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DAIRY GOAT PRODUCTION IN KENYA: A REVIEW

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ABSTRACT

In sub-Saharan Africa, dairy goat farming presents a viable option to ensure food and nutrition security in addition to playing an important socio-economic function among rural farmer households. Dairy goat production can improve people's livelihoods mainly by providing milk for household nutrition and agro-income. Additionally, the dairy goat enterprise supplies breeding stock, meat, skins, fibre (hair), manure, and also acts as an insurance against emergencies. Further, in most rural households, dairy goats also serve socio-cultural functions including weddings, blessing ceremonies and circumcision rites, among others. In 2009, the dairy goat sub sector contributed about 15.2% of the total livestock and 4.8% of the overall household incomes in Kenya. Milk production is a high-priority function for those involved in dairy goat production. In the year 2006, exotic dairy goat genotypes (Alpines, Toggenburg and Saanen) were introduced in various semi-arid lands of Kenya which were characterised by low, erratic rainfall amounts (below 750 mm annually), high day temperatures (29^o to 35^o Celsius), insufficient and low quality feeds, inadequate health care and inappropriate husbandry practices. Dairy goats are more adapted to semi arid conditions and climate change in general than dairy cows due to their smaller body size and physiology and thus they are becoming more important to the dairy industry. Goat milk is more nutritious than cow milk, is more digestible and is thus recommended for young children, the sick and the aged. Besides, dairy goats can survive a myriad of biotic stresses including diseases and parasites, have low feed and labour requirements, need little start-up capital and thus can be raised by the vulnerable members of the society. This review was aimed at describing dairy goat production and related husbandry practices among dairy goat farmers in Kenya. Policy guidance on the necessary interventions to improve the sub-sector is provided based on identified opportunities and constraints.

Key words: Kenya, dairy goats, production systems, productive performance, constraints, opportunities

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INTRODUCTION

Exotic dairy goats were introduced into Sub-Saharan Africa (SSA) during pre-colonial period and their population has continuously built up owing to land subdivision and rising demand for goat milk and other products [1]. Increasing human population in developing countries has led to an upsurge in demand for protein food which has significantly contributed to the increased demand for dairy goat products [2]. The enterprise has even gained popularity in non-traditional goat milk producing countries including New Zealand and China. This has been catalysed by increasing dairy products demand and climate change [3]. Worldwide, in the year 2017, the population of dairy goats was approximately 218 million heads whereby Asia hosted the largest share (52%); followed by 39%, 5%, 4% and <1% from Africa, Europe, the Americas and Oceania respectively [3]. The Kenyan dairy goat herd has about 200,000 animals, and are mainly composed of Alpines, Toggenburg and their crosses [4].

Dairy goats play an important role by acting as a source of livelihood through support to household nutrition and income from milk, meat, manure, and breeding stock [5]. Dairy goat farming therefore, improves household diets, agro-income, and food security among the rural farming communities [6]. Income generation through the sale of surplus milk and breeding stock is ranked as the top reason for keeping dairy goats [5]. The annual goat milk production in Kenya is about 6.3 million kilograms, which is about 0.02% of the national annual milk output [7]. The productivity of the sub sector has however been constant [1] and has not bridged the gap in the national milk demand [8]. Consequently, gross and net margins from the sale of goat milk often change due to fluctuating prices resulting from the ever-dynamic demand and supply in various ecological zones as well as the underdeveloped dairy goat and products market [9].

The dairy goat enterprise is deemed profitable under smallholder production systems and the margins are influenced by the prevailing production factors [10]. The venture, therefore, provides a good business opportunity for small-scale farmers and special interest groups especially the youth, women, and the elderly because of the low capital and labour resource requirements [11]. In addition, dairy goats are easier to keep because they need less land among other production inputs, have higher prolificacy, and are hardier than exotic dairy cows. Further, demand for dairy goat products in Kenya is increasing due to climate change and the fast growing human population that has resulted to increased land fragmentation and urbanization [7].

Small ruminants, including dairy goats, are more adaptable to climate change than large ruminant species [12] due to their smaller body size, higher heart and respiration rates [13]. However, they are also vulnerable to direct and indirect effects of climate change, including heat stress (at over 35^{o}C) and emerging infectious diseases [14]. Therefore, climate change is challenging the contributions of dairy goats to farmer livelihoods and, therefore, mitigation measures are necessary to support productivity of the enterprise [14].

Dairy goats have lower feed and water requirements, have a shorter reproductive cycle [7], are resilient and adaptable to environmental stresses including insufficient and low-quality feeds, tick-borne and respiratory health hurdles, endo and ectoparasites, and limited feed supplementation [15]. Further, they can convert unused vegetation into valuable milk, meat and income, and thus are well adapted to small, low resource-oriented farms [16].

The growth of the Kenyan dairy caprine sub sector is however faced by various constraints including lack of market for dairy products, diseases, poor breeds and breeding practices, low access to quality feed, lack of supplements, insecurity [4] and climate change[1]. Therefore, the Kenyan dairy goat breeding and improvement programs have not been able to generate enough breeding stock [17]. Other challenges include farmers' lack of information on standard dairy routine husbandry practices and limited resources [4]. Most dairy goat farmers however have had formal education and could comprehend technical information on dairy goat husbandry [5].

Dairy goat research and development programs need to adopt a holistic approach that will solve production challenges including poor feeds, nutritional management, genetic improvement, health care, resilience to climate change and marketing [1]. This review was aimed at describing the dairy goat production and husbandry practices among dairy goats farmers in Kenya and providing policy guidance on the necessary interventions to improve the sub-sector based on identified opportunities and constraints.

REVIEW METHODOLOGY

Multiple databases were used as sources of information in this literature review. The most used platforms were the Google scholar, research gate and university repositories. The databases accessed included PubMed, Scopus, CAB Abstracts, and Web of Sciences [18], as well as conference proceedings, doctoral dissertations and textbooks. A number of broad search terms were used to

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establish a list of research articles that were mostly peer-reviewed. The snowball method was used in identifying most relevant articles. The literature sources were analyzed using two criteria. The first and main one was that the source had to be appropriate and relevant to the purpose of this task. Secondly, the sources had to be from credible peer-reviewed journals. The credibility of the journals used was gauged using the Scimago Index (current year and h-index or frequency of citations). Information from other sources and journals that had research articles aligned to this review was also included. In addition, the highest numbers of journal articles used had been published within the last 10 years. With all these factors put into consideration, the data was critically assessed and only the well written articles coupled with standard research protocols were considered. Sixty three (63) credible publications were reviewed over a period of three months, and used to develop this article.

THE REVIEW

Dairy goat breeds

The indigenous goat genotypes in Kenya are mainly the Galla and the Small East African Goat (SEAG) [19]. These two are hardy meat goats well suited to the Kenyan arid and semi-arid lands (ASALs). The Galla, also called Boran or Somali goats, are native to Northern Kenya ASALs [19] while the SEAG is indigenous in Tanzania, Kenya, and other East Africa regions [20]. Among the Galla, approximately 19% of males and 8% of females are reported to be polled [21] while most of the SEAG are horned [22]. Both the SEAG and the Galla are often upgraded through crossbreeding for improved milk and meat production using exotic dairy goats [23]. Thus the two genotypes are often used as the foundation stock due to their resilience, hardiness and diseases resistance [24].

Exotic dairy goat breeds currently found in Kenya include the Toggenburg, German Alpine, British Alpine, Saanen and the Anglo-Nubian [24, 25]. These genotypes were introduced into the country in the mid-1990s and were used to upgrade the indigenous goats [8]. Kenya has approximately 28 million goats of which less than 1% is true dairy genotypes and their crosses with the SEAG and the Galla [24, 25]. It is estimated that the Alpines and their crosses constitute 95% of the Kenyan dairy goat herd [23] and are mainly found in central Kenya [8]. The rest of the dairy genotypes and their crosses are distributed in Eastern, Western, and the Coastal Kenya counties [25].

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Entry, spread and distribution

The German Alpine genotypes were introduced in central Kenya through the Integrated Small Livestock Project (ISLP) [8]. On the other hand, the Toggenburg got entry to the Eastern Kenya highlands through the Farm-Africa Dairy Goat and Capacity Building Project [26]. The two projects aimed at improving the productivity (meat and milk yields) of local goats through crossbreeding with the high milk-yielding Toggenburg and Alpine breeds [8]. The Toggenburg was further introduced in Machakos and Kitui counties by the Kenya Red Cross, Kenya Climate Smart Agriculture Project (KCSAP) and Farm-Africa through farmer livelihood improvement projects. The German Alpine, Saanen, and the Toggenburg were also introduced in Western Kenya, Nyeri, and Meru counties by development agencies including Heifer Project International (HFI), German Technical Corporation (GTZ), and Farm Africa respectively [25].

Role of dairy goats in improving farmers' livelihoods

Goats account for about 30% of Africa's ruminant livestock and produce about 17% and 12% of meat and milk respectively [27]. In Kenya, dairy goats provide milk for household consumption and sale [4], thus supporting farmer livelihoods. Kiura *et al.* [25] reported that in Kenya, dairy goats were mainly kept to provide milk for household use (71%), and raise incomes through sale of breeding stock (48%) and milk (44%). Further, smallholder dairy goat farming had been promoted by development organizations and policy makers as an option to boost farmers' incomes [5] and thus improve rural livelihoods. In 2009, dairy goat production was deemed viable and contributed about 15.2% and 4.8% of the total Kenyan livestock and overall household incomes respectively [28].

Various dairy goat research and development projects have been carried out to improve farmer livelihoods in Kenya. The programs have been executed by global organizations, sub-regional and regional associations, non-governmental agencies (NGOs), and national bodies with various levels of achievement [28]. The overall aim of most of these projects has been to improve household nutrition, food security and reduce poverty through genetic upgrading of local genotypes for improved milk and meat productivity. By so doing, these projects have raised the agro-incomes of smallholder farmers through production and sale of breeding stock, milk, culls and manure for soil nutrients recycling. Technical training programs transfer knowledge and husbandry skills to dairy goat farmers and this impacts positively on the success of the enterprise [28].

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Dairy goat production systems

In the developing world, where dairy goat production supports largely livelihood improvement of low and medium-income farmers [29], farming systems have changed to match with the overwhelming challenges precipitated by unrelenting natural and economic situations by adapting to integrated crop-livestock production systems. In these areas therefore, dairy goats are semi-extensively reared and grazed on communal lands that hardly support the minimum nutritional needs mainly due to overstocking and subsequent land degradation [29]. In East Africa, dairy goats have been mainly reared under smallholder mixed crop-livestock production systems [1]. In Kenya for instance, the Alpines, the Toggenburg and their crosses were found among the smallholder mixed crop-livestock farming systems in the highlands of Kenya [8] where intensive and semi-intensive production practices were carried out.

In the semi-arid lands of Kitui county, Ndeke *et al.* [30] observed that dairy goats were kept mainly under free-range (extensive) and semi-extensive conditions. In Central and Eastern highlands of Kenya, dairy goats were kept under the intensive systems (zero grazing). In this system, the animals were fully confined in well aerated pens with raised slatted floors to enable efficient and effective cleaning [4, 31]. In the incidences where production systems are changing to semi-extensive, strategic breeding programs need to be designed to promote conservation of these genetic resources and improve their unique attributes including adaptability, suitability and efficiency in water use under harsh environmental conditions [29].

Feeding and nutritional management

Feeding of dairy goats varied with region and among individual farmers. In central Kenya, these small ruminants were fed mainly on Napier grass (*Pennisetum purpureum*), maize crop residues, local green grasses and hay [32]. According to Kiura *et al.* [25], dairy goats were often stall-fed with an average of 10 kg forage mixture of grasses and legumes per goat per day. Further, these small ruminants were often offered feed on the basis of forage availability without regard to proportion of grass or legume, physiological status or productive performance [25].

In Kitui and Machakos counties, stall-feeding was introduced during the initial phases of the dairy goat livelihood improvement programs. This system has however been replaced by other less intensive systems [30]. In Central Kenya highlands, forage was harvested, chopped, and placed on feed troughs inside the goat pens while potable water and mineral-vitamin supplements were offered *adlibitum* [31]. However, many goat farmers consistently fed their stock with non-improved forages citing different challenges ranging from limited availability of

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appropriate feed species suited for different agro-ecological zones, certified seed shortages, limited agronomic knowledge and skills [33].

Fodder trees with improved crude protein content and suitable for dairy goats included Luceana (*Leucaena leucocephala*), Mulberry (*Morus alba*), Calliandra (*Calliandra calothyrsus*), Sesbania (*Sesbania sesban*), while the grass forage species included Napier grass (*Pennisetum puerperium*), and Rhodes grass (*Chloris gayana*) [31]. The nutritional profiles of some of the locally available feed resources for dairy goat are tabulated in Table 1.0 [34]. In the semi-arid lands, natural grasses and herbaceous shrubs were the main livestock feed resources coupled with preserved crop residues from maize stover, peas, cowpeas, and green grams [35]. Dry acacia pods from *Acacia nilotica* and *A. tortilis* were also common feed resources for dairy goats in these areas, often used during the dry periods [36].

Forage feeds were inadequate especially during the dry season [25] and their quality was influenced by climatic and edaphic factors [1]. Mbindyo *et al.* [4] reported that low feed access was attributed to high cost while specifically formulated dairy goat supplements were lacking [1]. Further, feed supplements were derived from agro-industrial by-products, fodder trees and shrubs whose quality was dependent on types, processing methods, stage of harvest and storage factors [1]. Quality forage feed production, conservation, value addition of crop residues and use of supplements is important. Further, the nutritional requirements for the various dairy caprine breeds and levels of productivity under various environmental conditions needs to be studied and documented [1].

Disease control

Kagucia *et al.* [32] reported that in Kiambu County, helminthiasis was the most prevalent dairy goats' disease (84.6%), then pneumonia (32.9%), coccidiosis (25.8%), and mastitis (25%). In the Mount Kenya region, Mbindyo *et al.* [4] reported that the main diseases that afflicted the dairy goats included pneumonia (41%) diarrhoea (36%), mastitis (15%), helminthiasis (9.6%) and skin disorders (5%). In the same area, diseases accounted for 33% of the challenges that faced dairy goat farming, while pneumonia and diarrhoea were the leading source of goat kid mortalities [4]. Kiura *et al.* [25] reported an overall disease prevalence of 30.2% among dairy goat farms, coupled with low availability of animal health service providers.

Kagucia *et al.* [32] observed that the majority of the farmers treated the animals, or used farm workers and neighbours. Albendazoles were used to control endoparasites once a year as opposed to a strategic 3-month drenching program and only a few of the farmers were consistently seeking the help of skilled veterinary officers [32]. It was observed that tick-borne diseases (such as anaplasmosis), diarrhoea, and pneumonia were the most prevalent in the semi-arid lands. Some farmers used sweet potato vines (*Ipomoea batatas*), among other herbal concoctions to treat diarrhoea and endoparasites respectively. Further, other farmers also used a mixture of couch grass (*Cynodon dactylon*) and *Mexican marigold* to make a concoction for ecto-parasites control [37]. Among most of the Kenyan smallholder farms, conventional veterinary drugs were expensive and thus hardly affordable [38], while other farmers had distrust or belief that the biomedicals were fake or counterfeit [39]. Herbal remedies from plant species (*Albizia anthelmintica, Myrsine africana,* and *Embelia schimperi*) have been confirmed to have some efficacy against gastrointestinal nematodes in sheep [40]. An aqueous extract of *A. anthelmintica* had anthelmintic properties against *Fasciola gigantica* trematodes in goats [41]. However, further studies are needed to evaluate the potential of the various plant species as effective anthelmintics [40] in dairy goats.

Dairy goat breeding in Kenya

Natural service and artificial insemination (AI) were the two reproductive methods being practiced in the breeding of dairy goats [25]. Dairy buck rotation problems had been earlier reported [4] while in some areas they were inadequate [25]. Further, there has been low uptake of AI in Kenya due to the high service cost coupled with low conception rates [42]. In central Kenya, for example, 98% of farmers still used natural mating and were reportedly willing to use the AI but perceived it as expensive [42]. There was therefore need to subsidize the service to encourage its uptake among farmers. In the Eastern Kenya counties of Kitui and Machakos, the initial dairy bucks supplied by the development agencies had not been replaced, and thus unplanned backcrossing with the SEAG was common, leading to genotypes with varying genetic values [30, 31]. This had the potential to dilute the genetic composition of the available dairy goat genotypes. Therefore, it is critical to sensitize the farmers on the importance of embracing AI technology to optimize selection in dairy goat breeding programs. In addition, farmers should be supported to access other modern reproduction technologies such as oestrous synchronization (ES) and Embryo transfer (ET) which are also perceived to be unavailable and expensive [42]. Finally, the buck rotation program can be properly monitored, and be supported with regular buck replacement [4].

Through community projects, dairy goat breeding has been undertaken to improve the hybrid vigour through crossbreeding of local breeds with exotic genotypes. In principle, improved dairy goat breeds have been introduced in the country through programs implemented to upgrade the local meat goat genotypes, mainly the Galla and the SEAG [8, 23]. Due to the breed improvement programs, Kenyan dairy goat breeds (Alpine, Toggenburg, Saanen) and their crosses exhibit various levels of gene mixing. The most admixed is the Saanen which has 84%, 7%, and 4% of their genome got from the Galla, Alpine, and Toggenburg respectively [43]. Further, the Kenyan Alpine and Toggenburg share genetic linkages with the Galla goats at 10% and 1% respectively. This genetic relationship of Galla with the exotic dairy goat genotypes is expected since the Galla has often formed the foundation stock in various dairy goat upgrading programs [43].

Reproductive performance

The different dairy goat genotypes available in Kenya vary in their reproductive capacity. Consequently, various stakeholders have had to re-orient their breeding strategies and designs to sustainably achieve their dairy goat breeding goals [44]. Reproductive traits perceived important by farmers include average daily gain (growth rate), body size, disease tolerance and fertility [45]. Compared to SEAG, the Galla goats are reported to have a faster growth rate and therefore shorter maturity period [46, 47]. Galla does are estimated to be approximately 15% heavier at all ages compared to the SEAG does [21]. In addition, Kiura *et al.* [25] reported that Toggenburg milking does weighed about 10 kg heavier than the Alpine and Saanen counterparts. However, the author indicated that the live weights of the three dairy goat breeds (Toggenburg, Saanen, Kenya Alpine) observed in Kenya were below the reported potentials.

Most pure and cross-bred dairy goat genotypes were reported to reach maturity at about 12 months [47]. For Saanen, Alpines and Toggenburg does, the average age at first service, weaning age, and kidding interval have been reported to be 13 months, 3-4 months, and 9-10 months respectively [24]. This partially corroborates an earlier observation by Ahuya *et al.* [31] who reported mean kidding intervals of 302 ± 117 days for Toggenburg dairy goats among smallholder farmers in Eastern Kenya highlands. The kidding interval for the Saanen x Toggenburg crosses was approximated at 380.8 ± 114.7 days [42]. Among the SEAG, Mtenga *et al.* [48] found out that the age at first service and kidding interval ranged from 638 to 984 days and 293 to 419 days respectively. Further, the average age at first kidding for the pure Toggenburg and the Galla × Toggenburg crosses was reported to be 976.0±79 and 1066.7±37.7 days respectively [30]. In the same study, the average kidding intervals for the Toggenburg, the Galla and the Galla x Toggenburg crosses were found to be 371.7±63.1, 464.6±28.7 and 439.2±39.5 days respectively. Mtenga *et al.* [48] reported that the kidding interval was affected by the previous kidding season while the age at first kidding was significantly influenced by the period of kidding.

The breed factor has also been reported to significantly influence the number of services per conception as well as the litter size. The average litter size for the Galla, Toggenburg and Galla × Toggenburg crosses was reported to be 1.25 ± 0.02, 1.0 ± 0.07, and 1.29 ± 0.04 kids respectively [30]. Further, the Galla × Toggenburg crosses and the Galla posted an average of 1.36 ± 0.07 and 1.6 ± 0.05 services per conception respectively [30]. Mortality rates during pre-weaning and post-weaning periods were also significant factors to consider in dairy goats breeding. Mtenga et al [48] reported an average mortality rate of 40.6 and 25.7 percent for SEAG at pre-weaning and post-weaning periods respectively. SEAG kids with less than 1.5kg birth weights had the highest pre-weaning mortality rate compared to those with birth weights of over 2.6 kg. In addition, twins posted a higher pre-weaning mortality rate of 48.3% compared to 38.5% observed in the singles [48].

Non-genetic factors, mainly the kidding period and season, influenced reproductive performance and mortality rates while poor nutritional management and poor health care likely prevented the SEAG crosses from exploiting their genetic ability [48]. Despite feed supplementation, the reproductive performance of the pure bred Toggenburg was found to be significantly lower than that of the Galla and the Galla × Toggenburg crosses in the Kenyan semi-arid lands [30] and thus the crosses were therefore the better adapted genotypes. The reproductive performance of various exotic breeds of dairy goats in Kenya is summarized in table 2.0 [24].

Milk production performance

The milk production capacity was perceived by farmers as the most important productivity trait in dairy goats [44]. The Galla goat, often referred to as the queen of the ASALs had the potential of producing 2 kg of milk per doe per day [23]. Further, each exotic and crossbred dairy does produced on average 2.2 kg of milk daily and about 503 kg per lactation period. Waineina *et al.* [24] reported milk production levels of 1.7, 1.82, and 2.53 litres per doe per day for the Toggenburg, the Kenyan Alpine, and the Saanen genotypes respectively. This was against a documented potential of 3.61, 4.09, and 4.2 litres per breed per day, implying that the potential of these dairy goat genotypes had not yet been fully exploited. Kiura *et al.* [25] further corroborates that the milk production levels of the three dairy goat breeds (Toggenburg, Saanen, Alpine) were below the reported potentials, producing mean milk yields of 1.4 litres per doe per day with no breed difference. In central Kenya, Kagucia *et al.* [32] reported mean daily milk production of 1.26

litres per doe with a range of 0.5 – 3.5 litres. On the other hand, Ogola *et al.* [28] reported an average milk production level of 1.9 litres per day which was closer to that of crossbred dairy goats.

In terms of lactation period, the Alpine was reported to have the longest average lactation period of 218 ± 46 days in smallholder farms [49] and was often used as the recurrent parent in breeding programs to increase the milk yield and the lactation period. The estimated period of peak milk yield post kidding for the Alpine pedigrees was reported to increase with an increase in genetic purity of the pedigree from 4 weeks (50% Alpine) to 8 weeks (>87.5% Alpine). Likewise, the peak milk yield increased from 0.75 Kg/day for 50% Alpine to 1.02 Kg/day for >87.5% Alpine [49]. Among the dairy crosses in smallholder farming systems of Kenya highlands, Kinuthia [50] reported a lactation period milk yield of 141.60 ± 27.14 kg from the FI Alpine crossbreds. This was significantly high compared to that of the Saanen and Toggenburg crosses which averaged 65.39 ± 11.92 kg. However, when Saanen and Toggenburg were cross-bred with Alpine bucks, the lactation period milk yield increased significantly to 108.24 ± 65.51 kg [50].

Importance of goat milk

Goat milk and its products (yoghurt, cheese and powder) have high significance in human nutrition and thus are used more to feed starving and malnourished communities in the developing world compared to cow milk [51]. Goat milk is composed of various important nutrients and thus important for health and nutrition of the young, elderly [52, 53, 54] and goat kids. Moreover, goat milk is also used as therapy against various health challenges including gastrointestinal disturbances, vomiting, colic, diarrhoea, constipation, and respiratory disorders [52, 55, 56]. Further, caprine milk has beneficial and therapeutic effects especially for those who suffer from milk lactose intolerance and allergy [57].

Three fatty acids present in goat milk (caproic, caprylic and capric) are known to have medicinal effect to various human ailments [55]. Further, goats milk has higher protein, nonprotein N and phosphate which gives it greater buffering capacity compared to cow milk, and thus has the ability to treat gastric ulcers [56] Goat milk is also used to serve the needs of connoisseur consumers especially in the developed nations [47, 57].

Nutrients in goat milk

Goat milk possesses many advantages over cow milk, and is used as a nutritional and medicinal resource for infants and children [54]. Important nutrients found in goat milk include fat, protein, lactose, vitamins, enzymes and mineral salts. Most of the components of goat milk are greater than that of other milk producing animals [52]. For instance, goat's milk contains 25% more vitamin B6, 47% more vitamin A and 13% more calcium than cow's milk [52]. Goat milk contains slightly less total casein, but higher non-protein nitrogen than the cow milk counterpart [58]. The most remarkable difference in basic composition between goat (or cow) milk and human milk exists in protein and ash contents (Table 3.0) [59; 60; 61]. However, cow milk quality can be enhanced through appropriate nutritional strategies, such as the use of immunomodulator supplements [62], usually added as feed additives [63]. The chemical characteristics of goat milk enable it to be used to manufacture fluid beverage products (low fat, fortified, or flavoured) and ultra high temperature milk, fermented products such as cheese, butter milk, yogurt, and frozen products such as ice cream or frozen yogurt, butter, condensed/dried products, sweets and candies [53].

Dairy goat marketing

Dairy goat milk and other products marketing has been challenged by poor breeds, low acceptability of goat milk in various cultures[1], unorganized goat milk markets, irregular market for breeding stock[25] and the high cost of goat milk compared to cow milk [1]. The collapse of a milk processing facility in the Eastern highlands of Kenya led to low market access for caprine milk. There is need therefore, for farmers to be trained on milk value addition and other dairy products marketing strategies. Additionally, the government or other dairy value chain actors can intervene to revive or set up other goat milk processing infrastructure [4]. Dairy goat marketing policy guidelines, structures and standards need to be put in place to ensure dairy goat products quality and safety [1].

The current review focused on dairy goat production in limited areas especially the central and eastern highlands of Kenya and the semi arid areas in the eastern and western parts of the country. These are the areas where dairy goat production has been promoted by the non-governmental organizations. A future review should encompass recent research findings on dairy goat husbandry and optimum dairy goats' performance in controlled semi-arid conditions. Further, future research should find out the nutritional requirements of the various dairy goat genotypes and develop their nutritional supplements.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

In Kenya, the dairy goat production is practiced in the ASALs but mainly under the free browsing (extensive) as well as semi-extensive production systems. This exposes the goats to uncontrolled natural mating, low-quality fodders mainly from natural grasses and herbaceous shrubs as well as pests and diseases challenge. Lack of quality breeding stocks, poor feeding practices, and poor health management are some of the major factors negatively influencing dairy goat's productivity in Kenya. Therefore, it is quite important to sensitize farmers on the importance of pedigree breeding, quality feeding, and effective pests and diseases control. Farmers should be encouraged and supported to adopt quality breeding bucks and modern reproductive technologies to improve their dairy caprine genotypes. Further, the dairy goat farmers in semi arid lands of Kenya should be supported to adopt drought-resistant quality fodders including legume forage species such as Luceana (*Luceana lucocephala)*, Mulberry (*Morus alba*) and sweet potato vines (*Ipomoea batatas*). These fodders can be used together with other locally available materials such as crop residues, dry acacia pods, and then supplemented with commercial concentrates and mineral salts to form sustainable local quality feed resources. Rain water harvesting (roof catchment), water retention walls (cores) across streams and other water harvesting technologies should also be promoted in the semi-arid areas to improve the availability of clean drinking water and facilitate irrigated pasture and fodder production and consequent conservation. Finally, the farmers should be encouraged to seek modern and strategic animal health care services rather than relying on ineffective traditional remedies which often result in higher morbidity and mortality rates. In conclusion dairy goat's management is sub-standard and requires improvement, which can be achieved through enhanced knowledge and skills through extension services.

Conflict of interest

The authors declare that there is no conflict of interest in this review paper.

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Credit authorship statement

Mr Thomas Mutunga, Dr Salome Migose, Dr Bernard Gichimu and Professor Levi Musalia conceived and designed the research idea. Mr Thomas Mutunga did data collection and analysis, carried out the literature review and writing of the manuscript. Thomas Mutunga, Dr Salome Migose, Dr Bernard Gichimu and Professor Levi Musalia read and authorised the manuscript for publication.

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Table 1: Nutritional profiles of common fodders for dairy goats

Forage/Fodder	Dry matter (DM) (g/ kg)	Metabolisable Energy (ME) (MJ/ kg DM)	Crude Protein (g/ kg DM)	Calcium (g/ kg DM)	Phosphorus (g/ kg DM)
Banana (*Musa paradisiaca*) leaves	260	11.2	105	12.5	6.5
Calliandra (*Calliandra calothyrsus*) leaves	260	7.9	310	11.1	1.4
Fodder Sorghum (*Sorghum bicolor*)	250	8.3	71	7.5	3.5
Fresh lucerne (*Medicago sativa*)	300	8.0	194	14.0	2.4
Kikuyu grass (*Pennisetum clandestinun)*	200	9.5	120	6.2	3.4
Leucaena (*Luceana leucocephala*) leaves	280	6.5	250	15.5	2.1
Lucerne hay (*Medicago sativa*)	900	8.9	170	14.1	2.4
Maize (*Zea mays*) cobs	900	7.4	32	1.2	0.4
Fodder maize (*Zea mays*)	350	11.2	80	2.7	2.0
Maize (*Zea mays*) silage	350	11.2	80	2.7	2.0
Maize (*Zea mays*) stover	282	7.4	49	2.6	1.8
Napier grass (*Pennisetum purpureum*)	175	8.4	90	6.0	4.1
Napier (*Pennisetum purpureum*) silage	280	9.0	75	6.2	4.0
Oats (*Avena sativa*) hay	900	8.0	115	7.2	4.1
Oats (*Avena sativa*) straw	920	7.4	44	2.4	0.6
Rhodes (*Chloris gayana*) grass	280	8.2	89	5.0	3.1
Rhodes (*Chloris gayana*) hay	850	9.2	80	5.0	3.1
Sesbania (*Sesbania sesban*) leaves	270	8.7	285	22.1	2.8
Desmodium	400	10.4	124	20.0	2.3
Sorghum (*Sorghum bicolor*) silage	300	9.3	75	3.5	2.1
Sugarcane (*Saccharum officinarum*) tops	210	8.8	124	3.2	2.8
Sweet potatoe (*Ipomoea batatas*) vines	100	9.0	165	17.9	2.4
Vetch (*Vicia sativa*) hay	890	8.8	208	11.8	3.2
Wheat (*Triticum aestivum*) straw	890	6.3	36	1.8	0.5

Source: Paterson *et al.* [34]

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Table 2: Productive and reproductive performance of various dairy goat breeds in Kenya

Goat Sex	Trait	Goat Breed			
		Toggenburg	Alpine	Saanen	Average
Bucks	Birth weight (kg)	3.0±0.35	3.0±0.76	2.5±0.71	2.88±0.63
	Weaning age (months)	3.4±0.87	3.40±0.57	3.85±1.90	3.48±1.03
	Age at first mating (years)	1.68±0.39	1.24±0.35	1.61±1.41	1.46±0.84
Does	Weight at birth (kg)	2.65±0.49	2.55±0.50	2.33±0.44	2.55±0.49
	Weaning age (months)	3.47±0.93	3.35±0.55	3.04±0.88	3.34±0.79
	Age at first service (years)	1.47±0.34	1.15±0.21	1.08±0.25	1.27±0.32
	Kidding interval (months)	8.67±1.29	8.48±1.24	11.08±4.5	9.09±2.50
	Lactation length (days)	6.55±1.14	6.55±1.59	8.39±3.12	6.92±2.00
	Lifespan (years)	6.23±2.22	5.10±1.71	8.19±2.51	5.98±2.28
	Milk yield (L)	1.70±0.13	1.83±0.12	2.53±0.18	2.02±0.35

Source: Waineina *et al.* [24]

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Table 3: Comparison between nutrient composition of goat and cow milk

Nutrient composition	Milk	
	Goat	**Cow**
% Protein	3.48	3.2
% fat	5.23	3.42
Calories/100ml	70.0	69.0
Vitamin A (i.u./gram fat)	39.0	21.0
Vitamin B (UG/100ml)	68.0	45.0
Riboflavin (ug/100ml)	210.0	159.0
Vitamin C (mg ascorbic acid/100ml)	2.0	2.0
Vitamin D (i.u/gram fat)	0.7	0.7
Calcium	0.19	0.18
Iron	0.07	0.06
Phosphorus	0.27	0.23
Cholesterol (mg/100ml)	-	15.0
%Ash	0.75	0.65
%lactose	4.11	4.47
Casein (g/100g protein)	82.70	82.65
Whey protein (g/100g protein)	17.30	17.35

Source: Kaberia *et al.* [59], Ceballos *et al.* [60], Guetouache *et al.* [61]

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