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Mulberry leaves as a feed source for livestock in Kenya: A Review

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A B S T R A C T

In Kenya, Mulberry is grown in less than a piece of an acre by most of the farmers. Current acreage of mulberry stands at 250, spread over Western, Nyanza, and Rift Valley and Coastal regions. Mulberry leaves are highly palatable and digestible (70-90%) to ruminants and can be fed to non-ruminants as part of feed ingredient. Protein content and essential amino acid profile in the leaves and young stems varies from 15 to 35% depending on the variety. The Mulberry leaves are highly applicable as supplements replacing concentrates for dairy cattle, as the main feed for goats and sheep, and as an ingredient in rabbits and pigs' diets. Farmers growing mulberry fodder offer higher protein content to livestock than those relying on different varieties of Napier grass, which have failed to boost milk production despite the amounts fed. In non-ruminant production, fishmeal and soybean meals are the main source of protein. In ruminant production, cottonseed meal and canola meal are the main source of protein. These meals are expensive, inadequate in supply and of variable quality. This often leads to low egg production and poor-quality eggs, hence low income and poverty among farmers. Therefore, efforts have been made to identify locally available protein feed resources that can be used as a protein supplement for livestock. Mulberry leaf meal (MLM) has been identified as a locally available alternative protein and mineral source that are beneficial to livestock and have been proven to improve production.

Keywords: Mulberry leaf meal, Non-ruminants, Protein source, Ruminants

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Introduction

Nutrition is of major influence in livestock production. Main livestock species kept in Kenya include cattle (18 million), sheep (18 million), goats (28 million), camels (3 million), pigs (334,689) and poultry (31 million) (KNBS, 2010). Currently, about 60% of total households keep livestock, or about 7 million households, mostly keeping few livestock. The bulk (75%) of livestock keepers are rural and among the less well-off within the population. The feed industry in Kenya largely relies on imported feed ingredients like maize, maize germ/bran, wheat bran and pollard, soybean and its derivatives, sunflower cake, copra cakes, cottonseed cake, fish meal, and micro-ingredients (usually additives) from the East African Community (EAC), Southern African Developing Countries (SADC) regional market and other international markets (Oloo, 2010).

In the past 30 years, there has been increasing competition for protein foodstuffs between people in general and livestock. According to Thornton (2010), developing countries' share of worldwide use of cereals for animal feed nearly doubled (to 36%) from the first 1908s to the late 1990s. These foodstuffs are inadequate, and their incorporation in feeds makes them expensive while the low-quality ones are mainly utilized in animal feed manufacture. This leads to low productivity of the animals and incidences of poisoning. Increased protein ratio in dairy cows and goats, layers and broilers boost yields, as long as the bodybuilding nutrients are core within the formation of milk, eggs, and meat.

Mulberry leaf meal (MLM) is a plant protein source, which is readily available in rural areas of Kenya with acreage of 250 mulberry stands. Mulberry tree is hardy, deep-rooted, and does well in almost all types of soils, and it is locally available in Kenya because of favorable climatic conditions. It is drought tolerant and can survive in arid and semi-arid lands (ASALs) such as Kenya, which is 88% ASAL. Mulberry trees are commonly found in most rural compounds due to the presence of fruits, which are consumed by

people, leaves are used for feeding silkworms (Tuigong *et al.*, 2015) and livestock especially ruminant animals, the fruits are used as beverage for people and the trees are used for wood fuel and timber. Type II diabetes mellitus can be managed by taking a mixture containing black mulberry fruit and water. In addition, this fruit has been used for the treatment of mouth, tongue and throat inflammations. It is easy to propagate mulberry, hence it is a means of providing a cheap source of protein. According to Srivastava *et al.* (2006), Mulberry leaves contain β-carotene, which can be converted with varying efficiency by poultry to vitamin A and xanthophylls. Xanthophylls are good source of the pigmentation of egg yolk. It also contains minerals and β-glucans that are beneficial to livestock and have been proven to improve average daily gain, dry matter, and energy of nutrient digestibility in weaned pigs. Feeding Mulberry leaves causes an increase in body weight gains in growing lambs and goats as well as an increase in milk quality and quantity in dairy cows.

Mulberry plant

Mulberry belongs to the family Moraceae and comprises of 10–16 species of deciduous trees, growing wild and under cultivation in many temperate world regions. In Kenya, establishment of a mulberry cultivation orchard at the National Horticultural Research Centre (NHRC) in Thika was done in 1974 because of the introduction of sericulture. Some high yielding cultivars were imported from India and Japan in order to assess their performance under Kenyan climatic conditions (Tuigong *et al.*, 2015).

Mulberry is a multi-functional plant and a great source of nutrients and phytochemicals, which include flavonoids, which have antioxidant activity and phenolic constituents with major active components of biological activities (Rebai *et al.*, 2017). According to Srivastava *et al.* (2006) Mulberry has also been established as functional food due to health promotion and disease prevention. Mulberry leaves have been proven to have pharmacological and biological properties, which include antibacterial, antiviral, antitussive, hypoglycemic, hypotensive, antiatherogenic, diuretic and antioxidant (Rebai *et al.*, 2017).

According to Tuigong *et al.* (2015), Mulberries grows very fast when young, but the growth slows down later and rarely exceeds 15 meters. The arrangement of leaves is alternate, simple and often lobed and serrated on the margin. Lobes are mainly found in the juvenile shoots than on mature trees. Mulberry can be established through stakes or seeds. Yields depend on variety and location. In a quarter of an acre, it is possible to plant 3556 plants using a spacing of 5 x 2 feet. Pruning is done once a year to a height of 1.5-1.8 m and allowed to grow with a maximum of 8-10 shoots at the crown. This allows more shoots to grow from the base. In a six months period, the shoots are able to attain the height of 3 ft when three strong shoots are selected. Pruning is done at 1 ft above the ground to create a pruning/harvesting table (Sánchez, 2002).

Mulberry leaves are commonly used as feed for mulberry silkworm (Saddul *et al.*, 2004). In Kenya, over 600 farmers are involved in sericulture and the annual production is less than two tonnes of dried cocoons, while the national potential is over 10,000 metric tonnes. The leaves are highly palatable and digestible for herbivores and monogastric animals. There is a large variation in leaf production and quality in terms of protein content among the varieties (Sánchez, 2002). The leaves are harvested three or four times a year by a leaf-picking method or cutting whole branches or stems. Harvesting should be done in the mid-morning and stored in the leaf chamber for feeding mulberry silkworms. The leaves should be covered to preserve freshness. Leaf production depends on the variety, location, plant density, fertilizer application and harvesting technique. Harvested fresh leaves yield up to 40 tonnes/ha/year, which is approximately 10 tonnes of dry matter (Sánchez, 2002). In Kenya, on attaining maturity in the 3rd year, the tree should give 2 kg per tree, giving a total yield of 20 m/tons/ha/season of mulberry leaf. Kenya experiences two seasons, short and long rains. The long rains start in the month of March and end in May while the short rains start in October and end in December. Depending on the rainfall pattern, 3-5 harvests can be realized in a year.

Varieties of mulberry

Globally, there are about 68 species of the genus *Morus*, where the majority is found in Asia. The dominant species in Kenya is *Morus abla*. Tuigong *et al.* (2015) asserts that while some of the varieties thrive under rain, others require irrigation. A variation exists in leaf production and quality based on the protein content. This is due to differences in species, varieties, locations, type of soil and environmental conditions.

Morus alba- *Ex-Embu* variety has short internodes; purplish coloured bark prominent at the shoot tips. The type has many small leaves and is drought resistant. This variety is highly affected by leaf spot than other varieties but can be managed through timely harvesting of leaves.

Morus alba - *Ex-Thika* is characterized by large light green slightly drooping leaves, has long internodes and whitish bark. The variety is fairly drought resistant. The young shoot is weak and may need support to avoid falling or bending.

Morus alba - *Ex Limuru* is known by its small finger shaped deeply serrated leaves, very thin shoots with short internodes. The variety has high berry production and is thus not recommended for silkworm rearing due to low leaf harvest. Despite this, the variety is recommended for berry production.

Morus alba - *Ex-Ithanga* is known for its medium heart shaped and smooth light green leaves. It may sometimes produce a few lobed leaves. Its roots easily and is fairly drought tolerant. It is suitable for both silkworm rearing and berry production (Wangari *et al.*, 2013).

Benefits of mulberry

Mulberry tree has great potential due to its many applications. Every part of the plant can be value-added if industrially used. There are many products with medicinal value that can be derived from mulberry leaves and fruits. The Roots are used in a drug, which is used by patients with high blood pressure. According to Venkatesh and Chauhan (2008), root juice agglutinates the blood and is very useful in eliminating worms in the digestive system. Left over mulberry leaves from silkworm feeding is used as cattle feed as a supplement to increase milk production (Tuigong *et al.*, 2015). The leaves can also be used as a vitamin and mineral supplement in the diets of poultry and can improve egg production (Machii, 2002). Where silkworm production is not practiced, some of the farmers use the leaves to feed cattle and rabbits. The fruits are used as raw products in making of jelly, fruit sauce, cake, food colour, yoghurt, wine and juice. In addition, dried fruits and leaves are packaged for sale where the leaves make green tea while the dried fruits are processed into powder (Srivastava *et al.*, 2006). According to research, fresh fruits have medicinal value and have historically been used to prepare syrup and treat sore throat, high fever, and depression (Venkatesh and Chauhan, 2008).

Mulberry bark is used in making paper pulp and hence used in the paper making industry. Through intercropping with other plants, the tree acts as a good companion to grapes or passion fruits since its hard stalks support the climbers. When properly pruned, the tree is highly used for landscaping. Mulberry wood is highly resilient, shock resistant and tough hence can be used in making hockey sticks, and rackets for tennis, badminton, and squash. The sticks are used on fences, or woven into baskets and silkworm rearing trays (Tuigong *et al.*, 2015). This single plant, if exploited, can give rise to different income generating micro-enterprises that will lift living standards and create jobs for the many youths who are unemployed.

Nutritive value of mulberry leaves

Mulberry leaves contain significant levels of protein with good amino acid profile, carbohydrates, fats, minerals, fibers, and metabolizable energy (Sánchez, 2002). They also contain carotene, vitamin B1, folic acid, folinic acid, and vitamin D. The presence of glutathione in leaves has been reported. Copper, zinc, boron and manganese occur in traces. Phytate phosphorus accounts for 18% of total phosphorus. The amount of fiber in the mulberry leaves is lower compared to other types of forages (Sánchez, 2002). According to Ustundag and Ozdogan (2015), mulberry leaves supplementation up to 10% in poultry does not have an impact on the productive performance and egg quality. In addition, mulberry leaves decrease yolk cholesterol and increase pigmentation of egg yolk. Table 1 and 2 show the nutrient composition of fresh and dry mulberry leaves, respectively.

Table 1. Nutrient composition of fresh mulberry leaves.

Nutrient	Composition
Moisture %	71-75
Crude Protein %	5-10
Crude Fat %	0.64-1.50
Total Ash %	4.50
Crude fibre %	9.90-13.85
Carbohydrates %	8-13
Energy Kcal/100 g	69-86
Neutral Detergent Fibre (PDF) %	8-11
Acid Detergent Lignin (ADL) %	3.40-8.10
Hemicellulose %	2.50-12.80
Ascorbic acid, mg/100 g	160-280
β-carotene, mg/100 g	10.000-14.688
Iron mg/100 g	4.70-10.40
Zinc mg/100 g	0.22-1.12
Calcium mg/100 g	380-786

Source: Srivastava et al. (2006)

Table 2. Composition of dry mulberry leaves.

Nutrient	Composition
Moisture %	5.11-10.75
Crude Protein %	15.31-35.00
Crude Fat %	2.09-6.90
Total Ash %	8.91-11.81
Crude fibre %	9.90-13.85
Carbohydrates %	9.70-39.70
Acid Detergent Fibre (ADF) %	17.33-28.00
Neutral Detergent Fibre (PDF) %	19.38-35.77
Acid Detergent Lignin (ADL) %	3.40-8.10
Hemicellulose %	2.50-12.80
Ascorbic acid, mg/100 g	100-200
β-carotene, mg/100 g	8.44-13.13
Magnesium mg/100 g	720
Anti-nutritive factors	
Oxalates mg/100 g	183
Phytates mg/100 g	156
Tannic acid%	0.13-0.36

Source: Ustundag and Ozdoga (2015)

Table 3. Amino acid content of mulberry leaves.

Amino Acid	% of crude protein
Lysine	5.02-5.21
Methionine	1.58-2.03
Phenylalanine	4.34-5.15
Leucine	6.89-7.45
Isoleucine	3.99-4.74
Threonine	3.69-4.25
Histidine	2.22-3.56
EAA	28.68-31.13
Valine	4.52-5.16
Arginine	4.19-4.59
Asparanin	7.19-8.26
Glutamine	9.13-11.46
Serine	3.18-4.20
Glycine	4.93-5.94
Ala+Tyr	10.74-11.79
Non-EAA	44.02-50.96
Total AA	73.48-81.82

Source: Yao et al. (2000)

Use of mulberry leaves in non-ruminant nutrition

Mulberry leaves are used as a feed ingredient in non-ruminant nutrition. In poultry feeding, despite poor use of dry matter, crude protein and ether extract are highly digested by poultry (Al-Kirshi *et al.*, 2013). Poultry raised in mulberry gardens showed an increase in Vitamin K1 in the yolk (Machii, 2002). Inclusion of mulberry leaves also reduced odour in the manure emitted by poultry. Ammonium and hydrogen sulphate are the major contributors of odour in poultry manure. This study proved that mulberry leaves have an inhibitory effect on ammonium emission.

Mulberry leaves have been reported to have many biological activities, such as antioxidants, antimicrobial, antifungal, anti-allergic and hypoglycemic activities (Hajati *et al.*, 2014). Mulberry leaves exhibit antioxidant properties presumed to be a product of the synergistic action of free radical scavenging compounds such as carotenoids, flavonoids, moracins and others present in the leaves (Andallu *et al.*, 2014). They also improve FCR and egg mass due to the antioxidant activities of MLM, which gives healthy uterine and ovarian environments (Lin *et al.*, 2017).

Feeding of mulberry leaves to poultry resulted to hens laying eggs with deeper yellow yolk colour due to supply of xanthophyll (Lokaewmanee *et al.,* 2009). A study done by Islam *et al.* (2014) suggested that the inclusion of mulberry leaf meal could be used to formulate a low-cost broiler grower diet in order to produce low-cholesterol broiler meat. Mulberry leaf powder can make up to 30% of commercial feed without any adverse impact on the feed intake, growth, FCR and mortality of the broiler chicken. It also helps in cost reduction of feeds (Simol *et al.,* 2012).

Mulberry meal is important for growing-fattening pigs, with economic advantage of the daily ration, in both conventional and non-conventional diets. Animal response in the fattening period when more inputs are required in the pig production system suggest that mulberry can be a plant resource capable of being usefully integrated into pig rearing, through a perennial plantation with periodic cutting and fertilized with pig effluent (García *et al.,* 2017). According to a study done by Zhu *et al.,* 2019), 15% mulberry leaf powder supplementation reduced the growth performance and carcass traits, but improved meat quality of finishing pigs, possibly through the change of myofiber characteristics, enhancement of antioxidative capacity and increase of intramuscular fat. Dietary supplementation of β-glucan from mulberry leaves and Curcuma can improve average daily gain, gain/feed intake ratio, and dry matter and energy of nutrient digestibility in weaned pigs (Lee *et al.,* 2017).

In rabbit rearing, there is a very high probability that approximately 50% of the feeds used commercially can be replaced with mulberry foliage meal for adult rabbits (Bamikole *et al.,* 2005). When the mulberry forage together with some other locally sourced resources are utilized, they produce enticing productive indices in crossbred resulting to approximately seven rabbits per kindling remaining alive while approximately more than five of the totals being weaned. However, for the rabbits' diet, the mulberry should not be more than 40 percent due to its physico-chemical characteristics and digestive utilization (García *et al.,* 2017). The phytochemicals, which include the flavonoids, alkaloids, and phenolic acids, are the major factors that restrict how much mulberry leaves would be accepted and could efficiently be added into the commercial feeds produced for rabbits. They, too, play a major role in the improvement of health activities such as antioxidizing carried out in the blood of the rabbit and in optimizing the micro-flora population in the rabbit cecum (Hou *et al.*, 2018).

Mulberry leaves can be used as an ingredient in formulating fish feeds to replace fish meal. In a research carried out by Kaviraj *et al.* (2013), indicate that fish offal meal and MLM have the potential to be essential raw materials which could be effectively utilized in the production and formulation of Indian major carp's diet. When the right amount of MLM is added into the fermentation of FOM, it results to a fermented mixture that has the highest probability of successfully replacing approximately eighty percent of fishmeal in the formulation of the diet.

Effect of feeding mulberry meal on egg cholesterol content and blood cholesterol

By definition, cholesterol is a wax-like and fatty substance traceable in the body of every cell. In the human body, some cholesterol is needed to create hormones and vitamin D, which helps in the digestion of food. Normally, the body is responsible for forming all the cholesterol it requires. The cholesterol is also present in foods such as foods derived from animal sources like the yolks in the eggs, meat, and cheese. In case cholesterol concentration is very high in the blood, it can combine with other blood's elements, which results in the formation of plaque, which accumulates in arteries' walls. The excessive accumulation of plaque can result to health complications such as coronary artery disease, where the coronary arteries, due to the plaque's buildup, either get narrow or blocks completely.

The two primary forms of lipoproteins that carry cholesterol to and from body cells in the blood are the high-density lipoprotein, abbreviated as HDL and Low-density lipoprotein, abbreviated as LDL, Low-density lipoprotein cholesterol is commonly or popularly known as "bad cholesterol" since its excessiveness is unhealthy. This is because it causes a buildup of cholesterol in the arteries, hence heart attack risk. HDL or High-density lipoprotein, to the contrary, is often referred to as "good cholesterol" due to its role of protects the body against the narrowing of blood vessels.

According to Kamruzzaman *et al.* (2014), for the poultry that lay eggs, the cholesterol is biosynthesized in the liver, and is discharged into the plasma in a very low-density lipoproteins (VLDL) form, and moves into the ovary thus, forming yolk that contains high cholesterol. Therefore, the cholesterol levels in the Egg-yolk vary or differ from one species to the other for various birds, kind of strain as well as the oldness of fowl. Nevertheless, the contents of cholesterol found in the Egg-yolk can be changed through genetic selection and diet alteration. Diet alteration can be achieved by supplying feed

ingredients that reduce cholesterol. Mulberry leaf contains phytosterols (β-sitosterol, campesterol, stigmasterol, isofucosterol) Yamazaki *et al.* (1997), which have the same structure as that of cholesterol and functions in the intestine to decrease the rate at which cholesterol is absorbed and aids in minimization of cholesterol levels found in the blood vessels (Panja, 2013). The mulberry leaves also reduce blood cholesterol content. According to Kamruzzaman *et al.* (2014) supplementation meals consisting of mulberry leaf as a component to approximately, 9% reduced blood cholesterol in hens.

The liver has an essential role during the regulation of the deposit contents of the lipids and phospholipids in the egg yolk. Both the liver as well as the serum cholesterol are reduced when the Mulberry leaves are supplemented which results to a reduction in the egg yolk cholesterol. Fiber binds bile acids in the intestines leading to more acid excreted in the faeces. As a result, this leads to the reduction of the amount of bile acids going back to the liver, consequently forcing or pushing the liver to excrete more bile acids to compensate the ones lost in the faeces. The liver converts more cholesterol into bile acids in an attempt to produce more bile acids (Mayes and Botham, 2003) which decreases the cholesterol levels in egg yolk and plasma.

Mulberry leaves have phytosterol, which is associated with lower cholesterol absorption by the liver when the yolk is being synthesized (Islam *et al.*, 2014). Phytosterol completely limits the absorption of endogenous and dietary cholesterol occurring in the small intestine through its entry into micelles, which is necessary for the dissolving of cholesterol. Thus, consequently the cholesterol turns out to be insoluble, and hence, easily excreted in the stool. This could be the cause of reduction of cholesterol in the egg yolk. Mulberry leaves inhibit the oxidation of LDL-cholesterol (Panja, 2013). Thus, the free radicals lead to oxidation, which is a kind of destabilizing chemical for molecules like the low-density lipoprotein cholesterol. The oxidized low-density lipoprotein, LDL, turns out to be more reactive with the tissues surrounding it. As a result, it can lead to the production of inflammation that causes either diseases or damage to the organs. Once Low-density lipoprotein, LDL, experiences oxidation, it inhabits the endothelium of the arteries in the body, such as the carotid arteries, the coronary arteries, or the arteries that supply legs and arms with blood. The inflammation in the arteries produced by oxidized LDL is dangerous since these blood vessels carry blood to all organs and tissues. It increases the risk of having a heart attack or a stroke. Mulberry leaves decrease lipid peroxide content in the yolk (Machii, 2002). On average, humans consume approximately 217 mg of cholesterol in a single egg, but this could vary from 153 mg to 264 mg (Vorlova *et al.*, 2001). Notably, it is recommendable that the daily intake of dietary cholesterol for the average healthy person to be approximately 300 mg in one day.

Use of mulberry leaves in ruminant nutrition

Mulberry is one of the best forages for ruminant nutrition. Its high levels of crude protein and digestibility are far superior to those of poor foliage and agricultural by-products such as reject bananas that are commonly used (Catie and Rica, 2002). Mulberry leaves are highly palatable, which means the small ruminants avidly first up-takes or eats the leaves that are freshly sprouting and the growing stems, still in their young stages, also in situations where they have never been exposed to it before. For instances for the cattle like the cows, they eat the entire biomass under the condition that it is chopped finely. Previously, animals when issued or offered with both other forages and mulberry as an option, they choose mulberry as their favorable feed thus, leaving other forages, and even dig through a pile of various forages to look for mulberry. Mulberry can, therefore, be used as a replacement for the grain-based concentrates consumed mainly by the lactating cows and yield very good result. According to a study done by Vu *et al.* (2011) of partial of cotton seed with mulberry, feed supplemented with mulberry was favored and readily eaten by the bulls, and they had no problem in achieving dry matter intake.

The mulberry leaves are known to have both high crude protein as well as condensed tannins. The fact that the condensed tannins are present could be termed as essential since they enhance fermentation of the rumen. Because of their nutritive value being very high, and also having very positive impacts on the functionality of the rumen, yielding of the microbial, and metabolism of the body, and tree foliage is increasingly becoming acknowledged to have great potential in the production of feed resources that are of high quality for the ruminants, precisely as the supplier of crude protein. High level of digestion or digestibility of organic matter and high concentration of resources such as carbohydrates that are highly fermentable, sulfur, nitrogen, and vitamin among other minerals that are possibly present in the leaves of mulberry could lead to the efficiency of microbial protein synthesis being high in the rumen and as a result permits the supply of microbial protein to the small intestine of the ruminant animals (Vu *et al.*, 2011).

Meal from mulberry leaves together with urea could probably enhance or encourage increment in the inhabitants of ruminal cellulolytic bacteria of cattle (Tan *et al.,* 2012). Both the leaves and fruit of mulberry improve the richness of the overall ruminal bacteria in finishing steers (Niu *et al.,* 2016). Ruminal microbes lower the grade level of the carbohydrates' dietary to yield out VFA that functions as a stimulation chemical factor, which enhances the growth and advancement of the rumen. High content of fiber in the mulberry increases production of both the acetate and the ratio of its concentration to propionate concentration, leading to the decreased efficiency of metabolic energy utilization for fattening. Mulberry leaves supplementation enhances the digestion of nutrients in the rumen. In addition, supplementing with mulberry can improve how concentrated the acetate is in the rumen fermentation thus, promotes the gradual growth and properties of metabolic in the rumen epithelium (Ouyang *et al.,* 2019).

Mulberry leaves increase milk quality (protein and fat) and quantity. Mulberry feeds are excellent feeds for high yielding animals because the leaf CP and cell wall contents, combined with structural carbohydrates and ash are proof enough they are and thus, can be provided either in freshy or dryness forms in the compounded feeds (Mata, 2002). Feeding mulberry leaves to cows and goats increased the quantity of milk tremendously. There was also a drastic increase in the production of milk, protein, and fat in the cattle and goat because of the mulberry supplementation (Venkatesh *et al.,* 2015). In addition, supplementing the diet with mulberry leaves has been observed and proven to result in added body weight in both growing lambs and goats. The experiments done in the feeding of various sheep and cattle indicates that the mulberry leaves have very high nutritional value, which consequently has very major profitable value when used as a supplement to the roughage's diets proofed to be of poor quality (Kandylis *et al.*, 2009).

Limitations of mulberry

Due to its edible biomass, Mulberry has an expansive scope of lower metabolites. Each of these composites emerged by co-evolution with herbivorous creatures. Others are made in some biological phases of the plant in the directive of the metabolic procedures as mechanisms used to defend fight pests and diseases and as reserves of specific organic chains.

Mulberry anti-nutritive compound known as 1-deoxy nojirimycin (DNJ) probably have an impact on energy source absorption through prevention of polysaccharide hydrolysis and lowering metabolic energy. DNJ from mulberry could block α-glycosidase activity, which hydrolyzes polysaccharide into plain molecule (Has *et al.,* 2013). In poultry, the level of digestion for dry matters gotten from the mulberry leaves is poor because of its content being known to contain high neutral detergent fiber NDF (Ustundag and Ozdoga, 2015). Mulberry leaves contain high crude fiber and deoxynojirimycin, which raises chances for diabetes, but in poultry feed serve as anti-nutrition to prevent carbohydrate digestibility; therefore, its limited use as feed.

The Ca:P in mulberry leaves is 10:1, insinuating that Ca and P are unstable. The outcome is that P supplementation is necessary when high levels of MLM are contained in diets. The increase in Ca:P ratio could lead to some infertility issues in cows; therefore, it is recommended only as part of the total diet (García *et al.,* 2017). Ca:P ratio needs to be 2:1, with optimal being 1.75:1 in cows depending on class, size, and stage of production. The Ca:P relationship for growing chickens should be within the range of 1:1 to 2:1. The best ratio of Ca:P is 1.39:1 or 1.25:1 in pigs to increase daily gain and gain-to-feed, respectively. The ratio 1.66:1 to improve bone ash, which is significant for breeding sows

Mitigations

Incorporation of cellulolytic enzymes in mulberry leaf-based diets to improve degradability of CF hence improves digestion and utilization of nutrients. High crude fiber and deoxynojirimycin in mulberry leaf can be decreased by rumen liquor fermentation (Has *et al.,* 2013).

Conclusion

Mulberry is locally available in Kenya because of favorable climatic conditions. It is easy to establish, is perennial and drought tolerant and can flourish in dry and wet lands (ASALs) that make up 88% of the Kenya land mass. Mulberry fruits and leaves have several advantages not only as a livestock feed resource but also as human food. Incorporation of mulberry leaves in feed improves milk quality (protein & fat) and quantity in cattle and goats, FCR and egg mass in poultry. Feeding of mulberry leaves-based diets to poultry results in hens laying eggs with deeper yellow yolk colour. Mulberry leaves reduce cholesterol content of the egg and blood cholesterol level. Mulberry leaves a feed ingredient for broilers, pigs and fish enhances performance and carcass quality. Mulberry must not be established as a pure stand, but can be grown along the boundaries or as ornamental homestead shades (landscaping) due to its beneficial impacts. Mulberry leaves have been shown to be capable of replacing or complementing the use of commercial concentrates and can offer a sustainable and economic way of improving levels of livestock production in Kenya.

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