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The Effects of *Moringa oleifera* (L.) and *Medicago sativa* (L.) Supplementation on Milk Yield and Composition in Tropical Dairy: A Review

By

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Abstract

Addressing the growing demand for high-quality milk production and mitigating environmental impacts are crucial challenges in tropical dairy farming. This review examines the effects of supplementing dairy cow diets with moringa (Moringa oleifera (L.)) leaf meal (MOLM) and Lucerne (Medicago sativa (L.)) hay (LHM) on dairy production. The increasing global population, particularly in tropical Africa, necessitates the exploration of sustainable feed alternatives to enhance milk production and quality. The global dairy sector faces significant challenges in feed quality and availability, particularly in developing nations. This review examines dairy production systems focusing on Kenya's dairy industry and explores the potential of alternative feed sources. Kenya's dairy sector, contributing 14% of agricultural GDP and 3.5% of total GDP, demonstrates the economic significance of dairy farming in developing economies. While dairy cattle in developed nations produce in the range of 7,000-9,000 liters of milk annually, developing nations vary widely from 800 to 1,500 liters, highlighting a substantial productivity gap. Climate change, shrinking cultivable lands, and expensive conventional feedstuffs compound these challenges. The research investigates Moringa leaf meal and Lucerne hay as alternative feed sources to address these issues. Small-scale dairy farmers, who contribute 70-80% of Kenya's total dairy output, particularly stand to benefit from these feed alternatives. Moringa oleifera leaves contain 92% digestible protein and essential nutrients, while Lucerne hay provides 18-22% crude protein and vital metabolisable energy. Despite promising nutritional profiles, both feeds contain anti-nutritional factors requiring feed formulation consideration. The study analyses feed composition, biological roles, and impacts on milk production, providing insights for improving dairy productivity in tropical regions.

Keywords: *Dairy Cattle, Feed Supplementation, Greenhouse Gas Emissions, Medicago Sativa, Milk Composition, Moringa Oleifera, Milk Yield, Sustainable Farming.*

Background Information on Dairy Production

Livestock rearing is important for global food production. Dairy production on farms is typically reduced due to the low quality and scarcity of animal feeds in tropical countries, for example, Kenya. The increase in human population directly affects the demand for food. However, globally, there is shrinkage of cultivable lands, which makes the role of the livestock sector even more important, not only in terms of nutritional security but also employment generation. Feedstuffs, especially protein sources such as legumes, cereals and grains essential for animal development, have become very expensive and limited in many regions of the world (Misquitta *et al.*, 2022). Hence, it is required to look for a substitute source of feed which are edible, rich in protein and minerals and low-priced to fulfil the basic needs of animals.

Dairy cattle in developed nations produce an average of 7,000 - 9,000 litres of milk annually, compared to developing nations whose average milk yield per year is 800-1,500 Litres (Ouma, 2023)). Five million dairy cows in Kenya produce four billion litres of milk annually. Small-scale dairy farmers

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in Kenya contribute up to 70–80% of the country's total dairy output (Odero-Waitituh, 2017). The dairy industry is Kenya's single largest agricultural sub-sector. It contributes 14% of agricultural gross domestic product (GDP) and 3.5% of total GDP (Wambugu *et al.,* 2011). Most dairy cattle are raised by smallholders in zero-grazing (i.e., stall-fed) feeding systems, mixed stall-fed and grazing systems, or grazing-only feeding systems. Because it is an important source of nutrition and income for the rural population, the dairy cattle population has continuously increased in recent decades, from 3.25 million in 1995 to almost 4.6 million in 2017 (Bruinsma, 2017). However, Climate Change is real, and the livestock sub-sector, dairy production included, is highly vulnerable to Climate Change.

On the other hand, livestock, especially ruminants, contribute to greenhouse gas emissions through enteric fermentation and manure management or decomposition. Climate Change is not only a threat to achieving sustainable development but also deprives our livelihoods and economic sustenance. Most smallholder dairy farmers are found in the highlands, where demand for food crops restricts access to grazing areas and the availability of feed and fodder (Mutavi *et al.*, 2016). Despite its contribution to economic growth and food security, smallholder dairy production is impeded by inadequate year-round supply of high-quality fodder, unavailability and cost of high-quality concentrates and supplementary feeds (Siankwilimba, 2024). Because of the ability to sell dairy products anywhere globally, the dairy sector swiftly expanded internationally. The dairy cow plays a crucial function in the food sector and is a significant component of agriculture in many nations today. The dairy cow plays a significant role in the global agriculture sector aimed at ensuring food and nutritional security.

Overview of Dairy Production in the World

Milk production is a home activity for about 150 million families worldwide (Balem *et al.,* 2022). Smallholders produce milk in most developing nations, supporting household livelihoods, food security, and nutrition (Chagunda *et al.,* 2016). Milk provides relatively quick returns for small-scale producers and is an important source of cash income. In recent decades, developing countries have increased their share in global dairy production. This growth is mostly the result of an increase in the number of producing animals rather than a rise in productivity per head. In many developing countries, dairy productivity is constrained by poor-quality feed resources, diseases, limited access to markets and services (e.g., health, credit, and training) and dairy animals' low genetic potential for milk production. Unlike developed countries, many developing countries have hot and humid climates unfavourable for dairying.

Most former countries are located in the Mediterranean and Near East, the Indian subcontinent, the savannah regions of West Africa, the highlands of East Africa and parts of South and Central America. Countries without a long tradition of dairy production are in Southeast Asia and tropical regions with high ambient temperatures and humidity, from 530 million tonnes in 1988 to 843 million tonnes (Parry *et al.*, 2005). Global milk production has expanded by more than 59 per cent in the past three decades. With 22% of worldwide milk output, India is the world's top producer (Douphrate *et al.*, 2013). Due to poverty and, in some countries, unfavourable climatic circumstances, milk production declined drastically. The countries with the highest milk surpluses are New Zealand, the United States of America, Germany, France, Australia and Ireland. China, Italy, the Russian Federation, Mexico, Algeria, and Indonesia have the greatest milk deficits (Takahashi, 2024).

The dairy industry contributes significantly to the world's nutrition by generating 881 million tonnes of milk in 2019, which rises yearly (Asgharnejad *et al*., 2021). Around 6 billion people, or more than 80% of the world's population, regularly drink liquid milk and other dairy products (Asgharnejad *et al*., 2021. The proportion of developing nations in the world's dairy production has increased recently. The majority (81%) of milk produced worldwide comes from cattle, followed by buffaloes (15%), goats (2%), sheep (1%), and camels (0.5%) (Singh , 2022). Market demand, dietary customs, and socioeconomic features of individual households are other variables that may affect the existence of a dairy species (for example, poorer families typically rely more on tiny ruminants) (Kapaj *et al.*, 2017). Milk-producing animals are frequently cultivated in smallholder and subsistence farming systems in developing nations. These animals typically serve multiple purposes and thrive and produce despite challenging circumstances like limited resources, scant management, and harsh surroundings. Despite having a poor genetic capacity for milk production, they are well suited to the local environment (Hoffmann *et al.*, 2010).

The *Moringa oliefera* and *Medicago sativa* plants are presented as in Figure 1 and Figure 2, respectively.

Figure 1. *Moringa oliefera* plant
Source: Google (Feedipedia)

Figure 2. *Medicago sativa* plant

Overview of Dairy Industry/ Production Systems in Kenya

The liberalisation of the dairy industry in 1992, which brought about significant changes in how it operated and continues to influence the sector, was the dairy industry's most significant turning point (Ahmed *et al*., 2004). According to estimates, the industry accounts for 4% of the nation's GDP, 14% of the agricultural GDP, and 44% of livestock (Leggesse *et al.*, 2023). In addition to enhancing the nation's food and nutritional security with a per capita consumption of about 120 liters, it supports 1.8 million smallholder dairy farmers by creating an estimated 750,000 direct jobs and 500,000 indirect jobs (Ndiritu, 2022). The dairy industry is poised to

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significantly contribute to the national Big Four Agendas of food and nutrition security, manufacturing, universal health, and housing (Smith *et al*., 2013). In Kenya, milk production systems can be grouped into large and small-scale systems considering the size of operation, management level, and inputs run in open grazing, zero-grazing and semi-zero-grazing. A very important segment in the dairy value chain in Kenya is milk cooling, whose capacity has been expanded by the Government by placing over 350 coolers (Balikowa *et al.*, 2011). Milk cooling improves the microbial quality of raw milk to support the processing of quality milk and milk products (Fusco *et al.*, 2020).

Overview of Dairy Feeds in Kenya (Energy, Mineral, Protein and Vitamin Sources)

All animals depend on feed for survival, growth, and reproduction. Thus, it is important to understand its basic components, which are dry matter (DM) and water. DM consists of organic and inorganic substances. A comparison of nutrient content among diets should be made on a DM basis (Li *et al.*, 2021). Good forages for dairy cows include grasses such as Kikuyu and Napier, Boma Rhodes, Lucerne hay, Brachiaria, sweet potato vines, desmodium, sorghum, maise, and so on (Lukuyu *et al*., 2012). Good quality maise silage leads to other forages in the nutrition quality. Cereal grains (barley, corn, sorghum, rice, wheat) are the typical "high energy" feeds for dairy cows, but they are low in protein (Miller-Cushon *et al.*, 2014). Inadequate nutrition is a major constraint that negatively impacts the growth and viability of dairy cattle farming in Kenya. Maintaining access to adequate quantity and quality of feed resources is crucial for milk production in dairy cattle (Njarui *et al*., 2011).

Feeds are generally classified as forages, concentrates (energy and protein feeds), minerals and vitamins. From a nutritional standpoint, forages may range from very good feeds (lush young grass, legumes at a vegetative stage of maturity) to very poor feeds (straw) (Schroeder, 1996). Quality forage for maximum production and return. Grass and legumes High-quality forage can make up as much as two-thirds of the ration's dry matter because cows ingest 2.5 to 3% of their body weight in forage as dry matter. Cows often eat more legumes than grasses at equivalent developmental stages. However, high-quality forages fed to animals in balanced diets will supply a sizable percentage of the protein and energy needed for milk production (Murphy *et al.*, 2009).

Nutrient Requirements of Dairy Cows in Kenya

The high-producing dairy cow requires a diet that supplies the nutrients for high milk production. Carbohydrates, amino acids, fatty acids, minerals, vitamins, and water are all nutrients required by the lactating dairy cow to meet the demand of the mammary gland to produce milk and milk components (Guetouache *et al.*, 2014). However, to develop a cow that will produce a high milk yield, it begins with the nutrition of the calf and heifer. The nutrients dairy cows require are energy, fiber, protein, water, vitamins, and minerals (Erickson *et al.*, 2020). Pasture provides a balanced feed source and generally only provides a profitable response to supplementation if there is a pasture deficit. Energy is the key driver of milk production. It determines milk yield, composition (fat and protein content) and body weight. Energy is measured as megajoules (MJ) of metabolisable energy (ME) (Bangani *et al*., 2023).

In general, the NRC (2001) predicts that dietary CP contents between 16.5 and 17.5 % of the DM supply the protein requirements of early-lactation dairy cows under most conditions (Carder *et al*., 2017). Dietary CP should equal or below 16.5% as cows advance into the second half of lactation (Carder *et al*., 2017). Good forages for dairy cows include grasses such as Kikuyu and Napier, Boma Rhodes, Lucerne hay, Brachiaria, sweet potato vines, desmodium, sorghum, maise, and so on. Good quality maise silage leads to other forages in the nutrition quality. These are the nine essential nutrients in natural dairy milk: calcium, riboflavin, phosphorous, vitamins A and B12, potassium, magnesium, zinc and iodine (Stewart *et al.*, 2021). The six essential nutrients animals need are carbohydrates, protein, fat, water, vitamins, and minerals. With these food nutrients present in every meal, the livestock will grow healthy (Saha, & Pathak, 2021).

Importance of Dairy Production in Kenya

Dairy farming, which feeds the dairy industry in Kenya, is one of the lucrative agricultural activities with so much potential. The country is well-known as one of Africa's biggest milk producers, contributing 30-40% of the 5% that Africa produces to the global numbers (Smil, 2002). Dairy farmers in the country have a great opportunity to make a living while supplying the industry with quality and safe milk from an estimated population of over 4 million dairy cows (Yilma *et al.*, 2011). Although the market for processed milk and milk products has strongly grown over the past ten years, approximately 70-80% of the milk is distributed to the consumer through the raw milk market (Maina *et al*., 2018). Health and wellness pressures have continued to drive new product developments. Due to global health awareness, health-conscious consumers are expected to push the wellness trend, which will continue influencing drinking milk products (Priyadarshini *et al.*, 2018). Consumers are pushing processors to go clean on their products. Although there is no universal definition of what constitutes natural, clean label and healthy products, dairy companies have joined the worldwide phenomenon of producing products that consumers deem to be better for them (Priyadarshini *et al.*, 2018).

Biological Roles of Moringa Leaf Meal and Lucerne Hay Meal in Dairy Milk

Moringa is rich in nutrients and biologically active compounds and thus has great potential to be used as a supplement in livestock feeds. The leaves, seeds, and bark of Moringa can be readily consumed by cows, sheep, goats, pigs, chickens, and rabbits (Liu *et al.*, 2023). Consumption of Moringa has been proven to improve the health, growth performance, milk production, and meat quality of livestock.

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About 92% of the protein found in Moringa is digestible. Leaves also contain 8-9% lipids rich in Omega-3 fatty acids (Peñalver *et al.,* 2022). Moringa leaves are rich in minerals like calcium, iron, potassium and multivitamins, which are essential for animal performance and milk production and a good source of proteins (Su & Chen 2020), with about 47% bypass protein and with an adequate amino acid profile, that can increase the rumen microbial protein synthesis (Su & Chen, 2020). *Moringa oleifera* leaves meal is rich in protein, so it can be used as a supplement to increase milk production (Kholif *et al*., 2019).

Lucerne hay, also known as alfalfa hay, is a highly nutritious forage commonly used as a feed for livestock such as horses, cattle, and goats. The plant is a member of the pea family and is native to the Mediterranean region, but it is now widely cultivated around the world. Lucerne is an extremely useful forage for dairy cows; however, the plant has a high crown and, hence is sensitive to grazing. Highly winter-active cultivars are more susceptible to defoliation damage than semi-dormant or winter-dormant types (Pembleton *et al.,* 2010).

Nutritional Values of Moringa and Lucerne in Diary Milk

When cows were fed Moringa, their milk production increased to 10 litres per day from 7 litres per day when they were not fed on Moringa. During specific lactation stages, cows produced more milk, had greater antioxidant capacity, and had lower milk somatic cell counts than controls. Minerals like calcium, potassium, zinc, magnesium, iron, and copper are abundant in the leaves of *M. oliefera*. Vitamins such as vitamin A's beta-carotene, vitamin B's pyridoxine, nicotinic acid, and folic acid, as well as vitamins C, D, and E, are also contained in Moringa and with the addition of Moringa, milk protein and fat content increased.

The maximum quality can be obtained from Lucerne and Lucerne-grass pastures when they are grazed at the appropriate stage of maturity. Higher-performing cattle, such as stockers, grass-finished cattle, and lactating dairy cows, do well on Lucerne. It is a high-quality hay that provides vitamins A, K, and E and raises the calcium and protein levels in your horse's body. The Lucerne-eating cows, after that, experience weightlessness and continue to consume large volumes of the feed, which aids in their ability to produce more milk. Around 18–22% crude protein (CP) and 10MJ/kg DM of metabolisable energy (ME) make up the nutritional value of Lucerne. For calves, younger cattle, dairy cows, and pregnant cows in their late stages of pregnancy, alfalfa (green or fed as hay) is preferable.

Anti-Nutritional Factors Found in Moringa and Lucerne Feeds

However, Moringa leaf contains various anti-nutritional factors which may hinder the efficient utilisation, absorption, and digestion of nutrients and thus reduce the nutrient bioavailability and nutritional status (Devisetti, *et al*. 2016). Major anti-nutritional factors found in edible crops include saponins, tannins, phytic acid, gossypol, lectins, protease inhibitors, amylase inhibitors, and goitrogens. Anti-nutritional factors combine with nutrients and are the major concern because of reduced nutrient bioavailability. Moringa leaf meal has 46 antioxidants. Thirty-six anti-inflammatory agents. 18 amino acids (Khan *et al*., 2021).

Saponins are considered the main anti-nutritional factor in Lucerne, in which they cause a reduction of nutrient utilisation and feed conversion efficiency (Aganga *et al*., 2003). The main anti-nutritional components present in this plant are saponins, and their unfavourable effects on animal performance have restricted the optimum use of this high-protein plant as an animal feed. The anti-nutritional factors can be defined as those substances generated in natural food substances by the normal metabolism of species and by different mechanisms which exert effects contrary to optimum.

Conclusion

The research findings underscore the significant potential of *Moringa oleifera* and *Medicago sativa* hay in addressing feed challenges within the dairy sector. Field evidence demonstrates that Moringa supplementation increases daily milk production from 7 to 10 litres, enhancing milk protein and fat content. The high protein digestibility of Moringa (92%) and Lucerne's substantial crude protein content (18-22%) make them valuable alternatives to conventional feeds. However, their implementation requires careful management of anti-nutritional factors, including saponins, tannins, and phytic acid. These alternative feeds show promise for small-scale dairy farmers in tropical regions, where conventional feed costs and availability pose significant challenges. The successful integration of these feeds could help bridge the productivity gap between developed and developing nations while supporting sustainable dairy production. Future research should focus on optimal inclusion rates and processing methods to minimise anti-nutritional effects while maximising nutritional benefits.

Conflict

The authors declare no conflict to the submission and publication of thie paper.

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