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Moringa *(Moringa oleifera)* as an Alternative Feed Supplement for Dairy Animals

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ABSTRACT

Livestock production is very important part of agriculture sector, the dairy industry is particularly of increasing importance. The major constraint for dairy production in India is a shortage of quantity of feeds and fodders round the year which results in underfeeding of livestock and economic losses.To overcome this problem there is a need to identify available alternative feed resources to improve nutrients utilization of and performance of dairy animals. *Moringa oleifera* is fast growing, drought tolerant and easily adapted to varied ecosystems and farming systems. *Moringa oleifera* has higher availability across the country and produces leaves throughout the year which makes it suitable to use as a livestock feed. Various parts of this plant such as leaves, roots, seed, bark, fruit, flowers and immature pods has a different types of biological activities like antitumor, antipyretic, anti-inflammatory, antiulcer, antioxidant, hepatoprotective, antibacterial, immune-modulator, antifungal and lactogenic activities and work as therapeutic as well as preventive agent. It not only contains greater amount of nutrients but also low levels of antinutrients. Therefore, inclusionof *Moringa oleifera* can be recommended for feeding to dairy animals.

KEYWORDS: Dairy animal, Feed supplement, Moringa, Nutritional value

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INTRODUCTION

Dairy farming is critical for the rural economy particularly for small and marginal farmers, and its profitability depends on the supply of good quality feeds and fodder resources. Inadequacy and low quality of forage is a major constraint affecting the productivity of dairy animals (Misra et al., 2010). The use of locally available feed resources to formulate balanced diets can serve better solution to overcome this situation. Moringa is one of the most useful miracle trees available in India which belongs to the family Moringacae, commonly known as drumstick, horseradish tree' and sahjan. The use of *M. oleifera* as a feed supplement to ruminants has several advantages, as it ensures green fodder availability round the year and can be harvested several times. The dried leaves of moringa can be stored for a longer period without deterioration in nutritive value (Mendieta-Araica et al., 2011). Moringa leaves have been widely used as an alternative ingredient for animal feed because of its high content of protein, vitamins, minerals, omega 3 and 6 fatty acids, calcium, potassium, various phenolic and oxy-carotenoids (Su and Chen, 2020). *Moringa oleifera* has been under extensive research for its broad-spectrum pharmacological activities, comprehensive nutritional attributes and its uses as traditional medicine to promote lactation and enhance milk production as well as immunity in the animals. There is growing interest among the moringa growers across the world including India for adaptation of latest techniques for commercial cultivation of moringa and technology for preparing animal feed. The available literature on nutrient content, digestion, and absorption characteristics, and feeding effects and challenges in using *M. oleifera* as animal feed is discussed in this article.

Nutritional composition of M*oringa oleifera*

Moringa has been reported to possess quality sources of several nutrients including protein, calcium, Magnesium, Potassium, Iron, Vitamin A, and Vitamin C (Seshadri and Nambiar, 2003) and is also reported

to be inexpensive for livestock feeding compared to other leaf meals (Sarwatt et al., 2004). *M. oleifera* leaf contains high amounts of crude protein, vitamins, minerals, and fatty acids, and can provide two times the protein than milk ,9 times more protein than yogurt, 17 times more calcium than milk, 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 25 times more iron than spinach, and 15 times more potassium than bananas (Kamal, 2008). *Moringa oleifera* leaves strengthen neural response, enhances immune functions and improves health because of the large amount of microelements and polyphenol antioxidants. It promotes productivity and favorably influencing reproductive efficiency. Besides, high amount of magnesium in *M. oleifera* leaf has positive effects on milk yield. The reported nutritional composition of moringa leaf is given in Table 1.

Phytochemical analyses showed that *M. oleifera* leaves contains 16–19 amino acids, including all 10 essential amino acids that could act as a protein supplementary source in animal diets (Moyo et al., 2011 and El-Sohaimy et al., 2015). The comprehensive pattern of essential amino acids in *M. oleifera* leaf is modest and accounts for 52.19% of total amino acids. The abundances of minerals in *M. oleifera* leaf are relatively high compared with other tree leaves (Shi et al., 2018). These nutrients not only maintain osmotic balance but also help in activation of enzymes which are beneficial for growth, body function and maintenance (Anjorin et al., 2010).

Table 1. Nutritional composition of moringa leaf

Nutritional Composition			References
Proximate composition (% DM basis)	DM (%)	86.0-94.6	Sarwatt et al. (2004)
	OM	87.5-92.6	Zhang et al. (2017) Srivastva (2019)
	CP	19.5-33.5	
	EE	4.1-10.6	Sahu (2022)
	NDF	12.9-34.8	Tamble et al (2022)
	ADF	7.9-31.4	Punitha et al (2023)
	Total ash	7.4-15.0	
Fatty Acid (g/100g fatty acid)	Total SFA	29.7	Keshri (2019)
	total UFA	66.6	
	PUFA	4.46	
	MUFA	62.2	
Mineral contents (mg/kg, dry matter basis)	Calcium	24,700	Newton et al (2010) Teixeira et al. (2014) Keshri (2019) Sahu (2022)
	Phosphorous	4,400	
	Magnesium	190	
	Iron	318	
	Zinc	22	
	Sodium	0.04	
	Potassium	15.7	
	Copper	12	
	Manganese	92	
	Selenium	27.1	
Total carotenoids		40,139 µg/100 g	Seshadri et al (2003)

Anti-nutritional factors of M*oringa oleifera*

Several antioxidant compounds have also been reported in the leaves of *Moringa oleifera*. Some researchers reported that moringa leaves do not contain any antinutritional factor apart from negligible amount of tannin and saponins (Moyo et al., 2011; Kar, 2013). The antinutrient content in *M. oleifera* leaf depends on the cultivar and growing environment (Sultana et al., 2014). The content of tannins presents in *Moringa* leaves ranges from 12.0 to 20.6 mg g^{-1} (Teixeira et al., 2014). The amount of saponins in *M. oleifera* leaf ranges from 4.7–5 g kg^{-1}, although it provides a bitter taste. The content of phytates in an *M. oleifera* leaf is only 22.3 mg g^{-1}.

High concentrations of these antinutrients in any feed stuffs can severely affect the absorption of trace elements in food sources and hinder protein digestion. The relatively lack of anti-nutritional components and the high protein, lipid and sulfur containing amino acid contents encourage use of *Moringa oleifera* as animal feed supplement. Besides, drying of moringa leaves reduce or remove extractable condensed tannins by 15 to 30% in comparison with fresh foliage (Titi et al., 2013). This happens due to de-complexation between tannins and proteins and de-polymerization and oxidation of tannins. However, feeding moringa leaves even after presence of tannin is safe for ruminants because the tannin present in moringa is not active tannin (Karim et al., 2015). Apart from that, ascorbic acid (vitamin C) in moringa leaves can overcome the actions of inhibitors such as phytic acid and tannic acid which inhibits absorption of calcium, zinc and iron (Mallillin, 2014). Saponin and other phenolic compounds in moringa leaves alter the rumen fermentation and thereby increases propionate production which act as precursor of gluconeogenesis and helps in lactose synthesis (Zhang et al., 2017).

Effect of M*oringa oleifera* on methane gas emission

M. oleifera leaves are effective natural methanogen inhibitors and thus considered alternatives for critical antibiotic feed additives for alternating ruminal fermentation pathways (Soliva et al., 2005). Dong et al. (2019) examined the effects of dietary supplementation with *M. oleifera* leaves on the production performance and fecal methanogenic community in lactating cows and found that *M. oleifera* improved milk fat content and changed the composition and diversity of methanogens, and may reduce CH_4 emissions by modifying the composition of rumen microbiomes. Soliva et al. (2005) recorded a 17% decrease in daily methane emission with the complete extraction of *M. oleifera* leaves diet compared with diets containing rapeseed meal or soybean meal. Another *in vitro* study also indicated that CH_4 emissions can possibly be reduced by up to 50% by replacing soybean meal with *M. oleifera* leaf meal (Elghandour et al., 2017). Dey et al. (2014), were able to reduce methane level and increase the degradability of organic matter *in vitro* by wheat straw supplemented with *M. oleifera* leaves in buffalo diet. Such effects might be related to the existence of saponins or tannins in *Moringa* leaves. Pedraza-Hernández et al. (2019) proposed a novel and interesting strategy using *M. oleifera* extracts and live yeast cultures (*Saccharomyces cerevisiae*) as feed supplements. They showed that the combination of *M. oleifera* extract and *S. cerevisiae* in diet is highly effective against methane production, achieving low emission (11.7%) at 72 h of incubation. Keshri et al. (2022) observed that moringa improvde the degradability of dry matter and organic matter, gas production, short-chain fatty acids production and reduce methane gas production compared to TMR when fermented alone. Hence, *M. oleifera* leaves could be used as effective natural feed additive in ruminant diets, not only to reduce CH_4 production but also to enhance the ruminal efficiency of dietary nutrient use.

Effect of M*oringa oleifera* on intake and digestibility

M. oleifera leaf extract is a powerful ingredient for increasing feed intake, and the digestibility of nutrients. Dong et al.(2019) recorded significant effect on dry matter intake of lactating cow when supplemented *M. oleifera* meal at the level of 0, 3,

6 and 9%, respectively. Sahu (2022) reported that supplementation of *Moringa oleifera* leaf meal in the diet of Sahiwal cattle significantly increased the digestibility of nutrients, particularly DM (2.47 to 10.87 %) and CP (20.57 to 22.69 %). Aregheore (2002) found that goats fed with fresh *M. oleifera* leaves at 20 and 50% as replacement for grass had higher live-weight gain and higher digestibility of dry matter, crude protein, neutral detergent fiber, and organic matter. Fadiyimu et al. (2010) reported a predominantly high trend in crude protein intake, dry matter and nutrient digestibility and nitrogen retention in West African dwarf sheep fed with *Panicum maximum* meal with 25% *M. oleifera* leaves supplements. Moringa improves digestibility by stimulatingruminalbacteria to enhance digestion of feed ingredients andincreasenutrients availability for the host (Morsey et al., 2022). However, some studies suggested non-significant effect of moringa on DM intake (Zeng et al., 2017; El-Esawy et al., 2018; Malik et al., 2019; Keshri, 2019).

Moringa oleifera as galactogogue

Galactogogues are generally prescribed to lactating animal to augment and maintain milk production. The galactogogue, made of phytosterols, acts as a precursor for hormones required for productive and reproductive growth. Moringa is rich in phytosterols like stigmasterol, sitosterol and kampesterol which are precursors for hormones (Gopalakrishnan et al., 2016). These compounds increase the estrogen production, which in turn stimulates the proliferation of the mammary gland ducts to produce milk. It has positive effect on rumen environment and enhances microbial biomass (Sarwatt et al., 2004) and thus increases milk yield. Several researchers have demonstrated that moringa enhances milk yield by increasing feed intake, digestibility and ruminal fermentation (Kholif et al., 2015). Sarwatt et al.(2004) studied the effect of substituting *Moringa oleifera* leaf meal with cottonseed cake (CSC) (@ 0, 10, 20, and 30 %) on milk yield and composition of Holstein cows. They found that a combination of CSC with MOLM at 10% substitution (0.55 kg as MOLM and 0.8 kg as CSC) had significantly higher milk yield then control group; however, non-significant differences were observed among the groups in milk composition. Zhang et al. (2017) and Khalel et al. (2014) found the positive effect of *Moringa oleifera* on milk production in dairy cows that was due to its better nutrient utilization.

As a nutrient source supplement to forage, *M. oleifera* leaf meal improves not only growth performance but also milk output and the quality of cows and goats (Babiker et al., 2017). Kholif et al. (2019) showed that dietary *M. oleifera* leaf extract (up to 20 ml dose in basal diet) can enhance milk yield by 6% and energy-corrected milk yield by 12%. Zeng et al. (2017) noted that *M. oleifera* leaf meal completely replaced maize silage in lactating dairy cow diet but did not affect milk yield, or milk composition. Babiker et al. (2017) showed that the inclusion of 25% *M. oleifera* leaf powder as replacement for alfalfa hay in goat diets significantly affected milk composition, which had higher fat, lactose, and solid non-fat contents than the diet containing 40% alfalfa hay but lower cholesterol and glucose contents. Whereas, Singh et al. (2022) recorded no effect of moringa leaf meal on milk production and milk composition of lactating goats. Cohen-Zinder et al. (2016) observed a similar rise in milk fat, energy, and yield in cows fed with a compounded meal with *M. oleifera* leaves, chopped wheat hay, and sugar cane molasses (at dry matter ratio of 370:540:90, respectively) compared with the control diet of wheat straw. This condition is probably due to the high contents of phenolic components with antioxidative activity in *M. oleifera* silage as a beneficial factor to rumen microbial population (Verma et al., 2009).

Mendieta-Araica et al.(2011) reported non-significant effect on milk yield and milk composition including milk fat, total solids and non-fat solids between two groups. Cohen-Zinder et al.(2016) recorded significantly higher milk yield and 4% fat corrected milk by 1.91% and 4.26%, respectively, in moringa fed group. El-Esawy et al.(2018) recorded significantly 4% FCM higher in moringa supplemented group by 10.72% compared to control

group. Keshri (2019) recorded significantly improved milk yield (9.32 and 9.59 kg/day, respectively) in groups fed MOLM compared to control group (8.27 kg/day). Milk composition including milk fat % and total solid% was significantly higher in treatment groups whereas other content; lactose%, milk protein% and SNF% were non-significant among groups (Sahu, 2022).

Effect of *Moringa oleifera* on fatty acid profiling of milk

Effect of dietary incorporation of *Moringa oleifera* meal on fatty acid profiling of cow milk was studied by Zhang et al.(2017). They found that the fatty acid profile (g/kg total fatty acids) of cow milk was significantly affected when their feed supplemented with moringa. Keshri (2019) also reported significant effect of moringa supplementation on fatty acid composition of milk. Total PUFA and MUFA were significantly higher whereas, total SFA was lower in moringa supplemented group. Kholif et al.(2019) recorded significantly increased USFA whereas decreased SFA concentration in milk of moringa leaf supplemented animals.

Effect of *Moringa oleifera* on body weight gain

Protein present in moringa has better utilization with good rumen bypass characteristics. Its higher fat and mineral contents help in improving live weight gain by improving nutrient utilization efficiency. Aharwal et al.(2018) recorded 8.3% increase in body weight after feeding MOLM to buffalo calves @ 10% replaced of concentrate mixture. Body weight gain may be attributed due to the rich content of nutrients in dried moringa leaves and antimicrobial properties of *Moringa oleifera* leaf meal (Fahey et al., 2001).

***Moringa oleifera* as blood profile modulator**

Animashahun et al. (2006) affirmed that the comparison of blood chemistry profile with nutrient composition might indicate the need for adjustment of certain nutrients upward or downward for different group. The increase in Hb count is an indication that moringa leaf could boost blood production. Formation of haemoglobin and myoglobin requires iron (Elbashier and Ahmed, 2016) which is abundance in moringa leaves (Akangbe and Abu, 2022). Moringa leaves contain â-carotene and vitamin B12 which is required for formation and maturation of red blood cells in bone marrow (Samuel et al., 2015).

***Moringa oleifera* as antimicrobial agent**

Presence of alkaloids, flavonoids (mainly quercetin and kaempferol), saponins and tannins in all extracts have been linked to various physiological actions in the animals body (Abdulkadir et al., 2015). Flavonoids have a hydroxyl group that confers antioxidant activity on moringa leaf, hence, its use as a therapeutic agent (Seshadri and Nambiar. 2003). As a result, Moringa has been used over the years as a traditional remedy for some disease conditions. This is because of its rich phytochemicals that contain effective antibacterial, antimycotic, antiviral and potential anticancer activity. Antiviral activity of moringa leaf against Foot and Mouth Disease has been documented by Younus et al. (2015). The moringa leaf extracts antimicrobial properties have also been recorded on both the gram positive and gram-negative bacteria such as *Staphylococcus aureus*, *Escherichia coli* and the salmonella species (Abdulkadir et al., 2015). Antifungal properties of moringa leaves have also been observed (Donli and Dauda, 2003). *Moringa oleifera* also has been known to exhibit both anti-inflammatory and anticancer properties (Bharali et al., 2003).

Moringa oleifera decreased the adhesion and invasion of mastitis causing bacteria by modulating their adhesion factor. In addition moringa leaves have strong plasma antioxidant activity which helps in reducing somatic cell count in milk. (Zhang et al., 2017) fed different level (@ 0, 3, 6 and 9 %, respectively) of twigs and rachis of moringa to lactating cows and observed 25% decrease in SCC in cows fed 6% (w/w) moringa supplement compared to control cows. Kekana et al.(2019) also observed significantly lowest SCC in lactating cows fed moringa at 60 g/day/head as compared to control groups.

Effect of *Moringa oleifera* on reproductive efficiency

Nutrient is a key factor in regulating reproductive performance of animals. Moringa leaves have enough nutrients to enhance reproductive efficiency in dairy animals. Moringa is estrogenic plant, estrogen stimulates ovarian cyclicity, improves uterine tonicity leads to early uterine involution subsequently cause early initiation of estrous cycle. Titi et al.(2013) stated that sterols contained in moringa leaves are used as precursor for estrogens synthesis which stimulates reproductive functions. According to the study of Ogunsola et al. (2017), moringa leaves enhance reproductive function in females by increasing the secretion or availability of ovarian hormones namely progesterone and estrogens. In addition, Malik et al. (2020) studied about ovarian follicular waves in dairy animals and found that the average number of follicular waves was significantly improved in group supplemented with urea molasses multi-nutrient moringa block containing 15% moringa as compared to the control group. Moreover, Zn and Ca present in moringa leaves helps in early uterine involution (Islam et al., 2021). Where, calcium helps in maintaining the uterine muscle tone and zinc helps in augmenting the ovarian functions and uterine contractility which consequently commences the initiation of estrus (Ahuja and Parmar, 2017). .

Moringa leaves not only enhance reproductive performance but also reduce disease incidences due to their anitimicrobial property and estrogenic property (Tabares et al., 2014). The increased level of estrogen helps to stimulate and repair uterine endometrium tissue (Barjibhe, 2019). Andjani et al. (2016) stated that moringa leaves act as an anti-inflammatory agent that helps in reducing endometritis incidences.

***Moringa oleifera* as economical source**

To produce high quantity and quality milk, the dairy cows should consume a substantial quality and quantity feed. In general, high quality feed are relatively expensive. Therefore, it is important to find high quality feed with low cost and available round the year. CIRG estimated the cost of moringa feeding in dairy goat in the form of pellets @ Rs. 9-10 per animal per day assuming Rs. 2kg/adult @4.5-5kg) as compared to Rs. 15 per animal per day in case of traditional feeding system. Sahu, (2022) also calculated higher net return by 41.36% with benefit: cost of 3.31 in Sahiwal cows supplemented with moringa leaf meal as compared to basal diet. The supplementation of *Moringa oleifera* leaf meal was cost effective (B: C of 3.31) with improved economics of reproductive efficiency.

El-Esawy et al.(2015) reported significantly higher economic efficiency in the moringa supplemented group compared to control. Shankhpal et al. (2019) calculated lower feeding cost (Rs. 149.01 per day) with higher gross income (Rs. 175.67 /head/day) and net daily income (Rs. 46.21/head) in group of lactating cows which were fed with 15 kg moringa green fodder (by replacing 15kg hybrid Napier) for 90 days. Elaidy et al.(2017) calculated economic efficiency of dry *Moringa oleifera* leaves supplementation (@5, 10, 15 and 20%) and reported that feed cost per kg gain of calves was significantly on lower side with increasing the level MOLM up to 15% compared to control group. Sonkar et al. (2020) studied economic efficiency in Sahiwal cows and demonstrated increased profit (per kg milk) in moringa supplemented groups compared to control group. Ali et al. (2018) reported that incorporation of *M. oleifera* leaf meal at 12.5% level in concentrate mixture of growing goat replacing equal proportion of cotton seed cake could reduce cost of production of growing local goats by 12.8%. Dried moringa leaves could replace up to 20% of concentrate mixture in milch cows ration (Sonakar et al., 2021) and 15% in the diets of rams (Punitha et al., 2023), and 30% CP of soyabean meal in the ration of lactating goats (Singh et al., 2022).

CONCLUSION

Several studies indicate that *M. oleifera* leaves can sustainably be used as an alternative feedstuff for dairy animals when no other green fodder is available due to harsh and severe climatic conditions. Reduction in feed cost with improved production and

reproduction performances and health status aptly shown in several studies. However, some challenges still need to be addressed for large-scale adoption, like vulnerability to cold stress, flood, optimum cutting height etc. as a fodder crop. Policy makers should formulate programs on generating awareness among farmers, especially those are engaged in dairy production, to emphasize the planting of moringa as a fodder crop for their livestock.

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