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Application of munga (*Moringa oleifera*) in livestock feed: A review

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Abstract
There are prevalent usage of the plant *Moringa oleifera* in sequential style of cooking and medicinal remedies in various regions of the world. In recent years so many researches performed on supplementation of different parts of the *Moringa oleifera* plant mostly on the leaves as nutritional feed resource for livestock. Studies revealed *M. oleifera* as a rich source of essential nutrients protein, minerals, vitamins and essential amino acids with a comparatively low amount of antinutritional factors. It is also accomplished by bioactive compounds including phenolic and flavonoid compounds. In many studies it has been reported that *Moringa oleifera* consumption improves the health status, feed conversion efficiency and growth performance of various livestock species. There is limited literature available regarding clinical studies, bioavailability of nutrient, toxicity and the mode of action of the bioactive compounds, to which the health claims concern with consumption of *Moringa oleifera*. In order to get full utilization of the potential benefits of *M. oleifera* plant as a livestock feed, more researches in these areas are needed.

Keywords: *Moringa oleifera*, antinutritional factors, leaves, livestock performance

Introduction
Moringa oleifera popularly known as munga is used as a rich source of livestock feed because of its latent nutritional, antioxidant and phytochemical properties, in many tropical and sub-tropical areas. *Moringa oleifera* is able to sustain in diverse climatic conditions and can survive in less fertile soils and slightly affected by drought. The plant is known to be a fast growing multi-functional plant with different uses in agriculture, medicine, livestock, human and other biological systems [1]. Interesting point is that, every part of the *M. oleifera* plant, including the leaf, root, bark, seed, flower and pod is edible and contains compounds that are vital for good health of livestock [2]. *M. oleifera* leaves have been reported to contain higher amount of vitamins C than orange, higher vitamin A than carrots, more amount of calcium than milk, higher potassium than banana and higher iron than spinach [3]. *M. oleifera* application in livestock feed for improvement in growth performance, milk production and its quality have been reported in many literature with successful results.

Description of *Moringa oleifera*
Moringa oleifera is a tree species comes under family Moringaceae of the genus *Moringa*, which is cultivated over a large area in the world [4]. The genus *Moringa* includes 13 species of which 11 of them originated from Africa and Arabia and 2 from India (*M. concanensis and M. oleifera*) [5]. Historically, *M. oleifera* is native to India and Pakistan but because of its flexible adaptive features, such as, capability to grow fast, sustain in drought condition and its long life it is now grown in both tropical and subtropical areas in the world. *M. oleifera* species are known by a lot of traditional names which include super food tree, drumstick tree, miracle tree, tree of life, horseradish tree, benzoil tree or moringa. The average height of plant is 5 m and may grow a maximum of 10 m height in suited environmental condition. The colour of leaf is greenish, the flower has yellowish-white colour petals and dimension of petals ranges from 1.0–1.5 cm long and 2.0–2.5 cm broad. The stem/bark is whitish-gray in colour and is covered by thick cork and shape of seed is round or triangular having a brownish colour semi-permeable seed hull which is appended in long slender pods [6].

Nutrients in *Moringa oleifera*

M. oleifera, rich in nutrient containing least anti-nutritional factors is used as an alternative to livestock feed. Nutritional evaluation of different parts of plant like leaves, seeds and stems of the plant demonstrates that they are abundant in protein, essential amino acids, minerals, vitamins and other bioactive compounds [7, 8]. There are still scanty reports about the nutrient composition of roots of this plant. The proximate composition of *M. oleifera* leaf, seed and steam are presented in the table as low to high range reported by various scientists. The difference in the nutritional composition may be attributed to the factors such as growth rate, environmental factor, harvesting stage, type of soil and processing methods. The leaves and seeds carry large amounts of essential minerals, vitamins, amino acids, and fatty acids [9]. *M. oleifera* leaf contains both unsaturated and saturated fatty acid and more than half (57%) of the *M. oleifera* leaf fatty acids has been classified under unsaturated fatty acids with highest value of α-Linolenic acid while the rests are classified under saturated fatty acids (43%) [9]. Further, it was observed that *M. oleifera* leaves have about 16 to 19 amino acids, out of which 10 are classified under essential amino acids. *M. oleifera* leaves have been reported to be higher in calcium, potassium, magnesium and iron contents as compared to other plants such as *Vernomia anydalira*, *Manihot esculenta*, *Teiferia occidentalis*, *Talinum triangulare* and *Amaranthus spinosus* [9, 10]. It has been observed that the amount of vitamins A, B, C and E in the *M. oleifera* leaves are also high [11]. Beside this, the other parts of the *M. oleifera* plant such as roots, stems, flowers and fruits are rich in proximate, minerals, vitamins and fatty acids contents [12].

Phytochemicals in *Moringa oleifera*

Moringa oleifera leaves are abundance in nutrient and bioactive compounds. Yameogo *et al.*, 2011[13] observed good source of dietary antioxidants in *Moringa oleifera*, which include flavonoids such as kaempferol as well as quercetin. Siddhuraju and Becker., (2003) [14] observed the natural antioxidant contents of *Moringa oleifera* on dry weight basis from three various agroclimatic origins, 74–210 µmol/g phenolics, 70–100 µmol/g ascorbate (vitamin C), 1.1–2.8 µmol/g carotene and 0.7–1.1 µmol/g α tocopherol. Research findings reported that *Moringa oleifera* had higher antioxidant than well known fruits and vegetables. For example strawberries, carrots, soybean and hot pepper [15]. Moreover, the total phenolics content of *Moringa oleifera* leaves was about twice of the vegetables viz. broccoli, spinach, and cauliflower and total flavonoids were three times of the same vegetables mentioned above [16]. It also has reasonably high ascorbic acid content [13]. These antioxidants might be related with the direct capturing of free radicals to avoid DNA damage due to excessive oxidation thus provide safeguard to animals against many degenerative diseases and infections [17]. Studies revealed that Moringa leaves have also carry some unique compounds, which include rhamnose, isothiocyanate and glucosinolates [18, 19] as these compounds have strong hypotensive (blood pressure lowering) and spasmolytic (muscle relaxant) activities [20]. Other important compounds viz. benzyl glucosinolates, 4-(4-O-acetyl-α-L rhamnopyranosyl oxy), benzyl thiocyanate 4-(α-L-rhamnopyranosyl oxy) and benzyl isothiocyanate are also found. These compounds are well known for their hypotensive, anticancer and antibacterial activities [18]. Some flavonoid pigments, for example kaempferitrin, rhamnetin, kaempferol etc. are reported in Moringa flowers [18, 19]. Cytokine-type hormones were observed in 80% Moringa leaf ethenolic extract [21, 22].

The isothiocyanate found in moringa seed, acts as anticancer agents and reduces oxidative stress [23]. Phytosterols for example kampesterol, sitosterol and stigmasterol act as precursors for hormones, which induce estrogen production and stimulates proliferation of mammary gland ducts. In addition, the presence of flavanoids provides anti-inflammatory, antioxidant, antidiabetic properties as well as anti-proliferative and anticancer properties [3]. The phytochemical compounds of moringa have several biological actions including antidiabetic, hypocholesterolemic and hypertensive. It also regulates thyroid hormone, central nervous system and digestive system. Finally, we can conclude that *Moringa oleifera* is rich in phytochemicals and have significant medicinal properties.

Effect of *Moringa oleifera* in livestock production

Livestock health and growth performance

M. oleifera used as a livestock feed resource is potentially rich in nutrients as well as bioactive compounds. The leaf, seed and bark of this plant are willingly eaten by cattle, sheep, goats, pigs, chickens and rabbits as a constituent of the feed. The plant has reported to improve the health status, growth performance, milk production and its composition and meat quality of various livestock species. Reports on the immune responses of broiler chickens fed *M. oleifera* showed that it can increase the production of erythrocyte, leucocytes and the heamoglobin level, as well as by reducing the population of *Escherichia coli* and enhancing the *Lactobacillus* in the ileum improving intestinal health [10]. It has also reported that the broiler chickens fed *M. oleifera* leaf meal at the rate 1, 3 and 5% of DM intake showed significantly higher body weight gain, average daily gain and higher feed conversion ratio (i.e. number of kg of feed required to produce a kg of meat) than control group [24]. On the other hand, Makanjuola *et al.* (2014) [25] and Onunkwo and George (2015) [26] did not report any significant differences in the body weight gain and feed intake of broiler chickens fed *M. oleifera* leaf meal as compare to that of control group when *M. oleifera* included at 200, 400 and 600 g respectively in 100 kg of feed. These studies showed that *M. oleifera* leaf meal does not have any harmful effects on growth performance and can be used as rich protein source in poultry diets. Moreover, Adegun and Aye, (2013) [27] did not observed any body weight gain when *M. oleifera* leaf meal replace cottonseed cake (CSC) at 25, 50, 75 and 100% level in a ram diets when compared to control diet. In another report observed by Ndemanisho, *et al*. (2007) [28], when rumen fistulated goats fed CSC and *M. oleifera* leaf meal based concentrates average growth rate did not differ in respect to control group. On the contrary, Moyo *et al.*, (2012b) [29] found higher daily weight gain and feed intake in goats diet containing 200 g of *M. oleifera* leaf than those fed sunflower cake (SC) and control group. Furthermore, when commercially available readymade concentrate were replaced by *Moringa oleifera* leaves at 25, 50, 75 and 100% in Sirohi goat kids average body weight gain higher in 75% replacement followed by 50, 100 and 25% replacement [30]. In another study when *Moringa oleifera* leaves was replaced 50% and 100% of concentrate in Mehasana goat kid, the average body weight gain was higher than control group [31].

However, Adeniji and Lawal (2012) [32] reported a significant increase in body weight gain and feed intake in rabbits when groundnut cake is replaced by *Moringa oleifera* leaves at the rate of 20,40 and 60% in diet when compared to control

group. Mukumbo *et al.* (2014) [33] also observed higher average daily feed intakes and lower slaughter weight when pigs fed 7.5% *M. oleifera* leaf based ration than the control group. Moreover, when 5, 10 and 15% of calf starter was replaced with *M. oleifera* leaf meal in suckling buffalo calves average daily DM intake was decreased however average weight gain was higher than control group [34]. Generally, the increase in growth performance of livestock fed *M. oleifera* leaf based ration has been due to its more nutritional content, antioxidant and antimicrobial properties and also due to the presence of essential natural enzymes which help digestion of fibrous food in animals.

Significantly higher body weight gain, feed intake and feed efficiency in broilers fed 0.5% *M. oleifera* seed compared to control group were observed [35]. However, inclusion of 0.5% level of *M. oleifera* seed showed lowered body weight gain, feed intake, feed efficiency than the control diet. This performance reduction may be attributed to existing anti nutritional factors viz. phytate which has been noted to decrease bioavailability of minerals and reduce digestibility of protein and starch in animals [36, 37]. Also, during a nine day feeding trial in broiler chicks the administration of *M. oleifera* aqueous root extracts at 5, 10 and 15 g/L to treat *E. coli* reported no significant difference in body weight gain, feed intake and feed conversion ratio as compared to chicks provided commercial antibiotics [38]. However, there is still few published literatures regarding the effect of *M. oleifera* root, seed and stem meal feeding on livestock performance and more researches should be conducted towards this area.

Table 1: Proximate composition of *Moringa oleifera* (% dry matter basis)

Proximate composition	Range (low–high)*		
	Leaf	Seed	Stem
Protein	10.74^{a}–30.29^{b}	9.98^{c}–51.80^{d}	12.77^{e}
Fat	6.50^{b}–20.00^{c}	22.97^{g}–38.67^{f}	2.0^{e}
Crude fibre	7.09^{g}–35.00^{c}	20.00^{c}–22.93^{g}	–
Ash	7.64^{a}–10.71^{b}	3.60^{j}–5.00^{c}	8.41^{e}
Carbohydrate	13.41^{c}–63.11^{g}	18.00^{c}–40.09^{g}	–

References: a- Valdez-Solana *et al.* 2015 [8]; b- Moyo *et al.*, 2011 [9]; c- Aja *et al.*, 2013 [39]; d -Ochi *et al.*, 2015 [35]; e - Shih *et al.*, 2011 [12]; f- Olagbemide and Philip, 2014 [40]; g – Mabusela *et al.*, 2018 [41].

Milk production and its composition

Researches on animal production may improve economic growth and human health especially in developing countries by decreasing food insufficiency and malnutrition. The application of *M. oleifera* leaves in animal feed to improve milk production is gaining popularity because *M. oleifera* leaves are rich in minerals [42], which are vital for enhanced milk yield and its quality in ruminants [43]. It has been reported that *Moringa oleifera* contain more protein which is needed to boost the synthesis of microbial protein in the rumen of livestock [44].

Various studies on replacement of feedstuff with *M. oleifera* to enhance the milk yield and its quality in livestock such as goats, sheep and cows have been observed. Study conducted by Babiker *et al.* (2017) [45] reported significant increase in milk yield, milk fat, milk lactose and solid-not-fat in the goats and ewes when alfalfa hay replaced with 25% *M. oleifera* leaf powder as compared to the diet prepared with 40% alfalfa hay inclusion level. Moreover, more energy, catalase and serum contents were also noted in milk of goats and ewes fed with *M. oleifera* leaf diet as compared to those fed with 40% alfalfa based diet (Babiker *et al.*, 2017) [45]. They also found that there was more oxidative stability and vitamin C content of milk of goats and ewes those were fed with 25% *M. oleifera* leaf when compared to Alfalfa hay diet. Whereas, 50% replacement of concentrate mixture with Moringa leaves increased milk yield, milk fat, milk protein, lactose and solid not-fat percentage in lactating Bengal goat [46]. The improvement in the yield and quality of milk in goats and ewes fed with *M.oleifera* leaf when compared to those fed with Alfalfa hay was due to the presence of more micro nutrients viz. phosphorus, calcium, magnesium and potassium [45].

In creole dairy cows, supplementation of *Moringa oleifera* increased DM intake and milk yield in cows fed with 2 kg or 3 kg dry matter (DM) *M. oleifera* leaf when compared to cows fed only with *Brachiaria brizantha* hay [46]. In another study Khalel *et al.*, (2014) [47] formulated the ration with *M. oleifera* at 20 and 40% inclusion level in comparison with berseem forage (40% inclusion level).They observed that cows fed with *M. oleifera* based diet had significantly higher milk yield as compared to those fed with berseem hay. Moreover to this, there were increase ($P \leq 0.05$) in total milk solids, solid not-fat, milk fat, milk protein and ash of cows fed with *M. oleifera* based ration compared to those fed with the berseem ration.When cotton seed cake were replaced by Moringa leaf meal at various levels of 10, 20, or 30% of dry matter (DM) in dairy cow feed the milk production was significantly increased although, there were no effects observed on total solids, fat and protein contents of the milk by replacing cotton seed cake with *Moringa oleifera* leaf meal [49]. Althought, the limited substitution of alfalfa hay (≤50%) and maize silage with *Moringa oliefera* silage had no negative effects on milk yield and serum biochemical profile of lactating Holstein cows [50]. When *Moringa oleifera* leaves mixed with chopped wheat hay and sugar cane molasses in a ratio of 370:540:90 respectively on DM basis this silage was added in the total mixed ration (TMR) of lactating cows at the rate of 180 g/kg DM as replacement of wheat silage and hay. Controlled cows intake more digestible DM/day than the *Moringa oleifera* group it was not reflected in milk production which is more in the *Moringa oleifera* group. Milk fat content was also more in *Moringa oleifera* group, while protein content of milk was more in the control group [51]. The enhance in milk yield and its quality as a result of application of *M. oleifera* leaf was due to the positive effect of the Moringa leaf in the rumen of ruminants, which is due to increased rumen microbial population found in the rumen environment [47]. Another possible reason for the improvement in milk yield of cows fed with *M. oleifera* leaves might be due to the fact that *M. oleifera* leaf have good rumen bypass attributes which is vital for animal productivity [49].

Egg production and quality

Eggs are the nutrient rich food and are available in low cost. Both the rich and the poor family in many societies can afford that. For tackling the issue of malnutrition, the utilization of eggs as a human diet plays important role. Due to the enhancing demand of eggs there is requirement of ways of improving its production at a low feed cost both in terms of quantity as well as quality [52]. Researches have been found to improve poultry production at a low feed cost by the application of *Moringa oleifera* leaf meal in poultry diet [53]. Recent studies have reported that the addition of *M. oleifera* leaf powder in poultry diets increases the egg production as well as quality of eggs in poultry birds [54, 55]. The addition of

2.5 and 5% of *M. oleifera* leaf powder in layer birds diet increases the egg number per week, egg weight, egg width, egg surface, yolk height, yolk weight, albumen weight and yolk ratio as compared to the control diet [56]. When 5% *M. oleifera* leaf powder was used as a replacement to sun-flower seed meal in layer diet, there was significant increase ($P < 0.05$) in egg weight [57]. Whereas, 5% level of *M. oleifera* leaf powder include in layer ration it significantly improved the yolk colour and protein absorption [55] there were no harmfull effects on the laying performance when compared to the control diet. However, the inclusion level of 1, 3 and 5% *M. oleifera* whole seed meal in layer hens feed showed significantly enhanced egg yolk colour, but significantly decreased body weight, feed intake, the rate of egg laying, egg weight, and egg mass. Therefore, its inclusion at these levels was undesirable [41]. Presence of high xanthophylls in *M. oleifera* leaf has been found to improve colour in egg yolk, an indicator of egg quality by consumers [58]. It should be exercised that *M. oleifera* leaf powder might hamper the performance of laying when used above 15% inclusion level [59, 60].

Harmful compounds in moringa

Apart from the above enlisted nutritional content, *M. oleifera* has been found to have a relatively low amount of antinutritional factors such as phytates, saponins, tannins and oxalates [12]. According to Stevens *et al.* (2015) [10] *M. oleifera* seed contains phytate and saponin 2.23% and 3.89% respectively while reports on phytate and saponin content in Moringa leaf was 2.5% and 5.0% respectively. These were lower than those noted in other legumes such as soya bean meal. Likewise, it has been reported that oxalate content (Table 2) in *M. oleifera* leaf (2.754 g/100 g) was lower than spinach leaf (12.57 g/100 g), Green amaranth leaf (10.05 g/100 g) and Curry leaf (2.77 g/100 g) [61]. The oxalate content of moringa leaves are insoluble. While spinach leaves having high iron and calcium, contain 12.57 g/100 g oxalates, among which 11.89g/ 100 g are soluble oxalates [61]. These soluble oxalates may causes kidney stone in livestock. These findings demonstrate that moringa leaves can be provided as a livestock feed without any danger of kidney stone formation.

Table 2: Soluble and insoluble oxalates content in different leafy vegetable in comparison with moringa leaves [62, 61]

Vegetable/plants	Total oxalates (g/kg)	Soluble oxalates (g/kg)	Insoluble oxalates (g/kg)
Spinach	12.57	11.89	0.67
Green amaranths	10.05	4.67	5.38
Purple amaranths	8.10	3.55	4.54
Curry	2.77	-	2.77
Moringa	2.75	-	2.75
Onion	0.53	-	0.53
Coriander	0.51	-	0.51
Radish	0.20	-	0.20

In moringa, tannins were 12 g /kg of DM, whereas 65% supplementation of *Leucaena leucocephala* leaves in the diet of ruminants may give rise to tannins and phytates upto 29.40 mg /100g of dry matter [63]. Some other fodder tree leaves viz. *Sesbania sesban*, *Acacia angustissima* and *Acacia cyanophylla* have 31, 66, and 38 g/kg tannin contents, respectively [64, 65]. Apart from this, moringa leaves were deficient in lectins, trypsin and amylase inhibitors [66], but have sugar-modified glucosinolates [67], although their concentration varies greatly depending upon the soil type, climate and stage of growth [68, 69]. These compounds are being reported as agents which are responsible for the bitter or pungent taste of moringa leaves [70]. Although moringa leaves have saponins (4.7-5g/kg of DM) which provide a bitter taste to livestock while eating leaves, these do not have harmful effects on animals as well as human beings [71]. In order to find out the moringa's effects on health, research related to bioactive compounds and their phytochemicals require more attention to detect the catabolism and absorption of these compounds after consumption and researches therefore, should be directed towards these areas.

Moringa seeds contain more amount of phytates and glucosinolatesas compare to other vegetative parts [72, 66]. The presence of alkaloids and saponins in safe ranges and the least amount of tannins cause bitter taste of seeds, but these unwanted taste can be eliminated by using several treatments like boiling or extraction processes, gene manipulation, and supplementation with methionine or threonine [73].

The presence of antivitamin agents in many livestock feed may cause kidney and liver damage. However, moringa leaves are rich in vitamins [74, 75]. It has been reported that moringa leaves and moringa leaf meal are good sources of nutrient for cows sheep, goats, fish, rabbits, laying hens and broiler chickens [76, 49, 77]. Moringa leaves are palatable for livestock aside the antinutritional factors. These studies demonstrate that moringa have rich in nutrient than other leafy vegetables or fodders.

Conclusion and future perceptive

M. oleifera has gained popularity as a source of dietary feed stuff for livestock and feed industry. Current and ongoing researches have revealed that *M. oleifera* is a vital plant that having multifunctions approach in livestock production systems. Studies have revealed the rich nutrients content and bioactive compounds in *M. Oleifera* leaves, seeds and stems indicating that its application in animal feed improve nutritional status and livestock production. However, information about nutritional composition of other plant-parts of plant including the flowers, pods and roots is scanty. On addition, *M. oleifera* consumption has been reported to improve endogenous antioxidants as well as to prevent excessive production of free radicals. However, further research works are required to investigate the bio availability of its nutrients and phytochemicals upon consumption. There are positive reports on the use of *M. oleifera* in livestock diets as it increases livestock health, performance and product quality, despite that there is presence of some anti nutritional factors which may reduce the inclusion level. Moreover, research focussing on effect of the *M. oleifera* plant consumption on performance of other livestock species (e.g. cattle, sheep, goat and poultry) and products quality (e.g. milk, meat, egg and wool quality) and other areas considering environmental impact and socio-economic impact would be arising curiosity and more researches are required towards these area.

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