Review Article

Leverage of *Moringa oleifera* Supplementation on Performances, Biochemical, and Milk Profiles in Mammals

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Abstract | Nutritional supplements of *Moringa oleifera* to animals are considered one of the aids for improving health and production. *M. oleifera* leaves, seeds, and extracts are administered to animals for therapeutic and nutritional purposes. The effects of using *M. oleifera* and its extracts on animals' production and health have shown beneficial effects in several studies. The roles of *M. oleifera* and its extracts on nutrient digestibility, rumen fermentation and enzyme activities, growth and reproductive performances, antioxidants, and milk production and composition have been well documented. *M. oleifera* contains valuable chemical constituents such as proteins, essential fatty acids, vitamins, and beta-carotene. The *M. oleifera* composition varies depending on nutrient availability for production, species, and lifespan of trees. Extracts of leaves and seeds were used for the production of invaluable compounds. Knowledge of *M. oleifera* impacts on productive, reproductive, and therapeutic performances is more fragmentary and the present review is compiled and discussed owing to the importance of *M. oleifera* and its purified compounds.

Keywords | *Moringa oleifera*, Growth, Reproduction, Milk, Blood

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INTRODUCTION

Moringa oleifera (*M. oleifera*) is a tree plant generally referred to as a miracle plant. *M. oleifera* is a nutritious and medicinal tree species-rich in protein, minerals, and vitamins. *M. oleifera* is a native plant in Pakistan, India, Bangladesh, and Afghanistan (Fahey, 2005). Supplementation of *M. oleifera* to animals and humans has received increased attention for its high contents of certain micro and macro-nutrients, which are important in medicine and nutrition for both humans and animals (Oyeyinka and Oyeyinka, 2018; Gupta et al., 2018). Leaves of *M. oleifera* are reported to contain substantial amounts of vitamins such as A, C, and E (Saini et al., 2014a,b; Hekmat et al., 2015), minerals such as potassium, calcium, magnesium, iron, copper, and manganese (Hekmat et al., 2015), nutrients such as protein, fiber, carotenoids, and tocopherols (Jongrungruangchok et al., 2010; Moyo et al., 2011; Saini et al., 2014a,b). Some of the *Moringa* components are known to scavenge free radicals (DanMalam et al., 2001). Substantial variations in the contents of *M. oleifera* have been shown such as protein (19-29%), fiber (16-24%), minerals, vitamins, and others according to cultivar and sources (Jongrungruangchok et al., 2010; Moyo et al., 2012; Teixeira et al., 2014; Afzal et al., 2021; Al Mufarji and Mohammed 2022). *M. oleifera* leaves are known to contain calcium (4X) and protein (2X) compared to milk, vitamin C (7X) compared to oranges, potassium and iron (3X) compared to banana and spinach respectively, and vitamin A (4X) compared to carrots (Thurber and Fahey, 2009; Razis et al., 2014). The leaves of *M. oleifera* contain beta-carotene and other phytochemicals known for their antioxidant ability (rutin, quercetin, kaempferol, and caffeoylquinic acids); antioxidant vitamins (A, C, and E) and antioxidant micronutrients (zinc and selenium), which play important roles in fertility performance (Jaiswal et al., 2009; Vongsak et al., 2014; Afzal et al., 2020) as well as contributing to an improvement in growth performance (Warastomo et al., 2021; Pandey et al., 2022), blood metabolites (Akanmu et al., 2020; EL-Hedainy et al., 2020), and milk production and composition (Kholif et al., 2016, 2019; Mendoza-Taco et al., 2022). Due to the several aforementioned nutritional benefits of *M. oleifera,* this review is compiled and discussed such effects on mammals (Figure 1).

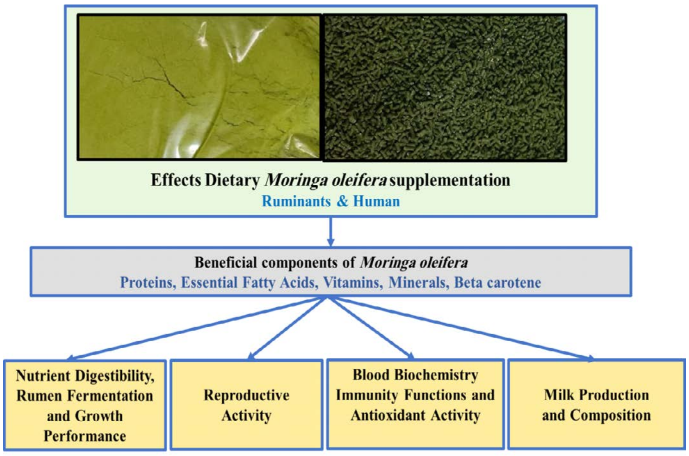

Figure 1: Effects of dietary *Moringa oleifera* supplementation on ruminants and humans

Nutrient Digestibility, Rumen Fermentation, And Growth Performance

Ruminant animals were supplemented with *M. oleifera* in different doses for enhancement of feed efficiency, rumen fermentation, and growth performances (Paul et al., 2013; Warastomo et al., 2021; Fadiyimu et al., 2010, 2016, 2017; Abdel-Raheem and Hassan 2021; Pandey et al., 2022). Fadiyimu et al., (2010, 2016; 2017) conducted studies in Nigeria for investigating the effects of the inclusion of 25, 50, 75, and 100% *M. oleifera* on nutrient digestibility and nitrogen balance of African ewes with an average body weight of 16.1 kg. The inclusion of *Moringa* in the diet improved the nutrient digestibility and growth characteristics, while the feed intake decreased by increasing the proportion of *Moringa* in the diet. Supplementing Rhodes hay in Ethiopia with graded levels of dried *Moringa* leaves improved dry matter intake, increased body weight, and nitrogen retention (Gebregiorgis et al., 2012) and reported that *Moringa* leaves can serve as a protein supplement for low-quality feeds. EL-Hedainy et al. (2020) conducted a study in Egypt for investigating the effects of 4 g *M. oleifera* seeds /head for 45 days on the productive performance and body measurements of male Barki five months old. They recorded the ability of *M. oleifera* seeds to improve the final body weights and daily gains of lambs, while body measurements did not differ significantly between groups. Bhokre et al. (2020) investigated the effects of *Moringa* leaf meal based diets for 90 days on the biometry and body condition score of Deccani lambs. Their results based on biweekly body measurements indicated that the mean body length, face length, and hip width of the developing Deccani lambs increased linearly throughout the experiment, and body length had a significant difference ($P < 0.01$) between the treatment groups. They also recorded significantly higher body conditions (BCS) ($P < 0.05$) in the 25% treated group from the third to sixth week. Warastomo et al. (2021) investigated the effects of *moringa* leaf flour on the physical properties of lambs with a body weight of 20 kg and aged 7-8 months for 75 days. They recorded that *Moringa* was not able to improve the physical properties of meat (pH, tenderness, and water holding capacity). Warastomo et al. (2021) investigated the effects of feeding *M. oleifera* meal (0, 25, and 50) on growth performance of Surti kids aged 6-8 months under intensive system of management for 14 weeks. The lambs showed best results at the supplement level of 25% concerning body weights and biometrics (body length and chest circumference).

The negative effects of replacing soybean meal with *M. oleifera* leaf meal on ruminal fermentation characteristics were investigated in goats and steers (Elghandour et al., 2017). They observed significant decreases in CH_4, ruminal ammonia-N, total protozoal number, and organic matter degradability, as well as increases in CO_2 production, fermentation pH, and total bacterial count. Conversely, Abdel-Raheem and Hassan (2021) carried out a study on growing buffalo calves about the effects of *M. oleifera* dietary inclusion on nutrient digestibility, rumen fermentation, and growth performance. They recorded an improvement in rumen fermentation, growth performance, blood metabolites, and mitigated ammonia and methane values. They attributed the differences between the results to the difference in the environmental conditions, the species, and the age of the animals, as well as the composition and levels of supplementing *M. oleifera*.

Reproductive Activity

Gonadal dysfunctions and reproductive hormonal imbalances were widely modulated through nutritional ingredients (Nagasawa et al., 1989; Downing et al., 1995; Mohammed and Attaai 2011; Gifre et al., 2017; Senosy et al., 2017, 2018; Mohammed and Farghaly 2018; Mohammed 2018; Mohammed 2019; Mohammed et al., 2012, 2020; 2021, Mohammed and Al-Hozab 2020; Ali et al., 2021), hormonal supplementation (Zarazaga et al., 1996; Mohammed et al., 2011), and both hormonal and nutritional supplementation (Mohammed and Attaai, 2011). Based on the negative influences of increased energy and protein in the diets of humans and animals on health and fertility (McEvoy et al., 1997; Dawuda et al., 2002; Mohammed et al., 2012), and because of the high cost of diet; *M. oleifera* and their purified extracts were given in small quantity as replacers instead of hormonal stimulation (Odeyinka et al., 2008). In addition, *M. oleifera* and its purified extracts might be used for treating reproductive dysfunctions.

Barakat et al. (2015) investigated the effect of *M. oleifera* leaf extract at the level of 20, 50, and 100 µg/ml on the expression of genes related to fertility and the increase of calcium ions in ovine oocytes. They indicated that genes related to oocyte maturation and meiotic progression were affected by *M. oleifera* extract. Furthermore, *M. oleifera* along with hormones improved the rate of ovine oocyte maturation and could act to induce mRNA expression and synthesis of the basic maturation-stimulating protein essential for maturation processes. Ajuogu et al. (2019) investigated the effect of *M. oleifera* leaf powder in levels of 5, 10, and 15 g/kg feed on the concentration of reproductive hormones and semen quality of New Zealand white rabbits. They revealed a significant dose-dependent reduction in the concentration of serum follicle-stimulating (FSH), luteinizing (LH), and estrogen hormones in females.

Sonbarse et al. (2020); Giuberti et al. (2021) recorded that the highest level of *M. oleifera* significantly increased the progesterone levels whereas the prolactin concentrations were not affected. In males, the concentrations of FSH and LH increased significantly in the *M. oleifera* treated groups. Semen volume, sperm count, and motility rate were significantly improved in dose-dependent *M. oleifera*. They added that *M. oleifera* might be used as an alternative to hormonal treatment to enhance reproductive performance for its high level of beta-carotene, protein, and other fine chemicals. Further studies are still required on the effects of *M. oleifera* on ovarian follicle development, oocyte quality, oocyte maturation and fertilization, and the viability of the embryos.

Blood Biochemistry

Blood indices and plasma metabolites are indicative of the body's health in both animals and humans. *M. oleifera* is widely cultivated as an important vegetable for human consumption (Lin et al., 2018). Therefore, blood indices and plasma metabolites were recorded in different studies on *M. oleifera* supplementation in both animals and humans (Al Mufarji and Mohammed 2022; Al Mufarji et al., 2022; Al Masruri et al., 2022). Fadiyimu et al. (2010, 2016; 2017) carried out an investigation in Nigeria on the effects of 25, 50, 75, and 100% *M. oleifera* on blood indices and plasma metabolites of African ewes with an average body weight of 16.1 kg. They showed that the packed cell volume (PCV), hemoglobin (Hb), red blood cells (RBCs), and white blood cells (WBCs) of the animals treated with *M. oleifera* were within the normal physiological range in contrast to the ewes of the control group, whose values were less than normal. Moyo et al. (2012) examined the antioxidant activity of *M. oleifera* leaf extract on the enzymatic activity of the liver in goats of South Africa. They showed that *M. oleifera* extract could be a potential source of compounds with powerful antioxidant potential. Meel et al. (2018) investigated the effect of *M. oleifera* leaves at levels of 25, 50, 75, and 100% on blood and plasma components of Sirohi goat kids in India. They showed that the red blood cells, hemoglobin, total protein, and albumin increased significantly while the white blood cells and glucose decreased in the 100% treatment. EL-Hedainy et al. (2020) investigated the effect of *M. oleifera* seeds (4 g/head) for 45 days on growth performance and body parameters of males aged five months in Egypt. They showed the ability of *M. oleifera* seeds to improve the concentrations of total protein , as well as maintained all blood serum components within the normal range.

The effect of *M. oleifera* extract (50 mg/kg DM) on blood and plasma measurements of lambs has been investigated by Akanmu et al. (2020). The results revealed that most of the blood treatments were not affected by *M.* extract treatment as an anti-methanogenetic additive and all the biochemical parameters except for the decreased alkaline phosphatase; did not differ between treatments, as well as reduce intestinal methane emission. They revealed that the extract was not toxic to sheep as an anti-methane additive at a rate of 50 mg/kg DM.

Yasoob et al. (2022) reported that *M. oleifera* leaf powder when was supplemented to rabbits during heat stress resulted in reduced glucose, total cholesterol, low-density lipoprotein cholesterol, and triglycerides contributing to reduced intestinal methane emissions, alleviate heat stress, and increased meat yield. *M. oleifera* leaves may improve physiological parameters, and blood and plasma components. *M. oleifera* contains high lipid contents, thus might be considered as key constituents of the plasma membrane and they are essential for the functionality of all cellular membranes, as well as lipids form membrane vesicles or lipid droplets (LDs) that are involved in the transport of proteins, hormones, or fat-soluble vitamins (A, D, E, and K) in cells and extracellularly, for example in the bloodstream (Vachier et al., 2002).

Immunity Functions And Antioxidant Activity

Immunity functions and antioxidant activity of animals and humans could be improved through the use of feed additives (Kassab and Mohammed 2013, 2014 a,b; Mohammed 2019; Ali et al., 2021; Ademosun et al., 2019, 2022; Al Mufarji and Mohammed 2022). Bioactive compounds in *M. oleifera* have been shown to enhance immunity functions, antioxidant activities, and tissue protection in mammals (Kekana et al., 2020; Wen et al., 2022). Wen et al. (2022) examined *M. oleifera* polysaccharide effects on immune indices of serum and organs in addition to colonic microflora of mice. They indicated that *M. oleifera* polysaccharide gave a positive effect on immune performance and intestinal health. Kekana et al. (2020) investigated the effect of *M. oleifera* meal to transition Holstein cows on antioxidant enzymes. The effects of *Moringa* and its extract on immunity functions and antioxidant activities are attributed to *Moringa* polyphenols extract, which might have immunomodulatory properties (Adjei-Fremah et al., 2019). *M. oleifera* leaves contain beta-carotene and other phytochemicals such as rutin, quercetin, kaempferol, and caffeoylquinic acids; antioxidant vitamins such as A, C, and E, and essential micronutrients such as zinc and selenium and all known for their antioxidant abilities. Hassan et al. (2021) reported the great protective effects of *M. oleifera* leaves extract against diseases and the widely persistent environmental toxins which disrupted cellular metabolic function. Up-regulation of genes for thermo-tolerance, antioxidation, and immunity over supplementing rabbits with oral *M. oleifera* leaf powder under heat stress was recorded indicating beneficial influences on liver functions in heat-stressed rabbits (Yasoob et al., 2022).

Up-regulation of the antiapoptotic BCL2A1 gene by *M. oleifera* leaves extract may suggest a protective effect against apoptosis induced due to heat stress. Therefore, further studies are still required to investigate phenolic compounds of *M. oleifera* for the treatment of various immune diseases.

Milk Production And Composition

Sustainable livestock development of milk and meat production requires appropriate strategies to be applied worldwide for covering the shortage of milk and meat requirements for humans. Because of the increasing demands for meat and milk in the world, specialists continue to explore new approaches to improve meat and milk yield through different nutritional strategies (Stamey et al., 2012; Alshaheen 2016; Hifzulrahman et al., 2019; Wang et al., 2019; Brady et al., 2021). *M. oleifera* inclusion for ruminants has changed milk yield and improved milk fatty acid profile (Kholif et al., 2016; 2019; Choudhary et al., 2018). Kholif et al. (2016) found that *M. oleifera* supplementation in lactating Anglo-Nubian goats increased milk production by 24.0%. The contents of saturated fatty acids decrease by 9.0% whereas conjugated linoleic acids (CLAs) increased by 57.0%. Choudhary et al. (2018) found that replacing mixed concentrate ration with 50.0% *M. oleifera* leaves in lactating Bengal goats contributed to a positive effect on milk yield and composition and increased milk production by 6.0%, milk fatty acid profiles of Nubian goats were enhanced with *M. oleifera* leaves treatments (10, 20, 40 ml/day) (Kholif et al., 2019). The percentage of saturated fatty acids decreased whereas the of unsaturated fatty acids, conjugated linoleic acid, and the arteriosclerosis index increased. They recommended the use of 20 ml for a practical approach. Olvera-Aguirre et al. (2020) studied the influence of feeding lactating ewes with *M. oleifera* leaf extracts on milk yield and milk composition. They showed that milk yield and composition were not significantly changed. Effects of *M. oleifera* essential oils (0.3 and 0.6 ml/day) supplementation on milk quality and fatty acid profile in dairy sheep were investigated by Selmi et al. (2020) and revealed increased milk fat, unchanged protein, decease urea nitrogen, decreased saturated, and decreased unsaturated fatty acid profiles.

Mendoza-Taco et al. (2022) investigated the impacts of *M. oleifera* leaf extracts (20 ml) on the physicochemical characteristics of yogurt prepared from sheep milk. *M. oleifera* leaf extracts positively affected the physical and chemical composition of milk and yogurt during storage. Milk production and composition were improved in the previous studies over *M. oleifera* supplementation due to the nutritional benefits of *M. oleifera* on nutrient digestibility, rumen fermentation, and growth

CONCLUSIONS AND RECOMMENDATION

The potential properties of *M. oleifera* as a source of protein and bioactive compounds for animals and humans have been reported in several studies. *M. oleifera* biomass-derived macromolecules and micromolecules differed according to culture conditions. The biomass-derived macromolecules of *M. oleifera* have been shown in ruminant species to enhance nutrient digestibility, rumen fermentation, growth performance, antioxidant, and tissue protection. Studies are still required on *M. oleifera* effects on female and male fertility concerning oocyte, semen quality, and embryo development. Bioactive compounds; carotenoids, could be efficiently transferred to the body and improve body growth and health. The bioactive compounds of *M. oleifera* as promising protectors of inflammation and oxidative stress processes have been reported in several studies. Moreover, *in-vivo* and *in-vitro* studies should be carried out on *M. oleifera* bioactive compounds to authenticate their possible applications over a wide range of growth, productivity, and reproductive performances, as well as therapeutic approaches in biopharmaceutical industries as potent drugs.

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NOVELTY STATEMENT

The present review article expressed a continuation of a novel dietary supplement of *Moringa oleifera* based on the previous studies on performances, biochemical, and milk profiles in mammals

CONFLICT OF INTEREST

No conflict of interest for the authors to declare.

AUTHORS CONTRIBUTION

Mohammed participated in experimental design, wrote and submit the review article, and prepared figures. Rashid Al Zeidi, Haitham Al Masruri, Aiman Al Mufarji, Ahmed Al-Madani, and Al-Hassan Mohammed collected references and prepared figures.

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