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Moringa oleifera: The Miracle Tree and its Potential as Non-conventional Animal Feed: A Review

Nazish Rizwan[1], Danish Rizwan[2], M.T. Banday[1]

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ABSTRACT

Moringa oleifera, a member of the plant family *Moringaceae*, has been recognized to have an abundance of nutrients and bioactive substances with the potential to positively affect health. Moringa has proven to be a versatile plant, with every part of it being used as either a food or a therapeutic agent. The favorable results of different scientific investigations on the use of moringa in human nutrition have prompted a quest to investigate its potential application in the livestock sector as an alternative to traditional animal feed. Moringa, being an excellent source of nutrients, particularly proteins, can be used as a source of protein in animal diets or as an alternative to conventional livestock feed and fodder. Many research articles have recently been published suggesting that moringa can be utilized as an unconventional feed or as a fortification agent in animal feeds at inclusion levels that have no negative impact on health, survival, mortality, growth rate, or reproduction. Furthermore, *Moringa oleifera* has been discovered to have an important role in the management of some animal illnesses, particularly avian coccidiosis, by exhibiting anti-coccidial properties.

Key words: Feed, Livestock, Moringa, Poultry, Ruminants.

Moringa oleifera (MO) is native to northern India and northern Europe, but it is also grown in the Red Sea region and other parts of Asia and Africa, including the United States (Singh *et al.,* 2019). *Moringa oleifera* is the most promising tree, with nutritional and therapeutic characteristics as well as environmental benefits. *Moringa oleifera* has a diverse range of applications. Water purification, human consumption, medicine, fuel wood, dye, conservation, cattle fodder and green manure are just a few of them (Koul and Chase, 2015). Natural resources, economic activities, food security, health, society and physical infrastructure, as well as society in general, are all affected by climate change. As per a report of FAO (2009) livestock sector accounts for 18% of worldwide GHG emissions (7.1 billion tonnes CO_2 equivalent). Although it produces just 9% of global CO_2, it produces 65% of human-related N_2O and 35% of CH_4, which have 310 times and 23 times the global warming potential (GWP) of CO_2, respectively. Considering these facts it is quite clear that the conventional feeding system is unsustainable and poses serious environmental challenges. Moreover due to high cost associated with conventional feed production, particularly due to fortification of feed with vitamins, minerals and proteins to safeguard animals from various dietary deficiencies, livestock industry faces a great challenge to survive especially in under-developed and developing countries. Being the most expensive and prime limiting factor in feed formulations, conventional protein diets are costlier and hence pave way for searching alternative, non-conventional, relatively cheaper sources for formulation of livestock feed. In order to form an economically viable and ecofriendly livestock feed production system, the research has been focus towards exploring numerous plants and agricultural by products for their potential to serve as animal feed or as a part of feed formulation, supplying essential nutrients (Su and Chen, 2020). In this context many plants have been analyzed for their nutrient content and they have shown promising results. *Moringa oleifera,* the Miracle tree, native to sub Himalayan region, is known to possess an excellent nutritional profile which has been studied extensively for many years for exploring its potential to be used in formulation of livestock feed. Being rich in nutrients, Moringa leaves, fresh pods, seeds and roots are widely used as human food and animal feed with various research investigations associating moringa leaf meal with fast growth, better utilization by animals including cattle, goats, chicken and fish along with high nutritional value. A good amount of literature is available to support the fact that *M. oleifera* especially its leaf can be used as an alternative protein source in animal husbandry as it has an excellent nutritional profile (Nouman *et al.,* 2013).

[1]Division of Livestock Production and Management, Faculty of Veterinary Sciences and Animal Husbandry, Shuhama-191 202, Srinagar, Jammu and Kashmir, India.

[2]Department of Food Science and Technology, School of Applied Sciences, University of Kashmir, Hazratbal-190 006, Jammu and Kashmir, India.

Corresponding Author: Nazish Rizwan, Division of Livestock Prodcuction and Management, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar-190 025, Jammu and Kashmir, India. Email: nazishkirmani@gmail.com

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Moringa oleifera

Origin, botanical and pedo-climatic description

Moringaceae, monogeneric plant family includes genus *Moringa*, encompassing 13 plant species. These species include *Moringa arborea, Moringa rivae, Moringa borziana, Moringa pygmaea, Moringa longituba, Moringa stenopetala, Moringa ruspoliana, Moringa ovalifolia, Moringa drouhardii, Moringa hildebrandi, Moringa peregrine, Moringa concanesis* and *Moringa oleifera* (Leone *et al.,* 2015). However *Moringa oleifera,* native to South Asia, particularly in India, Srilanka, Pakistan, Afghanistan, Bangladesh and some parts of Africa and Saudi Arabia, is the best known among *Moringaceae* family. It is commonly known as Drumstick tree, Miracle tree, benzoil tree, ben oil tree and horseradish tree (Trigo *et al.,* 2020). There are several vernacular names of Moringa plant in India such as Shigru, Shobhanjana, Teekshnagandha, Aksheeva, Mochaka, Munaga, Sajana, Saragavo, Shegata, Sahajano, Sitachini, Daintha, Kelor, Marum, Dandalonbin and Dandalun (Debajyoti *et al.,* 2017). Table 1 represents the scientific classification of *Moringa oleifera.*

Moringa oleifera is a fast growing, deciduous, soft wood tree, capable of reaching a height of about 12 m. The tree grows well in tropical and subtropical regions with an average rainfall of about 2000 mm and good sunlight. A temperature of 19-35^{o}C favors optimal growth of this plant. Owing to its good drainage, it is capable of growing in wide range of soil types, but grow best in slightly acidic to alkaline sandy loam soil. It is also capable of withstanding extreme temperatures, from over temperatures of up to 48^{o}C to slight frost (Saini *et al*., 2016). The tripinnate, compound, feathery leaves grow mostly at the tips of the branches. Moringa flowers have yellow-white colored petals with slight pleasant fragrance. The fruit of this tree is a trilobe capsule with a slender pod with 15-20 seeds, which changes color from green to brown upon maturity. The seeds are round or triangular in shape, each covered by a woody shell and three papery wings (Su and Chen, 2020).

Nutritional composition of *Moringa oleifera*

The "Miracle tree", *Moringa oleifera* is known for its nutritional and nutraceutical potential. All parts of this plant including leaves, pods, seeds, flowers, fruits and roots are edible and form a part of traditional diet of people living in tropical and sub-tropical countries (Islam *et al*., 2021). The different parts of Moringa act as the storehouse of various essential nutrients (Table 2). The leaves of Moringa contain approximately 20-35% protein on dry weight basis with majority of essential amino acids. They also contain high content of minerals such as calcium, potassium, zinc, iron, copper and magnesium (Mohanty *et al.,* 2021). The leaves of Moringa plant are known for their omega 3 and omega 6 polyunsaturated fatty acid content especially that of α linolenic acid and linolenic acid. Palmitic acid has been noted to be the main saturated fatty acid present in these leaves, accounting for about 16-30% of the total fatty acid content The leaves, flowers and pods of moringa plant are also rich in vitamins like vitamin A, vitamin C, vitamin D, vitamin E, riboflavin, folic acid, pyridoxine and nicotinic acid (Gopalakrishnan *et al.,* 2016). As compared to leaves, stem and immature pods of *Moringa oleifera* have slightly lower nutritive content. The pods contain low amount of lipids and proteins, have abundance of dietary fiber and have a significant amount of unsaturated essential amino acids (Granella *et al.,* 2021). The seed of Moringa plant are having a good oil content ranging between 30-40% (Leone *et al*., 2015), rich is saturated and unsaturated fatty acids including oleic acid, palmitic acid, stearic acid and archidic acid (Saini *et al.,* 2016). The seeds also contain a substantial amount of macronutrients and micronutrients such as sodium, potassium, calcium, magnesium, phosphorus, zinc, copper; and essential and hydrophobic amino acids (Liang *et al.,* 2019). Moringa flowers are also rich in many nutrients, including proteins, dietary fiber, lipids, carbohydrates, potassium, calcium, polyunsaturated fatty acids and antioxidants (tocopherols) (Sánchez-Machado *et al*., 2010).

Phytochemical composition of *Moringa oleifera*

The human population around the globe is known to use medicinal plants for treatment of various pathological conditions since time immemorial. These plants form an important tool in comprehensive health care. The numerous therapeutic effects of Moringa have been discerned in both Ayurvedic and Unani medicine. All parts of this plant exhibit pharmacological effect and have been used as a traditional medicine in tropics and sub tropics since ages (Islam *et al*., 2021; Mughal *et al.,* 1999). *Moringa oleifera* is a reservoir of phytochemicals such as phenolic acids, flavonoids, flavonols, steroids, polyphenols, isothiocyanates, glucosinolates, sterols, sitosterols, phytosterols, terpenoids, catechins, caffeic acid, ferulic acid, procyanidins, chlorogenic acid and alkaloids, distributed among different parts of the plant (Brilhante *et al.,* 2017). The various functional and therapeutic properties of *Moringa oleifera* are accredited to this broad range bioactive compounds identified in different parts of this plant using various identification techniques such as GC-MS and HS-SPME (Falowo *et al.,* 2018). The presence of these phytochemicals constitutes a basis for extensive research and currently, the scientific community on an international level is exploring the potential of this tree in

Table 1: Taxonomical classification of *Moringa oleifera.*

Kingdom	*Plantae*
Sub-kingdom	*Tracheobionta*
Super division	*Spermatophyta*
Division	*Magnoliophyta*
Class	*Magnoliopsida*
Sub- class	*Dilleniidae*
Order	*Brassicale*
Family	*Moringaceae*
Genus	*Moringa*
Species	*oleifera*

the field of food, feed, medicine and cosmetics. Extracts of M. *oleifera* plant parts have been recognized to possess anti-inflammatory, hypoglycemic, hypolipidemic, antipyretic, analgesic, neuroprotective, anticancer, cytotoxic, anti-proliferative, anti-leukemia, anti-hepato-carcinoma and chemo-protective properties (Bhattacharya *et al*., 2018; Mahfuz and Piao, 2019; Ravani *et al.,* 2017). Table 3 summarizes the phytochemical compounds present in different parts of *Moringa oleifera*.

Various studies have suggested that Moringa is rich in anti-microbial compound, Pterygospermin, which is mainly concentrated in flowers and roots of the plant. This compound has been found to be effective as a powerful antibiotic and fungicide, showing a good response against microbial species like *Fusarium solani, B. sublitis, S. aureus, S. areogunosa* (Abdulkadir *et al.,* 2015; Pandey, 2012). Antibiotic activity has also been associated with presence of lipophilic components and various metabolites namely carboxylic acid, 2, 4-*diacetylphloroglucinol* and Chitinases. A significant percentage of antioxidants like Superoxide dismutase (SOD), catalase (CAT), *glutathione S-transferases* (GST) have been found to be present in the leaf extract of Moringa plant (Moyo *et al.,* 2013).

Anti-nutritional factors in *Moringa oleifera*

The undesirable chemical compounds present in both cultivated and wild plant species are termed as anti-nutritional compounds or anti-nutritional factors or anti nutrients or allelochemicals. These compounds are synthesized as secondary metabolites *via* normal metabolic pathways in plants, intended for own defense. However they have an impact on digestibility, bioavailability and utilization of nutrients especially proteins, minerals and vitamins in food derived from plants and also determine the use of a particular plant as food and fodder (James and Zikankuba, 2017). These anti nutritional factors include nitrates, oxalates, tannins, phytates, trypsin inhibitors, saponins, protease inhibitors, gossypol and cyanogenic glycosides (Su *et al.,* 2020). It has been seen that *Moringa oleifera* leaves has presence of anti-nutritional compounds such as tannins, saponins and lignin but in negligible amounts. There exists a variation in amount of these anti-nutritional components owing to diverse growth conditions and cultivars (Shih *et al.,* 2011). The leaves of Moringa contain 21 g/kg and 10.5 g/kg phytates and oxalates respectively. Moreover negligible amount of tannins, saponins, trypsin inhibitors and amylase

Table 2: Nutritional composition of leaves, seeds and pods of *Moringa oleifera* per 100 g.

Nutrient	Dry leaves	Fresh leaves	Pods	Seeds
Protein (g)	29.4	6.7	2.5	35.97
Calories	205	92	26	-
Fat (g)	5.2	1.7	0.1	38.67
Carbohydrates (g)	41.2	12.5	3.7	8.67
Moisture**%**	7.5	75	86.9	-
Fibre (g)	12.5	0.9	4.8	2.87
Potassium (mg)	1236	259	259	235.7
Phosphorus (mg)	252	70.8	110	75
Calcium (mg)	2185	440	30	45
Sulphur (mg)	870	137	137	0.05
Iron (mg)	25.6	0.85	5.3	-
Magnesium (mg)	448	24	24	635
Copper (mg)	0.6	0.07	3.1	5.20
Vitamin B1 (mg)	2.02	0.06	0.05	0.05
Vitamin B2 (mg)	21.3	0.05	0.07	0.06
Vitamin B3 (mg)	7.6	0.8	0.2	0.2
Vitamin C (mg)	17.3	220	120	4.5
Arginine (mg)	1325	406.6	360	540
Histidine (mg)	613	149.8	27.5	98
Lysine (mg)	1325	288	37.5	73
Tryptophan (mg)	425	107	80	-
Methionine (mg)	350	117.7	140	65
Valine (mg)	1063	476	135	125
Phenylalanine (mg)	1388	310.3	40	165
Threonine (mg)	1188	117.7	98	95
Leucine (mg)	1950	492.2	650	214

Source: (Dhakar *et al.,* 2011; Gopalakrishnan *et al.,* 2016; Liang *et al.,* 2019; Price, 1985).

Table 3: Phytochemical composition of *Moringa oleifera*.

Plant part	Compounds
Leaves	Niazirin and Niazirinin-nitrile glycosides, benzyl isothiocyanate, Niaziminin A, Niaziminin B, Niazimicin, pyrrolemarumine 400-O-a-L-rhamnopyranoside, hydroxyphenylethanamide, alpha and gamma-tocopherol, 2, 3-Butanedione.
Seeds	Methionine, cysteine, 4-(alpha-L- rhamnopyranosyloxy) benzylglucosinolate, Moringine, benzylglucosinolate, niazimicin, niazirin.
Pod	Isothiocyanate, nitrites, thiocarbamates,O-(1heptenyloxy) propyl undecanoate, O-ethyl-4-(alpha-L-rhamnosyloxy) benzyl carbamate, methyl-p-hydroxybenzoate, beta-sitosterol.
Bark	4-(alpha-L-rhamnopyranosyloxy) benzylgiucosinolate.
Flowers	D-glucose, quercetin, isoquercetin, kaemopherol, kaempferitrin and ascorbic acid, protein, D-mannose.
Root	Moringine, moringinine, spirachin, 1,3-dibenzyl urea, alpha- phellandrene,p-cymene,Deoxy-niazimicine,4-(alpha-L-rhamnopyranosyloxy)benzylglucosinolate.
Stem	4-hydroxyl mullein, vanillin, octacosonoic acid, beta- sitosterone and beta- sitosterol.

Source: (Paikra *et al.,* 2017).

inhibitors and no traces of cyanogenic compounds has been noted (Makkar and Becker, 1997; Teixeira *et al*., 2014). The saponins are present in moringa leaves but they amount for about 4.7-5 g/kg dry weight only (Moyo *et al*., 2013). Another study reported 10.58 mg phytates, 334.33 mg oxalates, 8.19 mg tannins and 3998.30 mg hydrogen cyanide per 100 g of moringa leaves (Auwal *et al.,* 2020). The level of oxalates has been estimated in moringa leaves and it is present in low concentrations (25.7 mg g^{-1}) , which is much lower than spinach which has an oxalate concentration of 125.7 mg g^{-1} (Radek and Savage, 2008). Trypsin inhibitors have not been detected in moringa leaves (Gidamis *et al.,* 2003). The anti-nutritional compounds in moringa seeds have been noted to be lower than leaves. The seeds of moringa contain 252.08 mg/100 g saponins and 47.93 mg/100 g tannins (Muhammed Fayis, 2017). Phytates have been found to be the most abundant anti nutritional compound in moringa seeds. The phytate content in moringa seeds was found to be 1380.6 mg PAE/100 g. Moreover saponins and tannin content in moringa seeds was found to be 154.95 mg DE/100 g and 62.2 mg CE/100 g respectively (León-López *et al*., 2020). Igwilo *et al.* (2013) reported presence of tannins, oxalates, phytates, saponins and cyanogenic glycosides in moringa roots. The tannins and oxalates were present in high content (45 mg/100 and 17.08 mg/100 g respectively). The content of saponins, phytates and cyanogenic glycosides showed presence in lower concentrations (4.20 mg/100 g, 0.07 mg/100 g and 2.72 mf/100 g respectively) (Igwilo *et al.,* 2013). Although these factors are present in negligible amounts, their effects can further be minimized by using various processes like chopping, soaking, drying, fermentation and steaming (Moyo *et al*., 2013; Radek and Savage, 2008; Teixeira *et al*., 2014).

Application of *Moringa oleifera* in livestock feeding

The leaves of woody plants are known for their high nutritional composition. However their use as animal feed is restricted due to presence of excessive fiber content and anti-nutritional compounds that have an adverse impact on the palatability, digestibility and nutrient utilization. This forms the basis for determining the suitability of a tree or plant to be used as an animal feed (Su and Chen, 2020). The remarkable nutritional and phytochemical composition of *Moringa oleifera* along with low amount of anti-nutritional factors, makes it suitable for animal feed. The use of Moringa as a feed or a feed supplement dates back to 1962 (Ramachandran *et al.,* 1980). The young branches, leaves and seed residues left after oil extraction have been fed to farm animals. In the recent past, Moringa is being considered to be used as an effective alternative to conventional diets for livestock. However the inclusion levels are significantly lower as the mode of action of improvement of production performance and health status is still being explored and understood (Mahfuz *et al.,* 2019).

Poultry

Moringa oleifera can be used in poultry as a dietary supplement due to its nutritional and therapeutic value (Abdel-Wareth and Lohakare, 2021). Various researchers have used leaf meal or leaf extract of this plant in poultry and it has been able to produce positive results. Improvement in bowel health, increased weight gain, decrease feed intake, improved feed conversion ratio, increased immune response and good anti-oxidant responses in broilers has been attributed to the use of moringa leaf meal as feed. It has been seen that broilers supplemented with *Moringa oleifera* have considerable increase in the level of high density lipoproteins in serum along with a significant decrease in Low density lipoproteins. This effect has been associated with higher fiber content in Moringa which results in lowering of cholesterol levels in the body. Hypocholesterolemic effect has been observed in egg cholesterol content which is much lower when poultry feed is supplemented with Moringa leaves (Olugbemi *et al.,* 2010). Broilers fed with diets containing 5% moringa leaf meal for 7 weeks have shown increased body weight and higher total feed intake and improved feed conversion ratio compared to a control group (Tazi, 2014). It has also been reported that Broliers fed with 0.05% of moringa fruit meal and 0.1% of moringa leaf meal for 42 days resulted in improved growth performance and carcass yield (David *et al.,* 2015). As reported by Alabi *et al.* (2017), inclusion of aqueous extracts of *Moringa oleifera* leaves at a concentration of 90 ml/liter of drinking water of broiler chicken can result in reduction of

feed intake by about 12.83% and an overall improvement in the feed conversion efficiency, suggesting the possible use of this extract as a replacement for synthetic growth promoters (Alabi *et al.,* 2017). A research study conducted by Rehman *et al.* (2018) studied the impact on moringa leaf powder supplementation on the quality of meat and bone morphometry in broilers and it was observed that diameter of breast muscle fibers, weight and weight length index of the tibia bone increased significantly with administration of 12-15 g/kg of moringa leaf powder Improvement of total hemoglobin percentage, total red blood cell count and packed cell volume was recorded in broilers upon inclusion of up to 20% of moringa in feed. In case of layers it has been reported that addition of 5-10% moringa in diets led to improved yolk color and albumin height, while as addition of about 10-20% moringa leaf meal in place of sunflower seed meal improved laying performance, egg weight, increases feed intake and increased feed conversion ratio by 20% (Rehman *et al.,* 2018; Abou-Elezz Fouad Mohammed *et al.,* 2012) reported that supplementation of feed with fresh leaves of *Moringa oleifera* could improve egg production, egg yolk color and egg mass (Abou-Elezz Fouad Mohammed *et al.,* 2012). Supplementation of feed of 27 week old hy-line grey commercial layers with moringa leaf at 5% resulted in higher feed conversion ratio, improved protein absorption without any notable effect on laying performance and egg quality (Lu *et al*., 2016). Similar effect of moringa leaf supplementation in layer diet on production performance and egg quality has been observed by (Briones *et al.* 2017). A research study on 64 week old hy-line brown hens suggested that dietary supplementation with moringa leaves improved egg production, weight and mass significantly. Haugh unit and shell thickness also showed significant improvement as a response to Moringa leaf supplementation at a rate of 3, 6 and g/kg (Abdel-Wareth and Lohakare, 2021). The administration of 2-6% of moringa leaf powder with diet to laying hens significantly decreases the cholesterol content in egg yolk. Moreover improvement in egg production, egg mass, shell thickness, yolk color, beta carotene, magnesium and calcium content in yolk has been noted by inclusion of 4-6% moringa leaf powder (Bidura *et al.,* 2020). These research findings clearly suggest that feeding Moringa leaf meal to chicken has no adverse effect on the normal physiology and growth with use within 1-10% considered to be the safe level (Mahfuz and Piao, 2019). Apart from inclusion of leaves, moringa seeds and pods have also been used to supplement poultry feed. Improved yolk color and higher percentage of linolelaidic acid content in yolk was observed when layers were fed with moringa seed meal (Mabusela *et al.,* 2018). The effect of Moringa seed meal on nutrient digestibility in finisher broiler chicken has been evaluated. It has been observed that inclusion of 0.02% seed meal in finisher broiler chicken enhances the nutrient digestibility (Abdulkarim *et al*., 2018). A significantly lower cholesterol level in egg yolk has been reported in hy-line layers fed with moringa pod meal (Ahmad *et al*., 2017). Moringa stem meal as a supplement was fed to laying ducks along with basal diet at varying concentrations (0-4%). The ducks fed with 2% moringa stem meal showed an increase in average daily feed intake and average daily gain. An improvement in feed conversion rate was observed in ducks fed with 4% moringa stem meal. Supplementation also had a positive effect on egg quality and the antioxidant activity of meal improved the immunological index as well (Yang *et al.,* 2020). Moringa stem meal, rich in crude fiber, fed to geese at varying levels ranging between 0-100 g/kg resulted in increase in feed/gain ratio in a linear manner with the increase in moringa stem meal inclusion. The inclusion of 100 g/kg of Moringa stem meal resulted in significant decrease in blood glucose level and an increase in alanine transaminase enzyme activity (Zhai *et al.,* 2020).

Ruminants

The potential of *Moringa oleifera* to be used as ruminant feed has been investigated as it is rich in nutrients but most distinct feature which has played a key role for its consideration as ruminant feed is it's methanogenic inhibitor content which has the capability to decrease methane emission in ruminants. Methanogenic inhibitors of moringa plant pose a great potential to be utilized on a large scale for livestock feeding programs which aim at minimizing the methane emission. Around 17% decrease in daily methane emission was observed in animals fed with *Moringa oleifera* and a total of 50% decrease in emission was recorded when it replaced soybean meal as feed (Elghandour *et al.,* 2017; Soliva *et al*., 2005).

Cattle

Conventional low quality diet supplemented with moringa leaves as protein additive has been noted to increase the dry matter intake, digestibility of diet and milk production cows of Creole Reyna breed (Reyes Sánchez *et al.,* 2006). Total mixed ration at level of 180 g/kg supplemented with Moringa silage fed to lactating Holstein cows resulted in higher milk yield as compared to control cows. The milk was also characterized by better anti-oxidative potential (Cohen-Zinder *et al*., 2016). Cows fed with formulated ration along with 20% inclusion of *Moringa oleifera* leaf had higher mean value of milk fat, total solids, crude protein and casein when compared to those fed with formulated ration containing 20% soybean meal (Mendieta-Araica *et al*., 2011). Dietary supplementation of moringa at the rate 6% in dairy cows resulted in milk with improved fat content (Dong *et al*., 2019). Partial substitution of alfalfa hay and maize silage with *Moringa oleifera* silage showed no negative effect on milk yield, nutrient digestibility and biochemical indexes of lactating Holstein cows (Zeng *et al*., 2018). Lactating cross bred cows were fed 15.0 kg of Moringa as green fodder for 90 days to evaluate its effect on milk yield, microbial protein synthesis and blood profile. (Shankhpal *et al*., 2019) reported that feeding cows with moringa resulted in improved α carotene content in milk and intestinal flow of microbial nitrogen. Furthermore the cholesterol content of milk decreased by 17.60%

(Shankhpal *et al.,* 2019). Moringa leaf meal fed to pregnant Holstein cows at the rate of 16.66 g/100 kg body weight, resulted in improved blood profile, antioxidant status and udder health in these cows (Kekana *et al.,* 2020). Micro supplementation of diet of lactating Jersey cows with moringa leaf meal showed a significant effect on the blood biochemistry and udder health of cows. A notable increase in serum protein and immunoglobulin G was observed. Micro supplementation with moringa leaf meal at 60 g/day/cow remarkably reduced oxidative stress, which in turn resulted in improvement of milk quality in terms of milk fat content and immunity in lactating cows (Kekana *et al*., 2019).

Buffalo

Effect of substitution of soya bean meal by moringa leaf meal on rumen fermentation, nutrient digestibility and growth performance of 8-9 months old buffalo calves has been investigated. It was noted that moringa leaf inclusion at the rate of 15% and 20% in concentrate mixture resulted in increase in digestibility of dry matter, crude fiber and organic matter, while the digestibility of crude protein showed a decline. Inclusion of moringa leaf meal at 15% inclusion rate resulted in improved final body weight, daily weight gain, feed conversion efficiency and plasma insulin growth factor I without any noticeable adverse effect on the growth of buffalo calves.(Abdel-Raheem and Hassan, 2021). The replacement of concentrate mixture and calf starter up to 10% by moringa leaf meal resulted in better body weight gain in Murrah calves (Roy *et al.,* 2018).

Sheep

Defatted Moringa seed meal at a level of 2-6 g/day when used as an additive in Barbarine lamb hay-soybean meal exhibited no effect on diet digestibility. The inclusion of intermediate level *i.e.* 4 g/day moringa seed meal in diet resulted in improved rumen fermentation (Ben Salem and Makkar, 2009). Replacement of conventional concentrate mixture by Moringa foliage as protein supplement at a level of 75% and 100% in rice straw diet resulted in favorable growth performance, leaner carcass and higher meat proportion in lambs (Sultana *et al*., 2017). The *Moringa oleifera* leaf meal inclusion at level of 25% in concentrate mixture resulted in the improvement of body condition score in Deccani lambs being reared under intensive farming system (Bala and Ramana, 2020).

Goat

Goats fed with moringa leaves at 20 and 50% inclusion levels have shown increased live weight gain, digestibility of dry matter, crude protein and organic matter (Aregheore 2002; Babiker *et al.,* 2017) reported that there was increase in oxidative stability and vitamin C content of milk in ewes and goats supplemented with *Moringa oleifera* leaf at 25% inclusion level when compared to those with Alfalfa hay. This may be attributed to presence of various nutrients along with essential elements such as calcium, potassium and magnesium (Babiker *et al.,* 2017). The concentrate diet of black bengal goats when replaced by moringa foliage resulted in improved average daily weight gain and better nitrogen retention clearly depicting the potential of moringa to serve as alternative to conventional concentrate mixture (Sultana, 2015). Inclusion of moringa leaf meal at a level of 15%, replacing 75% sesame meal in diet of lactating Anglo Nubian goats improved milk yield and composition in terms of total solids and lactose content. It also improved the level of unsaturated fatty acids and conjugated linoleic acid. Moreover, moringa leaf meal also enhanced rumen fermentation, feed intake and nutrient digestibility (Kholif *et al.,* 2015). Oral administration of moringa leaf extract for 88 days to Nubian goats as apart from basal diet resulted in significant increase in milk yield, milk energy, total solids, solid not fat, protein, lactose and ash content with a linear relationship with dose at which extract was administered. In general supplementation with moringa extracts led to enhancement of milk yield by about 6% and an increase in total conjugated linoleic acid by 17.4-23.2% (Kholif *et al.,* 2018). Replacement of conventional concentrate mixture with dried moringa leaves resulted in improvement of body weight without affecting feed intake and health of Mehsana goat (Pawar and Ankuya, 2017).

Non-ruminants

Pigs

The literature related to the use of moringa as feed for Pigs is limited and greatly restricted to the laboratory scale research. Some researchers have studied the impact of using moringa foliage as a replacement for conventional pig feed. It has been noted that finisher pig when fed with Moringa leaf at 5% intake level showed no negative impact on feed conversion ratio, cutability, backfat thickness and other carcass traits. Although the pigs fed with more than 5% moringa leaf meal exhibited better daily feed intake, their feed conversion ratio was lower as compared to those fed at 5% or below intake levels(Mukumbo *et al.,* 2014). The research findings of (Dany *et al*., 2016) suggested that inclusion of moringa leaf at 40% inclusion rate in Mexican hairless pigs had no effect on growth performance (Dany *et al.,* 2016). Furthermore it has been noted that increase in consumption of moringa feed resulted in increased amount of unsaturated fatty acids in fat and meat. However as reported that 10% inclusion level of moringa leaf in feeds of commercial prestarted and starter pigs had no impact on the average daily weight gains, highlighting the fact that a specific meal needs to be formulated for pigs based on their growth stage (Acda *et al.,* 2010). Weaner pigs fed with moringa leaf meal at varying inclusion levels ranging between 1-5% showed no significant effect on the final body weight and carcass parameters. However the growth rate of weaner pigs fed with 5% moringa leaf meal was better as compared to those fed with 2.5% meal and control diets (Oduro-Owusu *et al*., 2015). Cross bred finishing pigs fed with moringa meal at inclusion rates 0, 3, 6 and 9%, resulted in significant increase in the daily weight gain

with less impact on pork quality and amino acid profile. The fatty acid profile of finishing pigs underwent modification with an increase in unsaturated fatty acid content upon consumption of Moringa meal at 6% inclusion levels (Dong *et al.,* 2019).

Rabbits

Weaner rabbits fed with Moringa leaf meal at an inclusion level of 0-20% resulted in increase in average daily weight gain but no significant difference was observed in blood parameters (Nuhu, 2010). The growing rabbits fed with moringa leaf meal at varying inclusion levels in diets (up to 15%) exhibited no adverse effects on the hematological and serum biochemical response (Ewuola *et al*., 2012). Feeding New Zealand white rabbits with Moringa leaf meal as a substitute for alfalfa meal at level of 0%, 10%, 20% and 30% showed significant impact on growth performance, nutrient digestibility, meat quality, antioxidant capacity and biochemical parameters. The average daily weight gain and feed conversion ratio was much better at 20% inclusion level of moringa leaf meal. The leaf meal also had a significant impact on serum albumin, low density lipoproteins, cholesterol levels and superoxide dismutase activity (Sun *et al.,* 2018). Rabbits fed with 30% moringa leaf meal had a significant increase in body weight (Safwat *et al*., 2014).

Role of *Moringa oleifera* in disease management

Avian coccidiosis which is regarded as the most frequently encountered disease of importance to poultry, resulting in mortality of broiler globally has been so far tackled by use of anti-coccidial drugs. However plants with medicinal value could serve as an alternative to synthetic drugs. Extracts of Moringa leaves have been found to be effective against various bacterial, viral and parasitic infections. Acetone extracts of Moringa fed at the rate of 1-5 g/kg body weight of broiler chicken infected with Eimeria species showed improved gain in body weight and a significantly milder faecal scores. Moreover as compared to infected, untreated group of birds, those fed with moringa extracts had significantly higher hemoglobin and red blood cell count (Ola-Fadunsin and Ademola, 2013). Another research study evaluated the protective function of methanolic moringa extracts in chicken infected with Newcastle disease, which has a profound economic impact on poultry farms due to high mortality rates associated with this disease. Chicken fed with methanolic extracts of moringa at the rate of 200 mg/kg body weight for 42 days exhibited noteworthy survival rates validating the protective effect of Moringa against Newcastle disease (Eze *et al.,* 2012). Oral administration of aqueous eextracts of Moringa leaves at a dose of 150 mg/kg body weight for 21 days at an interval of 48 hours to sheep coinfected with *Fasciola gigantica* and *Colostritidium novyi* resulted in reduced fecal egg counts, improved gain in body weight and significant decrease in level of interleukin 2, interleukin 17 and immunoglobulin G (El Shanawany *et al.,* 2019).

CONCLUSION

M. oleifera could be a viable option in areas where traditional crops are being hampered by climate change. Furthermore, because all parts of *M. oleifera* are edible (leaves, roots, flowers, pods and seeds), they can be included into a variety of food matrices, enriching their nutritional profile with high quantities of proteins, fibre, vitamins and antioxidants. It also contains anti-inflammatory, anti-asthmatic, cholesterol-lowering, antimicrobial and analgesic properties, among others. *Moringa oleifera* has been used as a feed for different animals by various researchers either individually or in combination with conventional feeds at different inclusion levels, highlighting its potential to be used as an alternative to conventional feeds especially due to its rich protein content. Although Moringa is gaining popularity as a supplement in animal feeding system, but complete replacement of conventional feed by Moringa is still under question. The scare information is available pertaining to economics of moringa if it's used in place of traditional feed. Anti-nutritional factors, however present in substantially lower concentrations, can act as a limiting factor. Therefore it is quite necessary to pretreat the moringa feed in order to inactive the anti-nutritional factors and also properly investigate optimum dose or inclusion levels to be used in order to avoid any negative influence on the growth and reproductive performance of animal.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Abdel-Raheem, S.M. and Hassan, E.H. (2021). Effects of dietary inclusion of *Moringa oleifera* leaf meal on nutrient digestibility, rumen fermentation, ruminal enzyme activities and growth performance of buffalo calves. Saudi Journal of Biological Sciences. 28(8): 4430-4436. https://doi.org/10.1016/J.SJBS.2021.04.037.

Abdel-Wareth, A.A.A. and Lohakare, J. (2021). *Moringa oleifera* leaves as eco-friendly feed additive in diets of hy-line brown hens during the late laying period. Animals 11(4): 1116. https://doi.org/10.3390/ANI11041116.

Abdulkadir, A.R., Suhaili, Z. and Jahan, M.S. (2015). Antibacterial screening of different part of Drumstic tree (*Moringa oleifera* Lam). Available Online www.Jocpr.Com Journal of Chemical and Pharmaceutical Research. 7(4): 500-505. www.jocpr.com.

Abdulkarim, A., Sani, U., Adamu, S., Inuwa, H., Ahmadu, U. and Aljameel, K. (2018). Comparative effect of *Moringa oleifera* seed meal on nutrient digestibility of finisher broiler chickens. International Journal of Livestock Research. 8(5): 58. https://doi.org/10.5455/IJLR.20170611115020.

Abou-Elezz Fouad Mohammed, K., Sarmiento-Franco, L., Santos-Ricalde, R. and Solorio-Sanchez, J.F. (2012). The nutritional effect of *Moringa oleifera* fresh leaves as feed supplement on Rhode Island Red hen egg production and quality. Tropical Animal Health and Production. 44(5): 1035-1040. https://doi.org/10.1007/s11250-011-0037-5.

Acda, S.P., Masilungan, H.G.D. and Moog, B.A. (2010). Partial substitution of commercial swine feeds with malunggay (*Moringa oleifera*) leaf meal under backyard conditions. Philippine Journal of Veterinary and Animal Sciences. 36: 2.

Ahmad, S., Khalique, A., Pasha, T.N., Mehmood, S., Hussain, K., Ahmad, S., Shaheen, M.S., Naeem, M. and Shafiq, M. (2017). Effect of *Moringa oleifera* (Lam.) pods as feed additive on egg antioxidants, chemical composition and performance of commercial layers. South African Journal of Animal Science. 47(6): 864-874. https://doi.org/10.4314/sajas.v47i6.14.

Alabi, O., Malik, A., Ng'ambi, J., Obaje, P. and Ojo, B. (2017). Effect of aqueous *Moringa oleifera* (Lam) leaf extracts on growth performance and carcass characteristics of hubbard broiler chicken. Brazilian Journal of Poultry Science. 19(2): 273-280. https://doi.org/10.1590/1806-9061-2016-0373.

Aregheore, E.M. (2002). Intake and digestibility of *Moringa oleifera*-batiki grass mixtures by growing goats. Small Ruminant Research. 46(1): 23-28. https://doi.org/10.1016/S0921-4488(02)00178-5.

Auwal, M.M., Yelwa, J.M., Abubakar, I., Umar, J.B., Anchau, H.G. and Tanimu, F.B. (2020). The levels of antinutritional factors in *Moringa oleifera* and vernomia amygdalina leaves found in some part of plateau state, Nigeria. Oriental Journal of Physical Sciences. 4(2): 65-69. https://doi.org/10.13005/OJPS04.02.06.

Babiker, E.E., Juhaimi, F.A.L., Ghafoor, K. and 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. https://doi.org/10.1016/J.LIVSCI.2016.11.010.

Bala, D. and Ramana, V. (2020). Effect of feeding of Moringa (*Moringa oleifera*) leaf meal based diets on the biometry and body condition score of deccani lambs. Article in International Journal of Current Microbiology and Applied Sciences. https://doi.org/10.20546/ijcmas.2020.904.129.

Ben Salem, H. and Makkar, H.P.S. (2009). Defatted *Moringa oleifera* seed meal as a feed additive for sheep. Animal Feed Science and Technology. 150(1-2): 27-33. https://doi.org/10.1016/j.anifeedsci.2008.07.007.

Bhattacharya, A., Tiwari, P., Sahu, P.K. and Kumar, S. (2018). A review of the phytochemical and pharmacological characteristics of *Moringa oleifera*. Journal of Pharmacy and Bioallied Sciences. 10(4): 181. https://doi.org/10.4103/JPBS.JPBS_126_18.

Bidura, I., Partama, I.B.G., Utami, I.A.P., Candrawati, D., Puspani, E. *et al*. (2020). Effect of *Moringa oleifera* leaf powder in diets on laying hens performance, α-carotene, cholesterol and minerals contents in egg yolk. IOP Conference Series: Materials Science and Engineering. 823(1): 012006. https://doi.org/10.1088/1757-899X/823/1/012006.

Brilhante, R.S.N., Sales, J.A., Pereira, V.S., Castelo-Branco, D. *et al*. (2017). Research advances on the multiple uses of *Moringa oleifera*: A sustainable alternative for socially neglected population. Asian Pacific Journal of Tropical Medicine. 10(7): 621-630. https://doi.org/10.1016/J.APJTM.2017.07.002.

Briones, J., Leung, A., Bautista, N., Golin, S., Caliwag, N., Carlos, M.A., *et al*. (2017). Utilization of *Moringa oleifera* Lam. in animal production. Acta Horticulturae. 1158: 467-474. https://doi.org/10.17660/ACTAHORTIC.2017.1158.54.

Cohen-Zinder, M., Leibovich, H., Vaknin, Y., Sagi, G., Shabtay, A., Ben-Meir, Y., *et al*. (2016). Effect of feeding lactating cows with ensiled mixture of *Moringa oleifera*, wheat hay and molasses, on digestibility and efficiency of milk production. Animal Feed Science and Technology. 211: 75-83. https://doi.org/10.1016/j.anifeedsci.2015.11.002.

Dany, D.C., Jorge, O.O., Ángel, S.V., Enrique, S.D., Valentín, P.R. and Luis, S.F. (2016). Effect of *Moringa oleífera* meal inclusion on meat quality from the Mexican hairless pig. ARPN Journal of Agricultural and Biological Science. 11(4): 131-141. www.arpnjournals.com.

David, L.S., Vidanarachchi, J.K., Samarasinghe, K., Cyril, H.W. and Dematawewa, C.M.B. (2015). Effects of *Moringa* based feed additives on the growth performance and carcass quality of broiler chicken. Tropical Agricultural Research. 24(1): 12. https://doi.org/10.4038/TAR.V24I1.7 985.

Debajyoti, D., Dipsundar, S., Dinesh, B., Chandreyee, R., Sanatan, R. and Jayram, H. (2017). *Moringa olifera* (Shigru): A miracle tree for its nutritional, ethnomedicinal and therapeutic importance. CCRAS. http://www.journalijdr.com.

Dhakar, R., Pooniya, B., Gupta, M., Maurya, S., Bairwa, N. and Sanwarmal (2011). Moringa/: The herbal gold to combat malnutrition. Chronicles of Young Scientists. 2(3): 119. https://doi.org/10.4103/2229-5186.90887.

Dong, L., Zhang, T. and Diao, Q. (2019). Effect of dietary supplementation of *Moringa oleifera* on the production performance and fecal methanogenic community of lactating dairy cows. Animals. 9(5): 262. https://doi.org/10.3390/ANI9050262.

El Shanawany, E.E., Fouad, E.A., Keshta, H.G., Hassan, S.E., Hegazi, A.G. and Abdel-Rahman, E.H. (2019). Immunomodulatory effects of *Moringa oleifera* leaves aqueous extract in sheep naturally co-infected with *Fasciola gigantica* and *Clostridium novyi*. Journal of Parasitic Diseases. 43(4): 583-591. https://doi.org/10.1007/S12639-019-01130-6.

Elghandour, M.M.Y., Vallejo, L.H., Salem, A.Z.M., Mellado, M., *et al*. (2017). *Moringa oleifera* leaf meal as an environmental friendly protein source for ruminants: Biomethane and carbon dioxide production and fermentation characteristics. Journal of Cleaner Production. 165: 1229-1238. https://doi.org/10.1016/J.JCLEPRO.2017.07.151.

Ewuola, E.O., Jimoh, O.A., Atuma, O.V and Soipe, O.D. (2012). Haematological and serum biochemical response of growing rabbits fed graded levels of *Moringa oleifera* leaf meal. World Rabbit Science Association. 679-683.

Eze, D.C., Okwor, E.C., A., O.J.O., Nnabuike, O.D. and Olu, S.S.V. (2012). Effects of *Moringa oleifera* methanolic leaf extract on the morbidity and mortality of chickens experimentally infected with Newcastle disease virus (Kudu 113) strain. Journal of Medicinal Plants Research. 6(27): 4443-4449. https://doi.org/10.5897/JMPR12.792.

Falowo, A.B., Mukumbo, F.E., Idamokoro, E.M., Lorenzo, J.M., Afolayan, A.J. and Muchenje, V. (2018). Multi-functional application of *Moringa oleifera* Lam. in nutrition and animal food products: A review. In Food Research International. Food. Res. Int. 106: 317-334. https://doi.org/10.1016/j.foodres.2017.12.079.

FAO (Food and Agriculture Organization of the United Nations), (2009). Submission to UNFCCC AWG LCA, Enabling Agriculture to Contribute to Climate Change. Retrieved from: http://unfccc.int/resource/docs/2008/smsn/igo/036.pdf.

Gidamis, A.B., Panga, J.T., Sarwatt, S.V., Chove, B.E. and Shayo, N.B. (2003). Nutrient and antinutrient contents in raw and cooked young leaves and immature pods of *Moringa oleifera*, Lam. Ecology of Food and Nutrition. 42(6): 399-411. https://doi.org/10.1080/03670240390268857.

Gopalakrishnan, L., Doriya, K. and Kumar, D.S. (2016). *Moringa oleifera*: A review on nutritive importance and its medicinal application. Food Science and Human Wellness. 5(2): 49-56. https://doi.org/10.1016/J.FSHW.2016.04.001.

Granella, S.J., Bechlin, T.R., Christ, D., Coelho, S.R.M. and Paz, C.H., de O. (2021). An approach to recent applications of *Moringa oleifera* in the agricultural and biofuel industries. South African Journal of Botany. 137: 110-116. https://doi.org/10.1016/J.SAJB.2020.10.006.

Igwilo, I.O., Ezeonu, F.C., Ezekwesih-Ofih, J.O., Igwilo, S.N., Nsofor, C.I., Abdulsalami, M.S. and Obi, E. (2013). Anti-nutritional factors in the roots of a local cultivar of *Moringa oleifera* (Lam). Pakistan Journal of Biological Sciences. 17(1): 114-117. https://doi.org/10.3923/PJBS.2014.114.117.

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

James, A. and Zikankuba, V. (2017). *Moringa oleifera* a potential tree for nutrition security in sub-Sahara Africa. 5: 1. www.usa-journals.com.

Kekana, T.W., Marume, U., Muya, C.M. and Nherera-Chokuda, F.V. (2019). Lactation performance and blood metabolites in lactating dairy cows micro-supplemented with *Moringa oleifera* leaf meal. South African Journal of Animal Science. 49(4): 709-716. https://doi.org/10.4314/sajas.v49i4.12.

Kekana, T.W., Marume, U., Muya, M.C. and Nherera-Chokuda, F.V. (2020). Periparturient antioxidant enzymes, haematological profile and milk production of dairy cows supplemented with *Moringa oleifera* leaf meal. Animal Feed Science and Technology. 268: 114606. https://doi.org/10.1016/J.ANIFEEDSCI.2020.114606.

Kholif, A.E., Gouda, G.A., Anele, U.Y. and Galyean, M.L. (2018). Extract of *Moringa oleifera* leaves improves feed utilization of lactating Nubian goats. Small Ruminant Research. 158: 69-75. https://doi.org/10.1016/J.SMALLRUMRES.2017.10.014.

Kholif, A.E., Gouda, G.A., Morsy, T.A., Salem, A.Z.M., Lopez, S. and Kholif, A.M. (2015). *Moringa oleifera* leaf meal as a protein source in lactating goat's diets: Feed intake, digestibility, ruminal fermentation, milk yield and composition and its fatty acids profile. Small Ruminant Research. 129: 129-137. https://doi.org/10.1016/J.SMALLRUMRES.2015.05.007.

Koul, B., Chase, N. (2015). *Moringa oleifera* Lam: Panacea to several maladies. Journal of Chemical and Pharmaceutical Research. 7: 687-707.

León-López, L., Escobar-Zúñiga, Y., Milán-Carrillo, J., Domínguez-Arispuro, D.M., *et al.* (2020). Chemical proximate composition, antinutritional factors content and antioxidant capacity of anatomical seed fractions of *Moringa oleifera*. Acta Universitaria. 30: 1-11. https://doi.org/10.15174/AU.2020.2892.

Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J. and Bertoli, S. (2015). Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An overview. International Journal of Molecular Sciences. 16(6): 12791. https://doi.org/10.3390/IJMS160612791.

Liang, L., Wang, C., Li, S., Chu, X. and Sun, K. (2019). Nutritional compositions of Indian *Moringa oleifera* seed and antioxidant activity of its polypeptides. Food Science and Nutrition. 7(5): 1754-1760. https://doi.org/10.1002/FSN3.1015.

Lu, W., Wang, J., Zhang, H.J., Wu, S.G. and Qi, G.H. (2016). Evaluation of *Moringa oleifera* leaf in laying hens: Effects on laying performance, egg quality, plasma biochemistry and organ histopathological indices. Italian Journal of Animal Science. 15(4): 658-665. https://doi.org/10.1080/1828051X.2016.1249967.

Mabusela, S.P., Nkukwana, T.T., Mokoma, M. and Muchenje, V. (2018). Layer performance, fatty acid profile and the quality of eggs from hens supplemented with *Moringa oleifera* whole seed meal. South African Journal of Animal Science. 48(2): 234-243. https://doi.org/10.4314/sajas.v48i2.

Mahfuz, S. and Piao, X.S. (2019). Application of Moringa (*Moringa oleifera*) as natural feed supplement in poultry diets. Animals/: An Open Access Journal from MDPI. 9(7). https://doi.org/10.3390/ANI9070431.

Makkar, H.P.S. and Becker, K. (1997). Nutrients and antiquality factors in different morphological parts of the *Moringa oleifera* tree. The Journal of Agricultural Science. 128(3): 311-322. https://doi.org/10.1017/S0021859697004292.

Mendieta-Araica, B., Spörndly, R., Reyes-Sánchez, N. and Spörndly, E. (2011). Moringa (*Moringa oleifera*) leaf meal as a source of protein in locally produced concentrates for dairy cows fed low protein diets in tropical areas. Livestock Science. 137(1-3): 10-17. https://doi.org/10.1016/J.LIVSCI.2010.09.021.

Mohanty, M., Mohanty, S., Bhuyan, S.K. and Bhuyan, R. (2021). Phytoperspective of *Moringa oleifera* for oral health care: An innovative ethnomedicinal approach. Phytotherapy Research. 35(3): 1345-1357. https://doi.org/10.1002/PTR.6896.

Moyo, B., Masika, P., Hugo, A. and Muchenje, V. (2013). Nutritional characterization of Moringa (*Moringa oleifera* Lam.) leaves. African Journal of Biotechnology. 10(60): 12925-12933. https://doi.org/10.4314/ajb.v10i60.

Mughal, M.H., Ali, G., Srivastava, P.S. and Iqbal, M. (1999). Improvement of drumstick (*Moringa pterygosperma* Gaertn.)- A unique source of food and medicine through tissue culture. Hamdard Medicus. 42(1): 37-42. https://eurekamag.com/research/003/471/003471247.php.

Muhammed Fayis, E.K. (2017). Comparative Study of Anti-nutritional Factors in *Moringa oleifera* Leaves and Seed. The Bioscientist Journal. 5(1).

Mukumbo, F.E., Maphosa, V., Hugo, A., Nkukwana, T.T., Mabusela, T.P. and Muchenje, V. (2014). Effect of *Moringa oleifera* leaf meal on finisher pig growth performance, meat quality, shelf life and fatty acid composition of pork. South African Journal of Animal Sciences. 44(4): 388-400. https://doi.org/10.4314/SAJAS.V44I4.9.

Nouman, W., Siddiqui, M.T., Basra, S.M.A., Farooq, H., Zubair, M. and Gull, T. (2013). Biomass production and nutritional quality of *Moringa oleifera* as a field crop. Turkish Journal of Agriculture and Forestry. 37(4): 410-419. https://doi.org/10.3906/TAR-1206-29.

Nuhu, F. (2010). Effect of Moringa Leaf Meal (molm) on Nutrient Digestibility, Growth, Carcass and Blood Indices of Weaner Rabbits.

Oduro-Owusu, A.D., Kagya-Agyemang, J.K., Annor, S.Y. and Bonsu, F.R.K. (2015). Growth performance, carcass characteristics and economic efficiency of using graded levels of moringa leaf meal in feeding weaner pigs. Journal of Experimental Agriculture International. 7(3): 190-196. https://doi.org/10.9734/AJEA/2015/15262.

Ola-Fadunsin, S.D. and Ademola, I.O. (2013). Direct effects of *Moringa oleifera* Lam (Moringaceae) acetone leaf extract on broiler chickens naturally infected with Eimeria species. Tropical Animal Health and Production. 45(6): 1423-1428. https://doi.org/10.1007/S11250-013-0380-9.

Olugbemi, T.S., Mutayoba, S.K. and Lekule, F.P. (2010). Effect of Moringa (*Moringa oleifera*) inclusion in cassava based diets fed to broiler chickens. International Journal of Poultry Science. 9(4): 363-367. https://doi.org/10.3923/IJPS.2010.363.367.

Paikra, B.K., Dhongade, H.K.J. and Gidwani, B. (2017). Phytochemistry and pharmacology of *Moringa oleifera* Lam. In Journal of Pharmacopuncture. 20(3): 194-200). https://doi.org/10.3831/KPI.2017.20.022.

Pandey, A. (2012). *Moringa oleifera* Lam. (Sahijan)- A plant with a plethora of diverse therapeutic benefits: An updated retrospection. Medicinal and Aromatic Plants. 01(01). https://doi.org/10.4172/2167-0412.1000101.

Pawar, M. and Ankuya, K. (2017). Effect of feeding different levels of Moringa (*Moringa oleifera*) leaves on growth performance of mehsana goat kids. https://www.researchgate.net/publication/316990321.

Price, M.L. (1985). The *Moringa* tree what's inside uses of *Moringa*: Plant parts as an antibiotic cultivation of *Moringa* propagation of *Moringa* Species of *Moringa* seed sources web sites with more information Appendix: Information on a seed dehusker.

Radek, M. and Savage, G.P. (2008). Oxalates in some Indian green leafy vegetables. International Journal of Food Sciences and Nutrition. 59(3): 246-260. https://doi.org/10.1080/09637480701791117.

Ramachandran, C., Peter, K.V. and Gopalakrishnan, P.K. (1980). Drumstick (*Moringa oleifera*): A multipurpose Indian vegetable. Economic Botany. 34(3): 276-283. https://doi.org/10.1007/BF02858648.

Ravani, A., Prasad, R.V., Gajera, R.R. and Joshi, D.C. (2017). Potentiality of *Moringa oleifera* for food and nutritional security- A review. Agricultural Reviews. 38(03). https://doi.org/10.18805/AG.V38I03.8983.

Rehman, H., Zaneb, H., Masood, S., Yousaf, M., Ashraf, S., Khan, I., Shah, M., Khilji, M. and Rehman, H. (2018). Effect of *Moringa oleifera* leaf powder supplementation on pectoral muscle quality and morphometric characteristics of tibia bone in broiler chickens. Brazilian Journal of Poultry Science. 20(4): 817-824. https://doi.org/10.1590/1806-9061-2017-0609.

Reyes Sánchez, N., Spörndly, E. and 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. https://doi.org/10.1016/J.LIVPRODSCI.2005.09.010.

Aharwal, B., Roy, B., Lakhani, G.P., Baghel, R.P.S., Saini, K.P.S. and Yadav, A. (2018). Effect of *Moringa oleifera* leaf meal on feed intake and growth performance of murrah buffalo calves. Article in International Journal of Current Microbiology and Applied Sciences. 7(9): 1960-1973. https://doi.org/10.20546/ijcmas.2018.709.238.

Safwat, A.M., Sarmiento-Franco, L., Santos-Ricalde, R. and Nieves, D. (2014). Effect of dietary inclusion of Leucaena leucocephala or *Moringa oleifera* leaf meal on performance of growing rabbits. Tropical Animal Health and Production. 46(7): 1193-1198. https://doi.org/10.1007/S11250-014-0626-1.

Saini, R.K., Sivanesan, I. and Keum, Y.S. (2016). Phytochemicals of *Moringa oleifera*: A review of their nutritional, therapeutic and industrial significance. 3 Biotech. 6(2). https://doi.org/10.1007/S13205-016-0526-3.

Sánchez-Machado, D.I., Núñez-Gastélum, J.A., Reyes-Moreno, C., Ramírez-Wong, B. and López-Cervantes, J. (2010). Nutritional quality of edible parts of *Moringa oleifera*. Food Analytical Methods. 3(3): 175-180. https://doi.org/10.1007/S12161-009-9106-Z.

Shankhpal, S.S., Waghela, C.R., Sherasia, P.L., Sridhar, V., Srivastava, A.K. and Singh, D. (2019). Effect of feeding Moringa (*Moringa oleifera*) as green fodder on feed intake, milk yield, microbial protein dynthesis and blood profile in crossbred cows. Indian Journal of Animal Nutrition. 36(3): 228. https://doi.org/10.5958/2231-6744.2019.00038.0.

Shih, M.C., Chang, C.M., Kang, S.M. and Tsai, M.L. (2011). Effect of different parts (leaf, stem and stalk) and seasons (summer and winter) on the chemical compositions and antioxidant activity of *Moringa oleifera*. International Journal of Molecular Sciences. 12(9): 6077-6088. https://doi.org/10.3390/IJMS12096077.

Singh, A.K., Rana, H.K., Tshabalala, T., Kumar, R., Gupta, A., Ndhlala, A.R. and Pandey, A.K. (2019). Phytochemical, nutraceutical and pharmacological attributes of a functional crop *Moringa oleifera* Lam: An overview. The South African Journal of Botany. 129: 209-220.

Soliva, C.R., Kreuzer, M., Foidl, N., Foidl, G., Machmüller, A. and Hess, H.D. (2005). Feeding value of whole and extracted *Moringa oleifera* leaves for ruminants and their effects on ruminal fermentation *in vitro*. Animal Feed Science and Technology. 118(1-2): 47-62. https://doi.org/10.1016/J.ANIFEEDSCI.2004.10.005.

Su, B. and Chen, X. (2020). Current status and potential of *Moringa oleifera* leaf as an alternative protein source for animal feeds. Frontiers in Veterinary Science. 7. https://doi.org/10.3389/FVETS.2020.00053.

Sultana, N. (2015). The feeding value of Moringa (*Moringa oleifera*) foliage as replacement to conventional concentrate diet in bengal goats. Advances in Animal and Veterinary Sciences. 3(3): 164-173. https://doi.org/10.14737/JOURNAL.AAVS/2015/3.3.164.173.

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

Sun, B., Zhang, Y., Ding, M., Xi, Q., Liu, G., Li, Y., Liu, D. and Chen, X. (2018). Effects of *Moringa oleifera* leaves as a substitute for alfalfa meal on nutrient digestibility, growth performance, carcass trait, meat quality, antioxidant capacity and biochemical parameters of rabbits. Journal of Animal Physiology and Animal Nutrition. 102(1): 194-203. https://doi.org/10.1111/JPN.12678.

Tazi, S.M.A., El. (2014). Effect of feeding different levels of *Moringa oleifera* leaf meal on the performance and carcass quality of broiler chicks. International Journal of Science and Research. www.ijsr.net.

Teixeira, E.M.B., Carvalho, M.R.B., Neves, V.A., Silva, M.A. and Arantes-Pereira, L. (2014). Chemical characteristics and fractionation of proteins from *Moringa oleifera* Lam. Leaves. In Food Chemistry. Food Chem. 147: 51-54. https://doi.org/10.1016/j.foodchem.2013.09.135.

Trigo, C., Castelló, M.L., Ortolá, M.D., García-Mares, F.J. and Soriano, M.D. (2020). *Moringa oleifera*: An unknown crop in developed countries with great potential for industry and adapted to climate change. Foods. 10(1): 31. https://doi.org/10.3390/FOODS10010031.

Yang, S.L., Yang, R.C., Zhou, X., Yang, S.H., Luo, L.L., Zhu, Y.C. and Boonanuntan, S. (2020). Effects of feeding diets with processed *Moringa oleifera* stem meal on growth and laying performance and immunological and antioxidant activities in laying ducks. Poultry Science. 99(7): 3445. https://doi.org/10.1016/J.PSJ.2020.04.002.

Zeng, B., Sun, J.J., Chen, T., Sun, B.L., He, Q., Chen, X.Y., Zhang, Y.L. and Xi, Q.Y. (2018). Effects of *Moringa oleifera* silage on milk yield, nutrient digestibility and serum biochemical indexes of lactating dairy cows. Journal of Animal Physiology and Animal Nutrition. 102(1): 75-81. https://doi.org/10.1111/JPN.12660.

Zhai, S., Li, M., Li, M., Zhang, X., Ye, H., Lin, Z., Wang, W., Zhu, Y. and Yang, L. (2020). Effect of dietary Moringa stem meal level on growth performance, slaughter performance and serum biochemical parameters in geese. Journal of Animal Physiology and Animal Nutrition. 104(1): 126-135. https://doi.org/10.1111/JPN.13209.