Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Science

Feeding routines and feed quality on small-scale dairy farms in Baringo, Kenya

Utfodringsrutiner och foderkvalitet på småskaliga mjölk-gårdar i Baringo, Kenya

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Abstract

An increasing population together with a growing interest in consumption of animal proteins requires an intensified dairy production in Kenya. The average milk production of 4.4 litres per cow and day is neither efficient enough nor reach the genetic capacity of the exotic dairy cattle used in the smallholder dairy sector.

This study investigated feeding routines and feed quality in 31 smallholder dairy farms situated in the highlands (H) and lowlands (L) of Baringo. Semi-structured interviews, observations and registrations of milk yield (MY), body weight (BW) and body condition score (BCS) were performed. The measured animal characteristics differed between the production environments highlands (408.1 kg BW; 6.9 kg MY; 2.4 BCS) and the lowlands (373.8 kg BW; 6.3 kg MY; 2.6 BCS). Feed samples of basal feeds, supplementary forages and commercial concentrates (Dairy meal) were collected for further analysis. The most commonly used basal feed was pasture followed by grass-mixtures mixed with crop residues, milling by-products and Dairy meal. The most used home-grown feeds were Napier grass, Rhodes grass hay, maize silage, maize stover, oats hay and Star grass hay. The feed analysis showed that two basal feeds had sufficient nutritional content to be used as solitary feed component to an average cow in the production environments based on measured and calculated average body weights and milk yields.

There was a large variation in feed quality among the basal feeds and supplementary forages, the proportions of feed components in the mixtures varied depending on availability and season. The highest nutritional value, compared in crude protein (CP) and metabolisable energy (ME), among the basal feeds was in a mixture containing Columbus grass, Star grass hay, Napier grass, Lucerne, Dairy meal and wheat bran (14.4 % CP; 10.2 MJ ME/ kg DM). The lowest was seen in a mixture including Star- and Rhodes grass hay mixed with molasses to ferment in 24 hours (5.4 % CP; 7.3 MJ ME/ kg DM). A large variation was seen in the nutritive value of the Dairy meals (n=5), with one of the brands having a nutritional composition similar to a standard Swedish commercial concentrate (Lantmännen, 2017). Three samples had low levels of CP and high levels of calcium and magnesium suggesting alterations had been made to replace more expensive ingredients.

Keywords: Small-scale dairy farm, smallholder dairy farm, fodder, feed, Dairy meal, Kenya, Baringo, feed quality, feeding routines

Sammanfattning

En ökad befolkning tillsammans med ett ökat intresse och ekonomi för att konsumera animalieprodukter kräver en intensifiering av mjölkproduktionen i Kenya. Den genomsnittliga mjölkmängden på 4.4 liter per ko och dag är varken tillräckligt effektiv eller nyttjar den genetiska kapaciteten de exotiska mjölkkorna har som används inom den småskaliga mjölksektorn.

Denna studie undersökte foderrutiner och foderkvalitet hos 31 småskaliga mjölkproducenter i höglandet (H) och låglandet (L) i Baringo. Semistrukturerade intervjuer, observationer och registreringar av mjölkmängd (MY), kroppsvikt (BW) och hullbedömningspoäng (BCS) utfördes i studien. De registrerade egenskaperna skiljde mellan produktionsmiljöerna höglandet (408,1 kg BW; 6,9 kg MY; 2,4 BCS) och låglandet (373,8 kg BW; 6,3 kg MY; 2,6 BCS). Foderprover från det basala grovfodret, tillskottsgrovfoder samt kommersiella koncentrat (Dairy meal) insamlades för vidare analys. De vanligaste förekommande basala grovfodren var bete följt av gräsblandningar blandade med skörderester, kvarnbiprodukter och Dairy meal. De vanligaste egenodlade foderingredienserna var Napiergräs, hö av Rhodesgräs, majsensilage, majsrester efter skörd, havrehö och hö av Stargräs. Foder analyserna visade att två basala grovfoder hade näringsvärden som var tillräckliga för att kunna användas som det enda fodret i en foderstat till en genomsnittlig ko i produktionsmiljöerna, baserat på de uppmätta och beräknade genomsnittliga kroppsvikterna och mjölkmängderna.

En hög variation sågs i foderkvalitet mellan de basala grovfodren och tillskottsgrovfodren, varav proportionerna i blandningarna skiljde sig starkt beroende på tillgång och säsong. Det högsta värdet, jämfört i råprotein (CP) and omsättbar energi (ME), bland grovfodren sågs i en gräsblandning med Columbusgräs, Stargräshö, Napiergräs, Lucern, Dairy meal och vetekli (14,4 % CP; 10,2 MJ ME/ kg DM). Det lägsta sågs i en blandning med hö av Star- och Rhodesgräs blandat med melass för att fermentera i 24 timmar (5,4 % CP; 7,3 MJ ME/ kg DM). En hög variation sågs i näringsvärde för Dairy meal (n=5), där ett av märkena hade en näringssammansättning likt en standard svenskt kommersiellt koncentrat (Lantmännen, 2017). Tre av proverna hade låga halter råprotein och höga halter calcium samt magnesium, vilket indikerar att förändringar kan ha skett i fodret för att ersätta dyrare ingredienser.

Nyckelord: småskalig mjölkproduktion, foder, koncentrat, Kenya, Baringo, foderkvalitet, foderrutiner

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Abbreviations

ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
AI	Artificial Insemination
BAMSCOS	The Baringo Agricultural Marketing Services Cooperative Society
BCS	Body Condition Score
BW	Body Weight
EE	Crude Fat
CP	Crude Protein
DCP	Digestible Crude Protein
DM	Dry Matter
DMD	Dry Matter Digestibility
DMI	Dry Matter Intake
ECM	Energy Corrected Milk
FCS	Farmers' Cooperative Society
FG	Free grazing
HUV	Department of Animal Nutrition and Management
ME	Metabolisable Energy
MY	Milk Yield
NDF	Neutral Detergent Fibre
RR	Reticulo Rumen
SLU	Swedish University of Agricultural Sciences
SZG	Semi-zero grazing
TMR	Total Mixed Ratio
WSC	Water Soluble Content
ZG	Zero grazing

1 Introduction

Kenya is situated in the eastern part of Africa, with a population exceeding 48 million in 2016 (Worldbank, 2016), and an annual population growth of 2.6 percent (Worldbank, 2017). An improved socio-economic status through higher incomes and urbanisation leads to elevated consumption of animal proteins (Abdulai & Aubert, 2004; Makoni *et al.*, 2014). Although milk consumption levels in Kenya are already among the highest in Africa with an average of 100 kg per year per capita, a growing market for milk in the country will most likely occur (Muriuki, 2011). However, the national milk production is low due to several factors, in which the most important ones being inadequate feeding of dairy cows (Bebe *et al.*, 2008; Lukuyu *et al.*, 2011), and poor management techniques (Otte & Chilonda, 2002). Thus, production yield improvements should be possible and the milk will have a market.

Agriculture is still important and represents 35.6 percent of the national GDP (Worldbank, 2016b), posing the backbone of Kenya's economy. There are one million small-scale dairy farms producing 70 percent of the total milk production in the country (Muriuki, 2011). An ongoing intensification of the smallholder dairy sector is seen in Kenya where more exotic breeds such as Friesians and Ayrshires are being used. The farmers are intensifying the production through stall-feeding, growing fodder, purchasing feeds and becoming more dependent on external inputs and services (Bebe *et al.*, 2002), giving potential for an increased production. Still, the average milk yield in Kenya is 1344 litres per cow and year (Wambugu et al, 2011) compared to the Swedish average of 8679 kg ECM (Växa, 2016). In some areas, it is only possible to deliver the morning milk due to a lack of cooling facilities, which impedes increased production. In those areas, the afternoon milk is mainly used for personal consumption or sold on unofficial markets (Muriuki, 2011). The water sources are often seasonal, affecting both fodder production in quantity and quality, as well as animal water access and hygiene aspects (Orodho, 2006a). The lack of knowledge in applying feed conservation techniques and to use feed supplements rich in starch and protein further limits the productivity (Lukuyu *et al.*, 2011).

The limiting factors affecting the production negatively, suggests a need to investigate feeding- and management practices. Knowing the constraints of the farming systems, improvement potentials may be found to increase the profitability among Kenyan smallholder dairy businesses. The objective of this study was therefore to examine feeding- and management practices, feed quality of home grown as well as purchased feed components in smallholder dairy farms; to find key factors that are obtainable for the farmers to increase milk production. In collaboration with WeEffect and the Baringo Agricultural Marketing Services Cooperative Society limited (BAMSCOS), 31 small-scale dairy farms were visited to study feeding routines in the *highlands* and *lowlands* of Baringo with different production environments for agriculture

2 Literature review

2.1 Small-scale dairy farming in Kenya

Kenya is divided into seven different agro-ecological zones, categorized according to soil, landform and climatic characteristics suitable for crop production. The land is divided according to similar constraints and potentials as an inventory of land use (FAO, 1993). Approximately one third of the country is suitable for agriculture, including the Kenyan highlands, coastal plains and the lake region. The rest of the land is used for livestock-based pastoralism or agro-pastoralism farming. Small-scale dairy farming activity is mostly found in the central- and rift valley provinces and the coastal lowlands (Orodho, 2006a). The market opportunities are better in the highlands compared to the lowlands, because of the high density of people with a tradition for milk consumption (Bebe *et al.*, 2002).

Smallholder dairy farms keep on average 2 to 3 milking cows in addition to their young stock. The feeding systems mostly used can be categorized into three types: free grazing (FG), zero-grazing (ZG) or semi-zero grazing (SZG) (Orodho, 2006a). Table 1 describes some key numbers correlated with production and reproduction of dairy cattle from a survey including 987 small-scale dairy farms in the Kenyan highlands (Bebe *et al.*, 2003b).

Table 1. *Small-scale dairy farm characteristics based on results from Bebe et al., (2003b)*

	Zero-grazing	Semi-zero grazing	Free grazing
Farms (%)	44	33	23
Cows in herd (%)	62	55	51
Annual calving rate	0.52	0.51	0.69
Age at first calving (yr)	2.5	2.7	2.8
Productive life (yr)	3.8	4.0	4.8

Kenyan farmers have had a limited access to arable land since the colonial time, due to subdivision of land in combination with ownership shifting between freehold and communal. This has caused a transition in central Kenya from pasture-based systems towards ZG-feeding systems (Orodho, 2006a), with Napier grass being the most common basal feed (Muriuki, 2011). The average smallholder dairy farmer have access to 1.2 to 2.0 ha arable land (Muriuki, 2011). There are multiple factors affecting land tenure and thus subdivision, such as cultural constraints prohibiting women from land inheritance. There is also a tradition of parents giving land to each of their sons, causing a split of land into small uneconomic units (Orodho, 2006a).

The average milk yield in Kenya is 1344 litres per cow and year (Wambugu et al, 2011), which corresponds to 4.4 litres per day (305 day lactation period). In the north rift valley province, the milk production was reported to range between 3 to 14 litres among small-scale dairy farms; and 3 to 9 litres in the south rift valley (Lukuyu *et al.*, 2009).

The majority of dairy cows in Kenya are crossbreeds of *Bos Taurus*, with a high proportion of *Bos Taurus* and some infusion of *Bos Indicus* (Orodho, 2006a). *Bos Taurus* and *Bos Indicus* are species of the genus *Bos* under the family *Bovidae*. *Bos Taurus* includes the exotic breeds Friesian, Ayrshire, Guernsey and Jersey, whilst *Bos Indicus* include indigenous breeds such as East African Zebu, Boran and Sahiwal (Bebe *et al.*, 2003a). The Friesian- and Ayrshire-combination is one of the large-sized dairy crossbreeds most popular for dairy production in households where milk production has a significant impact on the family economy (Bebe *et al.*, 2003a; Lukuyu *et al.*, 2011). The *Bos Taurus* crosses contribute to 72 percent and the zebu cattle to 16 percent of the national milk output (Muriuki, 2003).

Artificial Insemination (AI) was highly popular among small-scale dairy farmers in the 1980-ies when the service was provided to a cheap cost by the Kenyan government. However, the use of bulls for natural insemination has increased since the collapse of the governmental AI-services during the liberalization of the dairy sector in 1992. Therefore, an increase in the private sector has been seen in providing AI- and other extension services to replace the former services provided by the government (Muriuki, 2003).

Murage and Ilatsia (2011) studied the use of breeding practices in ZG and SZG smallholder dairy farms in the Kiambu- and Nyandarua district, central Kenya. In general, it was most common to use AI (54.3 %), bulls (30 %) and thirdly a combination of both (15.7 %). The AI-services were mainly provided by private technicians (49.3%) and dairy cooperatives (33.6%). A positive correlation was seen between the use of AI-services and education, herd size and credit. Also, factors such as accessibility to breeding services and product markets had influence on the farmer's decision to choose among the available breeding services (Murage & Ilatsia, 2011).

Staal *et al.*, (1997) studied calving intervals in the Kiambu district, central Kenya, and estimated an average of 591 days among the 365 farms participating in the study. The prolonged calving intervals could be due to several factors in which feeding practices is one of them. Dunne *et al.*, (1999) showed that sudden reductions in dry matter intake (DMI) at around the time of insemination had a negative impact on embryo survival rate in heifers. The energy intake was reduced from maintenance requirement level down to 80 %, prolonging for two weeks post insemination date. The embryo survival rate was in general down to 40 %, compared to heifers getting a higher energy level in their diets, having an embryo survival rate of 65 to 71 %.

One of the major constraints in livestock production in Kenya is access to nutrition and water (Orodho, 2006a). In order to maintain milk production, it is crucial to have continuous access of feed and water. During pregnancy and lactation, the blood volume increases and thereby increases the cow's need for feed and water (Olsson, 2005). Milk is composed of 876 g water/ kg (McDonald *et al.*, 2011) and cannot, unlike urine, be concentrated by vasopressin. The risk of dehydration thereby increases rapidly if the water access is scarce (Olsson, 2005). Water scarcities in the African highlands were reviewed by Stroosnijder, (2009), suggesting farmers' notion of droughts rather being an indirect result of land degradation rather than prolonged drought periods. Nyessen *et al.*, (2009) studied land degradation in tropical highlands, meaning nearly all areas suffer from medium to very high natural water erosions caused by climate change. An acute need for soil- and water conservation is seen in those areas.

2.2 Feed and Nutrition

2.2.1 Nutritional requirements & chemical components in feed

The energy requirement for a dairy cow depends on the requirement for lactation, maintenance and body reserve storage. The requirement for lactation is affected by milk composition and milk yield. A dairy cow weighing 450 kg, producing 10 kg milk per day (5.2 % fat and 4.2 % protein) with a daily live weight gain of 0.4 kg requires 11.1 kg DMI and 125 MJ Metabolisable Energy (ME) per day (McDonald *et al.*, 2011). The dietary protein must satisfy the nitrogen demands of the rumen microorganisms and to supply the truly absorbable protein required to satisfy the demands for amino-acid nitrogen at tissue level (McDonald *et al.*, 2011).

The digestibility of the feed is to a great extent influenced by the fibre fraction, for which Neutral Detergent Fibre (NDF) is a commonly used analytical method.

The fibre fraction NDF affects feed intake, feed density, chewing activity and digestibility. The NDF is partly composed of Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL), where ADF represent cellulose and lignin and ADL represent the lignin fraction. The digestibility of NDF depends on the ADL fraction and the structure of the plant (McDonald *et al.*, 2011).

Plants in tropical climates are often C4 plants, which respond greater to sunlight in herbage yield and growth rate compared to C3 plants that is common in tempered areas (Kephart *et al.*, 1991). The C4 plants are, however, often less digestible due to complicated plant tissue structures and a high proportion of ADL (McDonald *et al.*, 2011). If the ambient temperatures are too high, a rapid reduction in herbage digestibility could occur from depletion of photosynthetic nutrients. A decrease in crude protein (CP) and degradable carbohydrate levels together with a higher ADL-level could be seen, leading to a reduced digestibility of the feed. Water scarcity could retard plant growth and slow down maturity of a plant, causing low dry matter (DM) levels but a higher digestibility (Van Soest 1994). The ADL fraction of NDF in crops gets higher over time. Therefore, the harvest interval of fodder crops and the age of the grass affect the animal performance to a large extent (McDonald *et al.*, 2011). Feeding recommendations, combining different sources, suggest a maximum NDF-inclusion of approximately 1.5 % of the body weight due to limitations of feed intake and a lowest recommended NDF-level in the diet of 28 % in order to not pass the limits of rumen passage rate (Spörndly, 2003).

The DMI is highly affected by physical regulation from chewing and distention of the reticulo-rumen (RR) (Allen, 2000). During feeding, the stretch receptors in the muscle layer of the RR-wall get activated and stimulate a response from the brain to trigger meal cessation. The individual threshold of distention of the RR depends on the animal’s energy requirements, hormonal levels and the filling effect of the diet. The filling effect is affected by the weight and volume of the diet. The fibre fraction NDF is good for prediction of filling effect and DMI increases with decreasing NDF value if the diet is composed of more than 25 % NDF. A higher rate of digestion and passage will reduce filling effects of NDF. Smaller particle sizes can thereby improve the DMI (Allen, 2000).

A combination of feed components may result in a positive associative effect, increasing the utilization of the feed (McDonald *et al.*, 2011). By supplementing forages of poor feed quality with starch and protein sources, the digestibility of the forage may be increased. However, the starch fraction must be determined carefully, since a high proportion may contribute to a rapid fermentation, affecting the pH level in the rumen. A low rumen pH may inhibit the microorganisms fermenting cellulose, reducing the digestibility of fibre. This could be referred to as a negative associative effect (McDonald *et al.*, 2011). The inclusion of concentrate in the diet is therefore suggested to not exceed 65 % (Spörndly, 2003).

Okello *et al.*, (2005) studied factors influencing milk yield and body conditions of cows in pasture-based system in semi-arid rangelands of Uganda. A close relationship was found between milk yield and body condition as the lactation curve dropped, suggesting cows using body reserves to maintain lactation when the herbage quality is low. The milk yield increased together with improved body condition when the wet season came back, with an improved body condition appearing two months after the increase in milk yield was seen.

Anti-nutritional components, especially tannins and saponins and high levels of fat may have a negative impact on feed digestibility. Deficiency in sulphur or nitrogen can reduce digestibility due to a decrease in microbial protein synthesis (McDonald *et al.*, 2011).

An elevated level of calcium in diets for dairy cows is not associated with any toxicity danger. However, it could interfere with zinc absorption or just replace other more expensive nutrients. High levels of magnesium in the diets are not associated with a risk for toxicity, since cattle are able to excrete high levels of magnesium in the urine. However, too high levels could cause negative effects on feed intake or osmotic diarrhoea. The suppressed feed intake would be due to magnesium-salts decreasing the palatability of the feed (NRC, 2001).

Body Condition Score (BCS) in practice

The process of Body condition scoring (BCS) gives a subjective rating of the animal's subcutaneous fat on the lower back, lumbar regions and around the hips (Hulsen, 2011). Roche *et al.,* (2009) suggested an optimal calving BCS between 3.0 and 3.25 since a lower value could reduce production and fertility while a higher BCS is associated with a reduced DMI immediately post calving, decreased milk production and a higher risk for developing metabolic disorders. Roche *et al.,* (2015) studied feeding levels and BCS pre-calving and concluded that a cow with an optimal BCS should be fed a restricted diet for 2 to 3 weeks pre-calving, whilst a cow with a lower BCS should be fed according to her nutritional requirements in this period. Walsh *et al.*, (2008) found that both breed and feeding system affected BCS (P < 0.001) in cows in a study conducted in a pasture-based system in Ireland. Holstein-Friesians had on average a lower BCS (2.77) compared to Montbéliarde (3.15) and Normande (3.16 BCS). Cows that were fed a high-concentrate diet (4 kg per day) had a higher BCS (0.1 BCS) than cows with a low-concentrate diet (no concentrate supplementation).

2.2.2 Feeding practices in Kenya

A trend of decreasing herd sizes and upgrading of crossbreeds to include more exotic genes is seen in the smallholder dairy sector in Kenya. Also, more feed is being purchased to invest in a higher milk production (Staal *et al.*, 1997). Dairy farming is mainly held in high-potential areas with farms using combinations of crop- and dairy systems. This combination has become more common, since manure is a valuable asset from the dairy production to fertilise cash crops on the farm. Cash crops are often referred to as coffee, tea and vegetables, in which commonly grown vegetables are maize, bean, sweet potatoes and kale. The most popular cattle feeds are Napier grass *(Pennisetum purpureum)* and natural grasses which are given to the cows in a cut-and carry system. Crop-residues from cash- and food crops are often used, in combination with purchased concentrates and milling by-products (Muriuki, 2003).

Kashongwe *et al.*, (2017) investigated feeding practices in Nakuru County, Kenya, including peri-urban (n=32) and rural (n=65) small-holder dairy farms. The study showed that the peri-urban dairy farmers provided Napier grass (68.4%) with additional concentrates (100%), oat forages (42.9%), and crop residues (28.6%). Rural farms were pasture-based (87.7%) with Napier grass (89.4%) and concentrates (93.9%) as supplements.

In the north rift valley province in Kenya (Kipkaren, Kabiyet, Chepkorio and Metkei), the most commonly used forages among small-scale dairy farms were Napier grass, Rhodes grass *(Chloris gayana)*, oats *(Avena sativa L.)*, maize (*Zea maize L*) for silage and Nandi setaria *(Setaria sphacelata)*. In the south rift valley province grown forages were Napier grass, Rhodes grass, Lucerne (*Medicago sativa*), Calliandra (*Calliandra calothyrsus Meisn.*), and Sesbania (*Sesbania sesban*) (Lukuyu *et al.*, 2009).

A study including a cross-sectional survey (n=41) and feed monitoring (n=10) was performed in the Embu district of central Kenya. The most commonly grown forage was Napier grass, and forage supplements used were Nandi setaria, sweet potato vines, green- and silver leaf Desmodium and Guatemala grass. Irregular feeding routines were seen over the year, in which the cows received different amounts of forages 10.8 kg DM (October = short dry season), 9.7 kg DM (November = wet season), 14.6 kg DM (February = long dry season); and concentrates 2.1 kg in October, 1.9 kg in November and 0.9 kg in February depending on season (Nyaata *et al.*, 2000).

2.2.3 Feed components

Forages used for livestock in Kenya

Napier grass *(Pennisetum purpureum)* is a high-yielding perennial grass, with a deep-root system giving a secondary effect to tolerate drought, high rainfall (Orodho, 2006b) and soil erosion prevention (Kashongwe *et al.*, 2017). Muia *et al.*,

(1999) studied the optimal stage of maturity for Napier grass in high and medium rainfall areas of Kenya, suggesting different harvesting intervals depending on climate. The CP concentrations and digestibility of organic matter was used as an indicator of optimal harvest stages, indicating optimal conditions for harvest when reaching 55 to 60 cm (7 to 8 weeks) in medium rainfall areas and 130 to 140 cm (9 to 10 weeks) in high rainfall areas.

Maize (*Zea maize L*) is the leading crop in the highlands of Baringo for human consumption (CGB, 2013). The maize stover is one of the most common forage supplements in Kenya fed to dairy cows (Methu *et al.*, 2001), and if including the whole maize plant, a higher feed value may be obtained (McDonald *et al.*, 2011). The optimal harvest time for whole maize silage is when the DM is 30 to 35 percent and the milk line, the white line on the corn fruit, reaches one third of the fruit (Ashley, 2001). To improve the nutritive value of the forage, legumes such as cowpea can be intercropped with maize (INRA *et al.*, 2017). Sorghum *(Sorghum bicolor)* is similar to maize in its plant structure by being a C4-plant, and can be used for grain, forage or as a dual-purpose crop. It can be cut and made into silage or grazed by cows if the height of the plant is adjusted to optimal height (INRA *et al.*, 2017). Sorghum is more drought-resistant than maize and occur in various different types with different feeding values (McDonald *et al.*, 2011).

Oat *(Avena sativa L.)* is commonly used as fodder in temperate, sub-tropical and high-altitude tropic climates; and is suitable for hay or silage (INRA *et al.*, 2017). The nutrient composition ranges depending on the proportion of hull to kernel fraction, giving a higher crude fibre (EE) fraction if the hull fraction is bigger. The CP content varies between 70 to 150 g/ kg DM, depending on the quality and use of fertilizers. The protein quality is however poor with low levels of the essential amino acids methionine, histidine and tryptophane (McDonald *et al.*, 2011).

Rhodes grass *(Chloris gayana)* is mainly suitable for pasture or hay. Promising intercropping outcomes has however been seen with legume forages or maize (CIAT, 2005). Rhodes grass varies in nutritional composition, with decreasing protein content with age (INRA *et al.*, 2017). The feeding value declines rapidly after flowering, suggesting a good quality hay if harvested right before or in early flowering (CIAT, 2005). In Ethiopia, Rhodes grass is recommended to be grown up to 2400 metres above sea level (Mengistu, 1985). The chemical composition of Rhodes grass was studied in central Kenya, in which the digestibility of the feed was higher during the wet season compared to the dry season (Abate *et al.*, 1981).

Star grass *(Cynodon dactylon)*, also known as Bermuda grass, is often used as pasture, cut and carry, hay or silage, and is palatable to most livestock. However, the nutritive value is in general low, causing a need for supplementation to cover all nutritional requirements for dairy cows, see table 2(CIAT, 2005; INRA *et al.*, 2017).

Nandi setaria *(Setaria sphacelata)* is a common grass in Kenya, suitable for pasture, cut and carry, silage and in some cases hay. It can withstand unfertilized soil but respond well to fertilizers. The CP content varies highly depending on the use of fertilizers (6-20 %) (CIAT, 2005). In table 2 and 3 are some nutritional characteristics and compositions of common grasses and fodders fed to dairy cattle in intensive feeding systems in Kenya.

Table 2. *Nutritional characteristics of common grasses and fodders fed in intensive feeding systems in Kenya (from Jackson et al., 1991).*

Forage	Regrowth stage (weeks)	CP (g/ kg DM)	OMdig	ME (MJ/ kg DM)*
Kikuyu grass	8	191.0	67.0	9.4
Rhodes grass	6	77.0	60.1	8.2
Star grass	10	102.0	58.2	8.2
Nandi setaria	4	122.0	62.4	8.6

*Estimated by Jackson *et al.*, (1991)

Table 3. *Nutritional composition and degradability of fodder from intensive feeding systems in Kenya (Jackson et al., 1991)*

Forage	CP (g/kg DM)	NDF (g/ kg DM)	Ash (g/ kg DM)	DMD(%)
Green maize chop	141.6	693.1	125.4	81.1
Fodder sorghum	173.4	653.5	132.4	78.9
Banana leaves	54.2	757.4	131.7	50.0
Sweet potato vines	205.3	426.3	179.3	77.8
Oat fodder	87.7	680.1	102.6	66.0
Cabbage	154.4	258.1	98.4	97.1
Napier grass	89.5	705.9	132.7	62.9

Modified from Kamande, (1988) and Abate & Abate, (1991) in Jackson *et al.*,(1991).

Agro-industrial by-products and commercial feeds

Poor feeding strategies among smallholder dairy farmers in the Kenyan highlands suggest a need to include agro-industrial by-products and concentrates in the feed ratios (Lukuyu *et al.*, 2011). Agro-industrial by-products can be used as a protein- and starch sources for dairy cows. Commonly used agro-industrial by-products in Kenya are brewers waste, wheat bran, wheat pollard, cotton-seed cake, sunflower-seed cake, fish meal and molasses (Orodho, 2006b; Muriuki, 2011).

Commercial concentrates are often referred to as Dairy meal in Kenya (Orodho, 2006b). Some commercial feeds available for purchase, apart from Dairy meal, are dairy cubes and calf pullets (Muriuki, 2011). Kashongwe *et al.*, (2017) found that commercial concentrates were used by both peri-urban- (100 %) and rural-(93.9 %) smallholder dairy farms in Nakuru County, Kenya.

In Kenya and Uganda, small-scale dairy farmers expressed a concern regarding the poor quality or sub-standard of commercial feeds sold on the market. Farmers reported this suspicion due to minimal effects on milk production following use of these concentrates (Lukuyu *et al.*, 2009).

A Swedish commercial standard concentrate is composed of 18 % CP, 6.1 % Crude fat (EE) and 13.4 MJ ME/ kg DM, suitable for a forage quality of 10.5 to11 MJ ME/ kg DM, 14 to 16 % CP and 46 to 56 % NDF (Lantmännen, 2017). Commercial concentrates in the Embu district, Kenya, were analysed for feed quality (DM, ash, CP, NDF, ADF and Dry matter digestibility (DMD) displayed in table 4 (Nyaata *et al.*, 2000).

Table 4. *Variation in the chemical composition between concentrates in the Embu district, modified from Nyaata et al., (2000).*

Concentrates	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	DMD (%)
1	90.9	6.7	20.0	52.5	24.6	52.8
2	84.4	9.4	14.1	75.2	51.7	47.9
3	84.3	7.1	13.9	50.1	14.1	59.7
4	85.0	5.8	14.3	54.8	14.0	60.0
5	79.8	6.0	15.7	58.9	16.8	63.0
6	83.6	11.0	15.5	64.9	14.1	63.5

Crop residues

Farmers who grow cash crops such as maize, beans and peas often have valuable by-products on their farms which could be used as feed supplements. Zero-grazing smallholder dairy farmers commonly grow high-yielding fodder crops and mix it with crop residues to feed their animals (Orodho, 2006b). Commonly used crop residues are maize stover, banana pseudostems, bean husks, sweet-potato vines, tree leaves and crushed sugarcane (Orodho, 2006b; Nyaata *et al.*, 2000).

Methu *et al.*, (2001) studied the chemical composition of maize stover grown in the highlands of central Kenya. The chemical composition was affected by the type of post-harvest handling method used. Maize stover that was harvested under dry conditions had a higher feed quality compared to if harvested under rainy conditions. The maize leafs recorded the highest CP-levels (83 g/ kg DM), compared to the stem (66 g/ kg DM) and husks (48 g/ kg DM).

Bean stover and pea husks can be valuable forage for cattle if harvested and stored properly; being rich in protein, calcium and magnesium compared to cereal straws (McDonald *et al.*, 2011). Njarui *et al.*, (2011) studied feeding routines in 136 smallholder dairy farms of semi-arid tropical areas of Machakos district in southern Kenya. Maize stover was the most commonly used crop residue, followed by pigeon pea residues. The pea residues were used by 75 % of the farms during peak harvest time in September. However, bean- and cowpea residues are less important since the quantity harvested is low. A majority of the farmers (94.9%) interviewed stored crop residues for their livestock.

Leguminous trees and shrubs

Leguminous trees and shrubs, often referred to as multi-purpose trees, are used for browsing or as supplements to dairy cows in the tropics. Commonly used species are Calliandra (*Calliandra calothyrsus Meisn.*), Leucaena (*Leucaena leucocephala*), Gliricidia (*Gliricidia sepium*), Sesbania (*Sesbania sesban*) and Acacia (*Acacia nilotica*) (McDonald *et al.*, 2011). Paterson *et al.*, (1999) studied the use of Calliandra as supplement for dairy cows in Embu district in Kenyan highlands, seeing the same additive effect on milk production if supplementing the cows 3 kg of fresh Calliandra leaves as 1 kg of Dairy meal. Nyaata *et al.*, (2017) studied intercropping between Napier grass and Calliandra, in the same district, suggesting an optimal harvest interval of two months. The results indicated that one ha of the Napier grass and Calliandra mixture is sufficient for two dairy cows.

The low use of multipurpose trees in Kenya is suggested to be due to lack of knowledge in preparation- and management techniques. Factors affecting animal performance and productivity negatively such as anti-nutritional factors are also preventing the use of fodder trees (Paterson *et al.*, 1998). Anti-nutritional compounds often found in leguminous trees and shrubs are condensed tannins, which are acting beneficial if low to moderate levels in feed (20-45 g/ kg DM) as they protect protein from degradation in the rumen. If the levels of condensed tannins exceed 55 g/ kg DM, the digestibility could however be affected negatively (McDonald *et al.*, 2011).

2.2.4 Pasture management

Okello *et al.*, (2005) studied the nutritive value in natural pastures of semi-arid rangelands of Uganda and found that the CP-levels (70 g/ kg DM) was higher in the end of the wet season while NDF-levels increased (840g/ kg DM) during dry seasons. There was a significant difference in herbage yield and growth, with a peak in the end of the wet season.

Changwony, *et al.*, (2015) studied the nutrient quality of natural pastures, dominated by Kikuyu- and Star grass, in the Lake Naivasha area, Kenya. Estimated energy levels between 8.2 and 11.2 MJ/kg DM was found, both CP- and energy levels declined significantly at a higher herbage maturity stage.

Unimproved, over-grazed pastures leading to degradation of lands is a serious problem, which affects FG-dairy farms in the rift valley province of Kenya (Lukuyu *et al.*, 2009). Stocking rate has a larger impact on animal performance than nitrogen-fertilization on Star grass pastures, where a low stocking rate increase herbage allowance and the possibility to choose on a wide range of grass. The increase in nutritive value of the pasture had no significant correlation with average daily weight gain. However, if the stocking rate exceeds 2.5 cows per ha it is suggested necessary to increase nitrogen-fertilization, to increase herbage quantity and allowance (Hernández Garay *et al.*, 2004).

Mwebaze, (2002) studied pasture management in three districts of Uganda with different production environments: Mbarara (semi-arid rangeland), Kabale and Mbale (high-altitude zones, intensively cultivated). The use of fertilizers on pastures was 63.6 %, 85.7 % and 73.9 % respectively, however, chemical fertilizers were merely used by Mbale district (34.8 %).

The most commonly found natural pastures in Kenya are composed of Star grass (*Cynodon dactylon*), also known as Bermuda grass, and Kikuyu grass (*Pennisetum clandestinum*) (FAO, 1985). Tropical forage legumes, such as Calliandra and Desmodium, could contribute to sustainable production systems with the capacity to meet the requirements to balance the nitrogen cycle of grazed pastures. The main constraints holding the strategy back among smallholder farmers are the lack of acceptability and fear of anti-nutritional substances affecting production. However the improvement of soil quality could be a useful help in addition to providing a more nutritious pasture for the animals (Thomas, 1995).

2.2.5 Fertilization of fodder crops

There is a great variation in nutrient quality of manure from smallholder dairy systems in east Africa, depending on feed quality and intake, contamination with soil and addition of organic material to the compost. In which higher protein levels in feed, often seen in ZG-systems, tends to result in a better quality of the manure (Paul *et al.*, 2009). Composting of solid manure can cause different levels of nutrient loss depending on the manure handling technique used; where cutting and mixing of solid manure caused the greatest nitrogen-losses compared to compaction or covering the piled-up manure with porous tarpaulin. The compost had however a low fertilizing effect, suggesting a more effective use if applied to the land immediately after collection (Sommer, 2001).

Intercropping between different fodder crops is sometimes performed to improve feed quality as well as nitrogen level in the soil (Orodho, 2006b). Napier grass is commonly intercropped with Desmodium and Calliandra in the Embu district (Nyaata *et al.*, 2000). Further intercropping between Napier grass and other leguminous fodder trees is suggested as a strategy to encounter seasonal challenges (Kashongwe *et al.*, 2017).

2.2.6 Feed conservation

Feed conservation is applied to some extent among smallholder dairy farms in Kenya, but the fodder quality remains poor due to inadequate knowledge in feed conservation techniques and access to feed storage facilities (Lukuyu *et al.*, 2011). More than 60 % of the farmers in Nakuru County have feed scarcity in the dry seasons, suggesting needs for improvements of haymaking and to treat maize stover to remain adequate quality during storage (Kashongwe *et al.*, 2017). In a study conducted in the Embu district, merely one out of the 41 farms visited performed feed conservation by making Napier grass hay (Nyaata *et al.*, 2000). In semi-arid tropical areas of Machakos district in southern Kenya, Njarui *et al.*, (2011) found that nearly all the interviewed farmers (97.5 %) conserved feed; hay (94.9 %) and silage (5.1 %). Among the interviewed farmers, 92.9 % experienced seasonal fluctuations in feed availability.

Martinsson, (2003) suggested a desirable Swedish silage quality to be composed of at least 11.0 MJ ME/ kg DM, 130-160 g CP/ kg DM and 475-525 g NDF. However, under tropical conditions, forage is often difficult to ensile due to a high-buffering capacity with low water-soluble content (WSC). To prevent poorly preserved silage, with increased levels of *Clostridia* or *Enterobacteria*, strategies such a using additives or acid is a possible solution. Legumes may also be mixed with cereal crops, wilt wet forage, add cereals or molasses to increase the levels of WSC (McDonald *et al.*, 2011).

Molasses can be used as a sugar additive with a purpose of increasing the dry matter content and providing a drop in pH-level and ammonia (McDonald *et al.*, 2011). Addition of molasses to Napier grass may improve fermentative quality, feed intake and digestibility compared to untreated Napier grass silage, due to the organic matter, CP and NDF digestibility being higher with addition of molasses (Bureenok *et al.*, 2012). Locally available additives such as maize bran and fresh Leucaena leaves could be used to improve the quality of fodder grass silages (Mtengeti *et al.*, 2013).

The digestibility of maize silage is not affected by the maturity of the plant from the milky- to the hard dough stage. However, if left to harvest beyond the hard dough stage difficulties could occur in the process of packing the material air-tight prior fermentation. A straw length of 20 mm is recommended to stimulate rumination. Due to sensitivity to air exposure it is recommended to have a long narrow silage pit (McDonald *et al.*, 2011). Oat silage is a good alternative in areas too cool for maize (INRA *et al.*, 2017). The harvest should be at 250 to 450 g/ kg DM, when the crop is still green and are in the milky or soft cheese stage to obtain a proper fermentation process in the material (McDonald *et al.*, 2011).

Whole maize and whole wheat silage can be conserved in small-scale format using plastic bags (Ashbell, 2001). This could be a good alternative for smallholder dairy farmers not having capital to dig earth pits every year or hire heavy machines performing packing (Mtengeti *et al.*, 2013). Wilted and chopped Napier grass conserved in plastic bags of 5 or 10 kg is an alternative strategy used to preserve feed in small-scale scheme in Tanzania (Lyimo *et al.*, 2016).

Haymaking could be difficult in areas with high ambient temperatures and short periods of rain. In those places, many crops need to be harvested in an early stage of growth during wet conditions, which could have a negative impact on haymaking (McDonald *et al.*, 2011).

Hydroponic fodder is a technique in which barley, oat or wheat grains are soaked in water, hanged to dry, and then soaked again. The next step would be to spread the grains on wilted trays and to spray them with water three times a day for 5 to 8 hours (Sneath & McIntosh, 2003). Seven days of sprouting showed a 21.9 % loss in DM and 2.0 % loss in gross energy (GE). The CP, ash and minerals (except potassium) were higher in the barley sprouts. There was no significant difference in *in sacco* degradation between the barley sprouts compared to the grains. The presence of a grass juice factor in hydroponic barley is suggested to improve animal performance (Dung *et al.*, 2010).

3 Material and Method

3.1 Study site

The study was conducted as a Minor Field Study in Baringo, located in the western parts of central Kenya, north of Nakuru town (figure 1), with an aim to find key factors related to feeding- and management routines that are obtainable for small-holder dairy farms to increase milk production.

The study was performed during September and October 2017 during rain-season. Baringo is categorized into two agro-ecological zones: semi-humid/ humid areas (21 %) and semi-arid/ arid areas (79 %). The semi-humid/ humid areas have well-drained and fertile zones more located in the highlands, and the semi-arid/ arid areas have more complex soils and a warmer climate having more economic activity in the lowlands. Baringo varies in topography between altitudes of 700 to 3000 metres above sea level and the annual rainfall is in general from 1000 to 1500 mm in the highlands, and around 600 mm in the lowlands. The seasons in the area is dry season between December to March/April, long rain season between April/ May to early June, a cool dry season between late June to October and short rain season between November and December (CGB, 2013). The farms visited were located in the south of Baringo, with altitudes (above sea level) varying between 1500 to 2600 metres, in which farms located on an altitude below 2000 meters is considered "lowlands" in this study, and farms above 2000 meters is referred to as "highlands" (fig. 1), according to recommendations by the manager of the Baringo Agricultural Marketing Services Cooperative Society limited (BAMSCOS).

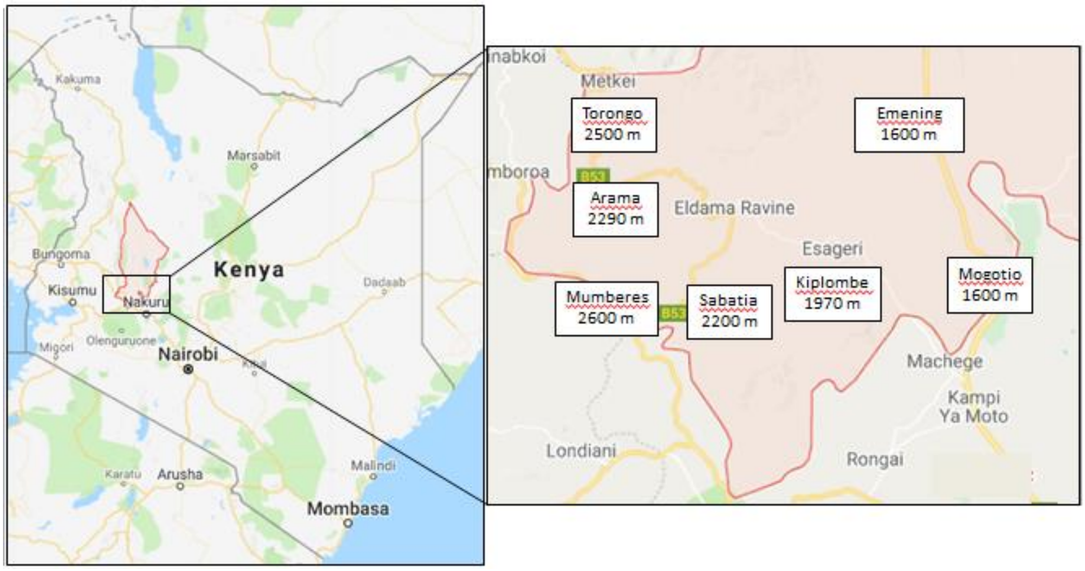

Figure 1. Map over study site and the villages included in the study, figures display the villages' altitude in meter (Designed by Maja Möller, SLU).

The study was performed in collaboration with WeEffect and their partner organization BAMSCOS. WeEffect is a Swedish non-governmental organization working towards diminishing poverty by supporting local organizations and cooperatives to empower people within local communities. WeEffect is active in Africa, Asia, South-America and Europe. In Kenya, their main focus area is to strengthen smallholder farmers' ability to perform sustainable farming, leading to an improved production (WeEffect, 2017). BAMSCOS is an umbrella organization composed of 19 agricultural dairy- and coffee marketing cooperatives with 12,194 active members, supported financially by WeEffect. BAMSCOS was formed in 2012, with an aim to improve and facilitate access to markets for farmers to support them to receive better payments for their produce (Changwony, 2017).

3.2 Selection of farms

Seven primary dairy cooperatives were chosen by BAMSCOS to be included in the study and contacts were provided by the manager of BAMSCOS. Three of the farmers' cooperative societies (FCS) were situated in the highlands (Arama, Mumberes and Torongo), three in the lowlands (Emening, Kiplombe and Mogotio) and one with active members in both regions (Sabatia). Thereby, two production areas were visited: *Highlands* (H) and *Lowlands* (L).

As an introduction to each FCS, a brief interview was performed with the manager of the FCS regarding active memberships, provision of extension services and aspects their members should improve (Appendix I), and the study objectives were explained. The FCS were asked to perform a random selection of farms with the criteria that farmers were milking in the afternoon. Due to the long travelling distances, the morning milkings could not be included in the study. The farmers were informed about the study visit one day in advance. In total, 31 farms participated in the study, with the distribution of farm described within the parenthesis as followed; Arama (H, 3), Emening (L,4), Kiplombe (L,4), Mogotio (L,4), Mumberes (H,4), Torongo (H,4), Sabatia highlands (4) and Sabatia lowlands (4). The geographic study area can be seen in fig. 1.

3.3 Data collection

The data collection was based on semi-structured questionnaires (Appendix II-V) and observation protocols (Appendix VI) on farm level. Each farm was visited once during the afternoon milking for individual measurements of the cows and feed sampling. Identification of feedstuffs was performed on each farm with assistance from the extension officers from BAMSCOS and the FCS in addition to the interview. The feeding systems were categorised as followed:

- Free grazing (FG): the cows were allowed to graze freely both day and night, and possibly supplemented with Dairy meal
- Semi-zero grazing (SZG): a prepared enclosure of which the cows were held part-time and supplementary fed forage if necessary.
- Zero grazing (ZG): the cows were permanently held in an enclosure/ unit with no access to pasture. All feeds were offered in the enclosure.

3.3.1 Semi-structured interviews

The semi-structured interview of 15 to 30 minutes was held with the owner or manager of the farm. The interview included socio-economic questions (Appendix II), more specific questions regarding feeding routines, manure handling and water source. Depending on the feeding system, different protocols were used for FG- (Appendix III), SZG- (Appendix IV) and ZG- systems (Appendix V) to avoid irrelevant questions. Sometimes the farms could have systems that needed additional questions apart from the protocols, which was the reason for using semi-structured interviews. The interviews were performed in collaboration with a student conducting a study on milking routines for which additional questions were asked.

Questions regarding feed ratios and feed production were either asked during the observation or the interview depending on time of arrival in combination with time for milking. If an employee performed the milking, those questions were asked to the owner/ manager of the farm during milking.

3.3.2 Observations and animal recordings

Feeding- and management practices and housing were observed during and around milking whereas the animal recordings were performed during milking. The observations comprised the following aspects: feed rations, feed storage facilities, water access (scale 1 to 3) feed access (scale 1 to 3), water quality (scale 1 to 3), feed preparations, crop residues used for feeding, shade possibilities and the numbers of cattle in different animal categories (Appendix VI). The scale (1 to 3) was referred to 1 = poor/ low, 2 = medium and 3 = rich/ high level of quality or amount of feed/ water.

Animal recordings included information regarding breed, lactation stage, lactation number, weight and body condition score (BCS) for each individual cow (Appendix VI). A maximum of five lactating cows were observed and registered per farm. If the farm had a higher number of lactating cows, a random selection was made. A total of 114 cows were included in the study (52H; 62L), of which 113 registrations of milk yield were made and 110 cows were measured for live body weight.

Body Condition and Body weight

An assessment of body condition was performed during milking. The process of BCS gives a subjective rating of the animal's subcutaneous fat on the lower back, lumbar regions and around the hips. The scoring interval (1 to 5) responds to 1 being a very thin cow whilst 5 represent a very fat cow. A BCS of 3.0 to 3.5 is optimal; a value below 3.0 is considered low (Hulsen, 2011).

The BCS was performed according to a BCS-scale inspired by Hulsen (2011) and Bechir *et al.*, (2010). Photographs were taken on each cow's behind and sorted to be able to trace back the ratings of each individual cow.

A weight-measuring tape was used to determine an approximate weight of the animals. The measurements were performed after milking by either the extension officer from BAMSCOS or the author, depending on the milking system. The scale on the weight measuring tape has been developed by Kruuse© to suit dairy cattle in general with the purpose of measuring live-weight.

Milk Yield

The afternoon-milk was registered, in which the milk yield was weighed in a milk container by a digital fish weighing scale developed by Biltema© (art. no 26624) (kg ±0.01). Prior to the weighing of the milk, a sample of ca 10 ml were taken by the fellow student studying milking routines at the farms analysing pH and somatic cell count.

The daily milk yield was calculated based on the measured milk yields from the afternoon milking in combination with the different milking intervals. Milking intervals of 10 and 14 hours have been converted by assuming the afternoon milk yield is 0.404 of the daily yield, as referred to by Chládek *et al.*, (2011). Milking intervals of 9 and 15 hours, or more extreme intervals, has been calculated with the conversion factor 0.37 (Forsbäck *et al.*, 2010). Farms milking three times per day have been calculated according to Quist *et al.*, (2007), with 0.34 assumed as the afternoon proportion of the daily milk yield.

3.3.3 Feed- sampling and analyses

Feed were sampled from the basal feed, supplementary feed or other feed components used frequently on the farms. Feed sampling was only performed on farms using home grown or purchased feeds; therefore, a total of 21 feed samples were collected, and three additional feed samples were sampled on Dairy meal (concentrates) from different brands on behalf of BAMSCOS.

Samples of ca 50 to 200 g were collected, amount depending on moisture content, finely cut and put in a cotton bag. A digital weighing scale (g ±0.01) was used to perform the first step of the dry matter assessment. The first step of the dry matter assessment was performed the day of the sampling in which feed samples were weighed to determine the wet weight. Thereafter, the feed samples were dried outdoors in the sun at a temperature of 20 to 25 °C in a box with a thin cotton fabric in the bottom to favour drying. The drying continued for 24 to 72 hours, until the feed samples were easily broken and seemed dry. The samples were then weighed a second time in order to determine DM (%) and put into paper bags, marked, and stored in room-temperature to be further analysed in the laboratory at the department of Animal Nutrition and Management (HUV), Swedish University of Agricultural Science (SLU).

The DM-assessment was completed in the laboratory with two additional steps, where the samples were weighed-in and milled into a powder, followed by drying in an oven in 103°C for 16 hours and then cooled in an exsickator before weighing. The samples were then put in an oven (500°C) for three hours, followed by cooling in an exsickator prior to an additional weighing. The ash content was determined after the drying of samples in the last step of the DM-analysis.

The determination of CP was based on an analysis of the nitrogen content using the "Kjehldahl method" (NCF, 1976) in a 2520 Digestor, Kjeltec 8400 analyser unit and 8460 sampler unit from Foss©. The fibre fraction NDF was analysed according to Chai and Udén (1998) by using 100 % detergent strength with both amylase and sodium sulphite.

The metabolisable energy (ME) and digestibility of the feed samples were determined by an in vitro determination of organic matter digestibility for ruminants. The in vitro method ruminal fluid digestible organic matter (VOS) was performed according to Lindgren (1979; 1983; 1988). The method included 96 hours of incubation in 38 °C composing 0.5 g dried feed sample with 49 ml buffer and 1 ml rumen fluid. The residues from the incubation were combusted to receive the digestibility coefficient of the organic matter, the VOS-value. Due to inadequate analysis methods to determine the ME in total mixed ratio (TMR) samples and maize silages, the calculations for ME was based on the standard calculations for Swedish grasses. The ME of the grass mixtures, maize silage and the TMR was thereby calculated as followed:

- Leys incl. < 50 % legumes: MJ ME/ kg DM = 0.160*VOS – 1.91 (Lindgren, 1983; 1988)
- Leys incl. > 50 % legumes: MJ ME/ kg DM = 0.106*VOS + 2.93 (Lindgren, 1983; 1988)
- Straw MJ ME/ kg OM = 0.114*VOS + 0.47 (Lindgren, 1988)

The digestibility of the same feed mixtures was calculated as:

- Leys incl. < 50 % legumes: y = 0.90*VOS – 2.0
- Leys incl. > 50 % legumes: y = 0.62*VOS + 23.0 (Lindgren, 1983)

Determination of crude fat (EE) was performed on the Dairy meals by using a Foss, Denmark, Hydrotec 8000 and Soxtec extraction unit according to EC (1998).

Mineral analysis was performed on the Dairy meals according to Bahlsberg-Pålsson, (1990) at Lund University, Sweden, with an ICP Spectro Blue, model FM26.

3.3.4 Calculations and statistics

The data will be presented by descriptive statistics. Recommended energy levels for dairy cows, combining different sources, have been calculated as, "y" being the final recommendation (MJ ME) (Spörndly, 2003):

- (0.507*average $BW^{0.75}$) + 5.0*average MY = x
- (1.11*x) – 13.6 = y

Additional requirements should be added daily in late gestation period (7-9 months), with 5, 8 and 15 extra MJ ME/ day subsequently.

The digestible CP was calculated from combining different sources based on the daily energy requirement for maintenance as followed: 6.2g CP/ MJ and additional 60 g CP per litre of milk (4% fat) (Spörndly, 2003). The fat percentage has not been analysed, therefore the milk is estimated a fat percentage of 4 % to be able to use the following calculations. Additional requirement should be included depending on gestation month (7, 8 and 9) per 100 kg of LW (18, 30 and 54 g).

The maximum NDF-inclusion was calculated as 1.5 % of the average body weight, combining different sources in Spörndly (2003).

4 Results

4.1 Farm characteristics

The average numbers of lactating cows were 4.5 cows (H) and 7.9 cows (L). Further descriptions within brackets are referred to the number of farms per production environment (H/L). All 16 farms in the lowlands were fully dependent on dairy production as the main source of income as compared to only 10 farms in the highlands. Additional source of incomes seen in those farms (H) were motorbike services, crop production, extension- and veterinary services. The farms had had different shade possibilities for the cows (table 5) whereas if no shelter/ parlour were available, solely trees or bushes were used for sheds.

Table 5. *Describes general information of the farms highlands/ lowlands*

		Highlands	Lowlands
AI		15	9
Water source	Bore hole	6	-
	Pipe	5	2
	River	2	6
	Water harvest rain	2	2
	Dam	-	6
Second water source	Water harvest rain	7	6
Feed storage facility		11	12
Manure handling	Piled-up	7	6
	Slurry-pit	4	-
Environment	Shelter/parlour	12	7
	Open	3	9

4.1.1 Water source and harvesting

Farms in both areas had difficulties in water access during the dry season. Different water harvesting methods are displayed in fig.2. Farms not implementing water harvesting either had a reliable main source of water, or had a scarcity of capital to invest. Those farms had to take other measures to provide water to the cows during dry spells.

Ways of coping with water scarcity were: hiring assistance for bringing water in a trailer from the river (1L), collect water from the river using a motorbike (1H). A similar strategy was seen where water was collected from a dam using a donkey or a tractor for assistance (1L). Another way of coping with water scarcity during dry season was to bring the cows to the river (1H; 1L). Two farms had restricted water access during the study visits, and the cows were only allowed to drink certain times during the day (1H; 1L).

Figure 2. Different water harvesting methods seen in farms (Photo: Maja Möller, SLU)

4.1.2 Feed storage facilities

The capacity and design of the feed storage facilities were not the same between the different farms depending on herd size, personal priorities and owning capital to invest. Two examples of feed storage facilities are shown in fig. 3. Some farms had a possibility to grind feeds, which was often seen in farms mixing different feed components into a TMR or a dry- or fresh mix. Some farmers had a poor access to feed storage facilities, and grinded hay before putting it into bags for a more efficient use of space.

Figure 3. Feed storage facilities (Photo: Maja Möller, SLU)

4.1.3 Manure handling

The most common system of manure handling in the highlands was to pile up manure to dry before applying it on land (fig.4), whereas farms with an arranged slurry-pit was only seen in ZG-farms in the highlands. The lead off was to lands close to the dairy unit. There seemed to be a slight variation in utilization of manure, where some farms seldom used this resource, and some seemed to have a routine for it.

Figure 4. Slurry-pit and piled-up manure (Foto: Maja Möller, SLU)

4.2 Farmers' Cooperative Societies (FCS)

The different FCS varied in active memberships (members currently delivering milk via the FCS) as follows; Arama (55 %), Emening (46 %), Kiplombe (55 %), Mogotio (28 %), Mumberes (45 %), Sabatia (33 %) and Torongo (33 %). The active memberships vary over the year due to seasonal fluctuations affecting the production, in combination with competition from milk distributors from unofficial markets.

All of the interviewed managers (7 FCS) pointed out feeding, feed conservation and fodder production as aspects their members need to improve; together with pasture improvements (1 FCS), water harvesting (3 FCS) and breeding (5 FCS). Water harvesting was mentioned as a lacking resource due to ignorance among farmers in combination with a shortage of capital to invest. Natural insemination was most commonly used in two FCS, whilst two of them had most of their members using AI. Advisory or veterinarian extension services were offered in some areas (4 FCS), whilst two FCS were not offering those services. One FCS used BAMSCOS' extension officer for advisory services to their farmers.

4.3 Feeding- and management routines

The distribution of feeding systems between the farms were ZG (5H; 3L), SZG (7H; 2L) and FG (3H; 11L), in which most farms in the lowlands used pasture as basal feed. The basal feed is referred to as the main feed used in the cows' diets. However, some farms used mixtures of forages with equal proportions and are therefore described as "dry mixtures" or "grass mixtures". Pasture was used as basal feed in seven farms in the highlands and 13 farms in the lowlands, contributing to be the most common feed component in the farms visited.

In the highlands, most farms used pastures (7H), TMR (3H) and dry mixtures (3H) as basal feed for their cows. Most farms in both production environments used several feed components in their feed ratios, described in table 6. The dry mixtures composed of mixtures between oats hay, dry sorghum, Rhodes grass hay, crop residues, Napier grass and Ray grass. The TMR included mixes of: whole maize silage, whole maize, Rhodes grass hay, oats, sorghum, Napier grass, Lucerne and Dairy meal.

In the lowlands it was seen in one farm to use grass mixtures to give their cows including Napier grass, Columbus grass, Lucerne and Star grass hay. Five of the pasture-based farms in the lowlands gave no additional supplements. Three farms in the lowlands had ZG- systems and used "*One-day silage*" (maize stover and hay mixed with molasses); maize silage (mixed with wheat bran and Dairy meal) and a grass mixture (Columbus grass, Napier grass, Star grass hay and Lucerne). The "*One-day silage*" is referred to a forage-mixture of which molasses and water have been added and stored under anaerobic conditions in 24 hours to favour fermentation.

Table 6. *Feeding routines and feed components used in the 31 farms included in the study.*

Feeding routines	Component	Highlands (n=15)	Lowlands (n=16)
Cut-and-carry	Napier grass	9	5
	Kikuyu grass	3	-
	Whole maize	3	-
	Oats	3	-
	Rhodes grass	3	-
	Lucerne	2	2
	Nandi setaria	2	-
	Desmodium	2	-
	Sorghum	1	2
Feed conservation	Rhodes grass hay	8	8
	Oats hay	7	-
	Star grass hay	3	4
	Napier grass hay	2	-
	Nandi setaria hay	2	-
	Maize silage	5	6
	Oats silage	2	-
Crop residues	Maize stover	5	3
	Pea husks (dry)	2	-
	Bean stover (dry)	2	-
Purchased feeds	Dairy meal	12	14
	Mineral supplement	7	10
	Salt	11	19
	Molasses	3	4
	Wheat bran	-	2

4.3.1 Feed components

Cut-and-carried grasses

A majority of the farms (13H; 11L) grew and fed freshly cut grasses to their cows. The most frequent used freshly cut grass among the farms was Napier grass and was supplied to the cows by a cut-and-carry system (table 6) (fig. 5). The grasses were commonly mixed with crop residues, hay, silage or a combination of these. During the interview, one farm in the highlands claimed that the milk yield dropped during the dry season due to the scarcity of fresh grasses. This seemed to be a common understanding among the farms implementing a seasonal use of conserved feeds.

Figure 5. Cut-and-carried grasses from farms visited (Photo: Maja Möller, SLU)

Conserved feeds

A majority of the farms in both production environments made hay (13H; 11L), and some also made silage (6H; 6L) (table 6). Among the farms making whole maize silage, five farms conserved it without the use of any additives (1H; 4L), whilst the other five farms used molasses to assist the fermentation process (3H; 2L). Molasses was also used to make oats silage (2H), maize stover silage (1H) (fig.6) and sorghum silage (1H; 1L).

Figure 6. Preparation of maize stover silage (Photo: Maja Möller, SLU)

The silage was conserved and stored under- or above ground (fig. 7). It was more common to conserve above ground (4H; 6L) compared to underground (2H). During the interview, one farm in the highlands explained that they had recently changed strategy from underground to above ground, claiming it now being easier to avoid water accumulation during heavy rain.

Figure 7. Underground silage and silage stored above ground (Photo: Maja Möller, SLU)

One farm in the highlands found it more convenient to move silage from the above ground storage silo after 21 days of conservation to barrels placed in the feed storage facility. The silage was packed densely in the barrels to ensure an airproof environment for further storage (fig. 8).

Another use of barrels was observed at a farm in the lowlands where grinded Star grass hay and Rhodes grass hay (322 kg) were mixed with water (200 l) and molasses (9 kg), packed airtight to allow for 24 hours fermentation prior to feeding. This method is referred to as "*One-day silage*" (table 6). The same farm made a seven-day silage using barrels, mixing grinded maize stover (161 kg) with molasses (6 kg), sealed tightly in barrels and covered for seven days. One farm (L) mixed whole maize silage (incl. molasses) with wheat bran and maize germ in a covered concrete pit, packed it airtight to allow 24 hours fermentation. This method is also referred to as "*One day silage*" (table 6).

Figure 8. Different uses of barrels, left figure shows barrels used for moving of silage from storage to barrels. The right figure shows "*One-day silage*" fermentation process. (Photo: Maja Möller, SLU)

Pasture

There were 20 farms using pasture as basal feed in both FG- and SZG-systems, of which 17 relied on natural pastures while three had improved the quality and quantity by reseeding or applying fertilizers. Five of the farms using pasture as basal feed had grazing systems where the grazing area was divided into units of 0.4 to 2 ha each. One farm (H) had 0.6 to 1.2 ha per unit and claimed those paddocks being too big, suggesting an inefficient use of land due to the cows being selective.

Commercial feeds and agro-industrial by-products

In both lowlands and highlands, Dairy meal was the most commonly purchased supplement (table 6). It was more common to feed dairy meal during milking (52 %) compared to after milking (32 %).

One farm (H) instead purchased components for a homemade concentrate including: wheat bran, sunflower cake, cotton seed cake, salt, calcium, Dicalcium phosphate, dairy premix and brewers waste; components which are not listed in table 6. During the interview, the farmer explained this strategy as a way of coping with unreliable commercial Dairy meals, due to personal experience in finding inorganic compounds such as sand in the Dairy meal sack. There were at least two other farms with similar experiences, expressing a wish to know the nutrient composition of their purchased Dairy meal.

Extension officers at BAMSCOS and the FCS, claimed this being a general problem in the area. The lack of governmental regulations for feeding companies causes vulnerability among small-scale dairy farms with scarcities of resources risking their production if relying on a Dairy meal of poor quality.

Crop residues and multipurpose trees

The most commonly used crop residues are listed in table 6. In addition to those, one farm from each production environment mixed Dairy meal with either potato peels or Sukuma-wiki on a daily basis. From the semi-structured interviews some farmers expressed problems of feed scarcities during dry season. If feed resources were lacking, four farms in the lowlands used Acacia bark (fig. 9) and two farms used banana pseudostems. Some farmers said that other crop residues occasionally used in the lowlands were finger-millet stover, Ngóswe leaves, Sitwee leaves, Sukuma-wiki (fig. 9), sweet-potato vines, watermelon leaves and -shells. Farms in the highlands sometimes used cabbages, finger-millet stover, sorghum stover and weeds during dry spells.

Figure 9. Acacia bark and Sukuma-wiki fed to cattle during dry spells (Photo: Maja Möller, SLU)

Quantity of feed offered

The semi-structured interviews covered questions regarding the amount of basal feeds, forage supplements and other supplementary feeds offered to the cows. However, most farms were not aware of the quantities provided.

Merely two farms could tell an approximate quantity of the basal feed offered, in which one farm gave 38 kg wet weight per cow and day of a mixture including maize silage, wheat bran and maize germ. The second farm knowing the approximate quantity gave 20 kg wet weight TMR per cow and day including a mixture of whole maize, oats and dairy meal. Three farms claimed to apply *ad libitum* feeding of grass mixtures and/ or TMR to their cows.

For the forage supplements, one farm gave 3.5 kg hydroponic barley per cow and day. Another farm gave 2 kg Sukuma-wiki per cow and day and a third farm gave 2 kg Napier grass and 1 kg Desmodium per cow and day as forage supplements.

However, most farms could tell an approximate quantity of Dairy meal provided. The quantities ranged between 1.5 to 13.5 kg Dairy meal per cow and day with an average of 4 kg per cow and day.

Feeding of heifers

The semi-structured interviews covered questions regarding feeding of heifers, in which three farms gave the same forage mixtures including Dairy meal to the heifers as given the cows. Four farms gave forage mixtures without any Dairy meal included. Most farms held the heifers on pasture, of which 19 farms held the heifers on natural pastures while two farms held them on improved pastures that had been reseeded and/ or fertilized.

4.3.2 Chemical compositions of the feeds

The feed analyses of the basal feeds (table 7) showed a range in crude protein from 5.4 to 14.4 %. The ME values ranged between 7.3 to 10.7 MJ ME/ kg DM as described in table 7. The NDF-values ranged between 39.2 to 71.6 %. Nearly all basal feed samples were from mixtures, in which they have been categorized as crop residues, grasses, maize and milling by-products and abbreviated to single letters to fit in to table 7.

Table 7. *Chemical composition of basal feeds sampled (n=9) in the highlands and lowlands*

Sample	Ingredients*	DM (%)	Ash (%)	CP (%)	NDF (%)	VOS (%)	ME** (MJ ME/ kg DM)	DMD*** (%)
3H	G/C	29.2	11.4	10.1	57.0	71.2	8.6	62.1
15H	G/O	47.6	8.3	7.5	62.5	67.3	8.9	58.6
16H	G	42.5	7.6	7.5	67.2	60.8	7.8	52.7
30H	G/M/L/D	30.8	10.7	8.6	62.6	69.0	9.1	60.1
31H	M/O/D	27.7	9.4	12.1	46.6	79.0	10.7	69.1
13L	Sorghum	28.4	10.0	5.4	69.5	66.0	8.7	57.4
18L	G/L/D	57.1	9.2	14.4	49.7	76.0	10.2	66.4
19L	M/Mi	48.8	7.5	11.3	39.2	78.3	10.6	68.5
20L	Hay	43.3	10.3	5.4	71.6	57.7	7.3	50.0

**Estimated from Lindgren (1983; 1988)
***Estimated from Lindgren (1983)
*C= Crop residues: maize stover, bean stover, pea husks
G = Grasses: Napier grass, Ray grass, Sudan grass, Rhodes grass, Columbus grass, Nandi setaria, Kikuyu grass
L= Lucerne
M = Maize: whole maize silage or whole fresh plant
O = Oats
D = Dairy meal
Mi = milled by-products: maize germ, wheat bran

The feed analysis of the forage supplements showed a range in CP between 5.3 to 15.3 %. The ME ranged between 7.3 to 13.3 MJ ME/ kg DM (table 8).

Table 8. *Chemical composition of forage supplements sampled (n=10) in the highlands and lowlands*

Sample	Ingredients*	DM (%)	Ash (%)	CP (%)	NDF (%)	VOS (%)	ME** (MJ ME/ kg DM)	DMD*** (%)
1H	G/O	28.9	13.8	9.9	67.0	57.7	7.3	49.9
5H	G/C	47.2	10.5	8.5	61.8	65.4	8.6	56.9
26H	G/C	29.2	9.8	5.3	66.7	64.6	8.4	56.2
28H	O/D	94.0	15.2	10.4	53.8	59.1	7.5	51.2
29H	G/O/Mi	28.6	11.6	7.7	64.0	59.0	7.5	51.1
30H	Hydroponic barley	24.5	3.7	15.2	34.8	83.7	11.5	73.3
8L	Hay	93.8	12.3	9.9	60.9	70.6	9.4	61.5
9L	G/De	30.6	13.6	14.2	47.6	70.4	9.3	61.3
10L	Sukuma-wiki	18.9	11.2	15.3	21.2	95.4	13.4	83.9
11L	Acacia bark	44.3	10.9	7.7	37.2	47.8	5.7	41.0

**Estimated from Lindgren (1983; 1988)
***Estimated from Lindgren (1983)
*C= Crop residues: maize stover, bean stover, pea husks
G = Grasses: Napier grass, Ray grass, Sudan grass, Rhodes grass, Columbus grass, Nandi setaria, Kikuyu grass
L= Lucerne
M = Maize: whole maize silage or whole fresh plant
O = Oats
De= Desmodium
D = Dairy meal
Mi = milled by-products: maize germ, wheat bran

The chemical composition of Dairy meals showed a range in ash content varying between 8.3 to 23.0 % (table 9). The mineral analysis showed calcium contents varying between 10.1 to 42.1 g/ kg and the magnesium content between 3.3 to 19.0 g/ kg. The CP showed a range between 11.5 to 20.6 %. The EE ranged from 4.0 to 6.4 %, described in table 9.

Table 9. *Chemical composition of different brands of Dairy meals (n=5) from the study area*

	Mwanza	Milling	Sawa	Unga	KDFF
DM (%)	93.9	92.7	93.7	94.8	92.0
Ash (%)	23.0	8.3	19.2	7.0	19.4
CP (%)	11.9	18.6	11.5	20.6	15.8
NDF (%)	25.5	34.2	33.4	34.9	36.0
EE (%)	6.4	6.3	4.8	4.1	4.0
Ca (g/ kg)	42.1	10.3	21.1	10.1	28.2
K (g/ kg)	8.2	10.1	9.6	11.6	8.7
Mg (g/ kg)	19.0	4.1	4.7	3.3	12.9
Na (g/kg)	1.4	3.0	3.6	1.4	1.3
P (g/ kg)	4.3	5.2	4.9	7.1	4.7
S (g/kg)	1.6	2.0	1.4	2.0	1.7

4.4 Milk yield, BCS and Body weights

Overall, the most popular breed used was Friesians followed by Ayrshires. The BCS was on average 2.4 in the highlands, compared to 2.6 in the lowlands (table 10), described further in fig. 10 and 11. A higher body weight (408.1 kg) and milk yield (6.9 kg/ day) was seen in the highlands (table 10).

The semi-structured interviews included questions about the reason for favouring one breed over another, in which 17 of the farms visited preferred Friesians, 10 farms preferred Ayrshires, three farms preferred Sahiwal and one farm preferred Guernsey. The preference of Friesians was due to high milk yields in all farms preferring this breed, some farms also said that they grow fast and have good persistency in milk yield compared to other breeds. From the interviews, Ayrshires were said to have a lower feed consumption compared to Friesians, thicker and sweeter milk and an ability to cope with harsh climates. The Sahiwal was preferred in three FG-farms with no further motivation, and the Guernsey was said to have a high milk yield.

Table 10. *The distribution of breeds and the average BCS, Milk yield (MY) and Body weight (BW) per breed in the highlands (H) versus lowlands (L)*

	Cows (%)		Average BCS		Average daily MY (kg)		Average BW (kg)	
	H	L	H	L	H	L	H	L
Ayrshire	19.3	21.0	2.3	2.5	6.2	5.8	398.6	362.8
Bos Indicus	-	11.3	-	2.4	.	3.4	-	279.3
Bos Taurus	9.6	14.5	2.4	2.5	7.7	3.7	405.2	369.1
Friesian	69.2	37.1	2.4	2.9	7.2	9.5	415.6	442.4
Jersey	-	4.8	-	2.2	-	3.6	-	264.0
Sahiwal	-	11.3	-	2.4	-	3.7	-	293.4
Guernsey	1.9	-	2.5	-	3.1	-	246.0	-
In average	-	-	**2.4**	**2.6**	**6.9**	**6.3**	**408.1**	**373.8**

The distribution of cows (n=114) over the BCS-scale (1.0 to 5.0) are described in fig. 10 with different colour-code for the highlands (dark orange) and lowlands (beige).

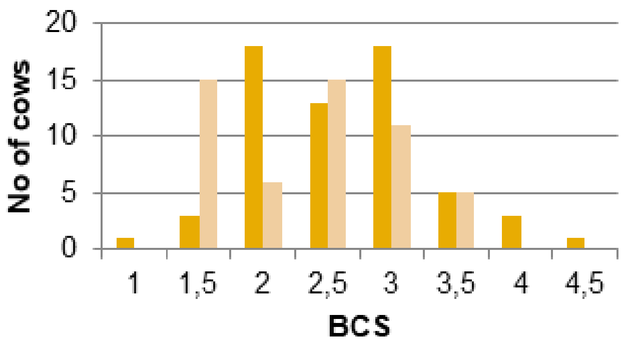

Figure 10 The distribution of cows in the BCS-scale of which the dark orange represents the high-lands and the beige represents the lowlands.

Figure 11 shows a BCS-chart over cows included in the study that had been categorized according to assessed body condition from 1.0 to 5.0.

Figure 11 BCS-scale which displays example-cows rated 1 to 5. The cows were rated during the study visits and are sampled randomly to fit into this scale to be use as a reference for this study (Photo: Maja Möller, SLU).

Nutritional requirements for cows included in the study

Nutritional requirements for the cows are presented in table 11, based on an average cow in the highlands (408.1 kg LW: 6.9 kg MY) and in the lowlands (373.8 kg LW; 6.3 kg MY).

Table 11. *Nutritional requirements based on average BW and MY in the highlands and lowlands of Baringo*

Nutritional components	Highlands	Lowlands
ME*	76.0 MJ	69.2 MJ
ME (gest 7 mo)	81.0 MJ	74.2 MJ
ME (gest 8 mo)	84.0 MJ	77.2 MJ
ME (gest 9 mo)	91.0 MJ	84.2 MJ
DCP** (m)	732.6 g	673.8 g
DCP[3]* (gest 7 mo)	806.1 g	741.1 g
DCP[3]* (gest 8 mo)	855.0 g	785.9 g
DCP[3]* (gest 9 mo)	953.0 g	875.7 g
Max NDF[4]*	6.1 kg	5.6 kg

*Based on measured and calculated average BW (H: 408.1 kg; L: 373.8 kg) and milk yield (H: 6.93 kg; L: 6.29 kg) using formula from Eriksson et al, (1976) and Andresen, (1994) in Spörndly (2003). (0.507*average $BW^{0.75}$) + 5.0*average MY = x; (1.11*x) – 13.6 = y. Additional requirement for late gestation (7,8 and 9 months) is added respectively daily (5, 8 and 15 MJ ME)

**The digestible CP (DCP) was calculated based on numbers from Magnusson *et al.*, (1990), AAes (1990), Arbetsgruppen (1990) and Bertilsson (1994) in Spörndly (2003) and the measured average BW and MY; 6.2g CP/MJ and additional 60 g CP per litre of milk.

[3]*DCP (gest 7,8,9) is referred to the gestation month, adding additional 18, 30 and 54 g CP per 100 kg of LW.

[4]*Calculated as 1.5% of measured average BW based on (Nycander, 1989 and Gustafsson, 1989) in (Spörndly, 2003)

5 Discussion

5.1 Feeding practices in Baringo

The most commonly used basal feed at the time of the visit was pasture, particularly seen in the lowlands. The most common grass grown on natural pastures in Kenya is Star grass (*Cynodon dactylon*), also known as Bermuda grass, and Kikuyu grass (*Pennisetum clandestinum*) (FAO, 1985), and Jackson *et al.* (1991) indicated a higher nutritional value in Kikuyu grass (19.1 % CP; 9.4 MJ ME/ kg DM) compared to Star grass (10.2 % CP; 8.2 MJ ME/ kg DM). Star grass hay was analysed in the present study (9.9 % CP; 9.4 MJ ME/ kg DM) showing similar CP-value observed in the study by Jackson *et al.* (1991).

In the supplementary feeds, two analysed forage mixtures (table 8) contained Kikuyu grass, Napier grass and oats hay (9.9 % CP; 7.3 MJ ME/ kg DM) and another sample with Rhodes grass, Kikuyu grass and maize stover (8.5 % CP; 8.6 MJ ME/ kg DM). The CP level is quite good in those mixtures, which could be due to the inclusion of Kikuyu grass. If those mixtures are compared to a similar mixture, not composed of Kikuyu grass, a lower CP-level was seen (5.3 % CP).

The present study did not include sampling of pastures. However, if the pastures had similar chemical compositions as the Star grass hay or the forage mixtures including Kikuyu grass it would be of a quality lower than a recommended desirable Swedish silage quality 11.0 MJ ME/ kg DM and 130-160 g CP/ kg DM (Martinsson, 2003).

According to Walsh *et al.*, (2008) a low-concentrate diet is associated with a lower BCS compared to a high-concentrate diet. Therefore, it would be suggested that an even improved BCS could be seen in the free-grazing feeding systems if supplementations of starch- and protein sources would be used. The supplements wheat bran, Desmodium and maize germ were mainly used by progressive farms in the study area. Generally, those farms considered their production more like a business compared to low-investment farms. Some low-investment farms had free-grazing systems and struggled with scarcity of resources to invest, whilst some farms were just not willing to supplement the cows if they survived and produced milk from solely pasture.

5.1.1 Basal feeds

It could be discussed whether the calculated energy levels (ME) from the analysed feeds in this study are overestimated compared to the true value, since available calculation methods and parameters are based on Swedish grasses (Lindgren, 1983; 1988). However, it is still relevant as an approximate estimation of the feed samples. In the basal feeds (table 7) the energy levels varied between 7.3 and 10.7 MJ ME/ kg DM. The CP content varied between 5.4 and 14.4 %.

In order to investigate whether the sampled basal feeds were of proper feed quality, calculations were made based the NDF-value in each sample and on recommendations, combining different sources, of a maximum NDF-inclusion of 1.5 % of the average body weight in the highlands (6.1 kg NDF) due to limitations of feed intake (Spörndly, 2003). These calculations were relevant to make in cases when *ad libitum* feeding was applied, which according to the semi-structured interviews was the case in three farms.

The first column in table 12 was based on the minimum required quantity to fulfil the calculated nutritional requirement for CP (from table 11), and the second column based on the required ME (from table 11). The third column was the calculated intake capacity based on a maximum consumption level of 6.1 kg NDF. If the minimal intake to fulfil the requirements for CP and ME was lower than the maximum capacity for DMI, a lowest recommended quantity of the feed (kg wet weight) was stated in the fourth column. However, if the feed had inadequate feed quality unfitting to fulfil the required levels for CP or ME, no further calculations were made.

The requirements were based on an assumption of 7 month into gestation due to the expected dry period occurring between 8 and 9 months gestation and a cow in the highlands due to higher requirements needed a higher milk yield and body weight compared to the lowlands. The DCP was estimated to 80 % of the CP level (estimated from Spörndly, 2003).

Merely four of the basal feed samples were of a feed quality good enough to fulfil the minimum required levels for CP and ME to sustain the current production level in the area (table 12) if provided *ad libitum* feed (without supplements). However when compared to a desirable Swedish silage quality of 130-160 g CP/ kg DM and 11.0 MJ ME/ kg DM (Martinsson, 2003), none of the basal feed samples (3H, 31H, 18L and 19L) reached the desirable quality.

The CP-content is in general lower than the ME-content in the analysed basal feeds, since a higher DMI is required to fulfil the CP-requirement (table 12). Therefore, a suggestion would be to primarily aim for higher protein contents in the forage mixtures.

Table 12. *The dry matter intake based on nutritional requirements and capacity to consume NDF based on basal feed samples.*

Feed sample	Min. intake* (kg DM) based on req. CP	Min. intake** (kg DM) based on req ME	Max. DMI [3]* (kg DM) based on NDF 1.5 % BW	Req. wet weight[4]* (kg) based on min. intake for CP/ ME
3H	10.0	9.4	10.7	28.2
15H	13.4	9.1	9.8	-
16H	13.4	10.4	9.0	-
30H	11.7	8.9	9.8	-
31H	8.3	7.5	13.1	30.0
13L	18.7	9.3	8.8	-
18L	7.0	7.9	12.3	14.0
19L	8.9	7.6	15.6	18.2
20L	18.7	11.1	8.5	-

* The digestible CP (DCP) was calculated based on numbers from Magnusson *et al.*, (1990), AAes (1990), Arbetsgruppen (1990) and Bertilsson (1994) in Spörndly (2003) and the measured average BW and MY; 6.2g CP/ MJ and additional 60 g CP per litre of milk. The required CP was calculated as CP/0.8 = DCP requirement estimated from Spörndly (2003).

** Based on measured and calculated average BW and MY in the highlands (BW: 408.1 kg; MY: 6.93 kg) using formula from Eriksson et al, (1976) and Andresen, (1994) in Spörndly (2003). (0.507*average $BW^{0.75}$) + 5.0*average MY = x; (1.11*x) – 13.6 = y. Additional requirement for late gestation (7) was added (5 MJ ME)

[3]* Calculated as maximum NDF being 1.5% of measured average BW based on (Nycander, 1989 and Gustafsson, 1989) in (Spörndly, 2003)

[4]*If the cow had the physiological capacity to consume the feed, the column describes how much the wet weight would be.

In the present study questions were asked regarding the quantities of feed provided to the cows, however most farms could not describe the quantities. Merely two farms knew the wet weights, in which one farm (sample 19L) gave 38 kg wet weight (48.8 % DM) per cow and day which corresponds to 18.5 kg DM. Another farm (sample 31H) gave 20 kg wet weight (27.7 % DM) which corresponds to 5.5 kg DM. The quantity provided of the first sample (19L) was enough to fulfil the required level for a sustained production in the area (table 12). However, for the second sample (31H) a quantity of at least 8.3 kg DM (30 kg wet weight) of the feed would be necessary to sustain the current average production level in the area (table 12).

In some of the visits, it was difficult to determine whether the whole maize plant (incl. cobs), or merely the maize stover was given to the cows. The confusion could have been partly due to the language barrier in combination with a strong understanding of maize cobs being a valuable human food. During the visits, many farmers and extension officers stressed the competing need of starch- and protein sources between animal husbandry and the human population in Kenya. Therefore, the use of maize cobs in the animals feed was mainly observed in progressive farms. Due to the competition of nutritional sources, it could be discussed whether protein- and starch rich supplements should be given to cows or if they rather should add value and refine products humans cannot consume. It can further be discussed whether focus should be on improved milk yields or more available maize for human consumption.

In one semi-zero grazing farm, the cows were fed a grass-mixture twice per day during milking and then held on an over-grazed small plot of pasture, suggesting a very limited time for a cow to consume enough feed. Similar findings were observed in other semi-zero grazing farms, suggesting a high reliance on pasture in those systems, even if over-grazed. In those cases, it seemed like farmers were over-estimating the cows' ability to consume feed.

The lowest CP and ME values were seen in Sorghum silage (5.4 % CP; 8.7 MJ ME/ kg DM); and the so called One-day silage composing Star- and Rhodes grass hay mixed with molasses to ferment in 24 hours (5.4 % CP; 7.3 MJ ME/ kg DM). It should therefore be discussed if further improvements in fodder production management can be made provided how many farmers depend on Sorghum silage during the dry season in the lowlands.

5.1.2 Forage supplements

Among the forage supplements, the level of CP varied between 5.3 and 15.2 %. The lowest feed value was seen in a mixture of wild forage (weeds), maize stover and Napier grass (5.3 %; 8.4 MJ ME/ kg DM). This mixture was composed of two of the most common forages fed to dairy cows among smallholder dairy farms in Kenya namely Napier grass and maize stover (Orodho, 2006b; Nyaata *et al.*, 2000; Lukuyu *et al.*, 2009; Kashongwe *et al.*, 2017). The high utilization of those feed components raises a concern due to the low nutritive value in this mixture. However, it is difficult to evaluate this mixture due to the large variation in proportions of feed components used in the mixtures. During the visits, most farms could not describe the proportions since the grasses were cut-and-carried daily and the composition varied depending on availability of feeds. Therefore, the farmers sometimes used wild forage to utilize available resources more efficiently. Similar to the present study, low nutritive values of Napier grass (9.0 % CP) (Jackson *et al.*, 1991) and maize stover (8.3 % CP) (Methu *et al.*, 2001) have been found in previous research and it can be suggested that the low CP value in the feed mixture in the present study could be due to several factors, such as fertilization of the maize and Napier grass, the post-harvest method used on the maize stover and what type of wild forage that was used in the mixture. For instance, according to Methu *et al.* (2001) a higher nutritive value of maize stover can be obtained if harvested under dry conditions, whereas the study visits in the present study were performed during the wet season. The mixture could be compared with one of the samples composed of solely wild forage, collected in the highlands. This wild forage (7.5 % CP; 7.8 MJ ME/ kg DM) had a rather low nutritive value and may not be optimal to use as basal feed for dairy cows.

The low nutritional value in the feeds suggests a need for improvement in fodder production to reach a higher protein- and energy level in the cows' diets. As described by Kashongwe *et al.* (2017) and Orodho (2006b), intercropping between different fodder crops may improve protein content in feed, for instance by using Desmodium or Calliandra as described by Nyaata *et al.* (2000). However, this would mainly be possible in high potential areas such as the highlands of Baringo due to the dry climates in the lowlands. By performing intercropping, a higher feed value could be obtained due to an increase in protein content from the inclusion of leguminous feeds in the mixture (Kashongwe *et al.,* 2017). Another benefit would be that the soil quality could improve from those leguminous plants. The manure handling technique and application on fodder production plays a huge role in improving soil quality and fertilizing the fodder crops (Sommer, 2001). Most farms piled-up manure for composting, which according to Sommer (2001) causes the highest nitrogen loss compared to compaction or coverage of the manure by tarpaulin. Generally, the composted manure has been found to have a low fertilizing effect which would suggests application of slurry immediately on land after collection being a better strategy.

It could be discussed whether the daily harvest of feed through a cut-and-carry system makes it difficult to harvest the grasses at an optimal nutritional level. The optimal harvest stage for Napier grass, based on the peak in CP, indicated different intervals depending on the rain distribution in the area (Muia *et al.*, 1999). However, by changing strategy to a possibly earlier harvest stage, a lower herbage yield may be obtained. Even Rhodes grass reaches a peak in nutritive value right before flowering (CIAT, 2005). One farmer claimed it being necessary to wait until post-flowering to receive a harvest for the next year. By adopting a harvesting strategy for the cut-and-carry system, adapted to the optimal harvest stage for the grown grass a higher ME and CP content in the feed may be obtained. This strategy could lead to a lower harvest yield, which needs to be considered before adopting this technique. Another strategy would be to harvest fodder at the optimal nutritional stage and make hay or silage.

5.1.3 Acacia bark

Acacia bark was analysed since it was commonly used as a supplement under desperate circumstances, such as prolonged droughts causing feed scarcity. Acacia bark was described as the most valuable resource for free-grazing dairy farms if the pastures were over-grazed or dried up during the dry season. The bark was described to make cows "on the edge of dying" to recover and survive by the interviewed farmers. However, the nutritive value (7.7 % CP; 5.7 MJ ME/ kg DM) was not as high as one may have expected.

According to Koech[1], it was a common mistake by farmers to not plan far ahead and sell hay prior to the upcoming dry season to get a fast income. Therefore, many farmers need to purchase hay during the dry season. On two of the farms visited, cattle had died during the last dry season due to scarcity of pastures and since no supplements were brought in. Improvements in planning for an unknown length of the dry season would therefore be recommended to avoid having to use Acacia bark as a last resort.

5.1.4 Dairy meals

The five analysed Dairy meals differed in chemical composition, especially CP and ash content. The CP levels were highest in the brands Milling (18.6 % CP) and Unga (20.6 % CP). The extension officers at the FCS and BAMSCOS had prior to the feed analyses claimed those being the best ones. The lowest CP- levels were seen in the brands Mwanza (11.9 % CP) and Sawa (11.5 % CP). Since none of the included Dairy meals had any declaration of their nutritional composition, a standard Swedish commercial concentrate (Lantmännen, 2017) was used to enable a comparison. This Swedish commercial concentrate contained 18 % CP and 6.1 % crude fat. The crude fat values were the lowest in Unga (4.1 %) and KDFF (4.0 %), which would indicate a lower energy level in those concentrates compared to Mwanza (6.4 %) and Milling (6.3 %). Thus, the highest feed quality in terms of protein and energy level was seen in the brand Milling.

An interesting observation is that the ash content in the Dairy meals was high and the highest levels were seen in Mwanza (23.0 %), Sawa (19.2 %) and KDFF (19.4 %). In addition, mineral analysis was performed due to the large variation in ash contents. In the Swedish concentrate (Lantmännen, 2017) the macro-mineral levels calcium (8.6 g/kg DM) and magnesium (4.5 g/ kg DM) were considerably lower than the Kenyan commercial concentrates analysed with calcium ranging from 10.1 to 42.1 g/ kg DM and magnesium from 3.3 to 19.0 g/kg DM. According

1. Koech, J. Extension Officer, BAMSCOS, 2017-10-02

to NRC (2001), high levels of calcium is not toxic to cows, however it could interfere with zinc absorption or replace more expensive nutrients. High levels of magnesium are also non-toxic since it can be excreted through the urine. It could however cause osmotic diarrhoea and disturb feed intake due to decreased palatability of the feed. It can therefore be suggested that alterations of the feed have probably been made to replace more expensive ingredients. As described by Lukuyu *et al.*, (2009), some commercial concentrates sold on the market in Kenya may be of substandard quality.

5.2 Productivity

The herd size in the study area was larger both in the highlands with 4.5 cows and 7.9 cows in the lowlands compared with the average 2 to 3 cows described by Orodho (2006a). All farms in the lowlands depended on dairy as their main source of income, compared to the highlands in which 44 % had other income sources on the side. It could be speculated that the higher number of cows seen in the lowland is due to a more traditional holding of cows where a large herd size is associated with wealth in many cultures. The lowlands have dry areas less prominent for other farming practices which also could explain the higher economic reliability on only pasture-based dairy as incomes in the lowlands. Another explanation could be the higher number of free grazing feeding systems seen in the lowlands, where the farm- and land size was not limiting for further expansion of the farm; as Muriuki (2003) explained being one of the reasons for switching over to zero grazing feeding systems. However, only one farm in the highlands claimed the inherited land size being an issue limiting the production, which would suggest a rather low problem with land access among the farms visited.

Many farms in the lowlands used natural insemination instead of the more advanced use of AI. All farms in the highlands used AI, compared to merely 56 % in the lowlands; the rest used bulls for natural insemination. In the Kiambu- and Nyandarua district of central Kenya, the use of AI was 54.3 %, a similar proportion as the lowlands (Murage & Ilatsia, 2011). The lower use of AI in the lowlands could be due to many factors, such as lack of knowledge, poor access to extension services, high investment with AI compared to production level obtained.

As indicated by Bebe *et al.* (2003a), the most commonly used breed in both production environments were *Bos Taurus*. Within this group of cows, the highlands had a clear majority of Friesians (69.2 %) while the distribution between different breeds varied more in the lowlands. It can be speculated that a higher intensification of the dairy systems is possible in the more prominent production environment, the highlands, in which efforts of improving breeds may have occurred sooner. In the lowlands, more free-range pasture-based systems have been used due to the dry climate making it more difficult to grow fodder. The harsh climate in the lowlands has probably been another reason for keeping indigenous breeds being more suitable for such environments, as they have been adapted to cope with feed scarcity and low water access.

The calculated daily milk yield based on measured afternoon milk showed a higher average milk yield in the highlands with 6.9 kg and 6.3 kg in the lowlands, compared to the average 4.4 litres per cow and day described by Wambugu *et al.* (2011). However, this comparison is not optimal due to the measurements being performed during different time intervals. The current study calculated daily milk yields based on one milking occasion; compared to Wambugu *et al.* (2011) measuring and calculating an average over the year. Apart from this, other factors influencing this difference could be speculated being partly due to the high number of exotic breeds included in the present study with a genetic capacity for higher milk yields. The average BCS is considered low being 2.4 in the highlands and 2.6 in the lowlands, compared to the recommended score of 3.0 to 3.25 according to Roche *et al.*, (2009). Okello et al., (2005) suggested that cows use body reserves to maintain lactation when the herbage quality is low. The milk yield increased together with improved body condition when the wet season came back, with an improved body condition appearing two months after the increase in milk yield was seen. In the present study the visits occurred five months after the end of the prolonged drought during October 2016 to May 2017, described by Koech[2]. The prolonged drought may have affected the low BCS scores in the study, together with poor feeding routines to maintain production and body condition.

Questions regarding lactation stage were included in the observation protocol. But since most farmers do not keep track on performance or calving records, this data was not considered reliable and thus not included in the study. However, some farms mentioned silent heats being a problem and they claimed it was a matter of feed-related issues. Many farms fed their cows differently over the year depending on available grasses for cut-and-carry. Most farms made silage and hay solely as preparations for the upcoming dry season, applying a seasonal use of different feed components. Those farms explained the cows being fed for survival during the dry season, not for improved production. Even though calving intervals was not evaluated, prolonged calving intervals as described by Staal *et al.* (1997) could be an issue in Baringo as well. According to Dunne *et al.* (1999), sudden reductions in DMI that may occur in irregular feeding routines, could lower the embryo success rate in heifers. A lowered fertility, milk yield and BCS could indicate that poor feeding routines are the common cause for affecting the production negatively.

2. Koech, J. Extension Officer, BAMSCOS, 2017-10-02

6 Conclusion and recommendations

In conclusion, the study showed that most basal feeds collected had inadequate nutritive quality to fulfil the cows' minimum requirement for maintaining the average body condition and milk yield without the use of supplements. A large variation in feed quality was seen among the basal feeds and supplementary forages, with the protein content being the primarily deficient nutritional component.

More alarming was the big difference in the nutritive value of the Dairy meals, with the brand Milling having the highest CP and EE value. Some of the Dairy meals analysed had elevated levels of calcium and magnesium, suggesting alterations have been made to replace more expensive ingredients.

It would be recommended to improve the protein content of the mixture by implementing intercropping of leguminous feeds to improve the protein content of the feed mixtures and soil quality. Instead of relying on Acacia bark when the production is threatened, a better planned feed conservation strategy should be used. A possibility would be to move from cut-and-carry systems and instead harvest grass at the optimal stage to receive the highest nutritive quality, make it into hay or silage and provide this to the cows all year.

To deeper penetrate the complex issue, future projects could study the amount of feed the cows are able to consume over a longer time as well as compare the contents of the Dairy meals with what the manufacturers claim they contain.

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- Kikuyu grass (*Pennisetum clandestinum*)

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Appendix I

Questionnaire FCS

How many farmers are members in this FCS? - Active?	
How much milk is delivered per day?	
Do you collect both morning and afternoon milk?	
Do you offer extension services to your members? - AI? - Veterinary services?	
Is your staff trained?	
How many employees do you have?	
What do you believe is the most important aspect for your members to improve?	

Appendix II

Questionnaire general farm information

Date:
Farm number:
FCS:
We are glad that we get the chance to visit your farm and learn about your production. We would like to inform you that you will remain anonymous in this study. No information will be used publicly that reveals your identity. It is a great asset to us to receive answers to our questions.

What is your age?	
Do you have an educational background?	
Have you grown up on a farm?	
If not, have you started the agricultural business yourself?	
How many lactating cows do you have?	
How often do you milk the cows, and at what time?	
How much milk does each cow yield per day on average?	
Is there a difference between dry and wet season?	
What is the calving interval?	
How long is the dry period for your cows?	
Is dairy production the main source of income for your household?	
If not, what other income sources do you have?	
How are your cattle housed?	
Are they housed differently during the day and night?	
Do you have access to light during milking?	
How do you handle the manure?	
Do the cattle have access to shade during the daytime?	
What breeds do you have?	

Do you have a strategy for breeding?	
Do you keep records on performance?	
Do you prefer specific breeds or crosses of breeds?	
Do you use natural or artificial insemination?	
How far into lactation do you serve or inseminate the cows?	
Do the cows have free access to water?	
If not, how often are the cows allowed to drink?	
What kind of water source do you use for the cattle?	
What type of feeding system do you have?	
Are there aspects you would like to improve with your production?	
Have you been part of any similar type of project before, aiming to improve milk production in this area? If so, what project?	
Do you have access to any advisory/ extension services?	

Appendix III

Questionnaire Free-grazing

Date:
Farm number:
FCS:

What type of land are they held on? (communal/ own land)	
How big are the areas?	
Do they graze together with other animals or other cow herds?	
Has the pasture been improved? If so, how?	
Do you provide any supplements?	
How much is given?	
Are the supplements given to all animal groups?	
How often are they fed and at what time?	
How do you prepare the feed?	
How much of each feed component do you given them on a daily basis, the feed ratio?	
Are the cows fed differently if they are in different lactation stages or just had a calf?	
How do you feed the rest of your cattle?	
Do you have access to feed storage?	
What are the advantages and disadvantages of your feeding strategy?	
For how long have you had this system?	
Does the feed availability fluctuate over the year?	
How do you handle the seasonal differences?	
Have you considered shifting towards semi-zero or zero-grazing?	
How would you like to improve your feeding?	

Appendix IV

Questionnaire Semi-zero-grazing

Date:
Farm number:
FCS:

What type of land are they held on? (communal/ own land)	
How big are the areas?	
Do they graze together with other animals or other cow herds?	
Has the pasture been improved? If so, how?	
Do you provide any supplements?	
How much is given?	
Are the supplements given to all animal groups?	
How often are they fed and at what time?	
How do you prepare the feed?	
How much of each feed component do you given them on a daily basis, the feed ratio?	
Are the cows fed differently if they are in different lactation stages or just had a calf?	
How do you feed the rest of your cattle?	
Do you make hay or silage?	
Please describe this method	
Do you have access to feed storage?	
What are the advantages and disadvantages of your feeding strategy?	
For how long have you had this system?	
Does the feed availability fluctuate over the year?	
How do you handle the seasonal differences?	
How would you like to improve your feeding?	

Appendix V

Questionnaire Zero-grazing

Date:
Farm number:
FCS:

What type of feed do you give your cattle?	
Do you produce or purchase this feed?	
How often are they fed and at what time?	
How do you prepare the feed?	
How much of each feed component do you given them on a daily basis?	
Are the cows fed differently if they are in different lactation stages or just had a calf?	
How do you feed the rest of your cattle?	
Do you have access to feed storage?	
Do you make hay or silage?	
Please describe your conserving method?	
What are the advantages and disadvantages of your feeding strategy?	
For how long have you had this system?	
Does the feed availability fluctuate over the year?	
How do you handle the seasonal differences?	
How would you like to improve your feeding?	

Appendix VI

Observation Protocol Feed Study

Date:
Farm number:
FCS:

Basal feed:

Supplements:

Protein source:

Starch source:

Mineral source:

Pasture

Natural pasture		Improved pasture
Fertilized	Yes	No
Re-seeded	Yes	No

Comments:

Feed sample

Name/ no			
Ingredients			
Sample weight approx.			
Wet weight			
Weight post DM-test 1			
DM (%)			

Comments:

Fodder production

Forage	Yes	No
Intercropping	Yes	No
Fertilizer	Yes	No
Multipurpose trees	Yes	No
Cash crops	Yes	No

Comments:

Animal Condition and milk production

Cow	1	2	3	4	5
Breed					
BCS					
Weight					
Milk yield					
Lactation number					
Lactation stage					

Comments:

Feed and water availability

Water access	1	2	3		
Water source	Stream	Springs	Pipe	Bore hole	Other
Water quality	1	2	3		
Feed access	1	2	3		

Comments:

Preparation of feed

Collection of wild forage	Yes	No
Grinding feed	Yes	No
Mixing feed	Yes	No

Comments:

Feeding trough

Fed on the ground	Feeding trough	Cut-tire	Other

Comments:

Feed conservation

Silage	Yes	No
Hay	Yes	No
Purchase hay	Yes	No
Hydroponic fodder	Yes	No

Comments:

Buildings

Environment	Open	Shelter/Parlour
Tied-up	Yes	No
Manure handling	Yes	No
Slurry-pit	Yes	No
Covered	Yes	No
Feed storage	Yes	No

Comments:

Animal Categories

Lactating cows	
Dry Cows	
Heifers recruitment (from 6 mo)	
Growing stock for meat production (from 6 mo)	
Calves (up to 6 mo)	

Breeding bull	

Comments:

Pasture-based system

Available land for fodder production	Yes	No
Farm-byproducts possible to use for feeding	Yes	No
Farm-by products used for feeding	Yes	No

Comments: