilert, U., 1978. Antibiotic principles of seeds of *Moringa oleifera*. *Indian Medical Journal* 38(235), 1013-1016.

Eilert, U., Wolters, B., Nahrstedt, A., 1981. The antibiotic principle of seeds of *Moringa oleifera* and *Moringa stenopetala*. *Planta Medica* 42(5), 55-61. DOI: https://doi.org/10.1055/s-2007-971546.

Ezeamuzie, I.C., Ambakederemo, A.W., Shode, F.O., Ekwebelem, S.C., 1996. Antiinflammatory effects of *Moringa oleifera* root extract. *International Journal of Pharmacognosy* 34(3), 207-212. DOI: https://doi.org/10.1076/phbi.34.3.207.13211.

Fabiyi, J.P., Kela, S.L., Tal, K.M., Istifanus, W.A., 1993. Traditional therapy of dracunculiasis in the state of Bauchi-Nigeria. *Dakar Medical* 38(2), 193-195.

Fahey, J.W., Dinkova-Kostova, A.T., Stephenson, K.K., Talalay, P., 2004. The "Prochaska" microtiter plate bioassay for inducers of NQO1. *Methods in Enzymology* 382, 243-258. DOI: https://doi.org/10.1016/S0076-6879(04)82014-7.

Faizi, S., Siddiqui, B.S., Saleem, R., Aftab, K., Shaheen, F., Gilani, A.H., 1998. Hypotensive constituents from the pods of *Moringa oleifera*. *Planta Medica* 64(3), 225-228. DOI: https://doi.org/10.1055/s-2006-957414.

Foidl, N., Makkar, H.P.S., Becker, K., 2001. The potential of *Moringa oleifera* for agricultural and industrial uses. In: *The Miracle Tree: The Multiple Attributes of Moringa*. (Ed.) Fugile, L.J. Church World Service, Dakar, Senegal. pp. 45-76.

Fuglie, L.J., 2001. *The Miracle Tree: The Multiple Attributes of Moringa*. Church World Service, Dakar, Senegal. pp. 1-172.

Fuglie, L.J., 2000. New Uses of Moringa Studied in Nicaragua. ECHO Development Notes 68. URL: https://www.echocommunity.org/en/resources/15db05d7-4693-425b-9d86-468143bd0ec9.

Fuglie, L.J., 1999. The Miracle Tree: *Moringa oleifera*: Natural Nutrition for the Tropics. Church World Service, Dakar. p. 67.

Galan, M.V., Kishan, A.A., Silverman, A.L., 2004. Oral broccoli sprouts for the treatment of *Helicobacter pylori* infection: A preliminary report. *Digestive Disease Science* 49, 1088-1090. DOI: https://doi.org/10.1023/B:DDAS.0000037792.04787.8a.

Gassenschmidt, U., Jany, K.D., Tauscher, B., Niebergall, H., 1995. Isolation and characterization of a flocculating protein from *Moringa oleifera* Lam. *Biochimica et Biophysica Acta (BBA) - General Subjects* 1243(3), 477-481. DOI: https://doi.org/10.1016/0304-4165(94)00176-X.

Grubben, G.J.H., Denton, O.A., 2004. *Plant Resources of Tropical Africa 2. Vegetables*. PROTA Foundation, Wageningen, Netherlands/ Backhuys Publishers, Leiden, Netherlands/ CTA, Wageningen, Netherlands. p. 668.

Guevara, A.P., Vargas, C., Sakurai, H., Fujiwara, Y., Hashimoto, K., Maoka, T., Kozuka, M., Ito, Y., Tokuda, H., Nishino, H., 1999. An antitumor promoter from *Moringa oleifera* Lam. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis* 440(2), 181-188. DOI: https://doi.org/10.1016/S1383-5718(99)00025-X.

Gyamfi, E.T., Kwarteng, I.K., Ansah, M.O., 2011. Effects of processing on *Moringa oleifera. Proceedings of the International Academy of Ecology and Environmental Sciences* 1(3-4), 179-185.

Islam, Z., Islam, S.M.R., Hossen, F., Mahtab-Ul-Islam, K., Hasan, M.R., Karim, R., 2021. *Moringa oleifera* is a prominent source of nutrients with potential health benefits. *International Journal of Food Science* 2021, 6627265. DOI: https://doi.org/10.1155/2021/6627265.

Kakengi, A.M.V., Kaijaye, J.T., Sarwatt, S.V., Mutayoba, S.K., Shem, M.N., Fujihara, T., 2007. Effect of *Moringa oleifera* leaf meal as a substitute for sunflower seed meal on performance of laying hens in Tanzania. *Livestock Research for Rural Development* 19(8), 120. URL: http://www.lrrd.org/lrrd19/8/kake19120.htm.

Korsor, M., Ntahonshikira, C., Kwaambwa, H.M., Bello, H.M., 2016. Comparative Performance of *Moringa oleifera* and *Moringa ovalifolia* Seeds and Seedlings Establishment in Central Namibia. *Net Journal of Agricultural Science* 4(2), 35-44.

Manh, L.H., Dung, N.N.X., Ngoi, T.P., 2005. Introduction and evaluation of *Moringa oleifera* for biomass production and as feed for goats in the Mekong Delta. *Livestock Research for Rural Development* 17(9), 104. URL: http://www.lrrd.org/lrrd17/9/manh17104.htm.

Mehta, J., Shukla, A., Bukhariya, V., Charde, R., 2011. The magic remedy of *Moringa oleifera:* An overview. *International Journal of Biomedical and Advance Research* 2(6), 215-227.

Moyo, B., Masika, P.J., Hugo, A., Muchanje, V., 2011. Nutritional characterization of Moringa (*Moringa oleifera Lam)* leaves. *African Journal of Biotechnology* 10(60), 12925-12933. DOI: https://doi.org/10.5897/AJB10.1599.

Muangnoi, C., Chingsuwanrote, P., Praengamthanachoti, P., Svasti, S., Tuntipopipat, S., 2012. *Moringa oleifera* pod inhibits inflammatory mediator production by lipopolysaccharide-stimulated RAW 264.7 murine macrophage cell lines. *Inflammation* 35, 445-455. DOI: https://doi.org/10.1007/s10753-011-9334-4.

Odeyinka, S.M., Oyedele, O.J., Adeleke, T.O., Odedire, J.A., 2008. Reproductive performance of rabbits fed *Moringa oleifera* as a replacement for *Centrosema pubescens*. In: *Proceedings of the 9th World Rabbit Congress*. June 10-13, 2008, Verona, Italy. pp. 411-415.

Ogbe, A.O., Affiku, J.P., 2011. Proximate study, mineral and anti-nutrient composition of *Moringa oleifera* leaves harvested from Lafia, Nigeria: Potential benefits in poultry nutrition and health. *Journal of Microbiology, Biotechnology and Food Sciences* 1(3), 296-308.

Olson, M.E., 2002. Combining data from DNA sequences and morphology for a phylogeny of Moringaceae (Brassicales). *Systematic Botany* 27(1), 55-73.

Olugbemi, T.S., Mutayoba, S.K., Lekule, F.P., 2010. *Moringa oleifera* leaf meal as a hypocholesterolemic agent in laying hen diets. *Livestock Research for Rural Development* 22(4), 84. URL: http://www.lrrd.org/lrrd22/4/olug22084.htm.

Oluwaniyi, O.O., Obi, B.C., Awolola, G.V., 2020. Nutritional composition and antioxidant capacity of *Moringa oleifera* seeds, stem bark and leaves. *Ilorin Journal of Science* 7(1), 53-65. DOI: https://doi.org/10.54908/iljs.2020.07.01.004.

Posmontier, B., 2011. The medicinal qualities of *Moringa Oleifera*. *Holistic Nursing Practice* 25(2), 80-87. DOI: https://doi.org/10.1097/HNP.0b013e31820dbb27.

Price, M.L., 2007. The Moringa tree. *ECHO Technical Note* 17391, 1-19. URL: https://allaboutmoringa.info/portfolio/the-moringa-tree-ebook-by-echo/.

Radovich, T., 2009. Farm and forestry production and marketing profile for Moringa (*Moringa oleifera*). In: *Specialty Crops for Pacific Island Agroforestry*. (Ed.) Elevitch, C.R. Permanent Agriculture Resources (PAR), Holualoa, Hawai'i. pp. 1-12.

Riry, F.H.S., Elkloub, K., Moustafa, M.E., Mousa, MAM, Hanan, A.H.A., Youssef, S.F., 2018. Effect of partial replacement of soybean meal by *Moringa oleifera* seed meal on Japanese quail performance during laying period. *Egyptian Poultry Science Journal* 38(1), 255-267. DOI: https://doi.org/10.21608/epsj.2018.5604.

Saa, R.W., Fombang, E.N., Ndjantou, E.B., Njintang, N.Y., 2019. Treatments and uses of *Moringa oleifera* seeds in human nutrition: A review. *Food Science and Nutrition* 7(6), 1911-1919. DOI: https://doi.org/10.1002/fsn3.1057.

Sánchez, N.R., Spörndly, E., Ledin, I., 2006. Effect of feeding different levels of foliage of *Moringa oleifera* to creole dairy cows on intake, digestibility, milk production and composition. *Livestock Science* 101(1-3), 24-31. DOI: https://doi.org/10.1016/j.livprodsci.2005.09.010.

Sonkar, N., Singh, N., Santra, A.K., Mishra, S., Roy, M., Khune, V.N., Pathak, R., 2020. Effect of feeding dried *Moringa oleifera* leaves on different haematological parameters and economics in lactating Sahiwal cows. *Journal of Entomology and Zoology Studies* 8(1), 333-337.

Subadra, S., Monica, J., Dhabhai, D., 1997. Retention and storage stability of beta carotene in dehydrated drumstick leaves (*Moringa oleifera*). *International Journal of Food Science and Nutrition* 48(6), 373-379. DOI: https://doi.org/10.3109/09637489709028585.

Sultana, N., Rakib, M.R.H., Hossain, S.M.J., Ahmed, S., Ershaduzamman, M., Talukder, M.A.I., 2017. Effect of replacement of conventional concentrate in a rice straw diet by Moringa foliage on lamb production performances. *Journal of Experimental Agriculture International* 15(5), 1-14. DOI: https://doi.org/10.9734/JEAI/2017/31329.

Teteh, A., Lawson, E., Tona, K., Decuypere, E., Gbeassor, M., 2013. *Moringa oleifera* leave: hydro-alcoholic extract and effects on growth performance of broilers. *International Journal of Poultry Science* 12(7), 401-405. DOI: https://doi.org/10.3923/ijps.2013.401.405.

Toye, A.A., Sola-Ojo, F.E., Olaniyan, O.M., Ojo, V. 2013. Nutrigenetic effect of *Moringa oleifera* seed meal on the biological growth programme of young broiler chickens. *Agrosearch* 13(1), 149-164. DOI: https://doi.org/10.4314/agrosh.v13i1.14.